COMMONWEALTH of VIRGINIA

DEPARTMENT OF ENVIRONMENTAL QUALITY

VWP Individual Permit No. 20-0514
Effective Date: Month DD, YYYY
Expiration Date: Month DD, YYYY

VIRGINIA WATER PROTECTION PERMIT ISSUED PURSUANT TO THE STATE WATER CONTROL LAW AND SECTION 401 OF THE CLEAN WATER ACT

In compliance with § 401 of the Clean Water Act, as amended (33 USC § 1341) and the State Water Control Law and regulations adopted pursuant thereto, the department has determined that there is a reasonable assurance that this VWP permit, if complied with, will protect instream beneficial uses, will not violate applicable water quality standards, and will not cause or contribute to a significant impairment of state waters or fish and wildlife resources. In issuing this VWP permit, the department has not taken into consideration the structural stability of any proposed activities.

Permittee: Caroline County Public Utilities

Facility Caroline County Rappahannock River Water Supply

Facility Address: 19095 Tidewater Trail, Fredericksburg, Virginia 22408

Activity Location: The project is located throughout Caroline County, Virginia. The proposed intake is located on the south side of the Rappahannock River off of Route 17. The proposed raw water pipeline connecting the intake to the proposed water treatment plant (WTP) is estimated to travel 35 miles starting from the intake located along the rights-of-way of Route 17 (Tidewater Trail), Route 301 (AP Hill Boulevard), Route 207 (Rodgers Clark Boulevard), and ending at the proposed WTP location on Gravel Hill Road off of Route 1 (Jefferson Davis Highway).

Activity Description: Caroline County Public Utilities proposes to develop a new raw water supply system to supply Caroline County, the Town of Port Royal and the Town of Bowling Green. The construction activities of the proposed project consist of the following activities: a raw water pump station and associated infrastructure, an intake structure located on the south bank of Rappahannock River, the installation of approximately 35 miles of water line for the transfer of raw water from the intake to the proposed water treatment plant (WTP) located in the vicinity of Carmel Church, VA, which will connect to a new distribution system as well as to parts of the existing distribution system. The withdrawal is used for municipal water supply. Permitted activities shall be conducted as described in the Joint Permit Application

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dated March 24, 2020, received on March 27, 2020, and supplemental materials, revisions and clarifications received through May 20, 2025.

The Permittee's authorized water withdrawal shall not exceed:

1,832	Million gallons per year,
237	Million gallons per month,
9.0	Million gallons per day,
7.0	Million gallons per day upon declaration of a drought warning.
6.0	Million gallons per day upon declaration of a drought emergency.

The permitted withdrawal will be used to provide a municipal public water supply. Other uses are not authorized by this permit.

The permitted activity shall be in accordance with this Permit Cover Page, Part I - Special Conditions, and Part II - General Conditions.

Bryant Thomas
Interim Director, Water Division

Date

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Part I – Special Conditions

A. Authorized Activities

1. This permit authorizes the construction of a new surface water intake, pump station, raw water pipeline, finished water pipeline connecting to the distribution system, water treatment plant, and surface water withdrawals from the Rappahannock River for public water supply.

2. This permit authorizes the total impact to 0.76 acres of surface waters, consisting of 0.06 acres of permanent impacts and 0.70 acres of temporary impacts as indicated below.

    a. Permanent impacts consist of 50 linear feet of stream.
    b. Conversion impacts consist of 0.03 acres of wetland impacts, conversion from forested to non-forested.
    c. Temporary impacts consist of 466 linear feet of stream and 0.45 acres of wetlands.
    d. Authorized surface water impacts described under this condition shall be as depicted on the impacts map[1] dated September 12, 2023, and the Narrative Description of Proposed Impacts dated October 19, 2023[2].

3. The permittee shall conduct authorized activities as described in the Joint Permit Application and supplemental materials, revisions, and clarifications. Any changes to the authorized activities or impacts map that affect permitted areas shall be submitted to the Department immediately upon determination that changes are necessary, and Department approval shall be required prior to implementing the changes.

4. The permit authorizes the temporary use of mechanical equipment in surface waters in accordance with all applicable permit conditions.

5. The permittee shall notify the Department of any changes in authorized impacts to surface waters, of any modifications of the intake structure, or any changes to the design or type of construction activities in surface waters authorized by this permit. Department approval shall be required prior to implementing the changes. Any additional impacts, modifications, or changes shall be subject to individual permit review or modification of this permit.

B. Permit Term

1. This permit is valid for fifteen (15) years from the date of issuance. A new permit may be necessary for the continuance of the authorized activities, including water withdrawals, or any permit requirement that has not been completed, including compensation provisions.

2. The permittee shall submit a new permit application at least 270 calendar days prior to the expiration of this permit if reissuance will be requested.

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[1] Refer to the 4th Additional Information Response – Appendix G – Project Drawings, dated September 12, 2023.
[2] Refer to the 5th Additional Information Response – Appendix I – Narrative of Proposed Impacts, dated October 10, 2023.

C. Standard Project Conditions

1. This permit does not constitute, convey, or imply authority to any permittee to unlawfully or incidentally take any threatened or endangered species that are protected by Virginia laws or regulations, pursuant to § 3.2-1000 through -1011; § 29.1-563 through -570; and 4VAC15-20 *et seq*. In accordance with recommendations from the Virginia Department of Wildlife Resources (DWR), the permittee shall comply with the following Time-of-Year Restriction (TOYR) and shall complete a mussel survey prior to performing instream work as specified below:

    a. Instream work in the Rappahannock River necessary to install the intake and/or associated infrastructure shall adhere to a TOYR and shall not be conducted from February 15th through June 30th and August 1st through November 15th of any year for the protection of the Atlantic Sturgeon and the Confirmed Anadromous Fish Use Area at the project site.

    b. Instream work in the Rappahannock River shall also adhere to a TOYR from April 15th through June 15th and August 15th through September 30th due to the presence of freshwater mussels.

    c. The permittee shall perform a mussel survey and relocation, per the Virginia Department of Wildlife Resources (DWR) and the U.S. Fish and Wildlife Service (USFWS) approved Freshwater Mussel Guidelines of Virginia, prior to commencing work.

        i. All work at stream crossing impact sites not listed in the final Freshwater Mussel Guidelines for Virginia shall occur when the stream is not flowing or behind cofferdams. No flow "dry" conditions can be naturally occurring (seasonal break in flow) or created through the installation of cofferdams or similar techniques to isolate the impact site.

        ii. Each mussel survey shall be performed from 100 meters upstream through 400 meters downstream of the impact area of the proposed Rappahannock River intake location. The survey shall be performed by a qualified, permitted biologist, no more than six months prior to the start of construction. Each survey shall be performed by a qualified, permitted biologist and conducted in accordance with DWR and U.S. Fish and Wildlife Services (USFWS) draft Freshwater Mussel Guidelines for Virginia dated November 16, 2018, or as amended.

        iii. The permittee shall submit a report, or reports, summarizing the results of each mussel survey to DWR and the Department for review and approval. The agencies shall review all of the surveys completed for impact areas. Based upon the results, DWR will provide final recommendations regarding the protection of listed species known from the area. The recommendations may include relocations of documented listed species, and/or requests for adherence to TOYR at sites not currently listed in Part I.C.1 and Part I.C.2. If mussel relocations are necessary, the Permittee shall coordinate with DWR and the USFWS. Mussel relocations shall be conducted in accordance with the DWR, and USFWS draft Freshwater Mussel Guidelines for Virginia dated November 16, 2018, or as amended.

    d. The permittee shall coordinate with the USFWS regarding potential impacts upon federally Endangered northern long-eared bats associated with and prior to any tree removal. The

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permittee shall comply with the following Time-of-Year Restriction (TOYR): No tree clearing shall occur from April 1 – November 14[3] of any year, in order to protect the Northern Long-Eared Bat (*Myotis septentrionalis*), a species listed as Threatened under the Federal Endangered Species Act. The permittee may elect to perform a survey, in accordance with the FWS Bat Survey Guidelines [4]for the Northern Long-Eared Bat within the project boundary and coordinate results with the U.S. Fish and Wildlife Service. Should the survey document the absence of the species within the project boundary and upon review and approval from the Department the TOYR may be removed.

2. Wells within a 1,000-foot radius from the project area shall be marked per Virginia Department of Health (VDH) standards to protect the wells from potential damage.

3. The activities authorized by this permit shall be executed in such a manner that any impacts to beneficial uses are minimized. As defined in § 62.1-44.3 of the Code of Virginia, "beneficial use" means both instream and off stream uses. Instream beneficial uses include, but are not limited to, the protection of fish and wildlife habitat, maintenance of waste assimilation, recreation, navigation, and cultural and aesthetic values. The preservation of instream flows for purposes of the protection of navigation, maintenance of waste assimilation capacity, the protection of fish and wildlife resources and habitat, recreation, cultural and aesthetic values is an instream beneficial use of Virginia's waters. Off stream beneficial uses include, but are not limited to, domestic (including public water supply), agricultural uses, electric power generation, commercial, and industrial uses.

4. No activity shall substantially disrupt the movement of aquatic life indigenous to the water body, including those species which normally migrate through the area, unless the primary purpose of the activity is to impound water.

5. Flows downstream of the project area shall be maintained to protect all uses.

6. No activity shall cause more than a minimal adverse effect on navigation, and no activity shall block more than half of the width of the stream at any given time.

7. The activity shall not impede the passage of normal or expected high flows, and any associated structure shall withstand expected high flows.

8. All required notifications, reports, and submittals shall include project name and permit number and be submitted electronically to withdrawal.permitting@deq.virginia.gov. Alternatively, they can be mailed to the office stated below, unless otherwise directed in writing by the Department subsequent to the issuance of this permit: Department of Environmental Quality, Attn: Water Permitting Division, P.O. Box 1105, Richmond VA 23218.

9. All reports required by this permit and other information requested by the Department shall be signed by the permittee or a person acting in the permittee's behalf, with the authority to bind the permittee. A person is a duly authorized representative only if *both* criteria below are met. If a representative authorization is no longer valid because of a change in responsibility for the overall operation of the facility, a new authorization shall be immediately submitted to the Department.

[3] Refer to the Appendix P – The Department of Wildlife Resources Time of Year Restrictions and Other Recommendations Guidance, dated September 29, 2023.
[4] Refer to Appendix Q – The U.S. Fish and Wildlife Service Bat Survey Guidelines, dated March 2024.

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a. The authorization is made in writing by the permittee.

b. The authorization specifies either an individual or a position having responsibility for the overall operation of the regulated facility or activity, such as the position of plant manager, superintendent, or position of equivalent responsibility. A duly authorized representative may thus be either a named individual or any individual occupying a named position.

10. All submittals shall contain the following signed certification statement:

"I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

11. Any fish kills or spills of fuels or oils shall be reported to the Department immediately upon discovery at (804) 396-0150 or https://portal.deq.virginia.gov/v2/prep/search. If the Department cannot be reached, the spill or fish kill shall be reported to the Virginia Department of Emergency Management (VDEM) at 1-800-468-8892 or the National Response Center (NRC) at 1-800-424-8802. Any spill of oil as defined in § 62.1-44.34:14 of the Code of Virginia that is less than 25 gallons and that reaches, or that is expected to reach, land only is not reportable, if recorded per § 62.1-44.34:19.2 of the Code of Virginia and if properly cleaned up.

12. The Department shall be notified in writing within 24 hours or as soon as possible on the next business day when potential environmentally threatening conditions are encountered which require debris removal or involve potentially toxic substances. Measures to remove the obstruction, material, or toxic substance or to change the location of any structure are prohibited until approved by the Department.

13. Virginia Water Quality Standards shall not be violated in any surface waters as a result of the project activities.

14. Continuous flow of perennial springs shall be maintained by the installation of spring boxes, French drains, or other similar structures.

15. All excavation, dredging, or filling in surface waters shall be accomplished in a manner that minimizes bottom disturbance and turbidity.

16. All in-stream activities shall be conducted during low-flow conditions whenever practicable.

17. Erosion and sedimentation controls shall be designed in accordance with the Virginia Erosion and Stormwater Management Regulation, 9VAC25-875.

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18. All construction, construction access, and demolition activities associated with this project shall be accomplished in a manner that minimizes construction materials or waste materials from entering surface waters, unless authorized by this permit. Wet, excess, or waste concrete shall be prohibited from entering surface waters.

19. All fill material placed in surface waters shall be clean and free of contaminants in toxic concentrations or amounts in accordance with all applicable laws and regulations.

20. Measures shall be employed at all times to prevent and contain spills of fuels, lubricants, or other pollutants into surface waters.

21. Machinery or heavy equipment in temporarily impacted wetlands shall be placed on mats or geotextile fabric, or other suitable means shall be implemented, to minimize soil disturbance to the maximum extent practical. Mats, fabrics, or other measures shall be removed as soon as the work is complete in the temporarily impacted wetland.

22. Stream channel restoration activities shall be conducted in the dry or during low flow conditions. When site conditions prohibit access from the streambank or upon prior authorization from the Department of Environmental Quality, heavy equipment may be authorized for use within the stream channel. The equipment shall be stationed on cobble bars.

23. Temporary disturbances to wetlands, stream channels, and/or stream banks during project construction activities shall be avoided and minimized to the maximum extent practicable.

24. All temporarily disturbed wetland areas shall be restored to preconstruction conditions within 30 calendar days of completing work in the areas, which shall include reestablishing pre-construction contours, and planting or seeding with appropriate wetland vegetation according to cover type (emergent, scrub/shrub, or forested), except for invasive species identified on the Department of Conservation and Recreation's (DCR's) Virginia Invasive Plant Species List. The permittee shall take all appropriate measures to promote and maintain the revegetation of temporarily disturbed surface waters through the second-year post-disturbance.

25. All temporarily impacted streams and stream banks shall be restored to their original elevations and contours within 30 calendar days following the construction at that stream segment, and the banks shall be seeded or planted with the same vegetative cover type originally present along the banks, including supplemental erosion control grasses if necessary but not including invasive species identified on DCR's Virginia Invasive Plant Species List. The permittee shall take all appropriate measures to promote and maintain the revegetation of temporarily disturbed surface waters through the second-year post-disturbance.

26. All materials (including fill, construction debris, excavated materials, and woody materials, that are temporarily placed in wetlands, in stream channels, or on stream banks) shall be placed on mats or geotextile fabric, shall be immediately stabilized to prevent the material or leachate from entering surface waters, and shall be entirely removed within 30 calendar days following completion of that construction activity. After removal, disturbed areas shall be returned to original contours, shall be stabilized, and shall be restored to the original vegetated state within 30 calendar days. The permittee shall take all appropriate measures to promote and maintain the revegetation of temporarily disturbed surface waters through the second-year post-disturbance.

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27. Temporary instream construction features such as cofferdams shall be made of non-erodible materials.

28. All non-impacted surface waters that are within the project or right-of-way limits, and that are within fifty feet of any project activities, shall be clearly flagged or demarcated for the life of the construction activity within that area. The permittee shall notify all contractors and subcontractors that no activities are to occur in these marked areas.

D. Surface Water Withdrawals

1. Surface water withdrawn from Rappahannock River and authorized under this permit is to be used for public water supply.

2. Except as specified in Part I.D.5, the withdrawal of water from Rappahannock River shall not exceed the following:

    a. A maximum daily withdrawal of 9.0 (Mgal/d);

    b. A maximum daily withdrawal upon drought warning declaration of 7.0 (Mgal/d);

    c. A maximum daily withdrawal upon an emergency drought declaration of 6.0 (Mgal/d);

    d. A maximum monthly withdrawal of 237 (Mgal); and

    e. A maximum annual withdrawal of 1,862 (Mgal).

3. The permittee shall install intake screens with openings no larger than one millimeter in width and height for mesh screens or a slot size of one millimeter in width for wedge-wire screens. The permittee shall ensure that the maximum approach velocity as measured by six inches or closer across the entire screen and does not exceed 0.25 feet per second.

4. The permittee shall submit a Drought Management Plan to the Department for review and approval within 180 days before the commencement of withdrawal. Any revisions to the approved plan shall be submitted to the Department for review and approval prior to implementing the change. The plan shall include, at a minimum, the following:

    a. Development of drought stages including when and how each stage will be implemented; and,

    b. Description of the conservation measures to be implemented during each drought stage.

5. When a drought is declared in the Northern Coastal Plain Drought Evaluation Region or by Caroline County in accordance with the County's Drought Management Ordinance, the permittee shall implement either the provisions directed by the Commonwealth, the Drought Management Ordinance or the voluntary or mandatory conservation measures as detailed in *Attachment A* of this permit, whichever is the most restrictive. The permittee shall be responsible for determining when droughts are declared. The permittee shall retain records documenting voluntary or mandatory conservation measures implemented during any declared drought period.

    Upon declaration of a drought watch, warning, or emergency within the Northern Coastal Plain drought evaluation region, or Caroline County; including the Towns of Bowling Green and Port Royal, the following conditions shall be implemented.

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a. The maximum daily volume withdrawn from the Rappahannock River shall not exceed 7.0 Mgal/d during a declared drought warning.

b. The maximum daily volume withdrawn from the Rappahannock River shall not exceed 6.0 Mgal/d during a declared drought emergency.

c. The authorized monthly withdrawal limit as authorized by Part I.D.2.c.

d. The Permittee shall provide weekly reports including the volume of water withdrawals from the Rappahannock River, and any voluntary or mandatory conservation measures implemented. Reports are to be submitted to the Department each Monday during a declared drought period, including any week where a drought declaration is lifted or reduced in declaration stage. The report shall include the following information:

i. The permittee's name and address;

ii. The permit number;

iii. The source(s) from which water is withdrawn;

iv. The location (latitude and longitude) of each point of water withdrawal;

v. Information listed in Part I.E.2;

vi. The daily volume of water withdrawn from the Rappahannock River (million gallons per day);

vii. The cumulative volume (million gallons) of water withdrawn each month and for the calendar year;

viii. The maximum daily volume (million gallons per day) of water withdrawn as calculated on the last day of the monitoring period;

ix. In the last report for the calendar year, the largest single day withdrawal volume (million gallons) that occurred in the year and the month in which it occurred; and,

x. The method of measuring each withdrawal.

6. The Permittee shall complete a study on the feasibility of reducing or eliminating the transfer of inter-basin flows and returning wastewater to the Rappahannock River Basin. The study and results of the study shall be submitted to the Department for review and approval within five years of permit issuance (DATE). The study shall include an implementation plan and schedule for any identified feasible alternative.

E. Water Withdrawal Monitoring, Recordation and Reporting Conditions

1. At least 120 days (DATE) before the commencement of withdrawal, the Permittee shall submit a *Monitoring and Operations Plan* for Department review and approval. Once approved, the plan shall be incorporated by reference and become an enforceable part of this permit. At a minimum, the plan shall include the following:

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a. Procedures for operating the intake to ensure compliance with all water withdrawal conditions of this permit; and

b. Procedures for recording withdrawals as well as all other monitoring and reporting requirements in Part I.E, including a sample of the reporting form or table that will be used.

2. On each day that a withdrawal occurs, the permittee must monitor and record the following, for each pump:

a. Date and time; and

b. Total amount of water withdrawn each day.

3. The permittee shall monitor withdrawals from the Rappahannock River on a daily basis using flow totalizer technology to confirm that the withdrawals are in compliance with this permit. Such meters shall produce volume determinations within plus or minus 10% of actual flows. A defective meter or other device must be repaired or replaced within 60 days. A defective meter is not grounds for not reporting the withdrawals. During any period when a meter is defective, generally accepted engineering practice shall be used to estimate withdrawals and the period during which the meter was defective must be clearly identified in the report.

4. The permittee shall report any withdrawal not in compliance with Parts I.D.2 by the fifth (5th) day of the month following the month in which the withdrawal or release occurred.

5. The permittee shall submit a water withdrawal monitoring report to the Department semi-annually. The semi-annual monitoring period shall be as follows: January through June and July through December. The daily records shall be tabulated by month. The report shall be submitted to the Department by February 10th and August 10th of every year within the permit term. The report shall include the following information:

a. The permittee's name and address

b. The permit number

c. The source(s) from which water is withdrawn

d. The location (latitude and longitude) of each point of water withdrawal

e. Information listed in Part I.E.2

f. The daily volume of water withdrawn from the Rappahannock River (million gallons per day)

g. The cumulative volume (million gallons) of water withdrawn each month and for the calendar year

h. The maximum daily volume (million gallons per day) of water withdrawn as calculated on the last day of the monitoring period

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i. In the last report for the calendar year, the largest single day withdrawal volume (million gallons) that occurred in the year and the month in which it occurred

j. The method of measuring each withdrawal

k. If during a semi-annual reporting period a drought warning or emergency is declared, the report shall include a summary of any voluntary or mandatory conservation measures implemented during the drought event.

6. Water withdrawal monitoring and reporting activities shall comply with this section, Part I.C, and Part II. All records and information that result from the monitoring and reporting activities required by this permit, including any records of maintenance activities to the withdrawal system, shall be retained for the life of the permit. This period of retention shall be extended automatically during the course of any unresolved litigation regarding the regulated activity or as requested by the Department.

F. Water Loss Auditing

1. By *DATE* the Permittee shall submit a Water Loss Auditing Plan in accordance with the American Water Works Association (AWWA) methodology using the most recent version of the AWWA Water Audit Software or another Department approved methodology to estimate water loss for Department review and approval. Once approved, the plan shall be incorporated by reference and become an enforceable part of this permit.

2. The permittee shall conduct annual water loss audits based on the approved Water Loss Auditing Plan and develop an annual comprehensive report. By MMDD, 2026, the permittee shall notify the Department that the water loss audit has been initiated. This document shall include activities completed or initiated since submission of the plan.

3. The first Water Loss Audit Report shall be submitted to the Department by the end of the fourth year of permit issuance (DATE, 2029). Thereafter, the Permittee shall report the results of the annual water loss audits in a report submitted at a minimum of every three years.

G. Leak Detection and Repair

1. The Permittee shall submit a Leak Detection and Repair Plan to the Department for review and approval by DATE. Once approved, the plan shall be incorporated by reference and become an enforceable part of this permit. The plan shall indicate how its implementation will be informed by the results of the annual water loss audits. The plan shall include:

a. A description of how the water loss audit results is expected to inform prioritization of actions to address water losses.

b. Where practicable, a process for the identification of equipment needs to quantify and reduce water losses.

c. A description of the plan's effectiveness in addressing water loss, including revisions to those elements of the Annual Water Loss Audit process that can be improved over the short and long term.

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2. The first Leak Detection Repair Plan shall be submitted to the Department by the end of the fourth year of permit issuance (DATE, 2029). Thereafter, the Permittee shall report the results of the annual water loss audits in a report submitted at a minimum of every three years.

H. Stream Modifications, Including Intake/Outfall Structures

1. Redistribution of existing stream substrate for erosion control purposes is prohibited.

2. Material removed from the stream bottom shall not be deposited into surface waters unless otherwise authorized in this permit.

3. Riprap apron for all outfalls shall be designed in accordance with Virginia Erosion and Stormwater Management Regulation, 9VAC25-875.

4. For streambank protection activities, structures and backfill shall be placed as close to the streambank as practical, while still avoiding and minimizing impacts to surface waters to the maximum extent practical. No material shall be placed in excess of the minimum necessary for erosion protection.

5. Asphalt and materials containing asphalt or other toxic substances shall not be used in the construction of submerged sills, breakwaters, dams, or weirs.

6. Any outfall structure shall be constructed and maintained to prevent downstream sediment deposition, erosion, or scour that may be associated with normal flow and any expected storm flows. Construction shall include the use of an appropriately sized riprap outlet protection apron at the outfall site.

I. Installation of Utilities

1. All utility line work in surface waters shall be performed in a manner that minimizes disturbance in each area. Temporarily disturbed surface waters shall be restored in accordance with Part I.C.22, C.23, and C.24, unless otherwise authorized by this permit.

2. Material resulting from trench excavation may be temporarily side cast into wetlands not to exceed a total of 90 calendar days, provided the material is not placed in a manner such that it is dispersed by currents or other forces.

3. The trench for a utility line cannot be constructed in a manner that drains wetlands (e.g., backfilling with extensive gravel layers creating a French drain effect).

J. Road Crossings

1. Access roads authorized by this permit shall be constructed to minimize the adverse effects on surface waters to the maximum extent practicable and to follow as near as possible pre-construction contours and elevations.

2. Installation of pipes and road crossings shall occur in the dry via the implementation of cofferdams, sheet piling, stream diversions or other similar structures.

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3. All surface waters temporarily affected by a road crossing shall be restored to their original elevations immediately following the removal of that particular temporary crossing. Temporary access roads shall be removed entirely following activity completion.

K. Project Construction Monitoring and Submittals (Impact Sites)

1. The permittee shall submit written notification at least **ten (10) calendar days** prior to the initiation of land disturbance or construction activities in permitted areas. The notification shall include preconstruction photographs, and a projected schedule for initiating and completing work at each permitted impact area.

    a. Pre-construction photographs shall be taken at each impact area prior to initiation of activities within impact areas.

    b. Photographs shall depict the impact area and the nonimpacted surface waters immediately adjacent to and downgradient of each impact area.

    c. Each photograph shall be labeled to include the following information: permit number, impact area number, date and time of the photograph, name of the person taking the photograph, photograph orientation, and photograph subject description.

2. Site inspections shall be conducted **once every calendar month** and recorded on the *Monthly VWP Permit Inspection Checklist* (*Attachment C)* by the permittee or by the permittee's qualified designee during active construction within authorized surface water impact areas. Monthly inspections shall be conducted in the following areas: all authorized permanent and temporary impact areas; all avoided surface waters, including wetlands, stream channels, and open water; surface water areas within 50 feet of any land disturbing activity; and all on-site areas designated for permanent preservation. The *Monthly VWP Permit Inspection Checklist* (*Attachment C)* shall be completed in its entirety for each monthly inspection and shall be kept on-site and made available for review by Department staff upon request during normal business hours.

3. The *VWP Permit Construction Status Update Form* (*Attachment B)* enclosed with this permit shall be completed in June and December of every year for the duration of this permit. The *VWP Permit Construction Status Update Form* (*Attachment B)* shall include reference to the VWP permit authorization number and one of the following statements for each authorized surface water impact location:

    a. Construction activities not yet started;

    b. Construction activities started;

    c. Construction activities started but are currently inactive, or;

    d. Construction activities complete.

4. The VWP Permit Construction Status Update Form (Attachment B) shall be submitted and must be received by the Department no later than January 10 and July 10 of every year.

5. The permittee shall notify the Department within 24 hours of discovering impacts to surface waters including wetlands, stream channels, and open water that are not authorized by this permit. The

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notification shall include photographs, estimated acreage and/or linear footage of impacts, and a description of the impacts.

6. The permittee shall submit a written notification of completion within 30 calendar days after the completion of all activities in all permitted impact areas authorized under this permit.

L. Compensatory Mitigation

1. All temporarily disturbed wetland areas shall be restored to preconstruction conditions within 30 calendar days of completing work in the areas, which shall include re-establishing pre-construction contours, and planting or seeding with appropriate wetland vegetation according to cover type (emergent, scrub/shrub, or forested), except for invasive species identified on the Department of Conservation and Recreation Invasive Alien Plant Species of Virginia list. The permittee shall take all appropriate measures to promote and maintain the revegetation of temporarily disturbed wetlands for a minimum of two years after the area is restored.

2. All temporarily impacted streams and stream banks shall be restored to their original elevations and contours within 30 calendar days following the construction at that stream segment, and the banks shall be seeded or planted with the same vegetative cover type originally present along the banks, including supplemental erosion control grasses if necessary but not including invasive species identified on the Department of Conservation and Recreation Invasive Alien Plant Species of Virginia list. The permittee shall take all appropriate measures to promote and maintain the revegetation of temporarily disturbed streams and stream banks for a minimum of two years after the area is restored.

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Part II – General Conditions

A. Duty to Comply

The permittee shall comply with all conditions and limitations of the VWP permit. Nothing in this chapter shall be construed to relieve the permittee of the duty to comply with all applicable federal and state statutes, regulations, toxic standards, and prohibitions. Any VWP permit violation, or noncompliance is a violation of the Clean Water Act and State Water Control Law and is grounds for enforcement action, VWP permit termination, VWP permit revocation, VWP permit modification, or denial of an application for a VWP permit extension or reissuance.

Nothing in this VWP permit shall be construed to relieve the permittee from civil and criminal penalties for noncompliance.

B. Duty to Cease or Confine Activity

It shall not be a defense for a permittee in an enforcement action that it would have been necessary to halt or reduce the activity for which a VWP permit has been granted in order to maintain compliance with the conditions of the VWP permit.

C. Duty to Mitigate

The permittee shall take all reasonable steps to minimize or prevent any impacts in violation of the VWP permit that may have a reasonable likelihood of adversely affecting human health or the environment.

D. VWP Permit Actions

A VWP permit may be modified in whole or in part, revoked and reissued, extended, transferred, or terminated in accordance with 9VAC25-210-180 of the Virginia Administrative Code.

1. During the drafting and authorization of a permit modification, only those conditions to be modified shall be addressed with preparing a draft modified permit. VWP permit terms and conditions of the existing permit shall remain in full force and effect during the modification of the permit.

2. This VWP permit may be modified upon the request of the permittee or upon department initiative when any of the following developments occur:
    a. When new information becomes available about the project or activity covered by the VWP permit, including project additions or alterations, that was not available at VWP permit issuance and would have justified the application of different VWP permit conditions at the time of VWP permit issuance;
    b. When a change is made in the promulgated standards or regulations on which the VWP permit was based;
    c. When changes occur that are subject to "reopener clauses" in the VWP permit; or

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d. When developments applicable to surface water withdrawals occur as specified in 9VAC25-210-380 of the Virginia Administrative Code.

3. When this VWP permit authorizes surface water withdrawals, it may be modified when any of the following developments occur:

   a. When the department determines that minimum instream flow levels resulting directly from the permittee's withdrawal of surface water are detrimental to the instream beneficial use, existing at the time of permit issuance, and the withdrawal of surface water should be subject to further net limitations or when an area is declared a surface water management area pursuant to §§ 62.1-242 through 62.1-253 of the Code of Virginia, during the term of the VWP permit.

   b. Significant changes to the location of the surface water withdrawal system are proposed such that the Department of Environmental Quality determines a new review is warranted due to the potential effect of the surface water withdrawal to existing beneficial uses of the new location.

   c. Changes to the permitted project or the surface water withdrawal, including increasing the storage capacity for the surface water withdrawal, that propose an increase in the maximum permitted withdrawal volumes or rate of withdrawal or that cause more than a minimal change to the instream flow requirements with potential to result in a detrimental effect to existing beneficial uses.

   d. A revision to the purpose of the surface water withdrawal that proposes to include a new use or uses that were not identified in the permit application or a modification of the existing authorized use or uses such that the use description in the permit application and permit is no longer applicable. Examples of uses include, but are not limited to agricultural irrigation, golf course irrigation, public water supply, manufacturing, and electricity generation.

4. When the permittee has submitted a timely and complete application for reissuance of an existing VWP individual permit, but through no fault of the permittee, the department does not reissue or reissue with conditions a VWP individual permit or the department does not provide notice of its tentative decision to deny the application before an existing VWP individual permit expires, the conditions of the expiring VWP individual permit shall be administratively continued in full force and effect until the effective date of a reissued permit or the date on which the department denies the application. Timely application shall be a minimum of 180 days for an individual permit or a minimum of 270 days for an individual permit for a surface water withdrawal, unless otherwise specified in the existing permit.

5. Any permittee desiring to continue a previously permitted activity after the expiration date of this VWP permit shall apply for and obtain a new permit or, if applicable, shall request an extension in accordance with 9VAC25-210-180 of the Virginia Administrative Code. Any permittee with an effective VWP permit for an activity that is expected to continue after the expiration date of the VWP permit, without any change in the activity authorized by the VWP permit other than as may be allowed under 9VAC25-210-180, shall submit written notification requesting an extension. The permittee must file the request 90 days prior to the expiration date of the VWP permit. VWP permit modifications shall not be used to extend the term of a VWP permit beyond 15 years from the date of original issuance. When a permit term, other than that of an Emergency Virginia Water

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Protection Permit, is less than 15 years, an extension of the permit terms and conditions may be granted in accordance with 9VAC25-210-180. Emergency Virginia Water Protection Permits shall not exceed a duration of one year or shall expire upon the issuance of a regular Virginia Water Protection Permit, whichever comes first.

6. This VWP permit may be transferred to a new permittee only by modification to reflect the transfer, by revoking and reissuing the permit, or by automatic transfer. Automatic transfer to a new permittee shall occur if the current permittee: a) Notifies the department of the proposed transfer of the permit and provides a written agreement between the current and proposed permittees containing the date of transfer of VWP permit responsibility, authorization, and liability to the new permittee; and b) the department does not within 15 days notify the existing permittee of its intent to modify the VWP permit.

7. After notice and opportunity for a formal hearing pursuant to § 62.1-44.15:02 of the Code of Virginia, a VWP permit can be terminated for cause. Reasons for termination for cause are as follows:

   a. Noncompliance by the permittee with any condition of the VWP permit;

   b. The permittee's failure in the application or during the VWP permit process to disclose fully all relevant facts or the permittee's misrepresentation of any relevant facts at any time;

   c. The permittee's violation of a special or judicial order;

   d. A determination by the department that the permitted activity endangers human health or the environment and can be regulated to acceptable levels by VWP permit modification or termination;

   e. A change in any condition that requires either a temporary or permanent reduction or elimination of any activity controlled by the VWP permit; and

   f. A determination that the permitted activity has ceased and that the compensation for unavoidable adverse impacts has been successfully completed.

8. The department may terminate this permit without cause when the permittee is no longer a legal entity due to death, dissolution, or when a company is no longer authorized to conduct business in the Commonwealth. The termination shall be effective 30 days after notice of the proposed termination is sent to the last known address of the permittee or registered agent, unless the permittee objects within that time. If the permittee does object during that period, the department shall follow the applicable procedures for termination under § 62.1-44.15:25 of the Code of Virginia and 9VAC25-230 of the Virginia Administrative Code.
9. This VWP permit may be terminated by consent, as initiated by the permittee. The permittee shall submit a request for termination by consent within 30 days of completing or canceling all permitted activities and all required compensatory mitigation requirements. When submitted for project completion, the request for termination by consent shall constitute a notice of project completion. The director may accept this termination on behalf of the department. The permittee shall submit the following information:

   a. Name, mailing address, and telephone number;

   b. Name and location of the activity;

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c. The VWP permit number; and

d. One of the following certifications:

i. For project completion: "I certify under penalty of law that all activities and any required compensatory mitigation authorized by a VWP permit have been completed. I understand that by submitting this notice of termination that I am no longer authorized to perform activities in surface waters in accordance with the VWP permit, and that performing activities in surface waters is unlawful where the activity is not authorized by a VWP permit, unless otherwise excluded from obtaining a permit. I also understand that the submittal of this notice does not release me from liability for any violations of this VWP permit."

ii. For project cancellation: "I certify under penalty of law that the activities and any required compensatory mitigation authorized by this VWP permit will not occur. I understand that by submitting this notice of termination that I am no longer authorized to perform activities in surface waters in accordance with the VWP permit, and that performing activities in surface waters is unlawful where the activity is not authorized by a VWP permit, unless otherwise excluded from obtaining a permit. I also understand that the submittal of this notice does not release me from liability for any violations of this VWP permit, nor does it allow me to resume the permitted activities without reapplication and issuance of another permit."

iii. For events beyond permittee control, the permittee shall provide a detailed explanation of the events, to be approved by DEQ, and the following certification statement: "I certify under penalty of law that the activities or the required compensatory mitigation authorized by this VWP permit have changed as the result of events beyond my control (see attached). I understand that by submitting this notice of termination that I am no longer authorized to perform activities in surface waters in accordance with the VWP permit, and that performing activities in surface waters is unlawful where the activity is not authorized by a VWP permit, unless otherwise excluded from obtaining a permit. I also understand that the submittal of this notice does not release me from liability for any violations of this VWP permit, nor does it allow me to resume the permitted activities without reapplication and issuance of another permit.

E. Inspection and Entry

Upon presentation of credentials, the permittee shall allow the department or any duly authorized agent of the department, at reasonable times and under reasonable circumstances, to conduct the actions listed in this section. For the purpose of this section, the time for inspection shall be deemed reasonable during regular business hours. Nothing contained herein shall make an inspection time unreasonable during an emergency.

1. Enter upon any permittee's property, public or private, and have access to, inspect and copy any records that must be kept as part of the VWP permit conditions;

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2. Inspect any facilities, operations or practices (including monitoring and control equipment) regulated or required under the VWP permit; and

3. Sample or monitor any substance, parameter, or activity for the purpose of ensuring compliance with the conditions of the VWP permit or as otherwise authorized by law.

F. Duty to Provide Information

The department may request (i) such plans, specifications, and other pertinent information as may be necessary to determine the effect of an applicant's discharge on the quality of state waters or (ii) such other information as may be necessary to accomplish the purposes of this chapter. Any owner, permittee, or person applying for a VWP permit or general permit coverage shall provide the information requested by the department.

G. Monitoring and Records Requirements

1. Monitoring of parameters, other than pollutants, shall be conducted according to approved analytical methods as specified in the VWP permit. Analysis of pollutants will be conducted according to 40 CFR Part 136 (2017), Guidelines Establishing Test Procedures for the Analysis of Pollutants.

2. Samples and measurements taken for the purpose of monitoring shall be representative of the monitored activity.

3. The permittee shall retain records of all monitoring information, including all calibration and maintenance records and all original strip chart or electronic recordings for continuous monitoring instrumentation, copies of all reports required by the VWP permit, and records of all data used to complete the application for the VWP permit, for a period of at least three years from the date of permit expiration. This period may be extended by request of the department at any time.

4. Records of monitoring information shall include:

   a. The date, exact place and time of sampling or measurements;
   b. The name of the individuals who performed the sampling or measurements;
   c. The date and time the analyses were performed;
   d. The name of the individuals who performed the analyses;
   e. The analytical techniques or methods supporting the information such as observations, readings, calculations and bench data used;
   f. The results of such analyses; and
   g. Chain of custody documentation.

H. Property rights

The issuance of a VWP permit does not convey any property rights in either real or personal property, or any exclusive privileges, nor does it authorize injury to private property or any invasion of personal rights or any infringement of federal, state or local laws or regulations.

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I. Reopener

This VWP permit may be reopened for the purpose of modifying the conditions of the VWP permit to meet new regulatory standards duly adopted by the board. Cause for reopening VWP permits includes but is not limited to when the circumstances on which the previous VWP permit was based have materially and substantially changed, or special studies conducted by the board or the permittee show material and substantial change, since the time the VWP permit was issued and thereby constitute cause for VWP permit modification or revocation and reissuance.

J. Compliance with State and Federal Law

As to the permitted activity(ies), compliance with a VWP permit constitutes compliance with the VWP permit requirements of the Law and regulations.

K. Severability

The provisions of this VWP permit are severable.

L. Oil and Hazardous Substance Liability

Nothing in this VWP permit shall be construed to preclude the institution of legal action or relieve the permittee from any responsibilities, liabilities, or penalties to which the permittee is or may be subject under § 311 of the Clean Water Act or §§ 62.1-44.34:14 through 62.1-44.34:23 of the State Water Control Law.

M. Unauthorized Discharge of Pollutants

Except in compliance with a VWP permit, unless the activity is otherwise exempted or excluded, no person shall dredge, fill, or discharge any pollutant into, or adjacent to surface waters; withdraw surface water; otherwise alter the physical, chemical, or biological properties of state waters regulated under this chapter and make them detrimental to the public health, to animal or aquatic life, or to the uses of such waters for domestic or industrial consumption, for recreation, or for other uses; excavate in wetlands; or on or after October 1, 2001, conduct the following activities in a wetland:

1. New activities to cause draining that significantly alters or degrades existing wetland acreage or functions;
2. Filling or dumping;
3. Permanent flooding or impounding; or
4. New activities that cause significant alteration or degradation of existing wetland acreage or functions.

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PERMIT DECISION RATIONALE
Virginia Water Protection Individual Permit No. 20-0514
Caroline County Rappahannock River Water Supply Project, Caroline County, Virginia

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This document provides pertinent information concerning the legal basis, scientific rationale, and justification for the issuance of the VWP permit listed below. The Department of Environmental Quality (Department or DEQ) has reviewed the application for the Virginia Water Protection (VWP) Individual Permit Number 20-0514 and has determined that the project qualifies for an individual permit. Based on the information provided in the application and in compliance with § 401 of the Clean Water Act as amended (33 USC 1341 et seq.) and the State Water Control Law and regulations, the Department has determined that there is a reasonable assurance that the activity authorized by this permit will protect instream beneficial uses, will not violate applicable water quality standards, and will not cause or contribute to significant impairment of state waters or fish and wildlife resources, provided the Permittee complies with all permit conditions. Surface water impacts have been avoided and minimized to the maximum extent practicable.

Approved:

_____
Bryant Thomas
Interim Director, Water Division

_____
Date

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The following details the application review process and summarizes relevant information for developing Part I - Special Conditions for permit issuance.

1. Contact Information:

Permittee/Legal Responsible Party

Caroline County Public Utilities
Attn: Joseph Schiebel
P.O. Box 424
Bowling Green, VA 22427
(804) 633-4390
jschiebel@co.caroline.va.us

Facility Location

Caroline County Rappahannock River Water Supply
19095 Tidewater Trail
Fredericksburg, VA 22408
(804) 633-4386

Agent Information

Roger Arnold, Hazen and Sawyer
1555 Roseneath Road
Richmond, VA 23230
(804) 266-1400
rarnold@hazenandsawyer.com

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2. Joint Permit Application Processing Dates:

The following details the timeframe and associated key dates of the permitting process:

1st Pre-Application Meeting Held	January 19, 2016
2nd Pre-Application Meeting Held:	May 20, 2019
Pre-Application Public Notice Issued:	October 17, 2019
Received Application:	March 27, 2020
Initial Request for Agency Coordination with: • Virginia Department of Health • Virginia Department of Historical Resources • Virginia Department of Wildlife Resources • Virginia Department of Conservation and Recreation • Virginia Marine Resource Commission • Virginia Institute of Marine Science • U.S. Fish and Wildlife Service • U.S. Environmental Protection Agency • U.S. Army Corps of Engineers • U.S. National Oceanic and Atmospheric Administration	April 17, 2020
Letters sent to Riparian Landowners:	April 17, 2020
Coordination with Tribal Nations:	April 27, 2020
1st Request for Additional Information Sent:	May 6, 2020
Permit Fee Deposited by Accounting:	May 21, 2020
Response to 1st Request for Additional Information Received:	June 8, 2020
Letters sent to Local Government(s):	November 13, 2020
2nd Request for Additional Information Sent:	September 29, 2021
Response to 2nd Request for Additional Information Received:	October 29, 2021
Virginia Institute of Marine Science Modeling Received:	February 14, 2023
3rd Request for Additional Information Sent:	February 23, 2023
Response to 3rd Request for Additional Information Received:	March 23, 2023
4th Request for Additional Information Sent:	July 12, 2023
Response to 4th Request for Additional Information Received:	September 12, 2023
5th Request for Additional Information Sent:	October 3, 2023
Response to 5th Request for Additional Information Received:	October 19, 2023
6th Request for Additional Information Sent:	December 15, 2023
Response to 6th Request for Additional Information Received:	January 16, 2024
Application Complete:	February 1, 2024
1st Draft Permit Package Issued:	March 13, 2024
2nd Draft Permit Package Issued:	April 11, 2024
Joint Publication with VMRC:	May 18, 2024
Public Notice Published in the Richmond Times-Dispatch:	May 18, 2024

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Public Notice Published in the Free Lance-Star:	May 18, 2024
End of 30-Day Public Comment Period:	June 18, 2024
Received Verification of Publication:	June 19, 2024
Public Notice for 1st Public Hearing Published in the Free Lance-Star:	August 25, 2024
Received Verification of Public Notice Publication for 1st Public Hearing:	August 25, 2024
DEQ's 1st Public Hearing Held:	September 25, 2024
7th Request for Additional Information Sent:	October 25, 2024
End of 1st 45-Day Public Comment Period:	October 25, 2024
Response to 7th Request for Additional Information Received:	December 20, 2024
8th Request for Additional Information Sent:	January 13, 2025
Response to 8th Request for Additional Information Received:	February 13, 2025
9th Request for Additional Information Sent:	March 12, 2025
Response to 9th Request for Additional Information Received:	May 12, 2025
Subsequent Response to 9th Request for Additional Information	May 20, 2025
3rd Draft Permit Package Issued:	June 16, 2025
4th Draft Permit Package Issued:	DATE
Public Notice for 2nd Public Hearing Published in the Free Lance-Star	DATE
Received Verification of Public Notice Publication for 2nd Public Hearing:	DATE
DEQ's 2nd Public Hearing Held:	DATE
End of 2nd 45-Day Public Comment Period:	DATE

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3. Project Location:

The proposed intake would be located on the south bank of the Rappahannock River along Route 17, with additional project infrastructure located throughout Caroline County. The proposed raw water pipeline connecting the intake to the proposed water treatment plant (WTP) is estimated to be 35 miles in length starting at the intake and located along the rights-of-ways of Route 17 (Tidewater Trail), Route 301 (AP Hill Boulevard), Route 207 (Rogers Clark Boulevard), and ending at the proposed WTP location on Gravel Hill Road off of Route 1 (Jefferson Davis Highway). The proposed water withdrawal would entail an interbasin transfer of withdrawals from the Rappahannock River to the Mattaponi River via two existing wastewater treatment plants discharging to the York River Basin as presented below.

Details on the proposed location of the intake and locations of return flows are presented below. Included are descriptive information of the river basin and sub-basin as well as details of the section, class and special standards of each location as contained in the Virginia Water Quality Standards (WQS) regulation (9VAC25-260).

Intake Location:

City/County:	Caroline County
Waterbody:	Rappahannock River
Basin:	Rappahannock River
Subbasin:	Lower Rappahannock River I
HUC:	Mount Creek-Rappahannock River – 02080104
U.S.G.S. Quadrangle:	Rappahannock Academy
State Watershed No:	RA49
WQS Section:	4
WQS Class:	II
Special Standards:	PWS, Chesapeake Bay, Coastal Zone Management (CZM)

Caroline County Inter Basin Transfer – Return Flow:

City/County:	Caroline County
Waterbody:	Polecat Creek
Basin:	York River
Subbasin:	Mattaponi
HUC:	020801050301
U.S.G.S. Quadrangle:	Ruther Glen No. 149 B
State Watershed No:	YO48
WQS Section:	03
WQS Class:	II
Special Standards:	None

Town of Bowling Green Inter Basin Transfer – Return Flow:

City/County:	Caroline County
Waterbody:	Mattaponi
Basin:	York River
Subbasin:	Mattaponi
HUC:	020801050205

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U.S.G.S. Quadrangle:	Bowling Green- 169D
State Watershed No:	YO47
WQS Section:	03
WQS Class:	II
Special Standards:	None

4. Project Description:

Project Purpose/Description

Caroline County Public Utilities proposes to develop a new public water supply system to supply Caroline County, the Town of Port Royal and the Town of Bowling Green with surface water from the Rappahannock River. The construction activities of the proposed project consist of the following: a raw water pump station and associated infrastructure: an intake structure located on the south bank of Rappahannock River: the installation of approximately 35 miles of water line for the transfer of raw water from the intake; a water treatment plant (WTP) located in the vicinity of Carmel Church, VA; a new finished water distribution system as well as utilizing parts of the existing distribution system. Each of these activities described below shall be constructed in accordance with the revised Project Design Plans received by the Department on September 9, 2023[1]:

A. Raw Water Intake:

The proposed raw water intake is located within the tidal freshwater portion of the Rappahannock River near the Moss Neck Community off of Route 17 in Caroline County, Virginia. Consistent with recommendations from the Department of Wildlife Resources, the intake's design will consist of cylindrical wedge-wire screens designed with one (1) millimeter (mm) openings and a maximum approach velocity of 0.25 feet per second (fps). The approach velocity is defined as the water velocity component perpendicular to the face of the screen, as measured by 6 inches or closer across the entire screen. In addition, the Department of Wildlife Resources recommends that a minimum 0.25 fps sweeping velocity should be considered in intake design. Sweeping velocity is defined as the water velocity component parallel to the face of the screen. The raw water intake will include a structure in the river to support the proposed screens. A temporary cofferdam for the purpose of dewatering is planned to be used during the construction of the intake.

B. Pump Station:

The proposed pump station will be located adjacent to the proposed raw water intake and will have the capacity to pump 13.90 Mgal/d.

C. Raw Water Distribution Line:

The proposed distribution line is approximately 35 miles long extending from the Rappahannock River between Pepmeir Hill Road and Burma Road to a site located west of Gravel Hill Road in Caroline County, Virginia. The project site runs parallel to portions of Route 17, Route 301, and Route 1. The installation of the water line will be constructed through a combination of open cut method and trenchless pipe installation methods. The Permittee shall submit to the Department

[1] Refer to Appendix G – *4th Additional Information Response – Project Drawings*, dated September 12, 2023.

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for review and approval the Final Construction Plans and Profile Drawings for the temporary and permanent impact sites identified in the Joint Permit Application[2] and the Preliminary Jurisdiction Determination dated August 28, 2020.

D. Water Treatment Plant:

The proposed WTP location is in Carmel Church, Virginia at the intersection between Route 1 and Gravel Hill Road. The site was chosen due to its proximity to the areas of new and existing development which were identified as primary growth areas in the 2010 Comprehensive Plan[3].

Two alternative future development scenarios were evaluated dependent upon the development of the Transit Oriented Development[4] during the 2027 and 2037 planning phases. The scenario that includes the development was chosen by the Applicant and the Department to estimate the water demands.

E. Treated Water Distribution Line:

The treated water distribution pipeline will be constructed within the same limits of disturbance as the proposed raw water intake for this project. There will be no additional area of disturbance or impacts associated with this finished water distribution pipeline. The distribution line runs parallel to the raw water distribution line and connects to the existing distribution line infrastructure.

Existing Water Supply System

Caroline County Public Utilities provides public water supply for Caroline County and the Town of Port Royal through the operation of three (3) water supply systems consisting of a total of fourteen (14) groundwater wells with an estimated total capacity of 1.36 Mgal/d. The Town of Bowling Green currently owns and operates one (1) water supply system consisting of three (3) groundwater wells with an estimated total capacity of 0.44 Mgal/d.

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[2] Refer to Appendix I – *5th Additional Information Response – Narrative Description of Proposed Impacts*, dated October 19, 2023.
[3] Refer to Chapter 8 of the 2011 Comprehensive Plan for more on Primary Growth Area's.
[4] Refer to Section 5 *Purpose of Water Use and Basis of Need* of the Permit Decision Rational.

Table 1: Existing Water Supply Systems – Groundwater Wells

Water Authority	System/Facility	Well Name
Caroline County	Milford Sanitary District (Groundwater Withdrawal Permit No. GWI000387)	Tower Well No. 1
		Milford 640 Well No. 2
	Highschool Poorhouse Tract (Groundwater Withdrawal Permit No. GWI000466)	High School Well No. 1
		Maintenance Shop Well No. 2
	Caroline County Central Water System (Ladysmith and Carmel Church Service Areas)	VSE Well No. 1
		VSE Well No. 2
		PETRO Well No. 4
		North Bound Well No. 2
		North Bound Well No. 3
		Econolodge Well No. 1
		Econolodge Well No. 2
		Days Inn Well No. 1
		Ladysmith Alliance Well
		Star Well
Town of Bowling Green	Town of Bowling Green Water System (Groundwater Withdrawal Permit No. GWI000471)	Chase Street Well No. 1A
		Cedar Drive Well No. 4
		West Broaddus Avenue Well No. 5

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5. Project Purpose & Need:

Purpose of Water Uses and Basis of Need

Pursuant to 9VAC25-210-360, the applicant shall demonstrate to the satisfaction of the Department that the project meets an established need for water to meet the project purpose. The purpose of the project is to establish a surface water withdrawal system to serve as the public water supply for Caroline County including residential and commercial uses. Subsequent to the first public hearing and comment period, the Applicant removed industrial cooling water demands from the requested withdrawal limits in additional information provided on December 20, 2024. Accordingly, industrial cooling uses are not authorized under this permit. Domestic public water supplies are an established off stream beneficial use of state waters as defined in §62.1-44.3 of the Code of Virginia.

Caroline County Public Utilities seeks to develop a new water supply source on the Rappahannock River that will include the construction of a new water intake, a raw water pump station, a raw water pipeline, a water treatment plant (WTP), and a finished water pipeline connecting the WTP to the County's existing distribution system. Water withdrawn from the Rappahannock River will be conveyed to consumers in Caroline County, the Town of Bowling Green, and the Town of Port Royal. Caroline County and the Town of Bowling Green have formed a partnership to address both service areas combined water supply needs. The Town of Bowling Green provided the Department with a letter of commitment on March 8, 2023, expressing what they identified as a critical need to partner with Caroline County and the proposed surface water withdrawal project.

As aforementioned, Caroline County and its regional partner's public water systems are entirely supplied by groundwater wells. The region has experienced significant declines in groundwater levels over the past two decades, thus stimulating the municipalities joint initiative to find an alternative water source to reduce their reliance on groundwater resources to meet the existing and future water demands.

The Department conducted a review of the applicant's analysis[5] for the projected water use and need for public water supply provided in the Joint Permit Application (JPA) which are summarized below:

A. Residential Uses and Need:

The water demand projections summarized in the Caroline County Water Master Plan and JPA were reviewed to determine the total water demand in for the water supply project. The Caroline County Water Master Plan included residential demand projections for scenarios with and without the Transit Oriented Development.

[5] Refer to Appendix F – *4th Additional Information Request Response – Summary of Water Demand Projections*, dated September 12, 2023, and Appendix K – *7th Additional Information Response – Updated Summary of Water Demand Projections*, dated December 20, 2024.

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Table 2: Weldon Cooper Regional Population Growth (2010-2020) & Projections (2030-2040)[6]

	Total Population*			
	2010	**2020**	**2030**	**2040**
Caroline County	28,545	31,020	32,753	36,588
	Percent Growth			
	2010-2020		**2020-2030**	**2030-2040**
Caroline County	9.02		5.59	11.71

*Encompasses Town of Bowling Green and the Town of Port Royal

Table 3: Caroline County 2016 Water Master Plan Population Projections

Year	2022	2027	2037	2047
Without TOD*	31,257	24,519	41,044	48,557
With TOD*	31,257	41,410	63,644	71,157

*TOD = Transit Oriented Development

B. Commercial Uses and Need:

The Commonwealth of Virginia is currently participating with the state of North Carolina and the federal government to study the feasibility of high-speed passenger service, between Washington, D.C. and Charlotte, N.C. The high-speed rail would serve as an extension of the presently available connections between Washington, D.C., and New York City. The proposed commuter rail project is planned to be built parallel with I-95.

Caroline County has demonstrated their commitment to the implementation of the Transit Oriented Development.[7] The mixed use project for the Carmel Church Community in Caroline County will be comprised of a commuter rail station (Amtrak), bus, bike, pedestrian and other potential forms of transport that the County believes will assist in the reduction of automobile traffic on I-95 coming from Central Virginia northward and reduce local and regional traffic growth.

The Caroline County Multimodal Transit-Oriented Development is a culmination of a larger historic planning process that includes a regional approach to meeting the growth and transportation needs of residents in the region, as well as a commitment by the Caroline County Board of Supervisors to lead the Community on a path of defined urban growth.

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[6] Reference: Weldon Cooper Center – VA Population Projections.
[7] Refer to Appendix J – *6th Additional Information Request Response – Transit Oriented Development Project Development*, dated January 16, 2024.

Water Need: Demand Projection

The Department authorizes water withdrawals to meet the justified water demands over the 15-year permit term. The Department evaluated the applicant's demand projections from the JPA and supplemental information.

The water demand projections in the County's 2016 Water Master Plan were developed by identifying areas of anticipated future development in lieu of a County-wide population increase. Each development area was assigned a development density based on future land use categorized as either residential, commercial, or industrial. The development density for each parcel was calculated based upon the size of each parcel, the percentage of developable land within the area, and a unit demand per acre estimate. In addition, the applicant applied a 5% increase from maximum day demand to account for water lost during treatment processing.

The Department evaluated Caroline County's requested water withdrawal demands by comparing the historical water use data reported to the Department for the existing water systems service areas and through the review of the applicant's projected demands for residential and commercial water use provided in the Joint Permit Application[8].

A. Residential Demand:

The Caroline County Comprehensive Plan, dated January 12, 2010, was used by the applicant to estimate the projected residential water demands for the proposed service area. Total residential water demand was calculated using the size of each growth area, a percentage of developable land within the area, a density of units based on anticipated zoning, a population growth rate of 2.61 per unit, and a daily water demand of 100 gallons per capita based on the Virginia Department of Health (VDH) Capacity Development Strategy guidance. The combined residential demand for the proposed service area is estimated to be an average of 2.47 Mgal/d within the 15-year permit term.

B. Commercial Demand:

Commercial demands were adapted from the *Caroline County Water Master Plan*, dated October 2016, to represent the scheduled operation of the water supply project. The demand of these additional users is estimated to be an average of 1.34 Mgal/d within the 15-year permit term.

Tables 4 and 5 present the demand projections for the service area as provided by the applicant and the requested withdrawal volumes, respectively. Note that the withdrawal volumes for Town of Bowling Green included domestic and commercial uses and are based on the average historical reported use.

[8] Refer to Appendix K – *7th Additional Information Response – Updated Summary of Water Demand Projections*, dated December 20, 2024.

Table 4: Caroline County's Service Area Water Demand Projections:

Service Area	Daily Demand (Mgal/d)	
	Year 2035	**Year 2040**
Caroline County/Port Royal		
Current Demands (2022) *	0.58	0.58
Average Residential	1.76	2.47
Average Commercial	1.01	1.34
Total Average Demand**	3.35	4.39
Total MAX Day	***5.89***	***7.73***
Town of Bowling Green		
Total Average Demand*	0.53	0.53
Total MAX Day	***0.83***	***0.93***
Proposed Service Area		
Total Service Area Average Day	***4.0***	***5.1***
Total Service Area Max Day	***7.0***	***9.0***

* Existing Average Demands
** The applicant applied an additional 5% allocation for water loss during the WTP process.

Table 5: Applicant Requested Water Withdrawal Volumes:

	Proposed Demand Volumes (2020 JPA)	**Proposed Demand Volumes (2024)**
Average Daily Volume (Mgal/d)	7.9	5.10
Maximum Day Volume (Mgal/d)	13.90	9.00
Maximum Monthly Volume (Mgal)	337	237
Maximum Annual Volume (Mgal)	2,884	1,862

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6. Alternatives Evaluated to Meet the Water Need (Least Environmentally Damaging Practicable Alternative)

Pursuant to 9VAC25-210-360.3, Applicants are required to evaluate alternatives for the purpose of establishing the least environmentally damaging practicable alternative. The Applicant considered six (6) alternatives as part of their application. Alternatives were identified in the *Caroline County and the Town of Bowling Green Regional Water Supply Plan*, dated October 5, 2011, and considered in the proposed surface water withdrawal project.

The Applicant identified four potential water supply alternatives which were previously considered in its 2017 Water Master Plan: 1) a no action alternative, 2) additional groundwater withdrawals, 3) a new surface water intake and withdrawal from the Rappahannock River and 4) purchase of finished water from neighboring utilities (Spotsylvania County, Stafford County, Hanover County, and the City of Richmond). Additionally, the County considered two alternatives: 1) a new withdrawal from the Potomac River and 2) additional water conservation measures. Each water supply alternative considered by the County is summarized below:

A. No Action Alternative:

The Applicant noted that based upon Weldon Cooper population growth estimates, the population of Caroline County has increased approximately 6.1% since the 2010 census, putting Caroline County in the top third of population growth rates in the Commonwealth. In addition, Caroline County has one of the lowest population densities in the Commonwealth and is located between the rapidly growing Northern Virginia and Richmond regions. Sufficient water supplies are necessary for development within Caroline County and current water demand projections exceed the current available groundwater supplies. Without access to reliable water resources for domestic, commercial, and industrial use, the County would be unable to achieve the goal of future economic development and growth. Therefore, the No Action Alternative was not considered a viable strategy for the County.

B. Additional Groundwater Withdrawal:

Caroline County is located along the Fall Line and approximately 88% of the land area lies in the Coastal Plain physiographic province. The remaining 12% is located in the Piedmont physiographic province. The Coastal Plain portion of the County is underlain by the Coastal Plain Aquifer system, which consists of an unconfined surficial aquifer and a series of confined aquifers, the largest of which is the Potomac Aquifer. The Piedmont portion of the County is underlain by significant bedrock with limited groundwater resources. Additional groundwater withdrawal would need to come from one of these systems.

The surficial aquifer of the Coastal Plain is exposed at the land surface and receives recharge directly from precipitation. Hydrogeologic processes such as evaporation, transpiration to plants, and base flow to streams occur within the surficial aquifer. The surficial aquifer provides recharge to deeper aquifers either as leakage through intervening confining units or as direct infiltration where it contacts an underlying aquifer. The surficial aquifer is moderately used across the entire Virginia Coastal Plain. The aquifer provides groundwater primarily to users of relatively small volume, which consists of predominately unregulated domestic and agricultural withdrawals.

Yield from the surficial aquifer is limited by aquifer thickness and is heavily influenced by precipitation, making surficial aquifer wells unreliable during droughts. Public water supply

development of a shallow surficial aquifer typically requires multiple wells or the development of high-capacity horizontal collectors to obtain sufficient yields. However, potential well yields would decrease during dry periods as the aquifer dewaters without recharge from precipitation.

The Piedmont physiographic province is primarily underlain by dense, near impermeable, bedrock that yields water primarily from secondary porosity and permeability provided by fractures in the rock, which serve as the principal places for the storage of water. Groundwater yields in this region are limited and not expected to be sustainable at rates needed to support a public water supply for Caroline County.

The confined aquifer system of the Coastal Plain has been determined to be over-allocated. In response, the Department has been working to reduce permitted withdrawals as part of the Coastal Plain Groundwater Initiative. The Department has actively reduced permitted withdrawals for a number of public water supplies in the Coastal Plain aquifer from 65 Mgal/d in 2014 to 48 Mgal/d in 2017. In its report to the General Assembly titled, *The Status of Virginia's Water Resources* (2018), the Department has indicated that recent reductions are not sufficient and continued withdrawal restrictions are necessary. Further, the Department requested that Caroline County reduce its utilization of ground water for public water supply purposes. Therefore, Caroline County would be unlikely to obtain a permit for expanded withdrawals from the confined aquifers of the Coastal Plain from the Department.

The use of additional groundwater is not a technically feasible water supply alternative for the County. The Department has placed restrictions on current and future groundwater withdrawals from the Coastal Plain aquifer system. Furthermore, research demonstrates limited potential yields from surficial aquifers or the bedrock aquifers of the Piedmont portion of the County. Therefore, the Groundwater Alternative was removed from consideration in the analysis.

C. New Withdrawal from Rappahannock River:

The northern border of Caroline County adjoins a 25-mile stretch of the Rappahannock River. The Rappahannock River was identified in the *Caroline County 2016 Water Master Plan* as the preferred water supply alternative for the County. Hydrologic analyses have indicated the river can provide sufficient water supply to meet the County's needs. The 25-mile section of the Rappahannock River along the County border is tidally influenced but consists of predominantly fresh water. A review of salinity data indicates that the source water would not need desalination for use as a public water supply. Additional water quality analyses have established that the source would require conventional treatment to include coagulation/flocculation, sedimentation, and filtration.

According to the applicants' analysis, the Rappahannock River is a feasible water supply option and would provide a high-quality and reliable source of supply for the County. The primary disadvantage to the Rappahannock River supply would be the need for long transmission lines to convey water from the river to population centers in the southern portion of the County. It is estimated that approximately 30 to 35 miles of pipeline will be required to convey water to the existing County systems.

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D. Purchase of Finished Water:

Caroline County has evaluated the possibility of purchasing wholesale finished water from an adjacent utility supplied by surface water. In this option, Caroline County would not operate a raw water intake or water treatment plant. Finished water would be supplied through metered distribution system interconnections. The wholesale water supply options are summarized as follows:

i. Spotsylvania County – Spotsylvania County operates the Ni River Reservoir, the Hunting Run Reservoir, and the Motts Run Reservoir. The County treats surface water at the Ni River WTP and the Motts Run WTP. Prior coordination between Caroline County and Spotsylvania County indicated that Spotsylvania County could supply up to 0.75 Mgal/d of finished water to Caroline County via a new transmission main approximately nine miles in length. Per the *Spotsylvania County Water and Sewer Master Plan* (dated August 2019 and revised in May 2021), Spotsylvania County states that the anticipated annual average day demand 19.4 Mgal/d for their existing service area is projected to exceed the safe yield of their existing water supply sources by 2065. Therefore, given that the current available supply is limited and the potential long-term availability of water supplies for purchase from Spotsylvania County is questionable, this option was not considered feasible.

ii. Stafford County – While no discussion of water purchase agreements has occurred between Stafford and Caroline Counties, the *Stafford County Water and Sewer System Master Plan,* dated June 5, 2018, was reviewed by the applicant to identify potential for providing purchased water available to Caroline County.

Stafford County's water comes from Lake Mooney (formerly named Rocky Pen Run Reservoir) and Smith Lake Reservoirs. Lake Mooney is filled by the Rappahannock River using a 40 Mgal/d pumping station. Stafford County operates two WTPs – the Lake Mooney WTP (which was placed in operation in December of 2014) and the Smith Lake WTP (which has been in operation since 1991). The Lake Mooney WTP treats raw water pumped from Lake Mooney Reservoir and the Smith Lake WTP treats raw water from the Smith Lake Reservoir.

The existing raw water reservoirs have storage capacity and a combined safe yield of approximately 17 Mgal/d based on the drought of record, with a safe yield of approximately 11.9 Mgal/d for Lake Mooney Reservoir and 5.1 Mgal/d for Smith Lake Reservoir. The combined safe yield of both reservoirs would satisfy projected customer demands for Caroline County through approximately 2045. Stafford County also has a number of other potential water supply options to serve the County including Abel Lake, Vulcan Quarry, an interconnection with Spotsylvania County, and additional water withdrawals from the Rappahannock River below the Fall Line. Current Stafford County water supplies are sufficient to meet projected demands through 2045 and do not account for selling water to other utilities.

The current combined production capacity of Stafford County's existing WTP's are adequate to satisfy Caroline County's near-term demands, but not the long-term planning demand. Stafford County's WTPs are capable of being expanded as needed to meet projected maximum day demands in the future. An additional capacity of 3.4 Mgal/d could be added to the Lake Mooney WTP; however, significant WTP upgrades would be needed.

To reach the demand centers of Caroline County, an approximately 35-mile pipeline would be required from the Lake Mooney WTP. Therefore, the potential long-term availability of water supplies for purchase from Stafford County is uncertain and this option was not considered feasible.

iii. Hanover County – Hanover County obtains surface water from the North Anna River, limited groundwater resources, and purchases of water from the City of Richmond and Henrico County. Hanover County operates the 4.0 Mgal/d Doswell WTP, while the South Anna WTP is currently inactive. Hanover County has an agreement with the City of Richmond to purchase up to 20 Mgal/d under a long-term water supply contract. Caroline County currently purchases 0.5 Mgal/d of water from the Doswell WTP for the Caroline County State Fair system.

iv. Caroline County previously assessed the purchase of up to 2 Mgal/d of finished water from Hanover County. The Doswell WTP capacity is fully allocated, so purchased water would originate from the City of Richmond, which would result in a significant water age and the potential for elevated disinfection byproducts. Hanover County is not currently utilizing its full 20 Mgal/d contract allocation from the City of Richmond. Further, Hanover County has long range plans to develop additional surface water supplies to be stored in a local quarry. Therefore, Hanover County appears to have sufficient existing and planned supplies to support long-term wholesale water sales to Caroline County. However, Hanover County is only committed to supplying up to 2 Mgal/d to Caroline County based on previous discussions between the two jurisdictions, which limits the feasibility of this option as a long-term water supply option.

v. City of Richmond – The City of Richmond obtains water from the James River and supplies finished water to Henrico County, Hanover County, and Chesterfield County. The City's safe yield for the James River was calculated to be 381 Mgal/d and the current treatment capacity is 132 Mgal/d. The City of Richmond has the capacity to supply both projected residential and wholesale demands through 2070 with excess capacity remaining. For the City of Richmond to supply Caroline County a pump station and 26 miles of transmission line to Caroline County, as well as treatment infrastructure to address elevated disinfection byproducts would be required. The transmission would cross multiple jurisdictions, waterways, and railroads. The high cost and complexity of this project prevent it from being a feasible water supply option for Caroline County.

vi. Fort A.P. Hill – Fort A.P. Hill has 20 groundwater wells with a total VDH permitted withdrawal capacity of 3.56 Mgal/d. The average day demand for these systems is projected to remain under 0.50 Mgal/d through the year 2050, resulting in an excess capacity of at least 3 Mgal/d. However, the Army would require an extensive feasibility study with no guarantee that a permanent water supply would become available. Caroline County would be required to negotiate an agreement with the Virginia American Water Company, who have a 50-year own/operate agreement with Fort A.P. Hill. Furthermore, Fort A.P. Hill would retain the right to terminate service to Caroline County during a state of emergency. Additionally, since Fort A.P. Hill is supplied by groundwater wells, this water supply option would not reduce Caroline County's reliance on groundwater. Caroline County investigated obtaining finished water from Fort A.P. Hill and concluded that this water supply alternative is not feasible.

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Most of the potential utility suppliers discussed above have limited long-term capacity (e.g., Stafford and Spotsylvania Counties), and would require substantial infrastructure requirements (e.g., Stafford County and City of Richmond), or have unfavorable contractual requirements (e.g., Fort A.P. Hill). The most feasible supplier of wholesale finished water would be Hanover County, which has available long-term capacity and would require the shortest pipeline length for interconnection. However, this water supply alternative is not feasible as Hanover County is not able to commit to supplying the full long-term demand of Caroline County and its partners. Caroline County may consider additional supply from Hanover County as an interim option, but it would not preclude the need to have a permanent long-term supply for Caroline County.

E. New Withdrawal from Potomac River:

During the January 2016 Pre-Application Panel Meeting, VIMS commented that the Potomac River should be considered as a potential source of water supply. The northern border of King George County adjoins the reach of the Potomac River spanning from Potomac Creek to Roiser Creek. Available water quality data within this section of the Potomac River were reviewed to identify the level of treatment that would be required for a WTP. Historical data from four water quality monitoring stations located along this section of the Potomac River indicate that salinity is typically substantially higher than the freshwater threshold of 0.5 parts per thousand (ppt). Based on the available data, salinity averages 2 ppt at the most upstream water quality monitoring station and 8 ppt at the most downstream water quality monitoring station. The Potomac River at King George County would require desalination using reverse osmosis (RO) membranes to maintain total dissolved solids (TDS) and chloride levels within the potable range for drinking water. RO technology would significantly increase the cost of treatment. Additionally, desalination with RO results in a concentrated brine waste product. Sustainably disposing of this brine can be a major obstacle for facilities considering RO technology as inland facilities must either discharge to surface water via a wastewater treatment plant (WWTP) or inject the waste brine into a deep underground well. Direct discharge of high-salinity brine to surface waters can negatively impact wetlands and aquatic resources and negatively affect WWTP processes, as well as the ecology of the receiving water. Existing WWTPs in proximity to Caroline and King George Counties are not capable of sufficiently diluting or accepting the brine discharge at the rates expected for Caroline County. Deep well injection of brine is not typical for this region and there is not an established precedent for deep well injection of high salinity wastewater.

In addition to the difficulty in treatment and wastewater disposal for a Potomac River supply, there would need to be substantially more infrastructure to supply Caroline County. While a feasibility study has not been performed for a Potomac River intake location, conceptually, it should be located as far upstream as possible for minimum salinity. To convey water from the northeast corner of King George County to the Route 301 Bridge at Port Royal would require approximately 25 miles of transmission mains. If the 301 Bridge was not used, the pipeline length could potentially be reduced to eight miles, but a new river crossing would need to be constructed. These lengths would merely get the water to the boundary with Caroline County, 30 to 35 more miles of pipeline would be needed to get to Caroline County's population center for a total of 43 to 55 miles of total pipeline from a Potomac River intake.

Overall, the Potomac River is a marginal water supply source for Caroline County that would require advanced treatment and substantial transmission infrastructure to make it a viable source of supply. The primary disadvantage is the potential infeasibility of RO brine disposal from the

brackish supply. For these reasons, the Potomac River is not considered a feasible water supply alternative for Caroline County.

F. Additional Water Conservation:

The implementation of additional water conservation measures to reduce the County's need for additional water supply were evaluated. Water conservation measures can be understood as the economically and/or socially beneficial reduction of water withdrawals, water use, or water waste. Demand management involves measures that promote the efficient use of water, including load management and load reduction or conservation. Demand management can forestall future supply capacity needs.

The Caroline County water system is comprised of three primary systems (Central, High School, and Milford) with a total population of approximately 7,000. Total water deliveries across these three systems equaled 554,400 gallons in 2014. Per capita deliveries were 79 gallons per capita per day (gpcd), which is below the national average of 83 gpcd. Caroline County's per capita demand is also less than the residential usage rate of 100 gpcd required for system planning in the VDH Waterworks Regulation.

Caroline County currently has various policies and measures in place to prevent water overuse and promote efficient water use. The County also has measures in place to prevent water loss due to leaks in the distribution system. Each of the County's groundwater wells is metered and withdrawal data are compared to water sales data to identify water loss. If a significant increase in water loss is observed, Caroline County will begin surveying for undetected leaks in the distribution system. Unaccounted for water for the Central System is high at approximately 19%, and a water audit was recommended in the *Caroline County 2016 Water Master Plan* to identify non-revenue water used by the County, meter discrepancies, and potential leakage.

Given the low per capita usage of water in the County, the potential incremental benefits of active demand management programs are expected to be insignificant. The benefits of additional water conservation as a water supply alternative are not sufficient to accommodate future population growth or potential reduction in the groundwater allocation for Caroline County. Therefore, the water conservation alternative was determined to be infeasible to meet long-term water supply needs. However, while this is not a feasible water supply option, the County is committed to water conservation for water supply sustainability.

Caroline County and its partners have few feasible options to supply an expansion of the water supply capacity to sustain growth while transitioning away from the Coastal Plain aquifer system as the sole water supply. No action, additional groundwater withdrawals, a Potomac River intake, and additional water conservation are all infeasible options for providing a permanent long-term water supply that meets the County's long-term needs. The option to purchase finished water from neighboring utilities is only feasible for limited, interim supplies. The review of the proposed alternatives discussed above confirms that the Rappahannock River is the best available water supply option for Caroline County.

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7. Evaluating Water Withdrawal Volumes Based on Beneficial Use Impacts and Flow-by/Release Requirements:

§ 62.1-11.E establishes that the "right to the use of water or to the flow of water in or from any natural stream, lake or other watercourse in this Commonwealth is and shall be limited to such water as may reasonably be required for the beneficial use of the public to be served." The Department is directed by § 62.1-44.15:22 to establish limits that preserve instream flow "to the volume of water that may be withdrawn as a part of the permitted activity and conditions necessary to protect beneficial uses." Pursuant to 9VAC25-210-370.B.3, the Department shall take into consideration the combined effect on the hydrologic regime of the surface water within an affected stream reach due to consumptive water uses in the development of instream flow conditions for new withdrawals. Further, 9VAC25-210-370.D.1 requires a determination that the amount of the surface water withdrawal is limited to the amount of water that can be put to beneficial use.

Department Recommended Withdrawal Limitations

This permit limits surface water withdrawals to the volume justified based upon the application materials submitted, modeling analyses, and evaluation of existing beneficial uses. The Department concluded that the water demand and statement of need is reasonable and has been adequately justified by the application through the information submitted in the VWP permit application process. Based upon this information, the permit proposes the following limits on the withdrawal volumes:

Withdrawals from the Rappahannock River shall not exceed the following:

- Maximum Daily: 9.0 Mgal
- Maximum Daily Upon Drought Warning Declaration: 7.0 Mgal
- Maximum Daily Upon Drought Emergency Declaration: 6.0 Mgal
- Maximum Monthly: 237 Mgal
- Maximum Annual: 1,862 Mgal

To ensure the protection of existing beneficial uses based upon the Department's review of the application materials, the maximum daily volume withdrawn from the Rappahannock River shall not exceed 7.0 Mgal upon the declaration of a drought warning within either the Northern Coastal Plain drought evaluation region or Caroline County, which includes the Towns of Bowling Green and Port Royal. In addition, the maximum daily volume withdrawn from the Rappahannock River shall not exceed 6.0 Mgal upon the declaration of a drought emergency within the Northern Coastal Plain drought evaluation region or Caroline County which includes the Towns of Bowling Green and Port Royal.

Based on the materials provided in the Joint Permit Application, as supplemented by the applicant, and the applicable permit term for the proposed withdrawal to be put to beneficial use, the Department has determined the proposed withdrawal volumes for the project, as limited in this permit, complies with applicable standards identified in 9VAC25-210-370.D.1.

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Return Flow / Consumptive Use

The preferred raw water intake site is located on the Rappahannock River in the northeastern portion of Caroline County. Water will be transferred to the Mattaponi River basin via effluent discharge from the two existing wastewater treatment plants (WWTP) identified in Table 6. Existing flows to the Mattaponi River Basin were estimated based on the current design flows of the Caroline County Regional WWTP and the Town of Bowling Green WWTP of 1.5 Mgal/d and 0.25 Mgal/d, respectively, at the time of this evaluation for the proposed permitting action. The Caroline County WWTP is currently authorized under the Virginia Pollutant Discharge Elimination System (VPDES) permit number VA0073504 for the expansion to 3.0 Mgal/d. Caroline County and the Town of Bowling Green will need to apply for authorization for the expansion of their VPDES discharge permits in the future if the plants are expanded to accommodate increased wastewater flows.

To estimate future transferred flows to the Mattaponi River basin associated with the Rappahannock River Water Supply Project, existing water demand data, future water demand projections and consumptive losses were analyzed. Consumptive loss represents the percentage of water withdrawn from the Rappahannock River that is consumed (e.g., evaporation, transpiration, incorporated into products or crops, consumed by humans or animals, or otherwise removed from the immediate water environment) and therefore does not contribute to additional discharges to the Mattaponi River basin. Historical groundwater well production records, monthly customer meter data, and Polecat Creek WWTP flow rate data were analyzed over the period from 2022 through 2024[9]. The average flow rate returned to the Mattaponi River is approximately 20.3% less than the average flow rate supplied into the distribution system. Therefore, a consumptive use rate of 20.3% was used for the updated interbasin transfer flow and beneficial use analyses.

The Caroline County Regional WWTP is located in the southwestern portion of the County and discharges to Polecat Creek, which flows into the Mattaponi River approximately 5 miles east of the Wastewater Treatment Plant. The Town of Bowling Green Wastewater Treatment Plant discharges to an unnamed tributary of the Mattaponi River, eventually flowing into the Mattaponi River approximately 1 mile west of the Caroline County Wastewater Treatment Plant.

Table 6: Existing WWTP Permitted Design Flow Capacity:

Facility	VPDES Permit No.	Receiving Basin	Location (coordinates)	Permitted Capacity (Mgal/d)
Caroline County WWTP	VA0073504	Pole Cat Creek, tributary to the Mattaponi River	37.96502 -77.42080	3.0*
Town of Bowling Green WWTP	VA0020737	Mattaponi River	38.04833 -77.36250	0.25**

*VA00073504 Current design flow is 1.5 Mgal/day.
**VA0020737 Permitted capacity as of June 1, 2025.

[9] Refer to Appendix E – *Beneficial Use and Aquatic Life Evaluation*, dated May 12, 2025.

Rappahannock Particle Tracking Model:

The proposed intake is within the tidal portion of the Rappahannock River. On behalf of Caroline County, the Virginia Institute of Marine Science (VIMS) completed a technical report entitled "*Apply a Particle Tracking Model to Analyze Impacts of Water Intake on Ichthyoplankton Mortality in Tidal Freshwater Region of the Rappahannock River*" (Report), dated February 3, 2023[10]. Caroline County submitted the Report to address concerns related to impingement and entrainment and water quality impacts.

VIMS employed a three-dimensional hydrodynamic model with particle tracking to simulate egg and larval mortality in response to the withdrawal. A range of flow conditions were simulated including a low flow period with an average inflow of approximately 165 cubic feet per second (cfs). During the low flow scenario, a maximum of 0.572% of simulated particles encountered the intake, as compared to a maximum of 0.21% under the high flow scenario. As stated in the report, this is expected because a lower discharge during the drought periods increases the period of time the simulated particles spend in the vicinity of the intake. However, the report concludes, and the Department agrees, that these results do not suggest a significant increase in the mortality of fish eggs and larvae relative to natural mortality as a result of the proposed maximum withdrawal. However, the Report indicates that due to the increase in mortality due to the withdrawal during low flow periods, species with spawning periods during dry summer months may be most impacted.

While habitat loss and mortality do not appear to be a significant concern with the proposed withdrawal per the VIMS model, the particle tracking results do raise the possibility of changes in how long it takes water to move through and out of the system as a result of changes in freshwater inflow to the system, particularly during low flows. VIMS compared simulated horizontal velocities at the intake site during the "withdrawal" case and the "normal" case with flows around the 10th percentile of long-term river discharge in the Rappahannock River. The Report concludes that the intake does not have significant impacts on hydrodynamics in the Rappahannock River.

Based on the report submitted by VIMS and the review of other data relevant to the proposed withdrawal, the Department has determined the proposed project, as governed in the draft permit, comply with applicable standards identified in 9VAC25-210-110 and that conditions in the draft permit were developed with full consideration of the criteria identified in 9VAC25-210-370 B.

8. Water Supply Plan Review:

The Department is required by § 62.1-44.15:20 C to give full consideration to any relevant information contained in the state water supply plan described in Subsection A of § 62.1-44.38:1. The 2011 *Caroline County and the Town of Bowling Green Regional Water Supply Plan*, the 2010 *Caroline County Comprehensive Plan*, and the *Caroline County Water Master Plan* were submitted by Caroline County, and were developed in accordance with the Water Supply Planning Regulation 9VAC25-780. These plans provided the basis of review for the proposed project.

Coordination with Department of Environmental Quality's Office of Water Supply Planning was requested on February 15, 2024, who responded on February 20, 2024. As a result of the updated water withdrawal request in December of 2024, the Department initiated a second coordination with the Department of Environmental Quality's Office of Water Supply Planning on June 2, 2025, who responded on June 5, 2025.

[10] Refer to Appendix A – *Apply a Particle Tracking Model to Analyze Impacts of Water Intake on Ichthyoplankton Mortality in Tidal Freshwater Region of the Rappahannock River,* dated February 3, 2023.

The Caroline County and the Town of Bowling Green Regional Water Supply Plan (Plan), dated May 13, 2011, was developed in accordance with the Water Supply Planning Regulation 9VAC25-780.

The Caroline County Rappahannock Intake is included in the *Plan*, dated May 13, 2011, as an alternative source. Demand projections for the proposed facility were not included in the *Plan*, as the facility was proposed at the time of submission; however, demand projections for public community water systems served by the facility were included in the *Plan* and could be considered in the evaluation of the permit request. The *Plan* states that existing sources for the region were not projected to meet demands through 2050. In particular, the community water systems of Caroline Utility System, Milford Service Area, and Town of Bowling Green were projected to experience deficits between 2020-2050. The development of a surface water source was noted in the *Plan* as an alternative to address identified deficits in groundwater supply. "For decades, water levels in the major aquifers, particularly in the Potomac Aquifer, the primary source for groundwater in the Coastal Plain, have been declining. Declining water levels have driven higher rates of land subsidence, which can lead to a loss of aquifer storage, and increased salt-water intrusion. In areas where water levels have fallen or are nearing the critical surface, new or existing groundwater withdrawals are unable to meet the regulatory criteria for issuance of a groundwater withdrawal permit. The Virginia Coastal Plain Groundwater Initiative began in 2014 and was designed to address this issue directly. These alternative water source requirements have since become more common in groundwater withdrawal permits as a tool to assist groundwater users in areas with the potential for supply challenges in investing time and resources towards developing alternative water sources. Many of the largest groundwater users have begun working to develop alternatives water sources such as surface water withdrawals, wells in shallow aquifers, and water reuse proposals. The development of surface water sources is "increasingly evaluated as an alternative to groundwater" throughout the region (*Virginia State Water Resources Plan, 2020*)[11].

9. Surface Water Impacts:

This permit authorizes the total impact of 0.03 acres (1,174 square feet) of permanent wetlands impacts, 0.45 acres (18,977 square feet) of temporary wetland impacts, 466 linear feet (10,364 square feet) of temporary stream impacts, and 50 linear feet (1,400 square feet) of permanent stream impacts. In addition, the proposed project would include six stream crossings subject to jurisdictional oversight by the Virginia Marine Resources Commission (VMRC) for installation of the proposed raw water pipeline.

Water quality impacts are expected to be temporary and minimal provided the Applicant abides by the conditions of the permit. A temporary loss of state waters shall occur. However, the impacts have been avoided and minimized to the greatest extent practicable.

Alternative Impact Analysis to Avoid and Minimize Impacts

Pursuant to 9VAC25-210-80 B, the applicant is required to evaluate alternatives to the proposed project detailing the specific on-site and off-site measures taken during project design and development to demonstrate that avoidance and minimization opportunities have been identified, and measures have been applied to the proposed activity to identify the least environmentally damaging practicable alternative.

[11] *Virginia State Water Resources Plan | Virginia DEQ. (n.d.). https://www.deq.virginia.gov/our-programs/water/water-quantity/water-supply-planning/virginia-water-resources-plan,* Virginia Department of Environmental Quality Publication, "*Virginia State Water Resources Plan – A Report of Virginia's Water Resources*" (January 13, 2022).

The alternatives evaluation comprises three (3) potential water intake areas, four (4) potential water treatment facility locations, a potential raw water main route, and an alternate raw water main route. The water intake areas are located in northern Caroline County along the Rappahannock River. The water treatment facility locations are located in southwestern Caroline County within three (3) miles (4.8 km) of Ruther Glen. The potential raw water main route runs from near the intersection of U.S. Route 1 (Route 1) and State Route 207 (Route 207) east along Route 207 into Bowling Green where it continues straight onto U.S. Route 301 (Route 301). The potential alignment continues along Route 301 to its intersection with U.S. Route 17 (Route 17) where it turns north and follows Route 17 and terminates near Moss Neck Manor Lake. The alternate raw water main route splits from the potential raw water main route in Bowling Green where it turns north on Route 2. The alternate route continues along Route 2 until its intersection with Route 17 where it turns east and terminates near Moss Neck Manor Lake. Below is a summary of considerations and criteria the applicant applied during the alternative evaluation to identify the least environmentally damaging practicable alternative.

Raw Water Intake and Pump Station Location Alternatives

To identify potential location alternatives for the raw water intake and pump station the applicant used salinity, wastewater discharges, river depth, sedimentation potential, floodplains, and impacts to wetlands as evaluation criteria. Salinity and wastewater discharge consideration were the initial screening criteria applied, allowing the applicant to narrow down sections of the Rappahannock River which would be suitable for alternative locations. Salinity was considered in the alternative criteria to minimize impacts from tidal salinity and avoid the need for desalination of raw water. A portion of the Rappahannock River bordering Caroline County is characterized as a tidal freshwater resource, as such, the applicant completed a salinity analysis (See 'Salinity Model' section below for more detail). Based on the results of the salinity analysis the applicant found that locations further upstream would be preferred when determining potential alternative locations. Wastewater discharge was included as a criteria element based on comments from the Virginia Department of Health during the pre-application panel meeting. The comments included concerns about intake locations in relation to wastewater discharges, and tidal excursion (the distance a water particle travels during a tidal cycle) pushing wastewater discharges upstream toward an intake because of decreased freshwater flows moving downstream[12]. The applicant narrowed the location parameters to reduce potential intake location alternatives to those located outside of a five-mile buffer zone of existing wastewater discharge locations and the tidal excursion buffer zone.

Once the initial salinity and wastewater discharge screening criteria were applied, the next criteria applied were river depth, sedimentation potential, floodplains, and impacts to wetlands. River depth considerations included the minimum water depth for intake submergence, sedimentation potential considerations included locations with limited sedimentation potential (e.g.: inside river bends, or wide, low gradient areas), floodplains considerations included preferred locations outside of the 100-year floodplain, and impacts to wetlands considerations included areas with smaller areas of wetlands as preferred. Based on these criteria, three potential parcels were identified, resulting in a total of three alternative locations. Intake location 3 was the most favorable and least environmentally damaging practicable outcome and therefore is the applicant's preferred location.

[12] Refer to Section 12 of this Document for Virginia Department of Health Comments

Raw Water Pipeline Alignment Alternatives

To identify potential alternatives for the raw water pipeline alignment the applicant used pipe length, potential impacts to wetlands, impacts to transportation infrastructure, easements, impacts to private property owners, and potential archaeological concerns as evaluation criteria. Although alignment lengths and wetland impact of the two alignment options were similar, minimization of impacts to private property owners and archaeological resources indicated that the applicant's preferred alignment is the least environmentally damaging, practicable alternative.

Water Treatment Plant Location Alternatives

To identify potential location alternatives for a water treatment plant (WTP) the applicant first identified general locations based on relative proximity to other water supply infrastructure and existing facilities within the proposed service areas. The favorable characteristics such as potential wetland impacts, cultural resources, WTP footprint, geospatial characteristics, and water availability that meets water quality standards for floodplains, development planning, land use, and parcel availability considerations. Caroline County worked to narrow down alternative site options under the above parameters and found that four alternative sites met the criteria above. The resulting preferred parcel selection (Alternative 4, Parcel 92-A-24) met the criteria above, as well as being in an area that allows Caroline County to serve their growing population without impeding future anticipated development.

Water quality impacts are expected to be temporary and minimal provided the Applicant abides by the conditions of the permit. A temporary loss of state waters shall occur. However, the impacts have been avoided and minimized to the greatest extent practicable.

Intake Location Assessment and Salinity Analysis

As a result of comments received by the Department of Wildlife Resources and the Virginia Institute of Marine Sciences during the January 19, 2016, and the May 22, 2019, pre-application panels, the applicant conducted a *Hydrologic and Salinity Analysis for the Rappahannock River* and was submitted to the Department for review on March 27, 2020, and is summarized below:

- March 27, 2020 – *Rappahannock River Hydrologic and Salinity Analysis*:

  The applicant coordinated with Virginia Institute of Marine Science to develop a salinity model to assess how the proposed water withdrawals from the Rappahannock River may affect instream flow and changes in salinity concentrations. A flow analysis was conducted by scaling the watershed area from the USGS Gauge No. 01674000 on the Mattaponi River near Bowling Green due to its location in the coastal plain physiographic province which is similar to the ungauged watershed area of the Rappahannock River. Because the County's intake would be located in the tidal portion of the river, withdrawals will not affect flow depths in the same manner as in a non-tidal stream. Withdrawals of approximately 10 to 20cfs are expected to have no measurable impact on the river's surface elevations.

  While surface water elevations are not expected to be influenced by the proposed intake, withdrawals will reduce freshwater flows downstream, allowing tidal influence to push brackish water from the Chesapeake Bay further upstream. At the January 19, 2016, pre-application meeting and again at the May 22, 2019, pre-application meeting, the Virginia Department of Wildlife Resources suggested that salinity should be modeled at multiple locations under varying flow

conditions to understand the impact of the withdrawals on saltwater intrusion in the river. Three potential intake locations along the Rappahannock River were identified by the applicant based on initial screening criteria. A hydrologic model was developed and applied to all three potential locations within a 10-mile stretch of the tidal freshwater Rappahannock River to assess the impact of the County's proposed withdrawals on salinity. Five water quality monitoring sites were identified to incorporate into the model[13]. These sites are described below starting at the furthest upstream location progressing downstream:

- Hayfield Bar (DEQ Monitoring Station: 3-RPP098.81) upstream of Intake Site No. 3
- Hop Yard Landing (DEQ Monitoring Station: 3-RPP091.55) downstream of Intake Site No. 2
- Hicks Landing (DEQ Monitoring Station: 3-RPP084.73) downstream of Intake Site No. 1
- Port Royal (DEQ Monitoring Station: 3-RPP080.19) downstream of Intake Site No. 1
- Station TF3.3 downstream of Intake Site No. 1

Initial data analysis conducted in 2020 by the Applicant consisted of comparing the predictor parameters (flows, tide height, and Chesapeake Bay salinity) with the water quality data. The data comparison indicated strong relationships with flow and tide data. A regression model was then developed at each of the water quality monitoring stations. In order to evaluate the potential effect on salinity from maximum day withdrawals, the salinity model was evaluated with just the monthly withdrawal variations, and the single highest salinity value was identified for each year.[14] The resulting river salinity based on these withdrawal values were compared to the baseline salinity estimates at the water quality monitoring stations. After assessing hydrology and salinity in the river in the vicinity of and downstream of the proposed water intake, the Applicant concluded that:

- Freshwater inflows are reliable and sufficient to supply the anticipated withdrawals for Caroline County.
- Salinity in the vicinity of the proposed intake would be in the range of fresh water, even during typical low flow conditions.
- Salinity levels downstream of the proposed intake would not change appreciably at the proposed withdrawal rates for Caroline County.
- Salinity impacts are not expected to occur for freshwater withdrawals or aquatic species downstream of the proposed intake.

Following the first Public Comment Period and Public Hearing (August 25, 2024 through October 11, 2024) the Department issued Applicant Additional Information Request Letters dated October 25, 2024, January 13, 2025, and March 12, 2025, requiring the Applicant conduct an updated Hydrologic and Salinity Analysis as well as a Beneficial Use and Aquatic Life Evaluation to depict predicted changes in salinity based on the

[13] Refer to Appendix B – *The Rappahannock River Hydrologic and Salinity Analysis*, dated March 27, 2020.
[14] Refer to Section 13 for pre-application comments related to Appendix B – *The Rappahannock River Hydrologic and Salinity Analysis*, dated March 27, 2020.

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updated water withdrawal and discharge volumes[15]. The Analysis was submitted to the Department for review on May 12, 2025, with additional information provided on May 20, 2025, and is summarized below:

- May 20, 2025 – *Rappahannock River Hydrologic and Salinity Analysis*:

  Salinity data was reviewed along the length of the tidal freshwater portion of the river from water quality monitoring locations with sufficient data to support modeling efforts. Data was collected from the USEPA STORET database7 and the Virginia Institute of Marine Science Virginia Estuarine and Coastal Observing System. Five water quality monitoring sites were identified to incorporate into the model[16]:

  - Hayfield Bar (DEQ Monitoring Station: 3-RPP098.81) upstream of Intake Site No. 3
  - Hop Yard Landing (DEQ Monitoring Station: 3-RPP091.55) downstream of Intake Site No. 2
  - Hicks Landing (DEQ Monitoring Station: 3-RPP084.73) downstream of Intake Site No. 1
  - Port Royal (DEQ Monitoring Station: 3-RPP080.19) downstream of Intake Site No. 1
  - Station TF3.3 downstream of Intake Site No. 1

  As requested by the Department, the Applicant provided an analysis of conductivity, which is a surrogate and indicator of salinity levels, at currently known agricultural intake locations downstream of the proposed intake location in order to evaluate predicted changes in salinity for agricultural uses resulting from the proposed withdrawal. The tidal section of the river is divided into three segments based on salinity, which can be evaluated using conductivity as referenced in Table 7. Assessment of salinity changes based on conductivity at each location was estimated using linear interpolation based on the modeled data at the monitoring locations evaluated. The locations as well as the number of known agricultural withdrawals are presented below:

  - Between the Proposed Intake and Hop Yard Bar – 3 agricultural withdrawals
  - Between Hop Yard Bar and Hicks Landing – 2 agricultural withdrawals
  - Between Hicks Landing and Port Royal – 1 agricultural withdrawal
  - Between Port Royal and TF3.3 – 8 agricultural withdrawals

[15] Refer to the 7th Additional Information Response – Appendix K – Updated Summary of Water Demand Projections, dated December 20, 2024.
[16] Refer to Appendix C – *Rappahannock and Mattaponi Hydrologic and Salinity Analysis*, dated May 20, 2025 for more information on the water quality monitoring sites.

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Table 7: General Description of Salinity Ranges for Estuarine Waterbodies

Salinity Regime	Salinity Range (ppt)	Specific Conductivity Rance (µS/cm)
Freshwater and Tidal Freshwater	Less than 0.5	Less than 1,000
Oligohaline	0.5 to 5.0	1,000 to 9,000
Mesohaline	5.0 to 18.0	9,000 to 29,000
Polyhaline	18.0 to 30.0	29,000 to 46,000
Seawater	Greater than 30.0	Greater than 46,000

Natural flows in the Rappahannock River at the proposed intake location are influenced by existing water supply operations and wastewater discharges. Several municipal withdrawals and discharges are located upstream of the proposed intake location including those owned and operated by the City of Fredericksburg, Spotsylvania County, and Stafford County. Discharges from the City of Fredericksburg, Spotsylvania County, and Stafford County wastewater treatment plants occur downstream of the Rappahannock River USGS Gauge No. 01668000, wastewater return flows were estimated at approximately 27.4 cfs (17.7 Mgal/d) on average and were added to the non-tidal river gauge flows at the fall line. The freshwater flows in the Rappahannock River are estimated for points downstream of the USGS gauge at Fredericksburg based on the following formula:

*Rappahannock R. gauge #01668000 flow + Spotsylvania, Fredericksburg, and Stafford return flows + (ungauged Rappahannock R area / Mattaponi R. gauge No. 01674000 area) * Mattaponi R. gauge No. 01674000 flow*

The Applicant provided data comparing differences in conductivity over 76 years of available water quality monitoring data (January 1, 1943, to May 31, 2019, total number of days of 27,910). Flows in the Rappahannock River follow the typical pattern in the Mid-Atlantic region with the highest flows in the spring and lowest flows in the late summer. These low flow conditions typically occur in August, September, or October. Extended dry periods can result in low, drought condition flows of approximately 30 cfs, which occurred in 1954, 1966, 1999, 2002, and 2007 during the evaluated 76-year period.

An analysis of potential impacts to agricultural producers utilizing the Rappahannock River for irrigation and salinity tolerances of common crops produced, was included and based on the U.S. Department of Agriculture 2022 Census of Agriculture profiles for Caroline, Essex, King George, and Westmoreland Counties. Corn, soybeans and wheat are the most common crops across the listed counties. Corn was determined to be the most sensitive to salinity of the crops evaluated (Table 8).

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Table 8: Relationship Between Crop Yield and Irrigation Water Salinity Using Conductivity as a Surrogate

Crop	Relative Yield Reduction				
	0%	10%	25%	50%	Maximum Tolerable Conductivity
	Conductivity (µS/cm)				
Corn	1,100	1,700	2,500	3,900	6,700
Soybean	3,300	3,700	4,200	5,000	7,000
Wheat	4,000	4,900	6,300	8,700	1,3000

The yield reduction rates and maximum tolerable salinity level, as referenced in the Virginia Cooperative Extension Publications titled *Managing Irrigation with Saline Water*[17] and *Understanding Salinity in Tidal Waters*[18], are used to compare the baseline and projected scenarios. The number of days when conductivity was in exceedance of 1,100 µS/cm during the 76-year simulation period for each scenario was used to assess the potential impact to known agricultural producers. *Appendix C Rappahannock River Hydrologic and Salinity Analysis,* dated May 20, 2025*,* provides the incremental change by month and year at each of the agricultural intake locations. The data were evaluated for the presence of dry periods to assess the predicted change in conductivity based on hydrologic conditions. The drought conditions were compared with the collected data, and the years 1999, 2002, and 2007 were identified as the 2nd, 3rd, and 8th worst drought years, respectively, over the model period. Significant drought periods are represented by naturally occurring elevated conductivity at each location due to the decrease in freshwater flows in the watershed.

A conductivity value of 1,100 µS/cm was established as a threshold above which salinity would be predicted to harm corn or other potential crops. The following tables from the *Rappahannock River Hydrologic and Salinity Analysis, dated May 20, 2025,* summarizes the potential change in the number of days within the specified conductivity ranges at nine of the known agricultural intake locations identified by the river miles between Water Quality Monitoring Stations along the reach.[19]

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[17] *Managing Irrigation with Saline Water* https://www.pubs.ext.vt.edu/BSE/bse-348/bse-348.html Virginia Cooperative Extension Publication BSE-348P, "*Managing Irrigation with Saline Water*" (Larsson et al. 2023).
[18] *Understanding Salinity in Tidal Waters* Virginia Cooperative Extension Publication BSE-349NP, "*Understanding Salinity in Tidal Waters – Information for Irrigators*" (Larsson et al. 2023). https://www.pubs.ext.vt.edu/BSE/bse-349/bse-349.html
[19] Refer to Appendix C – *Rappahannock and Mattaponi Hydrologic and Salinity Analysis*, dated May 20, 2025 for more information on the selected agriculture intake sample locations.

1. Downstream of Hop Yard and Upstream of Hicks Landing – Two Sample Point locations at 2.5 miles and 2.8 miles downstream of Hop Yard. Total river miles between Hop and Hicks Monitoring stations 6.5 miles.

Table 9: River Mile 2.5

Conductivity Range (µS/cm)	Baseline(days)	Projected (days)	Difference (days)	Difference (%)
0 to 1100	27,891	27,856	-35	-0.12
1100 to 1700	11	41	30	0.11
1700 to 2500	8	13	5	<0.01
2500 to 3900	0	0	0	0
3900 to 6700	0	0	0	0
Over 6700	0	0	0	0

Table 10: River Mile 2.8

Conductivity Range (µS/cm)	Baseline(days)	Projected (days)	Difference (days)	Difference (%)
0 to 1100	2,7890	2,7850	-40	-0.14
1100 to 1700	10	41	31	0.11
1700 to 2500	10	19	9	<0.01
2500 to 3900	0	0	0	0
3900 to 6700	0	0	0	0
Over 6700	0	0	0	0

2. Downstream of Hicks Landing and upstream of Port Royal – One sample point location 1.11 miles downstream of Hicks Landing. A total of 4.6 river miles between monitoring stations.

Table 11: River Mile 1.11

Conductivity Range (µS/cm)	Baseline(days)	Projected (days)	Difference (days)	Difference (%)
0 to 1100	27555	27499	-56	-0.20
1100 to 1700	133	124	-9	-0.03
1700 to 2500	130	134	4	0.01
2500 to 3900	83	138	55	0.20
3900 to 6700	9	15	6	0.02
Over 6700	0	0	0	0

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3. Downstream of Port Royal and upstream of TF3.3 – Six sample point locations. A total of twenty-six river miles between monitoring stations. Transition zone between freshwater (less than 1,000 µS/cm) and oligohaline (between 1,000 to 9,000 µS/cm). Historical baseline salinity levels at monitoring station TF3.3 regularly exceed the maximum tolerable salinity level for corn (6,700 µS/cm).

Table 12: River Mile 0.5

Conductivity Range (µS/cm)	Baseline(days)	Projected (days)	Difference (days)	Difference (%)
0 to 1100	26649	26649	0	0
1100 to 1700	472	472	0	0
1700 to 2500	295	300	5	0.02
2500 to 3900	170	170	0	0
3900 to 6700	262	260	-2	-0.01
Over 6700	62	590	-3	-0.01

Table 13: River Mile 1.6

Conductivity Range (µS/cm)	Baseline(days)	Projected (days)	Difference (days)	Difference (%)
0 to 1100	25706	25670	-36	-0.13
1100 to 1700	1030	1054	24	0.09
1700 to 2500	547	574	27	0.10
2500 to 3900	274	276	2	<0.01
3900 to 6700	314	303	-11	-0.04
Over 6700	39	33	-6	-0.02

Table 14: River Mile 8.0

Conductivity Range (µS/cm)	Baseline (days)	Projected (days)	Difference (days)	Difference (%)
0 to 1100	18591	18512	-79	-0.28
1100 to 1700	3147	3147	0	0
1700 to 2500	2270	2275	5	0.02
2500 to 3900	1988	1968	-20	-0.07
3900 to 6700	1914	2008	94	0.33
Over 6700	0	0	0	0

Table 15: River Mile 13.5

Conductivity Range (µS/cm)	Baseline (days)	Projected (days)	Difference (days)	Difference (%)
0 to 1100	14358	14302	-57	-0.20
1100 to 1700	3802	3780	-22	-0.08
1700 to 2500	2824	2824	0	0
2500 to 3900	2826	2873	47	0.17
3900 to 6700	2727	2864	137	0.49
Over 6700	1372	1267	-105	-0.38

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Table 16: River Mile 14.6

Conductivity Range (µS/cm)	Baseline (days)	Projected (days)	Difference (days)	Difference (%)
0 to 1100	13,824	13,688	-56	-0.20
1100 to 1700	3,719	3,696	-23	-0.08
1700 to 2500	2,942	2,917	-25	-0.09
2500 to 3900	2,974	3,050	76	0.27
3900 to 6700	2,774	2,855	81	0.29
Over 6700	1,677	1,624	-53	-0.19

Table 17: River Mile: 17.5

Conductivity Range (µS/cm)	Baseline (days)	Projected (days)	Difference (days)	Difference (%)
0 to 1100	12,591	12,526	-65	-0.23
1100 to 1700	3,523	3,517	-6	-0.02
1700 to 2500	3,067	3,063	-4	-0.01
2500 to 3900	3,183	3,263	80	0.29
3900 to 6700	3,072	3,116	44	0.16
Over 6700	2,474	2,425	-49	-0.18

As a result of potential increases in days above the 1,100 µS/cm threshold, Special Condition Part I.D.5 was developed to protect instream beneficial uses during these periods. The *Rappahannock River Hydrologic and Salinity Analysis* indicated the additional days of occurrence were during known low flow or drought periods.

10. Compensation for Unavoidable Impacts:

Wetland Impact Site W-11 includes impacts to 433 square feet of forested wetlands that are located approximately six (6) miles from the tidal Rappahannock River. Wetland Impact Site W-9 includes impacts to 423 square feet of forested wetlands that are located at the western edge of Gouldman Pond in Caroline County. The Department's Wetland Condition Assessment Tool (WetCAT) was used to conduct a desktop review of the permanent wetland impacts and noted that all tidal features end at the dam along Goldenvale Creek. There are no tidal wetland impacts mapped in the area of approximately 3,000 feet of tidal influence from Goldenvale Creek to the dam at Gouldman Pond.

Wetland impacts did not meet the threshold to require compensation per 9VAC25-660. Permanent impacts to streams will occur at Impact Site 26 and total 1,195 square feet (<0.03 acre) of impacts. Permanent impacts to wetlands from project construction will occur at two impact sites and total 1,174 square feet (0.03 acre) of impacts from conversion of forested wetlands to non-forested wetlands. Areas of conversion will be returned to original grade upon completion of construction activities and seeded with an appropriate wetland seed mixture upon completion of construction areas in the area in which the wetland is located.

No compensatory mitigation is required for this project.

11. Site Inspection:

A site inspection by the Department was not conducted as part of the application review process. Site inspections will occur during the pre-construction, active construction, and post construction phases.

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12. Relevant Regulatory Agency Comments:

As required by § 62.1-44.15:20 C and the Joint Permit Application review process, the Department consulted the appropriate state regulatory agencies and coordinated with various federal regulatory agencies. Agencies may submit written comments on proposed permits within 45 days after notification by the Department. Any written agency comments received were given full consideration and addressed in the VWP individual permit Part I - Special Conditions.

Summary of State Agency Comments and Actions

On April 17, 2020, comments were requested from the following state agencies: Virginia Department of Wildlife Resources, Virginia Department of Conservation and Recreation, Virginia Marine Resources Commission, the Virginia Institute of Marine Science, Virginia Department of Historic Resources, and the Virginia Department of Health. Failure to provide comments within 45 calendar days of the Department request for comments infers that the agency has no comments on the project activities. Comments and considerations were received from all agencies from which comments were requested.

Virginia Department of Health

The Office of Drinking Water provided comments via email May 1, 2020. In addition, a letter dated April 21, 2020 and received on May 18, 2020 provided additional comments from the Virginia Department of Health. The comments and considerations are summarized below:

Virginia Department of Health letter:

- Reviewed the Joint Permit Application and stated their recommendations in regard to the intake location for alternative No. 3. This alternative will have minimal tidal influence (e.g. salinity). It has no discharges within 5 miles upstream and no discharges within the tidal influence downstream. States that alternative location No. 3 is located approximately 19 miles upstream of Route 301 bridge crossing the Rappahannock River and is approximately 25 acres. The conceptual intake location is at the center of the parcel bordering the river. This location is on the outside of a natural bend in the river, which is anticipated to reduce the potential for sedimentation. Topography: The site is level, before dropping down at the river. The riverbank at the conceptual intake location has a high bank height of approximately 40 feet and the pump station would be constructed approximately 40 feet from the river due to a slope of approximately 1:1. The river is approximately 24 feet deep at this location.

- The Zone 1 and 2 watersheds are mainly undeveloped.

- Recommended Water Treatment Plant location alternative No. 4. It is near the main demands system demands.

- Requested a copy of the draft permit

- Site Access: The parcel has frontage along Route 17 and is accessible from an existing gravel driveway off Route 17 that is approximately 5,000 feet long.

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- Water Quality: Alternative intake location 3 has no upstream wastewater discharges within the five-mile buffer. The nearest downstream discharge (Four Winds Campground) is beyond the tidal excursion buffer.

- Wetlands and Streams: The parcel contains minimal wetlands and floodplains. Construction is not anticipated to impact wetlands or require a wetland/stream crossing.

- Cultural Resources: The Phase IA survey identified three architectural resources within 500 feet of the property. No archaeological resources were identified, but Phase IB was recommended for the property.

Virginia Department of Health - Office of Drinking Water Email:

- The comments provided relate to proximity to public drinking water sources (groundwater wells, springs, and surface water intakes). Potential impacts on public water distribution systems or sanitary sewage collection systems must be verified by the local utility.

- Identified 29 wells located within a 1-mile radius of the project site with eight of the identified wells located within a 1,000-foot radius of the project site.

- The Lake Caroline and Hanover Suburban Water System are located within a five-mile radius of the project site.

- The project is within the same watershed as the Hanover Suburban Water System.

- Recommend Best Management Practices be employed, including Erosion and Sedimentation Controls and Spill Prevention Controls & Countermeasures on the project site.

- Recommends well(s) within a 1,000-foot radius from the project site should be field marked and protected from accidental damage during construction.

- Recommends materials be managed while on-site and during transport to prevent impacts to nearby surface water.

Department of Environmental Quality Actions/Responses are summarized below:

- *As requested, the Department provided a copy of the draft permit to the Virginia Department of Health.*

- *Special Condition Part I C 2 requires the Permittee to mark wells within a 1,000 foot radius from the project site to protect the wells from potential accidental damage.*

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Virginia Marine Resources Commission

The Virginia Marine Resource Commission provided comments in a letter dated and received June 5, 2020. The comments and considerations are summarized below:

- Stated that Caroline County requested Commission authorization to construct a 13.9 million gallon per day raw water intake in the Rappahannock River, between Moss Neck and Olney Corner at N38.235086, W-77.307443, and a submerged 30-inch diameter transmission waterline beneath multiple streams to a proposed Water Treatment Plant in Carmel Church along Routes 17, 301, and 207 in Caroline County.

- Discussed the application with the Department and advisors at VIMS. In addition to the information requested by DEQ, the Virginia Marine Resource Commission determined that additional information must also be required by VMRC to process the application.

- Acknowledged that the proposed screen slot size and through-slot intake velocity represents the most protective available engineering application for reduction of adverse impacts to aquatic eggs, larvae, and juveniles for this reach of the Rappahannock River. However, they continue to advise that mortality of these organisms be expected from continuous intake operation.

- To accurately assess potential adverse impacts to local hydrology and aquatic resources, a hydrodynamic modeling approach that uses a fine resolution, three-dimensional, unstructured grid with particle tracking capabilities that demonstrate larval transport processes is necessary.

- Stated that the empirical regression model used in the County's analysis inaccurately assesses estimated population losses of aquatic organisms that encounter the intake over multiple tide cycles. As such, they continue to recommend the use of a tidal excursion and particle-tracking model employing various flow regimes.

- Remains concerned about the recent increase in requests for intakes in the tidal reaches of the Commonwealth. These areas provide critical habitat for spawning anadromous and resident fishes. Anadromous finfish species have been and continue to experience depleted stocks. Coupled with the existing "grandfathered" intakes, Virginia Marine Resource Commission is growing increasingly concerned about the collective impacts of these intakes to tidal freshwater reaches.

- Projects that adversely impact fishery resources were a subject of the 2020 General Assembly. The Assembly enacted legislation stipulating that any agency "that issues any permit that has an adverse impact on fish and wildlife or their habitat, may require compensatory mitigation for such adverse impacts as a condition of issuing the permit." Expressed concerns regarding proposed compensatory mitigation agreements between the agency and the Applicant. The Applicant shall be subject to the approval of the Secretary of Natural Resources, and may include environmental restoration projects, purchase of mitigation bank credits, or in-lieu payments to existing state funds related to conservation of fish and wildlife in their habitat.

- Stated that reliable mortality estimates predicted by the three-dimensional model are deemed necessary to provide the Commission with the information needed for an informed permit decision and assessment of the required compensatory mitigation.

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Department of Environmental Quality Actions/Responses are summarized below:

- *The Virginia Marine Resource 2020 Particle Tracking Model was conducted as requested; the results can be found in Section 7: Cumulative Impact Analysis (CIA) in this document.*

- *VWP Permit No. 20-0514 does not require compensatory mitigation for any "unquantifiable" impacts to anadromous fish caused by the operation of intakes (impingement and entrainment) or historical construction of barriers to spawning throughout the watershed. Virginia Marine Resource Commission is responsible for the requirement of any compensatory mitigation.*

Department of Wildlife Resources

The Department of Wildlife Resources provided comments by email dated and received June 2, 2020, the comments and considerations are summarized below:

- Noted that DEQ should have DWR's comments on file from the pre-application meeting and review (Refer to *Section 13: Public involvement during the Application Process – Pre-Application* of this document for summary of previous Department of Wildlife Resource comments).

- Noted that comments provided during the Pre-Application process remain essentially the same and stated the appreciation of the adherence to the recommendations for the intake sizing and intake velocity.

- Noted that they did not see anything in the Project's plans about adhering to the time-of-year restrictions or other guidance DWR provided in their previous comments.

- Recommends that they update their information to include DWR's recommendations for protection of anadromous fishes, including federally Endangered Atlantic Sturgeon, and listed freshwater mussels.

- Recommend consideration of salinity impacts and continued coordination with the Department of Wildlife Resources and the Virginia Institute of Marine Science regarding those impacts.

- Notes that it appears that both pipeline corridors appear to be co-located with major roadways

- States that due to limited capabilities at the time, the Department of Wildlife Resource were not able to efficiently review the pipeline corridors but reiterate the general comments regarding linear utilities.

- Recommends that if any in-stream work is necessary to install the pipeline that the lat/long coordinates for each stream crossing be provided for further review, along with a shapefile of the chosen route.

- Notes that North Anna River is located downstream of the new Water Treatment Plant site. The North Anna River at this location has been designated a Confirmed Anadromous Fish Use Area and Threatened and Endangered Species Water due to the presence of Atlantic Sturgeon. If any instream work in the South Anna River and/or its tributaries are necessary to develop the new treatment plant, recommend additional coordination with them regarding that work.

- Reiterates that all other/additional comments provided during the earlier review remain valid.

Department of Environmental Quality Actions/Responses are summarized below:

- *Special Conditions Part I C.1.a and b require the Permittee to adhere to recommended time of year restrictions.*

- *Special Conditions Part I C.1.c requires the Permittee to conduct and submit a mussel survey, as recommended by DWR, prior to construction in the project area.*

Department of Conservation and Recreation

The Department of Conservation and Recreation provided comments in a memorandum dated and received June 9, 2020. The comments and considerations are summarized below:

Water intake and Raw Water Pump Station:

- Searched its Biotics Data System for occurrences of natural heritage resources from the area outlined on the submitted map. Natural heritage resources are defined as the habitat of rare, threatened, or endangered plant and animal species, unique or exemplary natural communities, and significant geologic formations.

- The Dicks Creek at Rt. 17 Stream Conservation Unit (SCU) is located within the project site. SCUs identify stream reaches that contain aquatic natural heritage resources, including 2 miles upstream and 1 mile downstream of documented occurrences, and all tributaries within this reach.

- SCUs are also given a biodiversity significance ranking based on the rarity, quality, and number of element occurrences they contain. The Dicks Creek at Rt. 17 SCU has been given a biodiversity ranking of B4, which represents a site of moderate significance.

- The natural heritage resources associated with this site are: Aquatic Natural Community G3G4/S3S4/NL/NL.

- The associated Aquatic Natural Community is significant on multiple levels. First, the stream is a grade B, per the Virginia Commonwealth University – Center for Environmental Sciences (CES), indicating its relative regional significance, considering its aquatic community composition and the present-day conditions of other streams in the region.

- This stream reach also holds a "Healthy" stream designation per the Virginia Commonwealth University Interactive Steam Assessment Resource (INSTAR) and Virtual Stream Assessment (VSS) score. This score assesses the similarity of this stream to ideal stream conditions of biology and habitat for this region.

- Lastly, this stream contributes to high biological integrity at the watershed level (6^{th} order) based on the number of native/non-native, pollution tolerant/intolerant and rare, threatened, or endangered fish and macroinvertebrate species present.

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- Threats to the significant Aquatic Natural Community and the surrounding watershed include water quality degradation related to point and non-point pollution, water withdrawal and introduction of non-native species.

- Recommended the implementation and strict adherence to applicable state and local erosion and sediment control/storm water management laws and regulations, establishment/enhancement of riparian buffers with native plant species and maintaining natural stream flow to minimize adverse impacts to the aquatic ecosystem as a result of the proposed activities.

Water Treatment Plant:

- According to information currently in DCR's Biotics Data System (BDS), natural heritage resources have not been documented within the submitted project boundary including a 100 foot buffer.

- The absence of data may indicate that the project area has not been surveyed, rather than confirm that the area lacks natural heritage resources. In addition, the project boundary does not intersect any of the predictive models identifying potential habitat from natural heritage resources.

- The proposed Water Treatment Plant will fragment an Ecological Core C4 as identified in the Virginia Natural Landscape Assessment, one of a suite of tools in Virginia Conservation Vision that identify and prioritize lands for conservation and protection.

- Ecological Cores are areas of unfragmented natural cover with at least 100 acres of interior that provide habitat for a wide range of species, from interior-dependent forest species to habitat generalists, as well as species that utilize marsh, dune, and beach habitat. Cores also provide benefits in terms of open space, recreation, water quality (including drinking water protection), air quality (including carbon sequestration and oxygen production), along with the many associated economic benefits of these functions. The cores are ranked from C1 to C5 (C5 being the least ecologically relevant) using many prioritization criteria, such as the proportions of sensitive habitats of natural heritage resources they contain.

- Fragmentation occurs when a large, contiguous block of natural cover is dissected by development, and other forms of permanent conversion, into one or more smaller patches. Habitat fragmentation results in biogeographic changes that disrupt species interactions and ecosystem processes, reducing biodiversity and habitat quality due to limited recolonization, increased predation and egg, parasitism, and increased invasion by weedy species. Minimizing fragmentation is a key mitigation measure that will reduce deleterious effects and preserve the natural patterns and connectivity of habitats that are key components of biodiversity. Recommends efforts to minimize edge in remaining fragments, retain natural corridors that allow movement between fragments and designing the intervening landscape to minimize its hostility to native wildlife (native cover versus lawns).

Raw Water Pipeline-Rappahannock Academy Quadrangle:

- The Ware Creek at Rt. 614 Stream Conservation Unit is located within the project site. The Ware Creek at Rt. 614 SCU has been given a biodiversity ranking of B4, which represents a site of moderate significance.

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- The natural heritage resource associated with the site is: Aquatic Natural Community NC- Lower Rappahannock Second Order Stream G3G4/S3S4/NL/NL.

- The stream is grade B, as per the VCU CES, indicating its relative regional significance, considering its aquatic community composition and the present-day conditions of other streams in the region.

- This stream reach also holds as a "Healthy" stream designation as per the INSTAR Virtual VSS score.

- This stream contributes to high Biological Integrity at the watershed level (6^{th} order) based on the number of native/non-native, pollution-tolerant/intolerant and rare, threatened, or endangered fish and macroinvertebrate species present. Threats to significant Aquatic Natural Community and the surrounding watershed include water quality degradation related to point and non-point pollution, water withdrawal, and introduction of non-native species.

- To minimize adverse impacts to the aquatic ecosystem as a result of the proposed activities, recommends the implementation of and strict adherence to applicable state and local erosion and sediment control/storm water management laws and regulations, establishment/enhancement of riparian buffers with native plant species and maintaining natural stream flow.

Raw water pipeline-Bowling Green Quadrangle, Port Royal Quadrangle:

- Biotics documents the presence of natural heritage resources within the project boundary including a 100 ft buffer.

- However, due to the scope of the activity, DCR does not anticipate the project will adversely impact these natural heritage resources.

Raw water pipeline-Woodford Quadrangle:

- Does not document any natural heritage resources within the submitted project boundary including a 100-foot buffer.

- The absence of data may indicate that the project area has not yet been surveyed, rather than confirm that the area lacks natural heritage resources.

- The project boundary does not intersect any of the predictive models identifying potential habitat for natural heritage resources.

Raw water pipeline Ruther-Glen Quadrangle:

- Does not document any natural heritage resources within the submitted project boundary including a 100-foot buffer.

- Notes that a predictive model identifying potential habitat for natural heritage resources intersects the project boundary. However, based on DCR biologist's review of the proposed project, a survey is not recommended for the resource.

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Overall Project Comments:

- There are no State Natural Area Preserves under the Department of Conservation and Recreation's jurisdiction in the project vicinity.

- The current activity will not affect any documented state-listed plants or insects.

Department of Environmental Quality Actions/Responses are summarized below:

- *In a letter dated and sent via email July 10, 2020 Caroline County responded to the Department of Conservation Resource's comments. The Applicant stated that they will adhere to applicable state and location erosion and sediment control/storm water management laws and regulations, including, as practicable, replanting riparian buffer areas as disturbed as part of this Project with native plant species and maintaining natural stream flow.*

- *In addition, the Applicant stated that they will undertake efforts to retain natural corridors that allow movement between fragments including implementing landscape design with native plant species that prioritizes natural cover over lawn to soften and reduce the length of edge, where practicable.*

Department of Historic Resources

The Department of Historic Resources provided comments in an email dated and received May 28, 2020. The comments are summarized below:

- Based on the information provided, the proposed project has the potential to affect historic properties potentially eligible for listing on the National Register of Historic Places, including the North Anna Battlefield (DHR Inventory No. 042-0123).

- Several historic resources including several archaeological sites were identified as part of this project. As of May 28, 2020, DHR had not received copies of our archives of the Cultural Resources survey materials included in the permit application. Without additional information regarding the design and construction of the proposed facilities, DHR cannot fully assess the adequacy of the survey completed.

- Requests that the US Army Corps of Engineers or its agents consult directly with the Department of Historic Resources pursuant to Section 106 of the National Historic Preservation Act (as amended) and its implementing regulations codified at 36 CFR Part 800 which require Federal agencies to consider the effects of their undertakings on historic properties.

Department of Environmental Quality Actions/Responses are summarized below:

- *In response to the Department of Historic Resource's comments, the Department forwarded on June 4, 2024, Department of Historic Resource's comments to the applicant/agent regarding the additional information requested. The agent provided the Phase 1A and Phase 1B cultural resource survey reports via email on July 10, 2020, noting that the reports were included in the Joint Permit Application.*

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- *In addition to the cultural resources survey materials, the Department of Historic Resource's requested the shapefile for the water line be provided to them in order to complete their review. The Applicant provided the shapefiles for the project limits of disturbance and the centerline for the raw water pipeline via email on June 2, 2020.*

- *On February 13, 2023, Caroline County sent a letter to the Department of Historic Resource in response to the Department of Historic Resource's January 14, 2022 letter confirming the receipt of DHR's most recent letter concerning the proposed Caroline County Water Intake Project, including the comments requesting additional clarity on actions taken to avoid impacts to sites 44CE0914 and 44CE0915. In response, Caroline has adjusted the location of the proposed raw water intake facility at site 44CE0914 to avoid the scattered litter. The revised location avoids the scattered litter and remains within the area that was initially surveyed. To further minimize the potential for impacts to sites 44CE0914 and 44CE0915 during construction, fencing will be placed around the proposed project site to ensure that construction activities do not have the potential to affect the areas beyond the boundary of the site, and no activities will take place beyond the site boundaries. Furthermore, during construction, the contractor will be prohibited from stockpiling soil or using the site for construction staging activities.*

- *In the Caroline County 4th Additional Information Response (9/12/2023), provided to the Department, the County states the Phase 1A survey of archaeological and architectural resources identified three architectural resources within a 500-foot buffer of the intake parcel that are eligible or potentially eligible for listing with the National Register of Historic Places (NRHP). However, the intake is proposed to be constructed at the center of the 24-acre parcel along the river, which increases the buffer distance by 500 to 1,000 feet from these resources. The Phase IA survey found no archaeological resources in the project area; however, a Phase IB survey was recommended. The results of the Phase IB survey identified one archaeological site consisting of a scatter of lithic debitage dating to an unknown prehistoric period. As a result of the site's low artifact density and disturbance of the deposits by plowing, the site was determined to be not eligible for inclusion in the NRHP. Therefore, the project is not expected to adversely affect architectural or archaeological resources in the vicinity of the Rappahannock River.*[20]

[20] Refer to the 4th Additional Information Response Appendix H - Historical and Archaeological Evaluation, dated 9-12-2023.

Summary of Federal Agency Comments and Actions:

By email dated April 17, 2020 comments were requested from the following federal agencies: the U.S. Environmental Protection Agency, the U.S. Army Corps of Engineers, the U.S. National Oceanic and Atmospheric Administration, and the U.S. Fish and Wildlife Service. Comments were not received from the U.S. Environmental Protection Agency or the U.S. National Oceanic and Atmospheric Administration.

United States Fish & Wildlife Service

- Contacted the Department of Environmental Quality via email April 23, 2020 to request additional information to aid their review of the Project. Caroline County provided the additional information requested to U.S. Fish and Wildlife Service on July 13, 2020.

United States Army Corps of Engineers

- Provided a Preliminary Jurisdictional Determination on August 28, 2020.

- Indicated they were coordinating the project materials with U.S. Fish and Wildlife Service and the National Oceanic and Atmospheric Administration. The Department did not receive any additional comments from U.S. Fish and Wildlife Service or National Oceanic Atmospheric Administration.

- On December 1, 2020 the Applicant provided updated impact information to U.S. Army Corps of Engineers and the Department.

Summary of Tribal Nations Comments

By letter dated and mailed April 27, 2020, comments were requested from the following Virginia Tribal Nations: Chickahominy, Chickahominy Eastern Division, Monacan, Nansemond, Pamunkey, Rappahannock, and Upper Mattaponi. Application materials including the comment requests were sent via email using VitaShare on April 27, 2020. Comments were not received from the following Tribal Nations: Chickahominy, Chickahominy Easten Division, Nansemond, Pamunkey, or the Upper Mattaponi.

Rappahannock Tribal Nation

The Rappahannock Tribe provided the following comments in a letter dated and received June 8, 2020. The comments are summarized below:

- Requests consulting party status on this project during the state permitting processes and also requests consulting party status under the National Environmental Policy Act and Section 106 of the National Historic Preservation Act when those processes are started.

- Notes that their name is derived from the Rappahannock River and that the River is central to their Tribe's culture, history, and identity. Potential impacts to cultural resources and to river wildlife and habitats are therefore of the highest concern to the Tribe.

- Caroline County is within the Tribe's service area and has been a central location within the Tribe's ancestral, historic, and contemporary territory.

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- Members live along the proposed project route and are likely to be affected by the project.

- Notes appreciation for being given an opportunity to comment. Their comments are focused on the importance of accurately assessing cultural resources and archaeological impacts; impacts to anadromous fish; reducing the visual and auditory impacts of the pump station; and requesting careful assessment of potential impacts associated by the watershed transfer proposed in the project design.

- Would like to participate in consultation conversations and be updated on potential project changes.

- Requests for cultural resources and archaeological impacts be further defined before the project route is finalized. The Tribe notes appreciation for the efforts by the municipality to conduct Phase IA archaeological assessment to provide preliminary information regarding less damaging routes for the project and a Phase 1B archaeological survey of a potential raw water intake site and potential treatment plant. The survey identified archaeological remains associated with the prehistoric occupation of the Rappahannock River valley, a lithic scatter site 44CE0914. However, the archaeological consultant did not find the site eligible for listing in the National Register of Historic Places due to its lack of diagnostic artifacts and its disturbance through plowing. Archaeological methods used for this investigation included systematic shovel testing and metal detection survey. In the area of the pump station, culturally sterile subsoil appears to be relatively shallow and is covered with a thin layer of plow zone that contains artifacts associated with prehistoric occupation, that do not meet the criteria for eligibility in the National Register. However, because cultural resources have been identified at the site, and due to the considerable disturbance planned to build the pump station, the Tribe expects for an Unanticipated Finds Plan to be developed for this site and the project route generally, and for the Plan to include details requiring whether monitoring is planned during initial project grading. Furthermore, the area of testing does not go all the way to the water's edge. The Tribe requests additional information regarding how the pipe from the pump station to the intake will be constructed and what its potential is to disturb cultural materials in the area of the project that has not yet been tested.

- Requests impacts to anadromous fish be considered. The project application acknowledges that the project is likely to have impacts on anadromous fish and proposes to mitigate these impacts using a $75,000 mitigation fund for the project. The Tribe requests more information regarding how these impacts were assessed and quantified and would also like to know who will decide which mitigation project to be chosen for funding.

- Notes recovery of the Atlantic Sturgeon has not occurred as much in the Rappahannock River as on the James River and water withdrawals are known to be damaging to sturgeon spawning. Atlantic Sturgeon have been found in the Rappahannock River within two miles of proposed Intake #3. Therefore, although the water withdrawal location is not currently known to be an Atlantic Sturgeon spawning location, the Tribe requests that the withdrawal's viability as a spawning location and potential impacts be assessed by DEQ in the context of Atlantic Sturgeon recovery in the future.

- Notes efforts to rehabilitate and strengthen the Rappahannock River should consider engaging the Tribe's Return to the River program. This program works with native and non-native youth to teach them about the Tribe's connection to the river, traditional practices and lifeways, and provides them with information about the river's resources and how best to steward them.

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- Requests impacts of the proposed watershed transfer be fully evaluated. According to the application, the project proposes an interbasin transfer between watersheds, removing water from the Rappahannock River in the Rappahannock Watershed and discharge water into the North Anna River, part of the York River Watershed. Therefore, the project raises issues of potential considerable risk to the human and natural environment, the consequences of which are difficult to predict. Moreover, interbasin transfer water transfers have generated substantial controversy and raise complex issues of riparian rights and environmental law that often result in litigation, especially in eastern states such as Virginia. The application alludes to this issue in the Public Comments/Issues for Major Water Withdrawals or Interbasin Transfers dated March 27, 2020. The material in that section illustrates that potential for salinity issues have been discussed and analyzed and found to be of minimal impact. However, the Tribe remains concerned about potential impacts, especially to species like the Atlantic Sturgeon, which inhabit the Pamunkey, Rappahannock, and York Rivers, each of which has received a Critical Habitat Designation by the National Marine Fisheries Service pursuant to the Endangered Species Act. For the aforementioned reasons, the Tribe requests that the Department request additional information from Caroline County concerning the risks posed by transferring water from one watershed to another so that the Tribe and the public will have the ability to understand this aspect of the project's risks.

- Requests visual and auditory impacts be evaluated and reduced. The Tribe notes the application contains no information regarding the likely visual effect of this project on the river, how noisy the pump station would be, or how the setting and impacts to setting may differ in the different alternative water intake and pump station sites. The Tribe requests that the project conduct visual and auditory impact modeling prior to finalizing a site, and that options for ways to reduce visual impacts be discussed as part of tribal consultation and NEPA compliance.

- Requests that opportunities be developed for Tribal input and participation. The Tribe notes that their headquarters are close to Caroline County, and tribal members may be able to participate in fish mitigation activities through their Return to the River program. Additionally, the Tribe regularly holds archaeological events and lectures at the Tribal Center. The Tribes asks that the project proponent consider ways that artifacts and information learned during this project may be shared with tribal members in an informal setting, and ways to involve the Tribe as the project progresses.

Department of Environmental Quality Actions/Responses are summarized below:

- *The Department met with members of the Rappahannock Tribe on June 16, 2023 to discuss an overview of the Joint Permit Application and the permit processing steps. All future coordination with the Tribe was directed to the Department's Director of Regulatory Affairs and Outreach Division.*

Monacan Tribal Nation

The Monacan Tribe provided the following comments in a letter dated April 28, 2020 and received May 5, 2020. The comments are summarized below:

- Provided the Monacan Indian Tribe is a federally recognized sovereign tribe, headquartered on Bear Mountain in Amherst County.

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- Notes their ancestral territory and the active Monacan consultation areas, which does not include Caroline County. The Tribe declines to actively participate in the consultation of the project, due to the project being outside of the Tribe's ancestral territory.

- Requests to be contacted if: sites associated with native history may be impacted by this project, adverse effects associated with this project are identified, human remains are encountered during the project, unanticipated native cultural remains are encountered during the project, other tribes consulting on this project cease consultation, or the project size or scope becomes larger or more potentially destructive than currently described.

Department of Enivronmental Quality Actions/Responses are summarized below:

- *All future coordination with the Tribe was directed to the Department's Director of Regulatory Affairs and Outreach Division.*

13. Public Involvement during Application Process:

Pre-Application

Prior to the submittal of the Joint Permit Application, the applicant and the Department convened a pre-application review panel to receive comments on the proposed project from stakeholder agencies. The panel meeting was held on January 19, 2016. Representatives from the Virginia Department of Wildlife Resources [previously named Department of Game and Inland Fisheries], the Virginia Department of Health, the Virginia Institute of Marine Science, and the Virginia Marine Resources Commission were in attendance.

An additional meeting between the applicant and the Department was held on April 2, 2019. The Department inquired about project updates and advised an additional pre-application panel to be held due to the elapsed time and significant changes to project since the last panel. The second pre-application panel was held on May 22, 2019. Representatives from Virginia Department of Health, the Virginia Institute of Marine Science, and the Virginia Marine Resources Commission, U.S. Army Corps of Engineers, and Department of Historical Resources were in attendance. Comments were received from Virginia institute of Marine Science, and Department of Wildlife Resources.

Virginia Institute of Marine Science

In a letter dated and received June 11, 2019, Virginia Institute of Marine Science provided comments regarding the pre-application information provided for the Project. The comments are summarized below:

- The applicants preferred location of the proposed intake is situated in a relatively narrow (<400 feet wide) section of the Rappahannock River approximately seven feet below mean low water.

- The applicant has expressed agreement with using wedge wire screen intakes with a slot size of one millimeter, and a maximum through-slot velocity of 0.25 fps.

- Stated that they understand that the Caroline County's projected withdrawal demands through 2035 require an average of 7.9 Mgal/d with a maximum daily withdrawal of 13.8 Mgal/d.

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- The applicant provided information on Ichthyoplankton near the intake proposed furthest downriver, and an empirical regression model of salinity dynamics in the vicinity of each proposed intake.

- The selected screen slot size and through-slot intake velocity represents the most protective available engineering application for reduction of adverse impacts to aquatic eggs, larvae, and juveniles. However, mortality is expected, although at an unknown level, from continuous intake operation. The likelihood of mortality generally correlates with through-slot velocity and data provided by the applicant show reductions in likely impingement and entrainment from lowered through-slot velocity requirements until water demand reaches its modeled maximum in 2035. These same data also show average withdrawal through-slot velocities remaining below 0.15 fps under maximum water demand. Therefore, the projected steady increases in through-slot velocity over time from a low of ≤0.05 fps to meet demands at initial operation will delay maximum mortality likelihood until peak water demand is achieved.

- *The Ichthyoplankton Population Impact Analysis (2010)* provided by the applicant presents a representative suite of fish species of concern, and guidance on projected mortality levels based on estimated average weekly population levels. This study used data from weekly collections of eggs, larvae, and juveniles over a period of approximately 3.5 months in 2007. Samples were collected in the vicinity of the most downriver of the three candidate intake locations, which is approximately 10 to 11 river miles downriver of the preferred intake location.

- The reported species are likely incomplete due to study design and limited sampling, but the identified species and life stages can be expected in the vicinity of the preferred intake. Although, this study used a conservative withdrawal level much greater than the current requested withdrawals (18 Mgal/d maximum withdrawal versus the 7.9 Mgal/d average withdrawal and 13.8 Mgal/d maximum daily withdrawal), the study relied upon a volumetric ratio approach using arbitrarily defined near field and far field regions to calculate estimated population loss percentages.

- Tidal excursion can be accurately determined and is defined as the upriver and downriver extent of tidal reach from a fixed point (for this circumstance, the intake). Diurnal tidal dynamics can lead to aquatic life stages encountering the intake multiple times over many tide cycles depending on river flow and tidal excursion distances. Therefore, the Virginia Institute of Marine Sciences cannot attest to the accuracy of this study's results. The applicant and/or the regulatory agencies may wish to consider refining these mortality estimates if a more accurate portrayal of likely mortality is needed for the purposes of compensatory mitigation calculations.

- Recommended that a further study is warranted to evaluate tidal excursion and particle tracking model approach employing various flow regimes.

- The salinity dynamics models present changes resulting from withdrawals in the vicinity of each intake at the average withdrawal level rather than the maximum withdrawal level, and do not provide complete information on downriver effects to salinity intrusion. However, we view these models as sufficient due to the low withdrawal levels relative to upriver volume. Sea level rise will result in upriver salinity intrusion over time, and it is unlikely the proposed withdrawal levels will exacerbate this phenomenon.

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Department of Wildlife Resources

In an email dated and received June 27, 2019, the Department of Wildlife Resources provided the following preliminary comments and recommendations based on the pre-application materials:

- To protect resident aquatic species from impingement and entrainment, recommend the surface water intake be fitted with a 1mm mesh screen and that the intake velocity does not exceed 0.25 fps.

- In addition, to ensure continued access to necessary instream habitats, recommends that the intake not withdraw more than 10% instantaneous flow and/or result in significant changes in water quality, as depicted by changes in salinity.

- Expressed their discomfort with the modeling that has been done so far for the project, as its clearly depicts anticipated salinity changes during times when the system is vulnerable.

- It appears that the model looked at changes that may occur across an entire year assuming usage of the average day withdrawals. However, even with these obscured results, changes in salinity were expected to occur at all three sites assessed.

- Recommended that modeling be performed assuming usage of maximum day withdrawals during periods of drought to assess whether anticipated changes in salinity resulting from operation of the proposed intake.

- Stated that upon review of the modeling results, the Department of Wildlife Resources will make comments, as necessary, regarding the impact salinity changes may have on resident and migratory fauna.

- States that the Department of Wildlife Resources documents federal Endangered Atlantic Sturgeon in the project area. The stretch of the Rappahannock River has been designated a Threatened and Endangered Species Water due to the presence of this species. The Rappahannock River at this location has also been designated a confirmed Anadromous Fish Use Area.

- Recommended that if any instream work in the Rappahannock River is necessary to install the intake and/or associated infrastructure, that such work adhere to a time of year restriction protective of these species from February 15th through June 30th and August 1st through November 15th of any year.

- The segment of the Rappahannock River on which the proposed intake is located is known to be highly productive for freshwater mussels, particularly for alewife floaters and tidewater muckets, both of which are Tier IV a Species of Greatest Conservation Need (SGCN). Based on the productivity in this area, the Department of Wildlife Resources collects broodstock from this part of the river and also have released propagated mussels in the Rappahannock River. State threatened green floaters have been documented from below the Rappahannock River fall line, so must also be considered as potentially present in the project area. As such, the Department of Wildlife Resources recommends that prior to any instream work, a mussel survey be performed from 100 meters upstream through 400 meters downstream of impact areas. The survey should be performed by a qualified, permitted biologist, preferably no more than six months prior to the start of construction. If mussel relocations are necessary, they should be coordinated with Brian Watson

(brian.watson@dwr.virginia.gov) and no federally listed species should be relocated without first coordinating with the USFWS. Survey results should be made available to the DWR. Upon review of the results, DWR will make final recommendations regarding the protection of listed species known from the area.

- Recommended a time of year restriction for all instream work from April 15th through June 15th and August 15th through September 30th of any year.[21]

- Recommended conducting any in-stream activities during low or no-flow conditions, using non-erodible cofferdams or turbidity curtains to isolate the construction area, blocking no more than 50% of the streamflow at any given time, stockpiling excavated material in a manner that prevents reentry into the stream, restoring original streambed and streambank contours, revegetating barren areas with native vegetation, and implementing strict erosion and sediment control measures.

- Recommended the use of matting made from natural/organic materials such as coir fiber, jute, and/or burlap, to minimize potential wildlife entanglements resulting from the use of synthetic/plastic erosion and sediment control matting.

- Recommended that instream activities occur only in the dry, allowing concrete to harden and cure prior to contact with open water to minimize harm to the aquatic environment and its residents resulting from the use of the Tremie method to install concrete, grout bags, and traditional pouring of concrete.

- States that there are historical records of bald eagle nests being documented in the project area. Recommended using the Center for Conservation Biology Eagle Nest Locator to determine if any active eagle nests are known from the project area to ensure protection of bald eagles in compliance with the Bald and Golden Eagle Act. Recommended if active eagle nests have been documented in the project area that the project move forward in a manner consistent with state and federal guidelines for protection of bald eagles; and coordination, as indicated, with the U.S. Fish and Wildlife Service regarding possible impacts upon bald eagles or the need for a federal bald eagle take permit.

- Once the preferred route for the waterline has been determined, the Department of Wildlife Resources will provide comments about any such impacts that might have on wildlife and or/ resources under the Department of Wildlife Resource's jurisdiction. Preferably, such utilities be co-located within already-disturbed corridors.

- To minimize overall impacts on wildlife and natural resources, the Department of Wildlife Resources offered the following comments about development activities:

    - Recommended the applicant avoid and minimize impacts to undisturbed forest, wetlands, and streams to the fullest extent practicable. Avoidance and minimization may include relocating stream channels as opposed to filling or channelizing as well as using, and incorporating into the development plan, a natural stream channel design and wooded buffers.

[21] Refer to the Appendix P – The Department of Wildlife Resources Time of Year Restrictions and Other Recommendations Guidance, dated September 29, 2023.

  - Recommend maintaining undisturbed naturally vegetated buffers of at least 100 feet in width around all on-site wetlands and on both sides of all perennial and intermittent streams.
  - Recommended maintaining wooded lots to the fullest extent possible. Generally, the Department of Wildlife Resources does not support the creation of in-stream stormwater management ponds.

- Recommended that the stormwater controls for the project be designed to replicate and maintain the hydrographic condition of the site prior to the change in landscape. This should include, but not be limited to, utilizing bioretention areas, and minimizing the use of curb and gutter in favor of grassed swales. Bioretention areas (also called rain gardens) and grass swales are components of Low Impact Development. They are designed to capture stormwater runoff as close to the source as possible and allow it to slowly infiltrate into the surrounding soil. They benefit natural resources by filtering pollutants and decreasing downstream runoff volumes.

- Recommended that all tree removal and ground clearing adhere to a time of year restriction protective of resident and migratory songbird nesting from March 15th through August 15th of any year.

- Recommended coordination with the U.S. Fish and Wildlife Service regarding potential impacts upon federally threatened northern long-eared bats associated with tree removal.[22]

- Recommended adherence to erosion and sediment controls during ground disturbance.

- Noted that the project is located within 2 miles of a documented occurrence of a state or federal threatened or endangered plant or insect species and/or other Natural Heritage coordination species. Therefore, recommended further coordination with the Department of Conservation and Recreation regarding the protection of these resources.

Riparian Landowner Notification

The Department notified riparian landowners located identified by the applicant adjacent to the impact area and within one-quarter mile downstream of each distinct impact area by letter dated April 21, 2020. The Department received nine (9) letters returned by the U.S. Postal Service that were marked undeliverable.

The Department received an email on March 8, 2021, from a riparian landowner with the following concerns:

- When Caroline County was notifying property owners of intent to enter to inspect affected properties to glean information required to submit an application, they referenced VA Code 25.1-203 in their letter. However, the landowner notes they did not abide by the law in several ways:

  1. They failed to send a letter requesting permission to enter first. The first letter the landowner received was informing them of the County's entry.

  2. The letter the landowner received failed to declare the number of people that would be entering. The landowner notes that this is required by Code 25.1-203.

[22] Refer to Appendix Q – The U.S. Fish and Wildlife Service Bat Survey Guidelines, dated March 2024.

3. The landowner was suspicious that the County didn't do the inspections on the dates stated in the letter. However, they do not have any proof of this. The landowner did not observe anybody on the dates specified in the letter. They did, however, observe two persons on adjoining properties outside of the dates specified. When the landowner asked about this at a public meeting on the project, Caroline County was not able to provide the exact dates of when those inspections occurred.

- Additionally, the landowner expressed concern about the accuracy of the wetland delineations that were conducted. The landowner attached pictures that they took inside the limits of disturbance in the projected pipeline along Rt. 17. The sample areas in question are on pages 13 of 63 and 14 of 63 of a report published by Caroline County but not identified by the landowner. The landowner notes there are no streams or wetlands marked on the maps despite the presence of a spring fed stream, as seen in the pictures provided.

Local Government Notification

The Department notified Caroline County's Director of Planning and Community Development of the Joint Permit Application by email on April 28, 2020.

Public Meetings

Caroline County held multiple public meetings, one in the planning phase and four during the application process of the project to allow the public opportunities to provide input, comments, and questions regarding the proposed project and address community concerns. Public meetings, organized by the applicant, were held on the following dates:

- October 17, 2019
- November 20, 2023
- December 4, 2023
- December 11, 2023September 25, 2024
- January 22, 2024

14. Public Comments received during Comment Period:

The public notice was published jointly with the Department of Environmental Quality and the Virginia Marine Resource Commission in *The Free Lance-Star* and *The Richmond Times-Dispatch* on May 18, 2024. The public comment period began May 18, 2024, and ended on June 18, 2024. The public notice and draft permit were posted on the Department of Environmental Quality website and the Virginia Marine Resource Commission website for the duration of the public comment period.

During the 30-day public comment period, the Department of Environmental Quality received and individually reviewed correspondence from 264 separate commenters, 163 of which requested a public hearing. In addition, the Department of Environmental Quality reviewed the comments posted to the Virginia Marine Resource Commission website of which 31 were directly related to the Department of Environmental Quality Draft Permit. Comments on the Virginia Marine Resource Commission website were consistent regarding concerns as those received by Department of Environmental Quality. Based on the Department of Environmental Quality's analysis, the commenters met the regulatory threshold for convening a public hearing for this draft Surface Water Withdrawal permit action. Based on the significant interested raised by the community, the Department of Environmental Quality recommends that the

commenters' request for a hearing be approved; this decision is documented in Appendix L – *Disposition of Public Hearing Request*, dated July 17, 2024.

The notice seeking public comment and announcing a public hearing was published in *The Free Lance-Star* on August 25, 2024. The public notice was posted on the Department of Environmental Quality website and Virginia Regulatory Town Hall for the duration of the public comment period (October 11, 2024).

Public Hearing:

A Public Hearing was held on September 25, 2024, at the Caroline County Community Center Auditorium located at 17202 Richmond Turnpike, Milford, VA 22514 from 5:30 P.M. to 10:00 P.M. Jerome Brooks, Director of the Virginia Department of Environmental Quality's Piedmont Regional Office, served as the hearing officer. An information briefing was conducted by the Department of Environmental Quality immediately prior to the public hearing. Approximately 100 people attended the public hearing. There were 61 individuals who provided oral comments during the public hearing. The draft permit public hearing comment period opened on August 25, 2024, and closed on October 11, 2024. During the public comment period of the draft permit public hearing, there were 103 commenters.

On November 1, 2024, the Department of Environmental Quality published a Public Hearing Response and Notification of Application Suspension Letter[23] on Virginia Regulatory Town Hall and the Department website. The letter was also provided to each commenter via their provided email address or U.S. Postal Service address if provided.

In response to public comments received, the Department of Environmental Quality requested additional information and modeling from the Applicant and issued an *Additional Information Request Letter* dated October 25, 2024. Submission of the additional information and modeling was requested to be submitted within 60-days from the date of the letter (December 24, 2024). In the interim, all actions for the permit were suspended by the Department of Environmental Quality until the requested additional information and modeling was received. The Department of Environmental Quality received the requested information on May 12, 2025.

At TIME on DATE, a summary of comments public hearing was held at Location, ADDRESS. NAME OF HEARING OFFICER, Position Title, served as the hearing officer. Approximately X people attended the public hearing. X individuals provided oral comments during the public hearing. All comments consisted of general support/opposition for the project/permit issuance.

<u>Revisions to the Draft Permit as a Result of Public Comments:</u>

A. Changes to Part I – Special Conditions:

- *Section D – Surface Water Withdrawals*
  - No. 2: Revised water withdrawal limits for the proposed intake on the Rappahannock River.
  - No. 5: Establishes drought restrictions to protect beneficial uses upon declaration of a drought within the Northern Coastal Plain drought evaluation region or Caroline County,

[23] Refer to Appendix M - Public Hearing Response and Notification of Application Suspension Letter, dated November 1, 2024.

The Permittee shall implement voluntary or mandatory conservation measures under all drought declarations.
    - No. 6 requires the Permittee to complete and submit a feasibility study for returning water the Rappahannock River within five years of permit issuance (DATE)

- *Section F – Water Loss Auditing*
    - No. 1: Requires the Permittee to submit a *Water Loss Auditing Plan* within one year of permit issuance.
    - No. 2: Requires the Permittee to initiate Water Loss Audits based on the *Water Loss Auditing Plan* and to submit a comprehensive report of findings by DATE.
    - No. 3: Requires the Permittee to submit a *Water Loss Auditing Report* every three years with the first report submitted by DATE.

- *Section G – Leak Detection and Repair*
    - No. 1: Requires the Permittee to submit a *Leak Detection Repair Plan* within one year of permit issuance.
    - No. 2 Requires the Permittee to submit a *Leak Detection Repair Report* every three years with the first report submitted by DATE.

- *Section L – Compensatory Mitigation*
    - Nos 1-2: Established restoration of temporarily impacted wetlands pre and post construction.

B. Changes to Permit Decision Rationale:

- *Section 4 – Project Description– Purpose of Water Uses and Basis of Need*
    - Demands associated with industrial cooling water were removed from the total demand projections.
    - Footnotes were updated to refer to updated information submitted by the Applicant in the Additional Information Letter Responses

- *Section 5 – Project Purpose & Need – Purpose of Water Use and Basis of Need*
    - Demands associated with industrial cooling water were removed from the total demand projections.
    - Footnotes were updated to refer to updated information submitted by the Applicant in the Additional Information Letter Responses

- *Section 5 – Project Purpose & Need – Water Need: Demand Projections:*
    - Demands associated with industrial cooling water were removed from the total demand projections.
    - Table 4: Caroline County's Service Area Water Demand Projections revised to reflect the removal of industrial demands.
    - Revised the Department's water demand evaluation based on the Applicants requested reduction in demands submitted on December 20, 2024
    - Table 5: Water Withdrawal Volumes revised to reflect the Department's evaluation of the applicants revised proposed withdrawal volumes for the 15-year permit period.
    - Footnotes were updated to refer to updated information submitted by the Applicant in the Additional Information Letter Responses

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- *Section 7 – Evaluating Water Withdrawal Volumes Based on Beneficial Use Impacts and Flow-by/Release Requirements – the Department Recommended Withdrawal Limitations*
    - Revised the maximum daily, maximum monthly, and maximum annual withdrawal limits based on the Applicants requested reduction in demands submitted on December 20, 2024.

- *Section 7 – Evaluating Water Withdrawal Volumes Based on Beneficial Use Impacts and Flow-by/Release Requirements* – Return Flow / Consumptive Use
    - States that Caroline County and the Town of Bowling Green will need to apply for new discharge permits in the future if the plants are expanded in order to remain protected of water quality in the basin.
    - Updated the analysis of existing and proposed discharges into the Mattaponi River based on the revised Beneficial and Aquatic Life Evaluation, dated May 12, 2025.
    - Table 6: Updated both of the existing WWTP's capacities per the active Virginia Department of Pollution and Discharge permits.

- *Section 8 – Water Supply Plan Review*
    - Updated based on the revised coordination response.

- *Section 9 – Surface Water Impacts - Alternative Intake Location Assessment Based on Salinity Model*
    - Revised summary and evaluation of the *Rappahannock and Mattaponi Hydrologic and Salinity Analysis,* submitted by the Applicant on May 20, 2025, and the updated *Beneficial Use and Aquatic Life Evaluation,* submitted by the Applicant on May 20, 2025.

For further information see Appendix L – Disposition of Public Hearing Request, Appendix M – *Public Hearing Response and Notification of Application Suspension Letter*, Appendix N – *Agency Comment Response Document,* dated XXXX2025., and Appendix O – *Final Action Memorandum*, dated XXXX2025.

15. Special Conditions:

The following conditions were developed to protect instream beneficial uses, ensure compliance with applicable water quality standards, prevent significant impairment of state waters or fish and wildlife resources, and to provide for no net loss of wetland acreage and function through compensatory mitigation and success monitoring and reporting.

Section A Authorized Activities

Nos. 1 and 2 address the activities authorized by this permit, including impact types and limits.
No. 3 states that the authorized activities shall be conducted in accordance with the application materials and any subsequent materials received during the application process.
No. 4 authorized the temporary use of mechanical equipment in surface waters.
No. 5 requires the applicant to notify DEQ of any changes to the authorized activities or of new activities which require a VWP permit.

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Section B Permit Term

Nos. 1 and 2 address the permit term and re-issuance process to ensure that all permit conditions are completed.

Section C Standard Project Conditions

No. 1 requires that the Permittee adhere to time-of-year restrictions recommended by the Department of Wildlife Resources and the U.S. Fish and Wildlife Service for the protection of fish and wildlife resources.
No. 2 requires that all wells within a 1,000 foot radius of the project area be marked per VDH standards.
No. 3 addresses the requirement for the minimization of adverse impacts to instream beneficial uses.
No. 4 ensures that the project will be executed in a manner that limits the disruption of the movement of aquatic life.
No. 5 ensures that downstream flows will be maintained to protect both instream and off-stream beneficial uses.
No. 6 ensures the minimization of adverse effects on navigation.
No. 7 ensures the passage of high flows.
Nos. 8 through 12 set forth all reporting requirements concerning reports, compliance items, construction, monitoring, compensation, and restoration as required by current law and regulations.
No. 13 prohibits the violation of Water Quality Standards in surface waters as a result of project activities.
No. 14 requires maintenance of continuous flow of perennial springs for the protection of instream beneficial use.
No. 15 ensures that dredging and filling operations will minimize stream bottom disturbances and turbidity.
No. 16 requires instream activities to be conducted during low-flow conditions to protect instream beneficial uses.
Nos. 17 through 20 provide requirements and limitations on the entry of various materials (including concrete, fill, construction and waste material, fuels, lubricants, and untreated stormwater runoff) into state waters.
Nos. 21 and 22 limit the use of machinery and equipment in surface waters to protect beneficial uses.
Nos. 23 through 27 require temporary disturbances to surface waters during construction to be avoided and minimized to the maximum extent practicable and the restoration of such temporary disturbances.
No. 28 requires the identification of all non-impacted surface waters in the vicinity of the proposed activity to prevent unpermitted impacts.

Section D Surface Water Withdrawals

No. 1 states the use of the water withdrawal is for public water supply.
No. 2 establishes the water withdrawal limit for the intake on the Rappahannock River.
No. 3 ensures that intake structure specifications protect aquatic wildlife resources.
No. 4 requires the submission of a *Drought Management Plan* within 180 days of permit issuance (DATE).
No. 5 establishes drought restrictions to protect beneficial uses upon declaration of a drought within the Northern Coastal Plain drought evaluation region or Caroline County.
No. 6 requires the Permittee to complete and submit a feasibility study for returning water the Rappahannock River within five years of permit issuance (DATE)

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Section E Water Withdrawal Monitoring, Recordation and Reporting Conditions

No. 1 requires submission of a *Monitoring and Operations Plan* within 120 days of permit issuance (DATE).
Nos. 2 through 6 establish monitoring and reporting activities and procedures to protect all beneficial uses. Flexibility is provided as to the method by which the reports are submitted to allow for future improvements in the form DEQ receives data.

Section F Water Loss Auditing

No. 1 Requires the Permittee to submit a *Water Loss Auditing Plan* within 360 days of permit issuance.
No. 2 Requires the Permittee to initiate Water Loss Audits based on the *Water Loss Auditing Plan* and to submit a *Comprehensive Report* within by DATE.
No. 3 Requires the Permittee to submit a *Water Loss Auditing Report* every three years with the first report to be submitted by DATE.

Section G Leak Detection and Repair

No. 1 Requires the Permittee to submit a *Leak Detection Repair Plan* within 360 days of permit issuance (DATE).
No. 2 Requires the Permittee to submit a *Leak Detection Repair Plan* every three years with the first report to be submitted by DATE.

Section H Stream Modifications, Including Intake/Outfall Structures

No. 1 prohibits the use of stream substrate for erosion control to avoid additional impacts to state waters.
No. 2 requires upland disposal of material removed from stream substrate to avoid unpermitted impacts to surface waters.
No. 3 ensures riprap placement conforms to current law and regulation.
Nos. 4 and 5 direct the placement and contents of materials for the construction of submerged structures, and on-bank storage and staging of materials, to protect water quality and fish and wildlife resources.
No. 6 addresses the requirements for outfall structures.

Section I Installation of Utilities

No. 1 requires the minimization of disturbance to surface waters and restoration to preconstruction conditions following utility line installation.
No. 2 sets a 90-day time limit for temporary side casting during trench excavation to minimize impacts to surface waters.
No. 3 provides the requirements for trench construction to avoid the drainage of surface waters.

Section J Road Crossings

No. 1 provides specifications for access road construction to minimize adverse effects to surface waters.
No. 2 ensures pipes and culvert construction is conducted in the dry to protect water quality and wildlife habitat.
No. 3 requires that temporary impacts be restored immediately following construction to minimize impacts to water quality and fish and wildlife resources.

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Section K Project Construction Monitoring and Submittals (Impact Site)

Nos. 1 through 6 describes the compensatory mitigation required to mitigate for the permitted impacts.

Section L Compensatory Mitigation

Nos. 1 through 2 Established restoration of temporarily impacted wetlands pre and post construction.

16. General Conditions

General Conditions are applied to all VWP individual permits, as stated in the VWP Permit Program regulation.

17. General Standard

This project may result in minimal, temporary impacts to beneficial uses related to the propagation and growth of aquatic life as defined in the General Standard. Provided the Permittee abides by the conditions of the permit, no substances shall enter state waters in concentrations, amounts or combinations that would contravene established standards or interfere with beneficial uses or are inimical or harmful to human, animal, plant, or aquatic life.

18. The Department Finds That:

- The proposed activity is consistent with the provisions of the Clean Water Act and State Water Control Law and will protect beneficial uses.
- The amount of the surface water withdrawal is limited to the amount of water that can be put to beneficial use.
- The permit addresses avoidance and minimization of surface water impacts to the maximum extent practicable.
- Based on the size and location of the surface water withdrawal, the withdrawal is not likely to have a detrimental impact on existing instream or off stream uses.
- The effect of the impact will not cause or contribute to a significant impairment of state waters or fish and wildlife resources; adverse impacts on other existing beneficial users; or a violation of water quality standards.
- This permit is intended to prevent unpermitted impacts.
- The permit reflects the required consultation with and full consideration of the written recommendations of VMRC, VIMS VDH, VDACS, DCR, DWR, DHR, USACE, NOAA, and USFWS.

The Department recommends VWP Individual Permit No. 20-0514 be issued as proposed.

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Attachment A – Water Conservation

Mandatory Non-essential Water Use Restrictions
Virginia Drought Assessment and Response Plan

The following non-essential water uses will be prohibited during periods of declared drought emergencies. Please note the exceptions that follow each prohibited use. These prohibitions and exceptions will apply to uses from all sources of water and will only be effective when the Governor of Virginia or the Virginia Drought coordinator declares a Drought Emergency. Water use restrictions shall not apply to the agricultural production of food or fiber, the maintenance of livestock including poultry, nor the commercial production of plant materials, *provided that best management practices are applied to assure the minimum amount of water is utilized.*

1. ***Unrestricted irrigation of lawns is prohibited.***

   - Newly sodded and seeded areas may be irrigated to establish cover on bare ground at the minimum rate necessary for no more than a period of 60 days. Irrigation rates may not exceed one inch of applied water in any 7-day period.

   - Gardens, bedding plants, trees, shrubs and other landscape materials may be watered with handheld containers, handheld hoses equipped with an automatic shutoff device, sprinklers or other automated watering devices at the minimum rate necessary but in no case more frequently than twice per week. Irrigation should not occur during the heat of the day.

   - All allowed lawn irrigation must be applied in a manner to assure that no runoff, puddling or excessive watering occurs.

   - Irrigation systems may be tested after installation, routine maintenance or repair for no more than ten minutes per zone.

2. ***Unrestricted irrigation of golf courses is prohibited.***

   - Tees and greens may be irrigated between the hours of 9:00 p.m. and 10:00 a.m. at the minimum rate necessary.

   - Localized dry areas may be irrigated with a handheld container or handheld hose equipped with an automatic shutoff device at the minimum rate necessary.

   - Greens may be cooled by syringing or by the application of water with a handheld hose equipped with an automatic shutoff device at the minimum rate necessary.

   - Fairways may be irrigated between the hours of 9:00 p.m. and 10:00 a.m. at the minimum rate necessary not to exceed one inch of applied water in any ten-day period.

- Fairways, tees and greens may be irrigated during necessary overseeding or resodding operations in September and October at the minimum rate necessary. Irrigation rates during this restoration period may not exceed one inch of applied water in any seven-day period.

- Newly constructed fairways, tees and greens and areas that are re-established by sprigging or sodding may be irrigated at the minimum rate necessary not to exceed one inch of applied water in any seven-day period for a total period that does not exceed 60 days.

- Fairways, tees and greens may be irrigated without regard to the restrictions listed above so long as:

    - The only water sources utilized are water features whose primary purpose is stormwater management;

    - Any water features utilized do not impound permanent streams;

    - During declared Drought Emergencies these water features receive no recharge from other water sources such as ground water wells, surface water intakes, or sources of public water supply; and,

    - All irrigation occurs between 9:00 p.m. and 10:00 a.m.

- All allowed golf course irrigation must be applied in a manner to assure that no runoff, puddling or excessive watering occurs.

- Rough areas may not be irrigated.

3. ***Unrestricted irrigation of athletic fields is prohibited.***

- Athletic fields may be irrigated between the hours of 9:00 p.m. and 10:00 a.m. at a rate not to exceed one inch per application or more than a total of one inch in multiple applications during any ten-day period. All irrigation water must fall on playing surfaces with no outlying areas receiving irrigation water directly from irrigation heads.

- Localized dry areas that show signs of drought stress and wilt (curled leaves, foot-printing, purpling) may be syringed by the application of water for a cumulative time not to exceed fifteen minutes during any twenty four hour period. Syringing may be accomplished with an automated irrigation system or with a handheld hose equipped with an automatic shutoff device at the minimum rate necessary.

- Athletic fields may be irrigated between the hours of 9:00 p.m. and 10:00 a.m. during necessary overseeding, sprigging or resodding operations at the minimum rate necessary for a period that does not exceed 60 days. Irrigation rates during this restoration period may not exceed one inch of applied water in any seven-day period. Syringing is permitted during signs of drought stress and wilt (curled leaves, foot-printing, purpling).

- All allowed athletic field irrigation must be applied in a manner to assure that no runoff, puddling or excessive watering occurs.

- Irrigation is prohibited on athletic fields that are not scheduled for use within the next 120-day period.

- Water may be used for the daily maintenance of pitching mounds, home plate areas and base areas with the use of handheld containers or handheld hoses equipped with an automatic shutoff device at the minimum rate necessary.

- Skinned infield areas may utilize water to control dust and improve playing surface conditions utilizing handheld containers or handheld hoses equipped with an automatic shutoff device at the minimum rate necessary no earlier than two hours prior to official game time.

4. ***Washing paved surfaces such as streets, roads, sidewalks, driveways, garages, parking areas, tennis courts, and patios is prohibited.***

   - Driveways and roadways may be pre-washed in preparation for recoating and sealing.

   - Tennis courts composed of clay or similar materials may be wetted by means of a hand-held hose equipped with an automatic shutoff device at the minimum rate necessary for maintenance. Automatic wetting systems may be used between the hours of 9:00 p.m. and 10:00 a.m. at the minimum rate necessary.

   - Public eating and drinking areas may be washed using the minimum amount of water required to assure sanitation and public health.

   - Water may be used at the minimum rate necessary to maintain effective dust control during the construction of highways and roads.

5. ***Use of water for washing or cleaning of mobile equipment including automobiles, trucks, trailers and boats is prohibited.***

   - Mobile equipment may be washed using handheld containers or hand held hoses equipped with automatic shutoff devices provided that no mobile equipment is washed more than once per calendar month and the minimum amount of water is utilized.

   - Construction, emergency or public transportation vehicles may be washed as necessary to preserve the proper functioning and safe operation of the vehicle.

   - Mobile equipment may be washed at car washes that utilize reclaimed water as part of the wash process or reduce water consumption by at least 10% when compared to a similar period when water use restrictions were not in effect.

- Automobile dealers may wash cars that are in inventory no more than once per week utilizing handheld containers and hoses equipped with automatic shutoff devices, automated equipment that utilizes reclaimed water as part of the wash process, or automated equipment where water consumption is reduced by at least 10% when compared to a similar period when water use restrictions were not in effect.

- Automobile rental agencies may wash cars no more than once per week utilizing handheld containers and hoses equipped with automatic shutoff devices, automated equipment that utilizes reclaimed water as part of the wash process, or automated equipment where water consumption is reduced by at least 10% when compared to a similar period when water use restrictions were not in effect.

- Marine engines may be flushed with water for a period that does not exceed 5 minutes after each use.

6. ***Use of water for the operation of ornamental fountains, artificial waterfalls, misting machines, and reflecting pools is prohibited.***

    - Fountains and other means of aeration necessary to support aquatic life are permitted.

7. ***Use of water to fill and top off outdoor swimming pools is prohibited.***

    - Newly built or repaired pools may be filled to protect their structural integrity.

    - Outdoor pools operated by commercial ventures, community associations, recreation associations, and similar institutions open to the public may be refilled as long as:

        - Levels are maintained at mid-skimmer depth or lower;

        - Any visible leaks are immediately repaired;

        - Backwashing occurs only when necessary to assure proper filter operation;

        - Deck areas are washed no more than once per calendar month (except where chemical spills or other health hazards occur);

        - All water features (other than slides) that increase losses due to evaporation are eliminated; and

        - Slides are turned off when the pool is not in operation.

    - Swimming pools operated by health care facilities used in relation to patient care and rehabilitation may be filled or topped off.

    - Indoor pools may be filled or topped off.

- Residential swimming pools may be filled only to protect structural integrity, public welfare, safety and health and may not be filled to allow the continued operation of such pools.

8. ***Water may be served in restaurants, clubs, or eating-places only at the request of customers.***

Attachment B: VWP PERMIT CONSTRUCTION STATUS UPDATE FORM

Attached to VWP INDIVIDUAL PERMIT No. 20-0514

[DATE]

[PERMIT ACTION]

Date (check one):

☐ June____, _____

☐ December _____, _____

VWP Individual Permit Number: _____

Project Name and Location: _____

_____

Status within each authorized surface water impact location, as identified on the Wetlands Impact Maps and Summary Tables, dated September 11, 2023, and received September 12, 2023: (check one of the following status options for each impact number/location. Attach additional sheet(s) if needed.)

Authorized impact number	Construction activities not started	Construction activities started	Construction activities started but currently not active	Does this impact involve culvert(s)[1]?	Construction activities complete[2]

[1] Provide spot elevations of the stream bottom within the thalweg at the beginning and end of the pipe or culvert, extending to a minimum of 10 feet beyond the limits of the impact, with completion of all culvert installations.

[2] If all construction activities and compensatory mitigation requirements are complete, the permittee completes and signs the Termination Agreement section below within 30 days of last authorized activity and/or compensation completion. A completed and signed Agreement serves as Notice of Project Completion (9VAC25-210-180 H).

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information, the information submitted is to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violation.

Authorized Signature: _____

Print Name: _____

Title: _____ Phone: _____

Date: _____ Email: _____

TERMINATION AGREEMENT BY CONSENT – PROJECT COMPLETION

Permittee Name: _____

Permittee Mailing Address: _____

Permittee Phone: _____

I hereby consent to the termination of coverage for VWP Individual Permit No. 20-0514.

"I certify under penalty of law that all activities and any required compensatory mitigation authorized by a VWP permit have been completed. I understand that by submitting this notice of termination that I am no longer authorized to perform activities in surface waters in accordance with the VWP permit, and that performing activities in surface waters is unlawful where the activity is not authorized by a VWP permit, unless otherwise excluded from obtaining a permit. I also understand that the submittal of this notice does not release me from liability for any violations of this VWP permit."

Permittee Signature: _____

Impact Construction Status Table Continued (if needed)

Additional Page [#] of [#]					
Authorized impact number	**Construction activities not started**	**Construction activities started**	**Construction activities started but currently not active**	**Does this impact involve culvert(s)[1]?**	**Construction activities complete[2]**

Attachment C: MONTHLY VWP PERMIT INSPECTION CHECKLIST

An inspection of all permitted impact areas, avoided waters and wetlands, and permanently preserved waters, wetlands and upland areas must be conducted at least once every month during active construction activities. Maintain this record on-site and available for inspection by DEQ staff.

Project Name	**VWP Permit #**	**Inspection Date**
Inspector Name & Affiliation	**Phone # & Email Address**	

I certify that the information contained in this report is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

_____ _____

Signature of Inspector Date

	In Compliance?				
PERMIT REQUIREMENT	**Yes**	**No**	**Not Applicable**	**Location, Description, Notes & Corrective Action Taken (use additional note space below if needed)**	**Date Completed**
Surface water impacts are limited to the size and locations specified by the permit. No sedimentation impacts and no impacts to upland preservation areas have occurred[1].	☐	☐	☐		
Within 50 feet of authorized activities, all remaining surface waters and mitigation (preservation) areas that are inside the project area are clearly flagged or marked to prevent unpermitted impacts.	☐	☐	☐		
Authorized temporary impact areas have been restored to original contours, stabilized, and planted or seeded with original wetland vegetation type within 30 days of completing work in each area.	☐	☐	☐		
E&S controls consistent with the Virginia ESC Handbook are present and maintained in good working order.	☐	☐	☐		
Exposed slopes/stream banks have been stabilized immediately upon completion of work in each impact area, in accordance with the Virginia ESC Handbook.	☐	☐	☐		
Heavy equipment is placed on mats/ geotextile fabric when working in temporary wetland impact areas. Equipment and materials removed immediately upon completion of work.	☐	☐	☐		
Construction activities are not substantially disrupting the movement of aquatic life.	☐	☐	☐		
New instream pipes and culverts on <5% slope have been installed to maintain low flow conditions and are countersunk at both ends as follows: ≤ 24" diameter: countersunk 3" > 24" diameter: countersunk 6" or more. Any variations were approved in advance by DEQ.	☐	☐	☐		
Time-of-year restrictions are being adhered to.	☐	☐	☐		

[1] If unauthorized impacts have occurred, you **must** email a copy of this report to DEQ within 24 hours of discovery. Email: [Regional Office@deq.virginia.gov

	In Compliance?				
PERMIT REQUIREMENT	**Yes**	**No**	**Not Applicable**	**Location, Description, Notes & Corrective Action Taken (use additional note space below if needed)**	**Date Completed**
For stream channelization or relocation, work in surface waters is being performed in the dry, with all flows diverted until the new channel is stabilized.	☐	☐	☐		
Water quality monitoring is being conducted during permanent stream relocations.	☐	☐	☐		
Streams and wetlands are free from any sheen or discoloration that may indicate a spill of oil, lubricants, concrete or other pollutants.[2]	☐	☐	☐		

Inspection Notes

[2] Any fish kills or spills of fuels or oils shall be reported to DEQ immediately upon discovery at [REGION PREP PHONE]. If DEQ cannot be reached, the spill or fish kill shall be reported to the Virginia Department of Emergency Management (VDEM) at 1-800-468-8892 or the National Response Center (NRC) at 1-800-424-8802. Any spill of oil as defined in § 62.1-44.34:14 of the Code of Virginia that is less than 25 gallons and that reaches, or that is expected to reach, land only is not reportable, if recorded per § 62.1-44.34:19.2 of the Code of Virginia and if properly cleaned up.

From:	Arnold, Roger
To:	MRC - jpa Permits
Cc:	jschiebel@co.caroline.va.us; Tabor, Chris; Wright, Ben
Subject:	VMRC #20-0514
Date:	Monday, February 13, 2023 5:39:55 PM
Attachments:	VIMS Rappahannock River Model Report - Final.pdf

Hello,

Please find attached a copy of the final report prepared by VIMS for the particle tracking model of the Rappahannock River. This study was performed in response to VMRC's request in the letter dated February 8, 2021 as well as prior meetings with regulatory agencies.

Please let us know of any questions or additional needs.

Thank you,
Roger

Roger B. Arnold, P.E.

Senior Associate | Hazen and Sawyer
1555 Roseneath Road, Richmond, VA 23230
(804) 366-5415 (mobile)
rarnold@hazenandsawyer.com | hazenandsawyer.com

Received by VMRC February 14, 2023 / lra

Apply a Particle Tracking Model to Analyze Impacts of Water Intake on Ichthyoplankton Mortality in Tidal Freshwater Region of the Rappahannock River

Final Report Submitted to

Hazen and Sawyer
1555 Roseneath Road, Richmond, VA 23230

by

Qubin Qin, Jian Shen, Troy Tuckey

Virginia Institute of Marine Science
School of Marine Science
William & Mary
Gloucester Point, Virginia 23062

February 3, 2023

Received by VMRC February 14, 2023 / lra

1. Introduction

Caroline County, Virginia, seeks to develop a new water supply source in the upstream Rappahannock River that will include the construction of a new water intake. The currently proposed intake has the capacity to meet the average daily water demand of 7.9 million gallons per day (mgd) and a maximum daily demand of 13.9 mgd, based on projected water demands for the planning year of 2035. The proposed intake location is approximately 30 km upstream of the Route 301 bridge over the Rappahannock River near Port Royal. The impacts of the intake on the mortality of ichthyoplankton and the ecosystems in the tidal freshwater region of the Rappahannock River are not well known. The location of the water intake is influenced by the tide, and because of the interaction of tide and freshwater discharge, it creates a difficult situation to accurately analyze the environmental impacts of the intake.

One of the key potential impacts of the intake operation on marine resources is causing an increase in the mortality of fish eggs and larvae. Because of the complex geometry and large variations of freshwater discharge in this tidal freshwater region, tidal flow can transport ichthyoplankton back and forth across the intake and potentially increase mortality. However, ichthyoplankton transport pathways and retention time in this region are unknown. It is unclear if ichthyoplankton spawned in this freshwater region will be affected by the intake. To provide sound scientific-based information for the environmental assessment, a numerical modeling approach can be used to simulate ichthyoplankton dispersion and changes in mortality caused by the intake.

The Virginia Institute of Marine Science (VIMS) assisted Caroline County to conduct the modeling study. VIMS developed a fine-resolution model to simulate tidal flow and larval transport processes in the Rappahannock River. With the use of the model, the changes in hydrodynamic conditions in terms of currents and water exchange can be evaluated, which will provide valuable information for understanding the impacts of intake on ichthyoplankton transport and the living resources found in the adjacent region. VIMS used a particle tracking model to simulate fish egg and larval movement and to accurately evaluate probabilistic increases of mortality due to the intake under different hydrological conditions. The model results documented in this report provide supporting information for the risk assessment. This approach not only can address the current issues, but will also be able to address future needs in this region.

2. Methods

2.1. Fish ichthyoplankton in the study area

Fish community data from the VIMS Striped Bass Seine Survey (seine survey, hereafter) were used to characterize fish species in Chesapeake Bay river systems. The seine survey has been conducted since 1965, though the time series for this analysis was restricted to more recent years as abundance of fishes in Chesapeake Bay river systems have changed over time (e.g., decline of American shad). VIMS used the most recent 20 years of data (1999 – 2018) (Table 1). The seine survey is conducted during summer providing data on resident species, as well as others that use these habitats seasonally as nurseries for larvae and juveniles. Each year,

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sampling the fish community consists of five visits to each site that are conducted approximately two weeks apart. Fishes are sampled with a 30.4 m beach seine that is set from shore by anchoring one end of the net in place and extending the other end of the net as far offshore as possible or until a depth of 1.2 m is reached. The offshore end is then swept towards the shoreline while maintaining the same net extension thereby completing an arc. The two ends are hauled onshore and the catch is sorted to species, counted, measured, and released. The area covered is approximately one quarter of a circle.

The representative fish species in the region are blueback herring (spawn from April – May, semi-demersal eggs), Inland silversides (spawn from April – September, demersal and sticky eggs), and striped bass (spawn from April – June, buoyant eggs). The blueback herring and striped bass spawn in the middle of the river and inland silversides spawn along the shoreline near vegetation. These species were selected to represent a range of biological characteristics that the tidal freshwater ichthyofauna possess. These species are common to tidal rivers in Virginia and have published details about their life history that can be used in the modeling exercise. They represent managed species (striped bass, blueback herring) and forage species (inland silversides) that would be vulnerable to the intake and thus relevant to the discussion of potential impacts.

Table 1. Fish species composition and density (mean number of fish per 100 m^2) from the two seine survey sites in Chesapeake Bay river systems. Gray highlights indicate species identified in Arcadis (2010) and blue highlights indicate abundant species identified from seine survey catches for which larval mortality estimates will be sought for potential use in the particle tracking model.

Species	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Alewife					6.9								0.6			1.7				70.9
American eel	1.5	0.5	1.2		2.2	2.3			2.1	1.7			0.7	1.8		2.8		4.2		1.1
American shad		0.8	1.5		2.3	4.9		3.5	0.9			4.2	9.8	2.6	3.6	17.6	18.7	9.2	13.4	16.6
Atlantic menhaden				0.9														0.9		
Atlantic needlefish									3.4											
Atlantic silverside											1.7									
Banded killifish	3.8	1.6	1.5		16.7	29.7	10.9	2.5	27.9	13.9	24.0	60.0	288.7	99.0	3.2	33.9	18.1	27.2	44.8	12.5
Bay anchovy	4.6		1.1	1.7							0.7						3.4			
Black crappie	0.9	0.5	1.1			1.5				0.9										
Blue catfish		1.1	2.7		4.9	12.3	7.6	3.4	0.9	3.0	0.5	1.5	3.9	2.8	3.7	1.5	1.3	0.0	3.2	5.6
Blueback herring		62.9	7.2		23.6	112.2	1.5		9.2			24.8	147.1		70.9	25.0	40.6	3.6	26.7	20.9
Bluegill	2.6		2.8	0.7	2.5	2.4	3.1	1.9	2.6	3.4	0.9	0.5	3.2	2.3	3.2	3.0	3.1	2.2	5.1	4.2
Bluespotted sunfish																	1.3		0.5	
Bridle shiner																2.8				
Brown bullhead																2.4				1.1
Channel catfish	0.9	1.0		0.5	1.5	1.1	2.5	2.5	1.0		1.1		0.8	0.9	1.5		0.9			
Common carp										2.6		2.2	0.9						0.5	
Eastern silvery minnow	1.7	0.5	2.7	0.9	65.4	8.4	4.6	1.3		3.4	14.7	9.6	376.3	2.6	2.9	8.1	9.3	26.7	18.7	2.8
Flathead catfish																				1.1
Gizzard shad	2.0	0.5	0.7	10.5	2.2	1.1		2.2	1.5	5.0	232.7	2.4	6.3	8.7	0.7	2.1	0.8	0.0		
Golden shiner				0.5	1.5	0.9						0.9						3.4		
Hickory shad							1.5													
Hogchoker	7.5	1.1	1.1	3.2	4.4		1.4	11.4	2.4		3.6	6.8	5.7	5.1		9.0	1.9	2.8	6.7	3.6
Inland silverside				0.5	2.1	2.7		1.0	0.8	4.5	457.6	1.1	2.0	1.6	3.2	3.6	0.9	2.9	4.2	1.6
Largemouth bass	1.1			0.9			1.5	1.4			4.7		1.7	3.5	2.0	1.9		4.3	7.0	3.2
Longear sunfish										0.9										
Longnose gar																			4.9	3.0
Margined madtom							1.5													
Mosquitofish	4.6				1.1				0.5		7.7	1.7	9.4	13.4		4.3		5.9		
Mummichog	0.9		6.6		49.8	3.1	1.2		2.1		2.6	36.3	69.4	39.3		4.9		35.1		
Pumpkinseed	3.8			0.9	5.9		1.2	4.8	6.1	8.9	1.8	1.9	3.7	2.2	1.7	4.1	1.9	9.3	33.7	9.7
Redbreast sunfish								1.5				6.0	1.3	1.7	1.3			7.3	3.1	4.0
Satinfin shiner	14.3	6.9	8.6	6.0	33.6	7.6	29.0	6.0	14.2	11.2	1106.0	12.5	14.7	22.3	4.7	22.7	12.6	22.4	56.1	19.8
Smallmouth bass								3.4			4.6	0.9	3.4	1.5						
Spot	3.6																			
Spottail shiner	20.6	17.8	21.7	6.7	5.2	24.6	48.1	10.0	33.1	21.7	14.7	93.1	64.9	75.7	31.0	40.2	22.1	11.6	18.7	37.4
Striped bass	1.5	1.1	8.9	0.7	12.9	3.6	4.9	1.1	5.4	3.2	1.8	2.7	17.9		4.6	7.5	2.1	8.5	5.8	0.7
Tadpole madtom									0.9				0.9							
Tessellated darter	2.1	2.5	4.5	0.5	2.6	2.5	1.3	3.5	3.9	3.4	6.6	2.9	6.4	19.1		9.3	1.5	5.0	4.0	10.5
Threadfin shad	3.4											1.0	0.8	1.1	3.0					
White catfish												0.9								
White crappie							1.5													1.5
White perch	33.2	15.4	17.3	10.3	2.9	15.4	10.8	8.0	5.8	3.4	6.8	9.3	15.6	9.0	15.4	13.5	15.0	8.1	2.1	16.3
Yellow perch	5.4	2.6	5.5	3.5	10.5	1.3	3.5	4.2	6.4	2.3	9.9	2.1	3.1	1.4	0.6	1.7	2.0	3.0	2.2	3.3

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2.2. Model development

The Semi-implicit Cross-scale Hydroscience Integrated System Model (SCHISM) was developed for the Rappahannock River. SCHISM uses a semi-implicit time-stepping scheme applied in a hybrid finite-element and finite-volume framework to solve the Navier-Stokes equations and uses a Eulerian-Lagrangian method to treat the momentum advection. In the vertical dimension, the model uses a highly flexible and efficient hybrid coordinate system (Zhang et al., 2015). This model simulating the entire Rappahannock River was developed based on the published Chesapeake Bay model (Figure 1). First, the bay model grid was refined in the Rappahannock River using the bathymetry data provided by USGS and NOAA. After the refinement and calibration in hydrodynamics, the domain of the Rappahannock River was cut from the bay model and forms the model for the river only. The open boundary conditions for the Rappahannock River model were provided by the bay model, and the model incorporates the upstream and lateral freshwater discharges obtained from the EPA Phase 6 watershed model. The unstructured grid model is flexible and is capable of simulating complex changes in geometry within 1-10 m resolution.

This model was calibrated for the Rappahannock River for both surface elevation and salinity. The results show that the model simulated tidal range and salinity intrusion along the Rappahannock River were satisfactory, and the model is capable of conducting accurate simulations (Figures 2 and 3). The model grid was refined near the location of the proposed water intake to accurately represent the complex geometry and bathymetry (*in situ* measured data) in that region.

The proposed intake design has 1 mm slot openings with a maximum through slot velocity of 0.25ft/sec and a 13.9 mgd maximum withdrawal rate. The horizontal model grid is shown in Figure 4. Particularly, the intake area (60 feet long and 20 feet wide) is represented by 140 quadrilateral grid elements with a resolution as fine as 0.82 m (2.7 feet), and each intake screen is represented by 4 grid elements (12 in total for the 3 intake screens, Figure 5). The water depth is set to be 12.5 feet MLW at the intake area and the water column is represented by 5 vertical layers. The bathymetry data for the Rappahannock River were obtained from NOAA chart and bathymetry data for the area around the intake were provided by Draper Aden Associates. With this high-resolution model grid, the model is able to simulate complex dynamics in the near-field of the intake. In the model, water is withdrawn continuously at the location of the intake, and the withdrawal rate of water by the intake was set to be 13.9 mgd (i.e., 0.609 m^3/s). The withdraw rate for each grid element representing the intake is set to be 0.05075 m^3/s (= 0.609 $m^3/s \div 12$).

The hydrodynamic model was run first for the two-year period from 2010-2011 to provide the hydrodynamic field for the particle tracking model. The particle tracking model was run for the year of 2011. Two cases were conducted for evaluating the changes in hydrodynamics in the Rappahannock River due to the intake construction. Case “Normal” and Case “Withdrawal” refer to the one without and with the intake, respectively.

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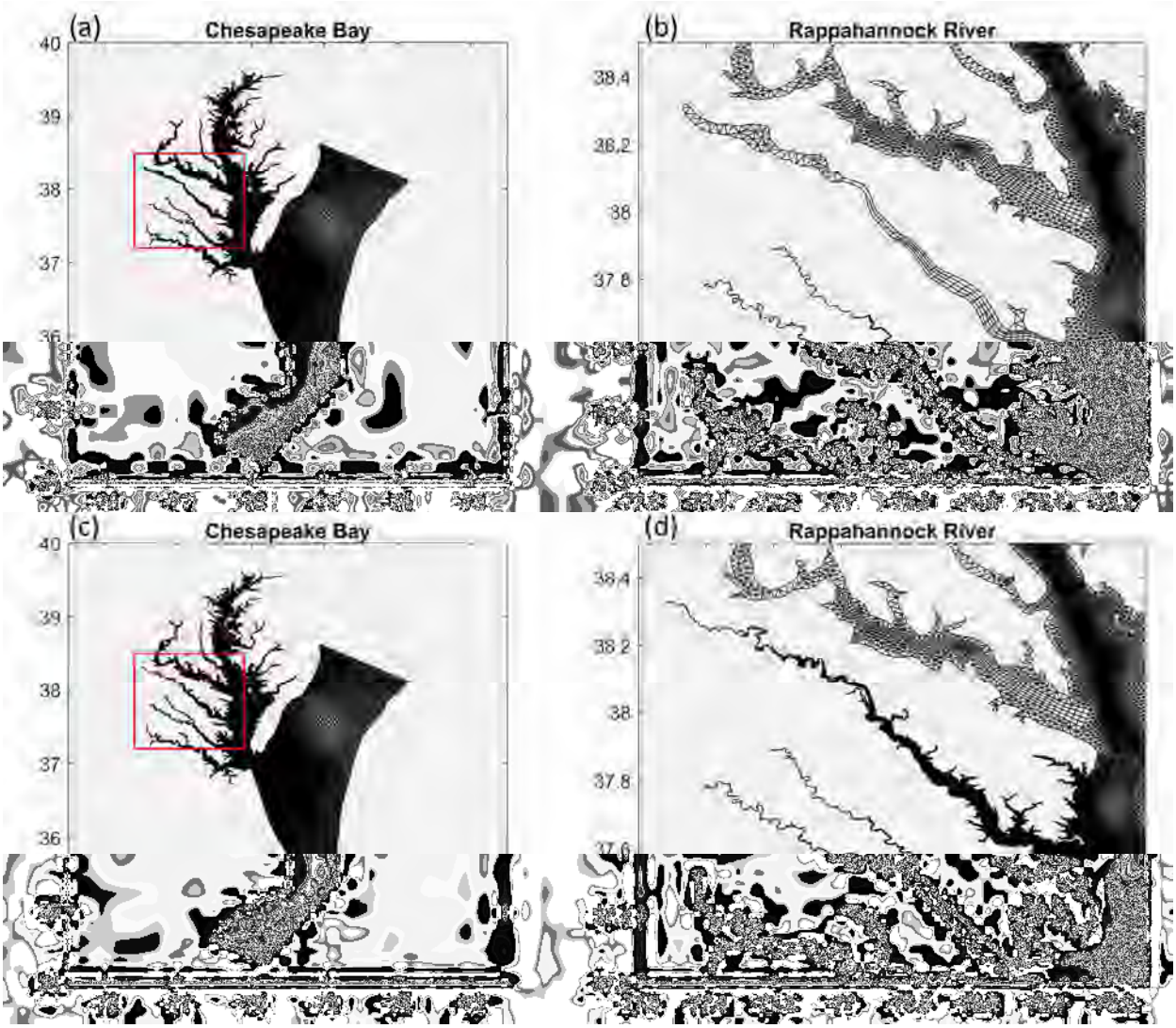


Figure 1. Comparison of the grid density in the old version of the bay model (a and b) and the new version (c and d).

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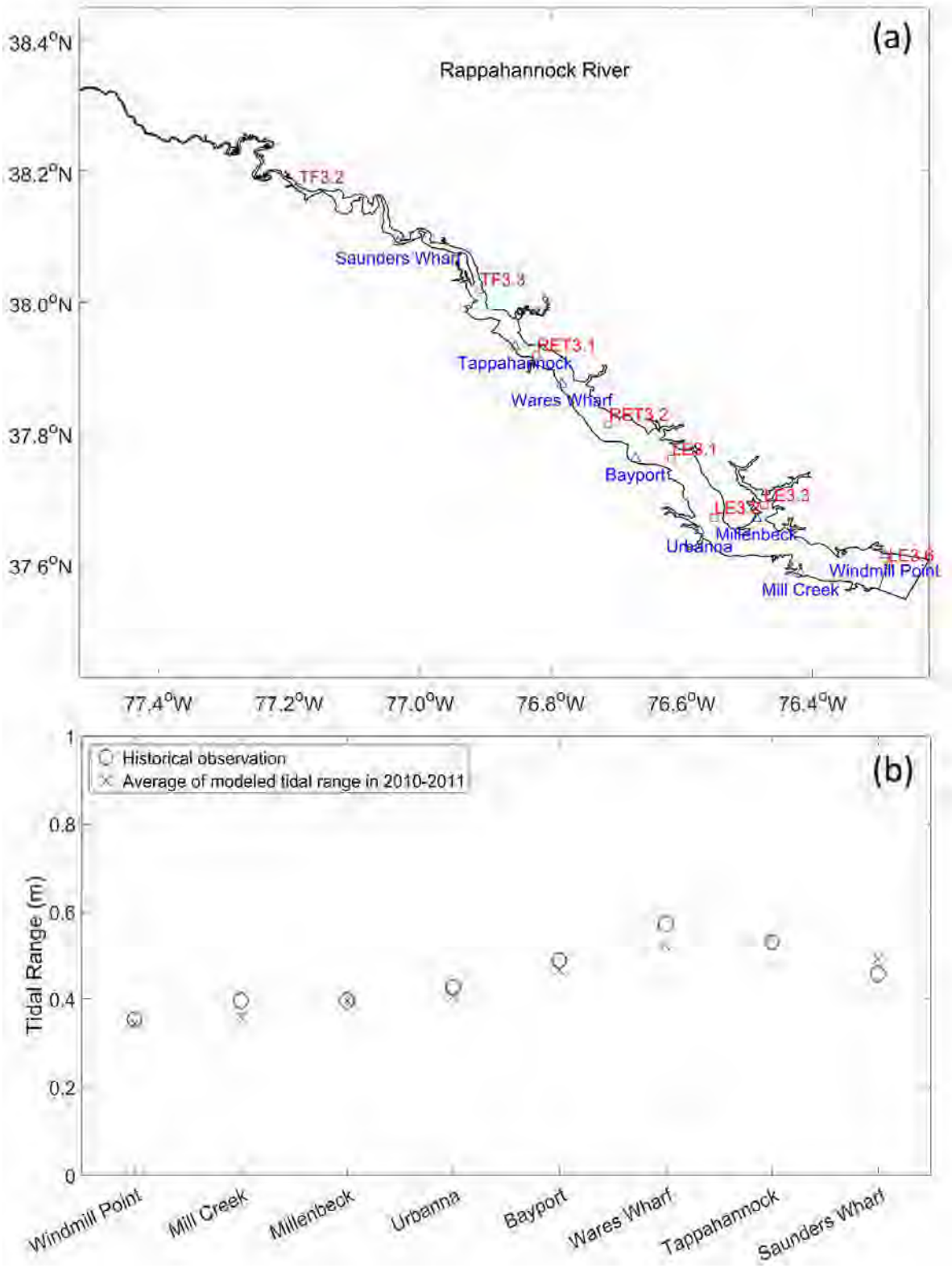


Figure 2. (a) Map of the Rappahannock River model domain with long-term monitoring stations (red squares) and NOAA tidal range stations (blue triangles); (b) Comparison of modeled tidal range and NOAA historical observations along the Rappahannock River.

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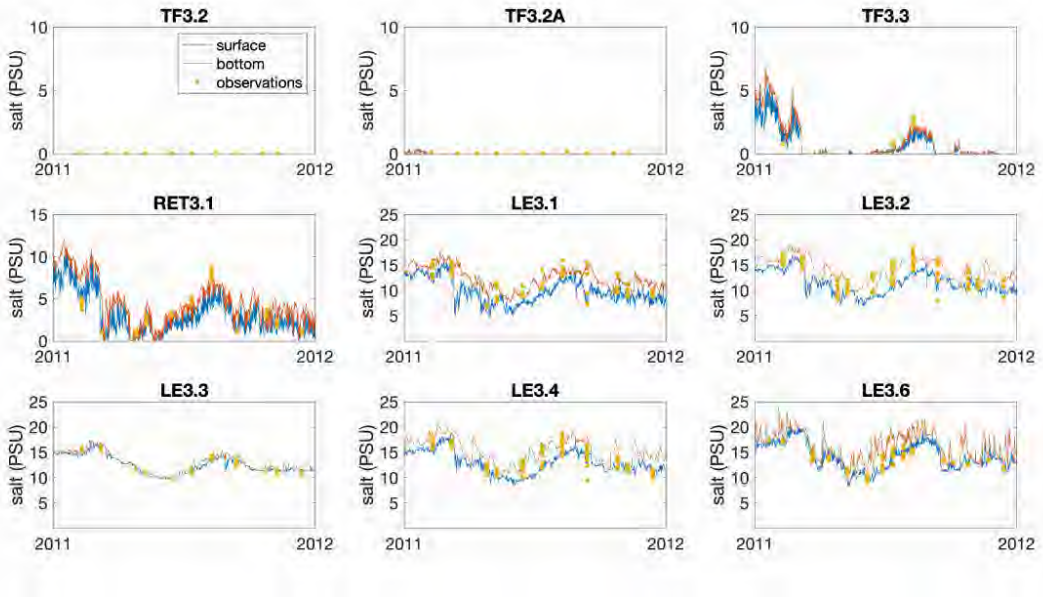


Figure 3. Comparison of modeled salinity and observations in the long-term monitoring stations along the Rappahannock River.

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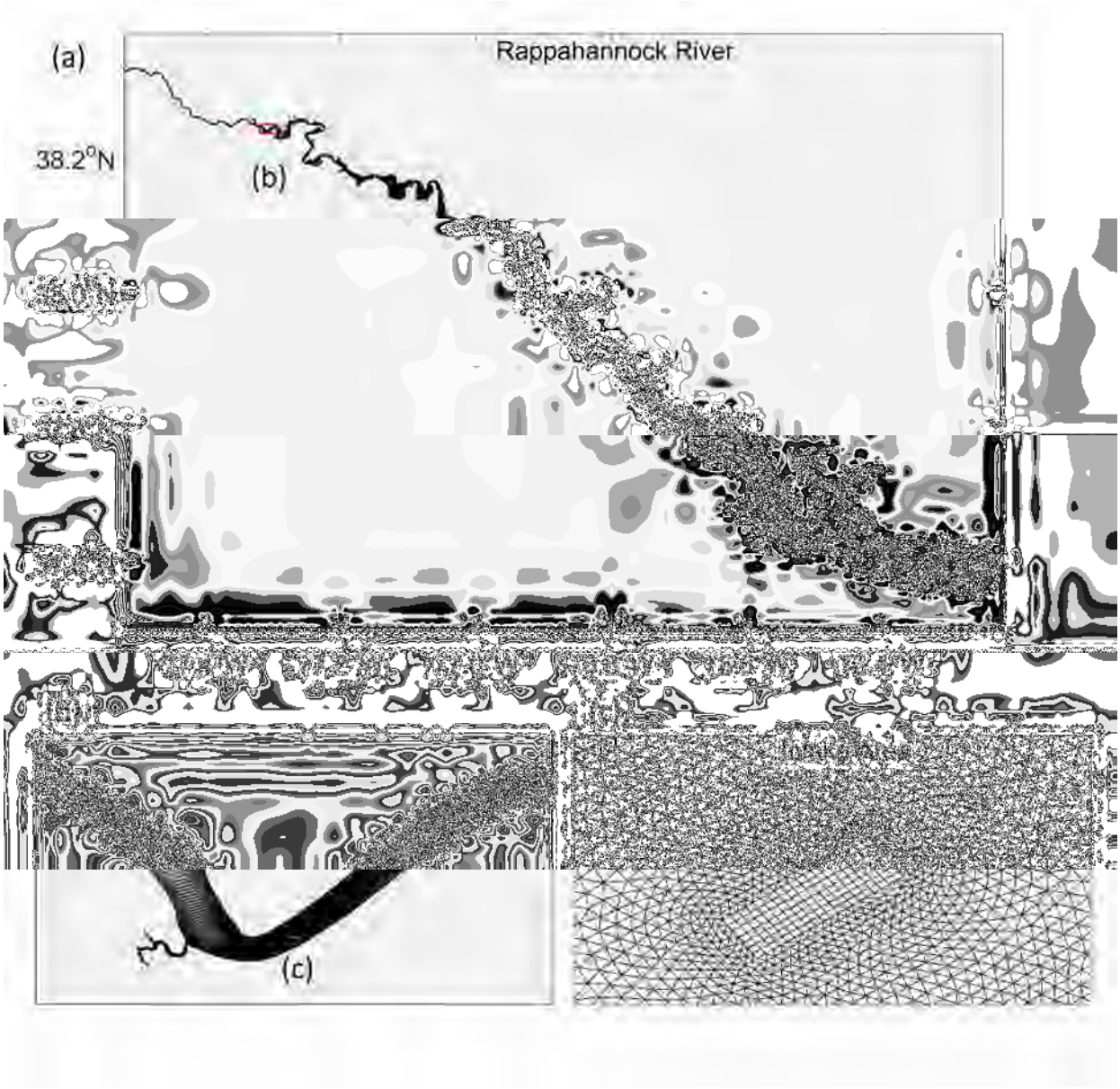


Figure 4. The extended Rappahannock River model grid with high resolution near the vicinity of the intake.

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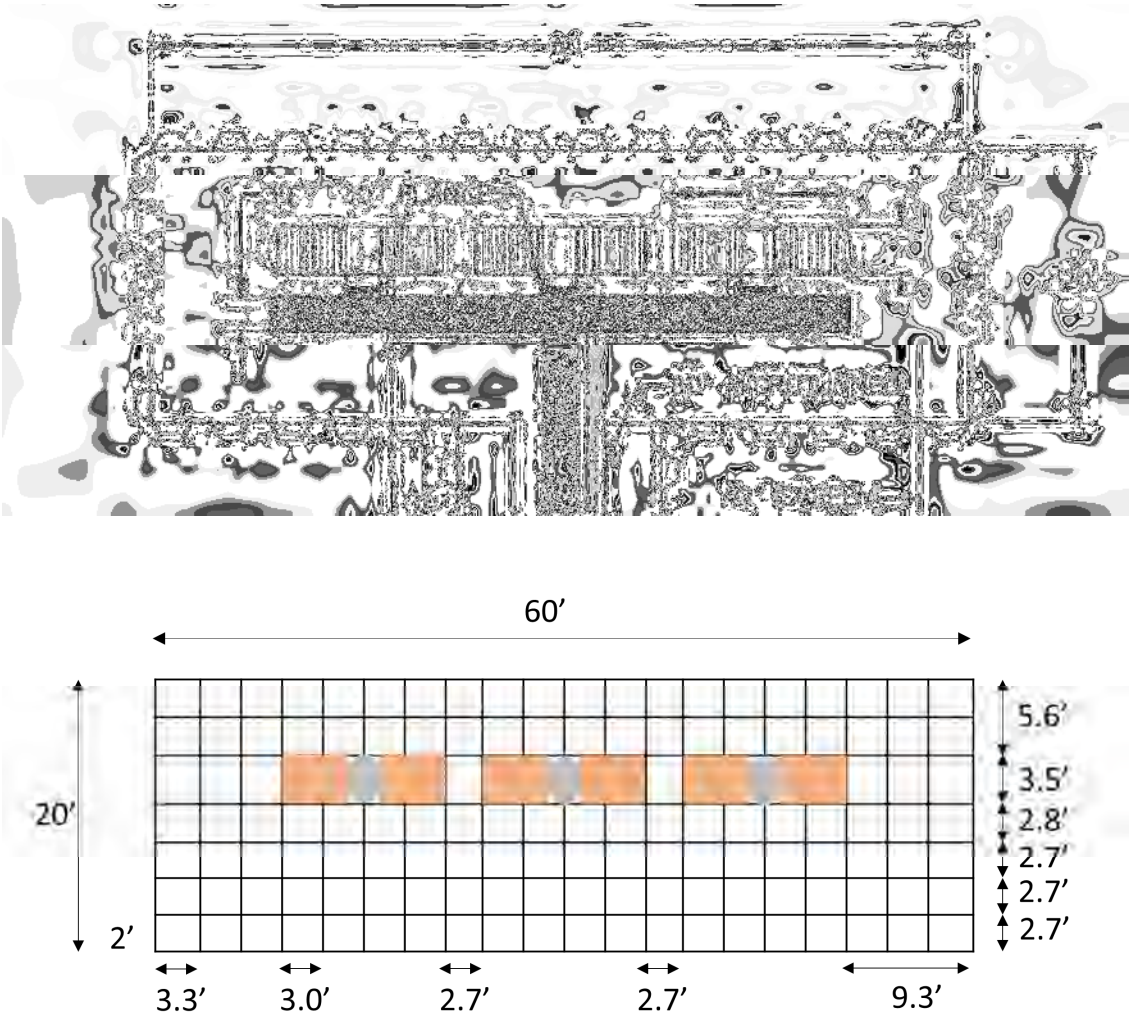


Figure 5. The grid designed for the intake area. Each of the 3 functional intake screens is represented by 4 grid elements.

2.3. Particle Tracking model

The Particle Tracking Model (PTM) has been broadly applied to coastal projects including studies of dredged material dispersion and fate, and oyster and larval fish dispersion and recruitment (e.g., Blumberg et al., 2004, Gallego et al., 2007, Torri et al., 2018). The particle tracking algorithms can incorporate transport, settling, deposition, mixing, and resuspension processes. In this study, we used a particle tracking model imbedded in the SCHISM modeling system (schism.wiki) to simulate fish egg and larval transport. Specifically, the SCHISM hydrodynamic model generated a hydrodynamic field for the PTM to use. The PTM is a Lagrangian particle tracker designed to allow the user to simulate particle transport processes (Chiu et al., 2018; Du et al., 2020). Each particle can represent an individual or a cluster of ichthyoplankton. Different densities and mortality rates of fish eggs and larvae of different species can be added to the PTM to simulate diverse physical and biological behaviors. Although

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the actual densities of eggs/larvae vary with time, we can estimate losses as a proportion of organisms in the river that encounter the intake and do not need absolute numbers. The combination of the high-resolution hydrodynamic model and the PTM, the complex dynamic fields with high swirl and vortices near the intake can be accurately simulated. Therefore, the removal of fish eggs and larvae can be simulated directly in our study with the use of the fine-resolution grid. When particles encounter the intake, they are removed from the system. This avoids uncertainty introduced by the probability method to determine entrainment that are used by some models with coarse-resolution grid (Varnell et al. 2008, Blumberg et al. 2004). The computed removal rate of particles provides an estimate of the conditional mortality rate resulting from the operation of the intake.

2.4. Particles that represent ichthyoplankton

It is well known that larval fish swimming behavior can alter the distribution of the larvae in aquatic systems. To better represent fish eggs or larvae, two different particles were used in the study - passive particles vs. active particles. The passive particles are neutrally buoyant particles, such as neutrally buoyant fish eggs or larvae. Their transport is strictly determined by the hydrodynamic field. The active particles are allowed to move upward or downward in the model to represent the rise of buoyant eggs or settling of heavier, demersal eggs in the water column, as well as the upward swimming behaviors of fish larvae.

For the fish eggs, their vertical speeds (ω) are dependent on the buoyancy and gravity of the particles, which is computed using the Stokes equation:

$$\omega = \frac{(\rho_e - \rho_w)}{18\mu} g R^2$$

where g is the gravitational field strength (m/s^2), R is the diameter of the spherical particle (m), ρ_e is the mass density of the egg (kg/m^3), ρ_w is the mass density of the water (kg/m^3), and μ is the dynamic viscosity (kg/(m*s)). μ = 0.001 kg/(m*s) at 20 °C. The velocity computed using the Stokes equation is usually applied for the particle Reynold number ($Re_p = \rho_w \frac{\omega R}{\mu}$) less than 0.5, i.e., $Re_p < 0.5$ (Dey et al., 2019). Outside of this range, the turbulent drag due to the wake behind the particle becomes important, which leads to a smaller vertical speed of the particles computed using the Stokes equation.

The characteristic size of fish eggs is about 1 mm in diameter. The mass density of fish eggs varies with species and environmental conditions such as temperature. The temperature effect on egg velocity through the change of mass density of eggs, however, is considered to be negligibly small (Sundby and Kristiansen, 2015). The eggs of striped bass in the Pamunkey River, a tidal freshwater river, have been reported to have a mass density of around 1.0018 g/cm^3, and a diameter of 1.84 mm (Bergey et al., 2003). In the tidal freshwater region where salinity is less than 0.5 psu, the mass density of the water is about 1.0 g/cm^3; thus, $\rho_P > \rho_w$ and the eggs can be considered as demersal eggs (Sundby and Kristiansen, 2015). This gives a settling velocity v = 0.0033 m/s (or 0.33 cm/s) and provides base velocity for fish eggs in the study area, since the egg diameters of silverside and blueback herring are not significantly

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different from that of the striped bass. The egg diameters are about 0.9 – 1.2 mm for the silverside and 0.87 – 1.11 mm for the blueback herring. However, ω = 0.0033 m/s results in Re_p = 6.1, beyond the allowable range for using the Stokes equation ($Re_p < 0.5$). Other empirical formulae for computing vertical speed for eggs have been used in the literature based on experiments (Sundby, 1983; Dey et al., 2019). Here we used the one for the spherical particle in Ferguson and Church (2004) as:

$$\omega = \frac{SgR^2}{18v + (0.3SgR^3)^{0.5}}$$

where $S = (\rho_e - \rho_w)/\rho_w$ and $v = \mu/\rho_w$ is the kinematic viscosity of the water (10^{-6} kg/(m*s) at 20 °C). Using this equation, the settling velocity for fish eggs in the study area is about 0.25 cm/s, a little less than 0.33 cm/s obtained from the Stokes equation. Using other empirical equations results in velocities with similar values.

Settling velocity computed using equations that are based on laboratory experiments, and speed can vary in natural systems due to different factors (Dey et al., 2019). In estuaries where the turbulent mixing is significant, turbulence strongly impacts the velocity. Experiments suggest that the settling velocity of the particle in turbulent flows can either increase or decrease compared to that in laminar flows (Brandt and Coletti, 2022). As a result, to broaden the applicability of the model we considered the settling velocities of eggs that span a wide range in nature and chose five representative vertical velocities (-1, -0.3, -0.1, -0.01, and -0.001 cm s^{-1}). By using a range of vertical velocities, we account for the variability in egg diameter and egg density that exists among fish species and represent the suite of fish that may be spawning in the vicinity of the intake rather than a single species. Note that the smallest velocity of -0.001 cm s^{-1} (about -0.86 m d^{-1}) is close to the values used in numerical models for the settling velocity of phytoplankton in estuaries (Shen and Qin, 2019).

In developing the model to include larval fish behavior, we assumed a constant upward swimming velocity for each active particle. Downie et al. (2020) argue that routine swimming speeds or the in-situ swimming speeds of fish larvae should be used in the model. Since we do not know the actual swimming speed for many species, we chose a range of possible swimming speeds. For example, the swimming speed of striped bass larvae is between 0.54 cm s^{-1} and 2.64 cm s^{-1} (Peterson and Harmon, 2001). Other species are likely to have faster and slower speeds compared with striped bass and swimming speed also depends on fish length. Thus, by using two different rates in the model we account for a wide range of potential swimming speeds that may be observed. We ignored the horizontal swimming speed of larvae since it is negligible compared to the horizontal advections dominated by currents. In total, we tested seven vertical velocities to represent different groups of eggs (buoyant, neutrally buoyant, and demersal) and larvae (Table 2). We believe the seven vertical velocities used in this study represent a variety of potential sinking/swimming velocities representative of eggs and larvae found in the Rappahannock River.

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Table 2. Particles, vertical velocity, and the representatives.

Particle	Vertical velocity (cm/s)	Representative
Passive	0	Neutrally buoyant eggs
Active	-1	Demersal eggs
Active	-0.3	Demersal eggs
Active	-0.1	Demersal eggs
Active	-0.01	Demersal eggs
Active	-0.001	Demersal eggs
Active	1	Larvae
Active	10	Larvae

2.5. Forward tracking and backward tracking

Both forward and backward particle tracking methods were used as each method provides a different perspective on the interaction between particles and the intake. For the forward tracking method, we chose the locations to release the particles and tracked their trajectories at each time point during the study period ($t = t_0, t_1, \dots, t_{end-1}, t_{end}$). The forward tracking method directly computes the percentage of particles that ultimately encounter the intake, which is the total percent removed. The maximum daily removal rate is further computed by counting the highest daily percent removed over the study period. For the backward tracking method, given a simulation period, the particles are released at the end of the period ($t = t_{end}$) within the model grid cells representing the intake, and the transport velocities and swimming or settling velocities are reversed in their directions, and we track the movement of the particles backward to the beginning of the period ($t = t_{end}, t_{end-1}, \dots, t_1, t_0$). The backward tracking method provides information on the origins of particles that encounter the intake.

Understanding the potential influence of a particular grid cell on the number of particles that are removed by the intake can be based on time or the number of particles that originate from that grid cell. The overall frequency of particles (or eggs and larvae) that are removed by the intake from one specific grid cell is defined as the ratio of the points in time that particles from that grid cell are removed by the intake divided by the total number of time points that exist during the chosen time period. Denoted as $f_{i,j}$, the frequency at the grid cell j at time point $t = t_i$, if there is more than one particle in that grid cell that is removed by the intake, the frequency equals 1 ($f_{i,j}$ = 1) at that time point, otherwise $f_{i,j}$ equals 0. The overall frequency of each grid cell over the computation period was computed as $\langle f_j \rangle = \frac{1}{N}\sum_i f_{i,j}$, where N is the total number of time points during the simulation period. For example, if the total simulation period is 1 day, and time is assessed every 1 hour, then N = 1 day / 1 hour = 24 hours / 1 hour = 24. If the frequency of a grid cell equals one, it means that this grid cell always has a fraction of particles that are removed by the intake during the simulation period (e.g., in the example provided, the frequency would be 24 time periods that the grid cell contained a particle that was removed by the intake divided by 24 hours that the simulation was run, 24/24 = 1). If the grid cell is located at the head of the estuary, it suggests how frequently particles released from the freshwater flow are

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removed by the intake. Note that for short run periods, the frequency only represents the frequency of particles at that location that are removed by the intake during that period (i.e., the frequency is dependent on the time period that was chosen and not representative of longer time periods). Thus, for areas that are relatively far from the intake, the computed frequency does not represent their long-term means. By examining the frequency distribution, the impact area can be evaluated.

The other method, based on counts of particles, that was used to assess the impact of individual grid cells we call: *Contribution*. The source of particles (or larvae or eggs) from each grid cell was evaluated by estimating the percentage of particles coming from that grid cell that are removed by the intake during the simulation period. For each time point t_i, $m_{i,j}$ denotes the number of particles in grid cell *j* that ultimately encounter the intake. In the back-tracking model, $m_{i,j}$ is computed by counting the number of particles in that grid cell at t_i. The contribution of one grid cell *j* over a portion of the computation period (from the beginning of the back tracking t_{end} to the time point t_i) was computed as $Contribution_{i,j} = \frac{1}{M_i} m_{i,j}$, where $M_i = \sum_j m_{i,j}$ is the total number of particles in the study area at t_i. Thus, the contribution of grid cell *j* over the entire computation period (from t_{end} to t_0) was computed as $Contribution_{0,j} = \frac{1}{M_0} m_{0,j}$.

2.6. Model scenarios

2.6.1. Forward tracking scenario

Multiple forward particle tracking scenarios were conducted to investigate the potential impacts of the intake on ichthyoplankton survival (Table 3). We first designed five forward tracking scenarios (Scenarios 1-5) to evaluate the impacts of release method (one-time release of all particles at a given time vs. continuous release of particles (scenario 5) over a period of time) and location on the percentage of particles that encounter the intake (Figures 6 and 7). By testing different release locations and release methods we are able to evaluate which method and location lead to the greatest removal of particles due to the intake. For one-time release scenarios, the release region is designed to be on the scale of tidal excursion that is between 6.8-9.9 km at the intake (Geyer and Signell 1992). Locations in the vicinity, upstream region, and downstream region of the intake were chosen for Scenarios 1-3, respectively. Scenario 4 was also run with a location further downstream of the intake, which was used as an additional scenario to Scenario 3 to verify if a downstream release would be significantly impacted by the intake. For Scenario 5, particles were released continuously over a period of 21 days (5/28/2011-6/17/2011) and the number of particles released each day was proportional to the freshwater discharge of the river (Figure 8). This assumes that the loadings of fish eggs or larvae are proportional to freshwater discharge. Thus, the scenario accounts for eggs or larvae transported by river discharge from upstream locations that are beyond the model domain. Also, these five scenarios show the movement of particles under moderate flow conditions. In Scenarios 1-4, released on 5/28/2011, particles experience a daily discharge of 50.69 $m^3 s^{-1}$ during the release date (May 28) and 5-day average discharge of 45.19 $m^3 s^{-1}$; for Scenario 5, the 21-day release occurs during an average discharge of 28.10 $m^3 s^{-1}$ (Table 4). These two discharge rates are

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between the median discharge of 28.3 m^3 s^{-1} and the mean discharge of 48.3 m^3 s^{-1} over the 116-year time-series (Figure 9).

Scenarios 6-13 were conducted to investigate the effects of flow on the percent of particles that encounter the intake. On timescales longer than the spring-neap tide cycle, the change in flow conditions are largely determined by variability in river discharge. Thus, the scenarios were designed to account for different river discharge rates. For high-flow, one-time release scenarios, particles were released on 3/7/2011 at a daily discharge rate of 781.56 m^3 s^{-1}, which was higher than the 99.8th percentile from the discharge time series. The mean discharge for the next five days reached 440.12 m^3 s^{-1}, exceeding the 99.2th percentile of the discharge rate for the time series. For low-flow, one-time release scenarios, particles were released on 7/17/2011 at a daily discharge rate of 6.37 m^3 s^{-1}, which was lower than the 10th percentile of the time. The mean discharge for next five days was 6.51 m^3 s^{-1}. For the high-flow, continuous release scenarios, particles were released continuously beginning on 3/7/2011 (Figure A1), at a 21-day-average discharge of 179.53 m^3 s^{-1} (above 96.3th percentile) and a 30-day-average discharge of 138.54 m^3 s^{-1} (above 94.5th percentile). For the low-flow, continuous release scenarios, particles were released continuously beginning on 7/17/2011 (Figure A2), at a 21-day-average discharge of 4.69 m^3 s^{-1} (below 10th percentile) and a 30-day-average discharge of 12.15 m^3 s^{-1} (below 23th percentile). Note that because we focused on the transport processes and not biological processes, the study period does not necessarily coincide with the spawning periods of the species. We chose the three periods in 2011 to investigate impacts of the intake under different flow conditions. The different spawning periods are also likely to experience different flow conditions, such as shifts between the wet and dry years, so the model results should be applicable across species and flow conditions.

In addition, 14 one-time release scenarios (Scenarios 14-27) and seven continuous release scenarios (Scenarios 28-34) were conducted for each vertical velocity of the active particles. Because it is more meaningful to assess worst-case situations for the intake-caused mortality of eggs or larvae, we focused on low flow conditions that potentially result in high conditional mortality rates.

For this study, we only released particles at the surface for all the forward tracking scenarios and did not explore the results if the particles were released at different vertical positions in the water column. We expect that any differences due to the vertical position of particle releases would be small because of the shallow water depth and strong vertical mixing found in this tidal freshwater estuary. All scenarios were tracked for 30 days after the release of particles.

To evaluate any potential bias resulting from the initial number of particles (10,000) that were released, we repeated the five scenarios with a 2.5-fold and a ten-fold increase in particle number (i.e., 25,000 and 100,000 particles, respectively). The results show that the percent of particles removed by the intake in the 2.5-fold and 10-fold scenarios are close to those from the original Scenarios (Figure A3). This indicates that 10,000 particles are sufficient to provide a robust estimate of potential impacts for this study, while more particles will further reduce

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uncertainties. Here, both the results of 10,000-particle cases and 100,000-paticle cases will be presented.

Table 3. The release method, location, flow condition, and vertical velocity of the 34 forward particle tracking scenarios. In those scenarios where particles are released continuously, the release period is 21 days, and the number of particles release is proportional to daily freshwater discharge. The vertical velocity of the particle can be either upward (+) or downward (-).

Scenario	Release method	Release location	Flow condition	Vertical velocity (cm s^{-1})
1	One time	Vicinity of the intake	Moderate	0
2	One time	Upstream of the intake	Moderate	0
3	One time	Downstream of the intake	Moderate	0
4	One time	Further downstream than Scenario 3	Moderate	0
5	Continuously	Head of the Rapp. of the model grid	Moderate	0
6	One time	same as Scenario 1	High	0
7	One time	same as Scenario 1	Low	0
8	One time	same as Scenario 2	High	0
9	One time	same as Scenario 2	Low	0
10	One time	same as Scenario 3	High	0
11	One time	same as Scenario 3	Low	0
12	Continuously	same as Scenario 5	High	0
13	Continuously	same as Scenario 5	Low	0
14	One time	same as Scenario 1	Low	-1
15	One time	same as Scenario 1	Low	-0.3
16	One time	same as Scenario 1	Low	-0.1
17	One time	same as Scenario 1	Low	-0.01
18	One time	same as Scenario 1	Low	-0.001
19	One time	same as Scenario 1	Low	1
20	One time	same as Scenario 1	Low	10
21	One time	same as Scenario 2	Low	-1
22	One time	same as Scenario 2	Low	-0.3
23	One time	same as Scenario 2	Low	-0.1
24	One time	same as Scenario 2	Low	-0.01
25	One time	same as Scenario 2	Low	-0.001
26	One time	same as Scenario 2	Low	1
27	One time	same as Scenario 2	Low	10
28	Continuously	same as Scenario 5	Low	-1
29	Continuously	same as Scenario 5	Low	-0.3
30	Continuously	same as Scenario 5	Low	-0.1
31	Continuously	same as Scenario 5	Low	-0.01
32	Continuously	same as Scenario 5	Low	-0.001
33	Continuously	same as Scenario 5	Low	1
34	Continuously	same as Scenario 5	Low	10

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Table 4. Statistics of Rappahannock River discharge on selected release dates and periods after the release.

Discharge condition	Release Date	Daily (m^3/s)	5-d mean (m^3/s)	21-d mean (m^3/s)	30-d mean (m^3/s)
Moderate	May 28, 2011	50.69	45.19	28.10	30.56
High	March 07, 2011	781.56	440.12	179.53	138.54
Low	July 17, 2011	6.37	6.51	4.69	12.15

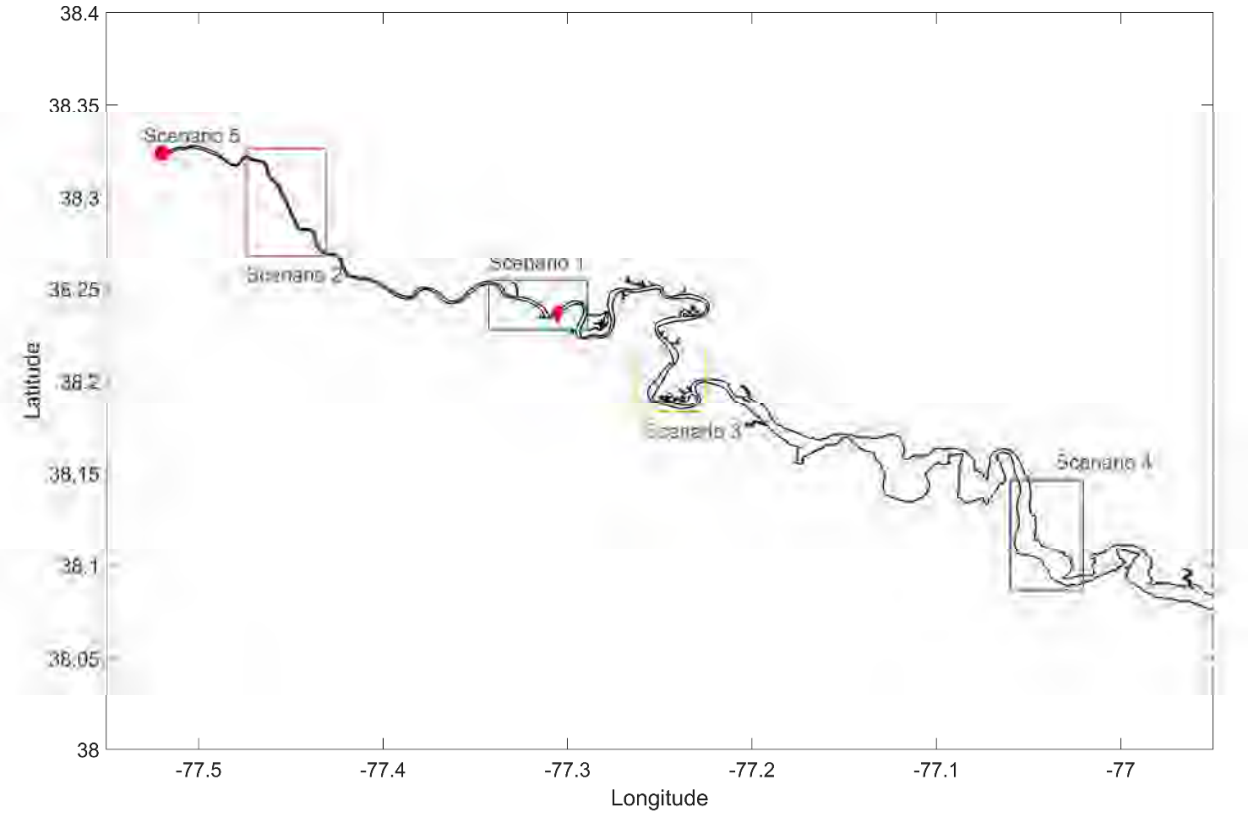


Figure 6. Map showing the release locations of the particles for the 5 scenarios of forward particle tracking (Scenarios 1-5). The red diamond shows the location of the intake.

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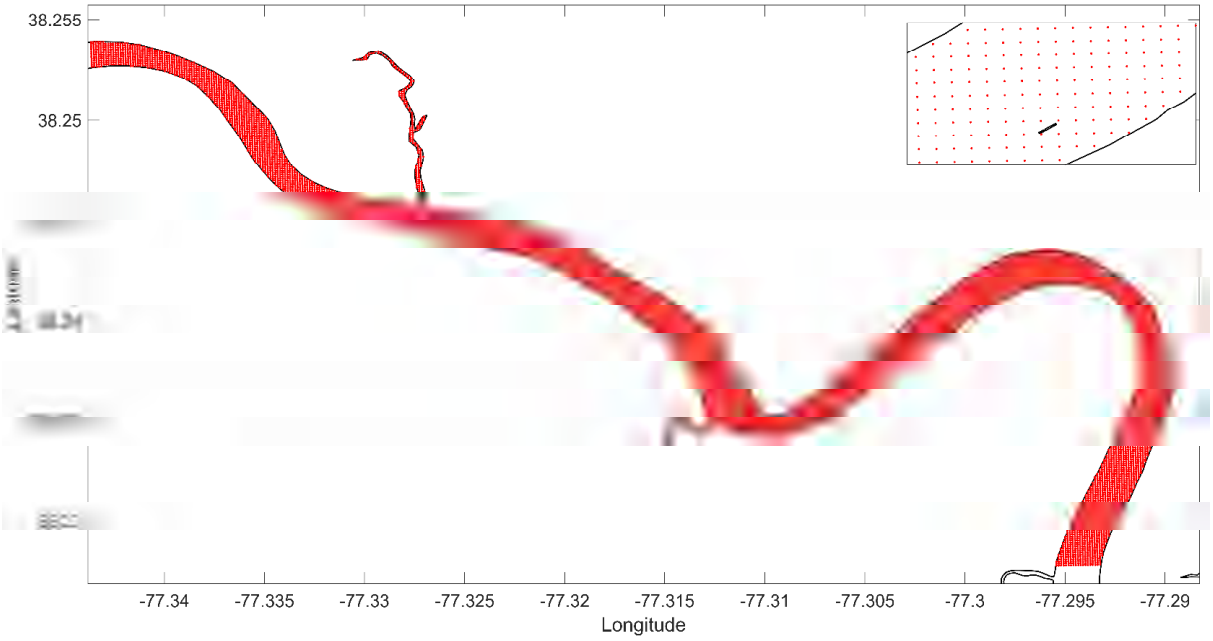


Figure 7. Initial distribution of 10,190 particles in Scenario 1, shown as an example. All the particles are released on 5/28/2011 at the surface of the area.

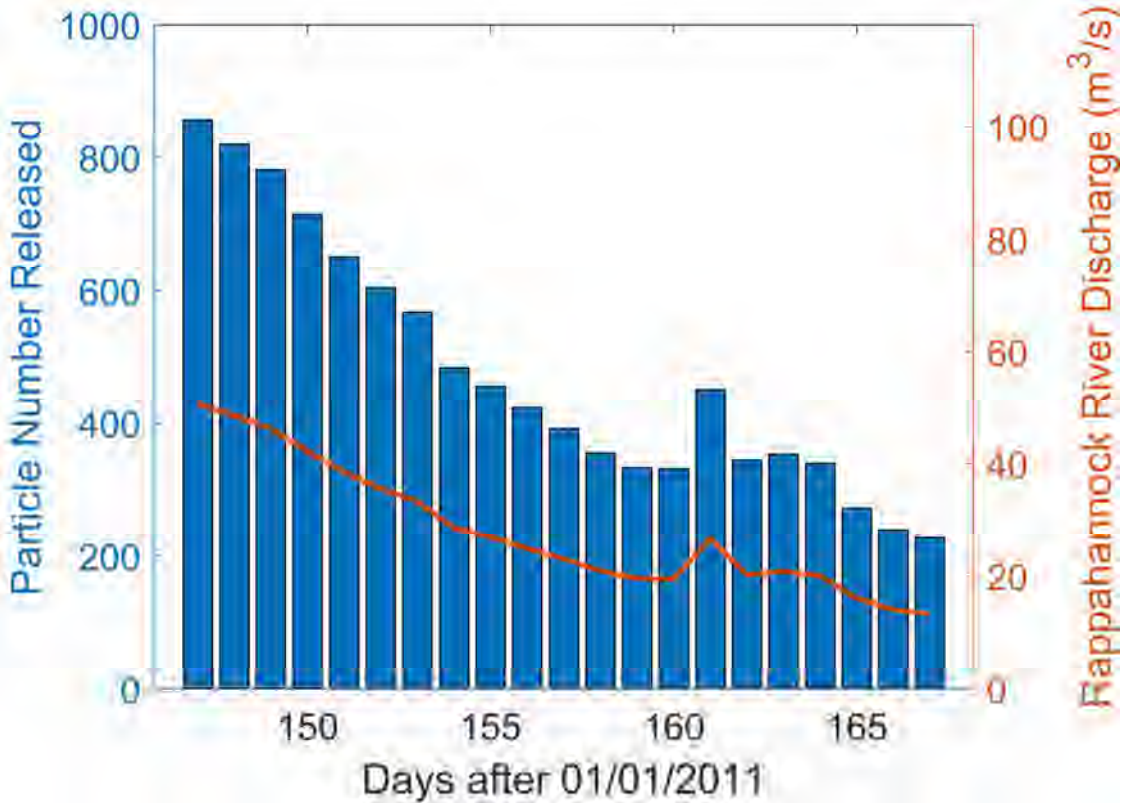


Figure 8. Particle release in Scenario 5 with 10,000 particles, at the surface of the uppermost grid cell in the Rappahannock River in the model for the 21 days (5/28/2011-6/17/2011). The number of particles released is proportional to the daily freshwater discharge of the Rappahannock River.

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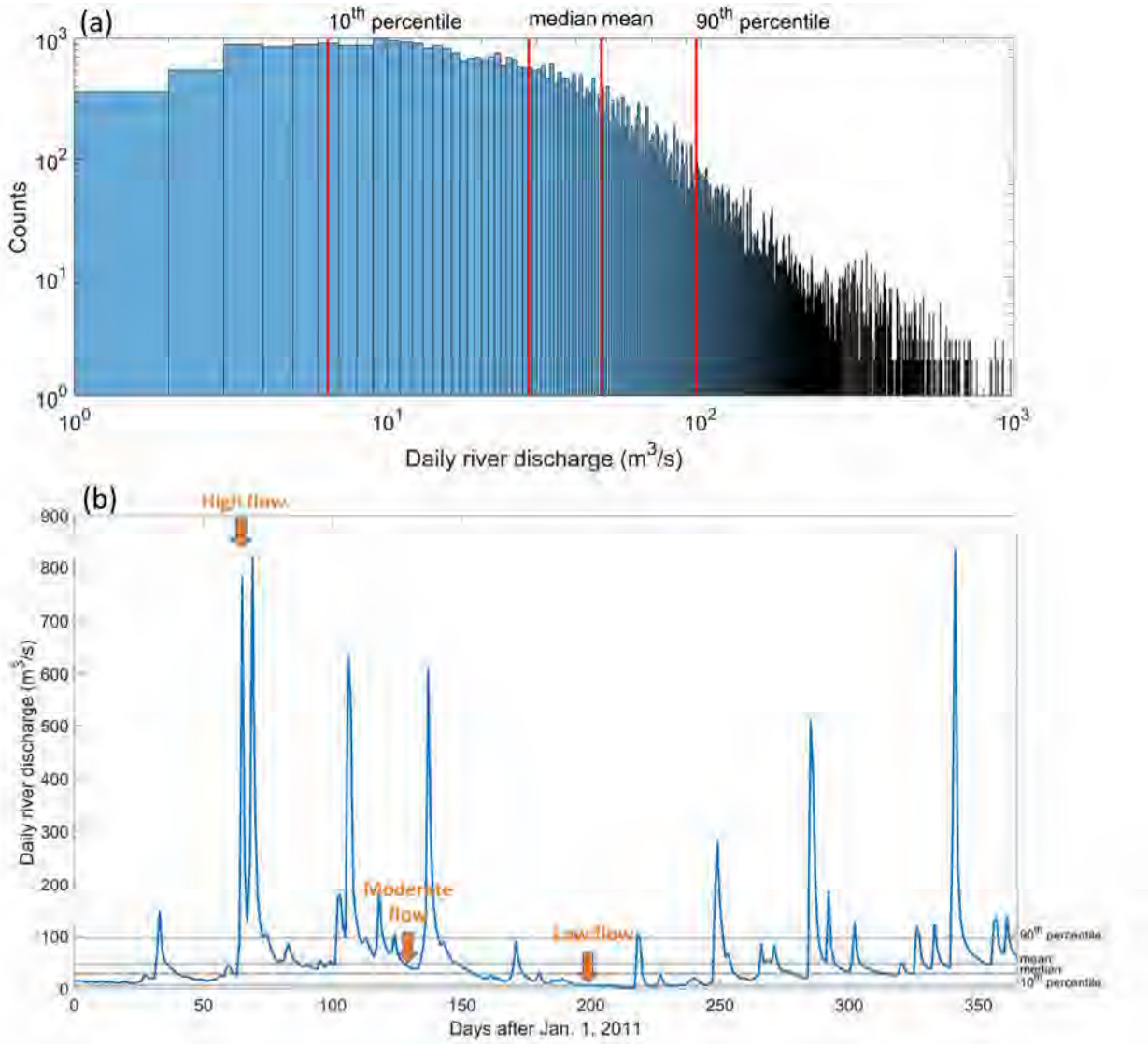


Figure 9. (a) Statistics of daily river discharge of the Rappahannock River from 1907 to 2022. (b) Daily river discharge of the Rappahannock River in 2011, the year used for the particle tracking model. Arrows mark the selected dates to investigate the impacts of river flow conditions.

2.6.2. Backward tracking scenario

Whereas the forward tracking scenarios are straightforward in how to estimate the percentage of particles that are removed by the intake for given release locations, the number of release locations is limited to those chosen a priori. To better understand the sources of larvae that are removed by the intake and the percentage of source contributions from different locations, we conducted a backward tracking scenario during a moderate flow condition.

The backward particle tracking method was applied to the Rappahannock River model. Starting from 6/27/2011, three particles were released every 10 min from the intake location and

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tracked from June 27 to May 28, and a total of 12,960 particles were released. The locations of particles were output every 15 minutes. Both the frequency of the presence of larvae that were removed by the intake in one grid cell and the contribution from each grid cell were computed.

3. Results and discussion

3.1. Impact of the intake on hydrodynamics

To evaluate the impact of the intake that has a water withdrawal rate of 13.9 mgd on local hydrodynamics, we conducted two model runs, Case "Normal" is the simulation without the intake, and Case "Withdrawal" is the simulation with the intake. The withdrawal of freshwater by the intake will likely have a larger impact on hydrodynamics during the low-flow, summer period. Therefore, we chose the summer of 2011 as our reference period, when discharge was at about the 10^{th} percentile of the long-term river discharge of the Rappahannock River,

We compared the horizontal velocities at the surface at one location in the intake area (Figure 10a-c). We found significant differences in the horizonal velocities between the two cases. The difference in horizontal velocities at the surface was up to 0.046 m s^{-1} with a mean of 0.010 m s^{-1} during this period, whereas the surface velocity had a mean of 0.191 m s^{-1} and a maximum of 0.343 m s^{-1} under "Normal" condition. The time series of elevations between the two cases were also compared at the same location (Figure 10d-f). There is a small decrease in elevation (on the order of 1 millimeter) when the intake was operating compared with "Normal" conditions, which indicates that the total volume of water does not change as tide dominates the transport of water into the Rappahannock River. The intake affects bottom horizontal velocities near the intake when operating during low-flow periods and at a maximum withdrawal rate of 13.9 mgd, but there is no significant change in water volume.

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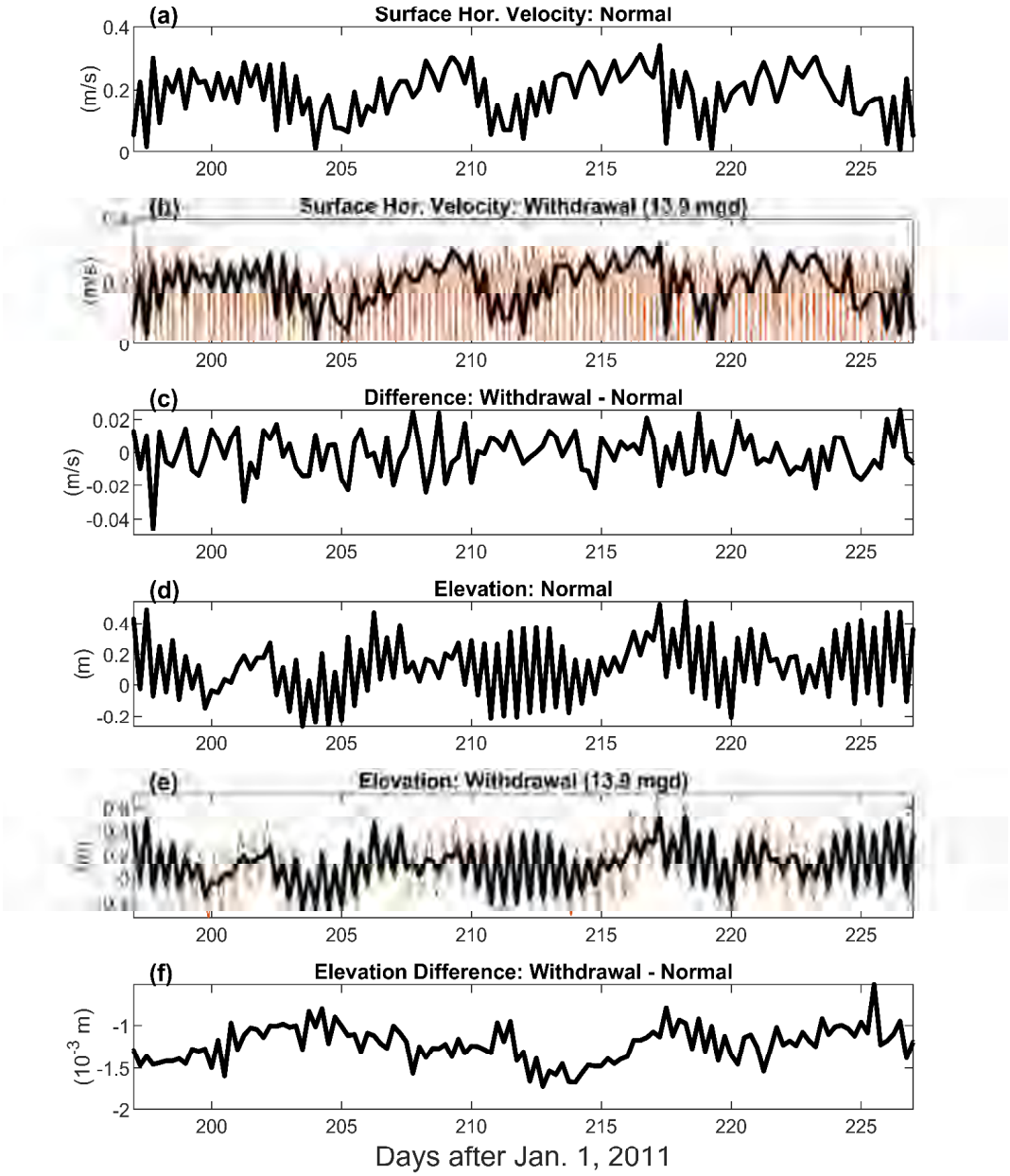


Figure 10. Time series of the speed of surface horizontal velocities (a-c) and elevation (d-f) at one location of the intake area under "Normal" (without the intake) and "Withdrawal" (with the intake) conditions and the difference between the two conditions. The comparison is based on data having the frequency of 6 hours (black lines). The data having a higher frequency of 15 minutes are also added to the withdrawal case for a better illustration of the model performance

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3.2. Scenarios for evaluating the impacts of release methods and locations

3.2.1. Backward tracking scenario

After 31 days of backward tracking (June 27 to May 28), the cumulative particle distribution covers the entire portion upstream of the intake and a short distance downstream (Figure 11). Ichthyoplankton originating from these areas are the only particles that may be impacted by the intake during the 31-day period.

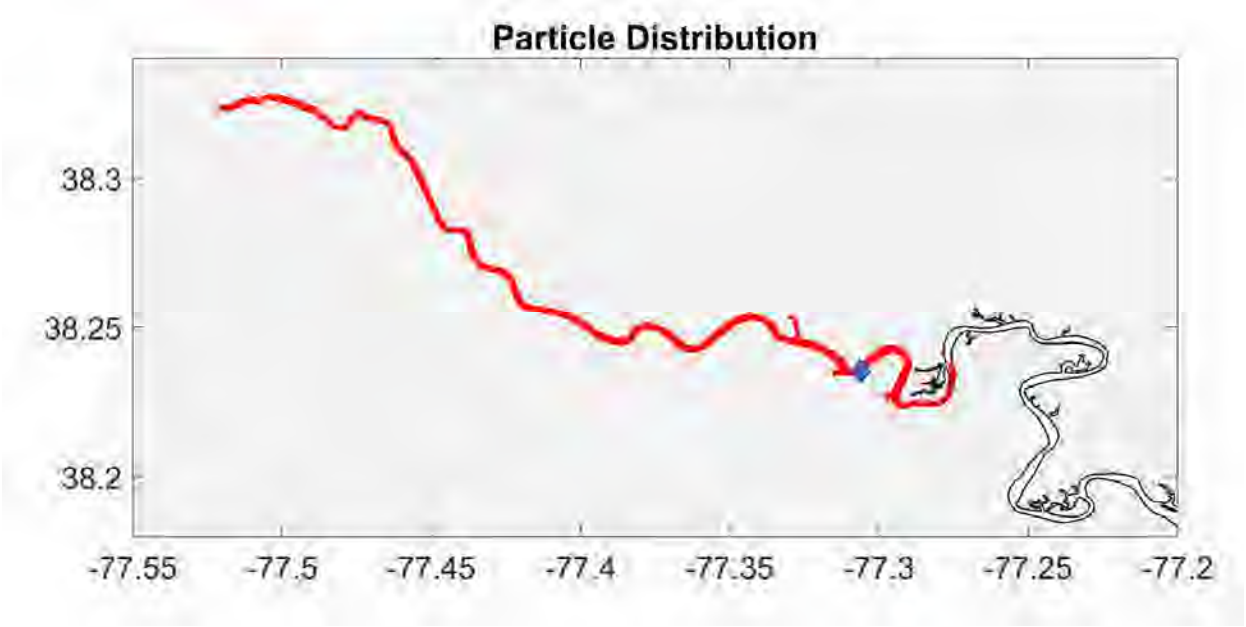


Figure 11. Cumulative distribution of particles originally released from the location of the intake in the back-tracking scenario. The blue diamond shows the location of the intake.

3.2.2.1. Frequency of the particle removal

Particles originating in the locations upstream of the intake had a relatively higher frequency of being removed by the intake compared with those that originated downstream of the intake (Figure 12). We found that the along-estuary gradients of the frequency were less than the cross-sectional gradients. In the cross-sectional direction, the deep channel shows a higher frequency than the shoals. The particles in the channel can be transported downstream at a higher rate than those at the shoals, and therefore have a higher chance to be removed by the intake. This is the opposite of the flushing effect, which usually shows stronger flushing by tidal currents in the channels than the shoals and less time for particles to be removed by the intake.

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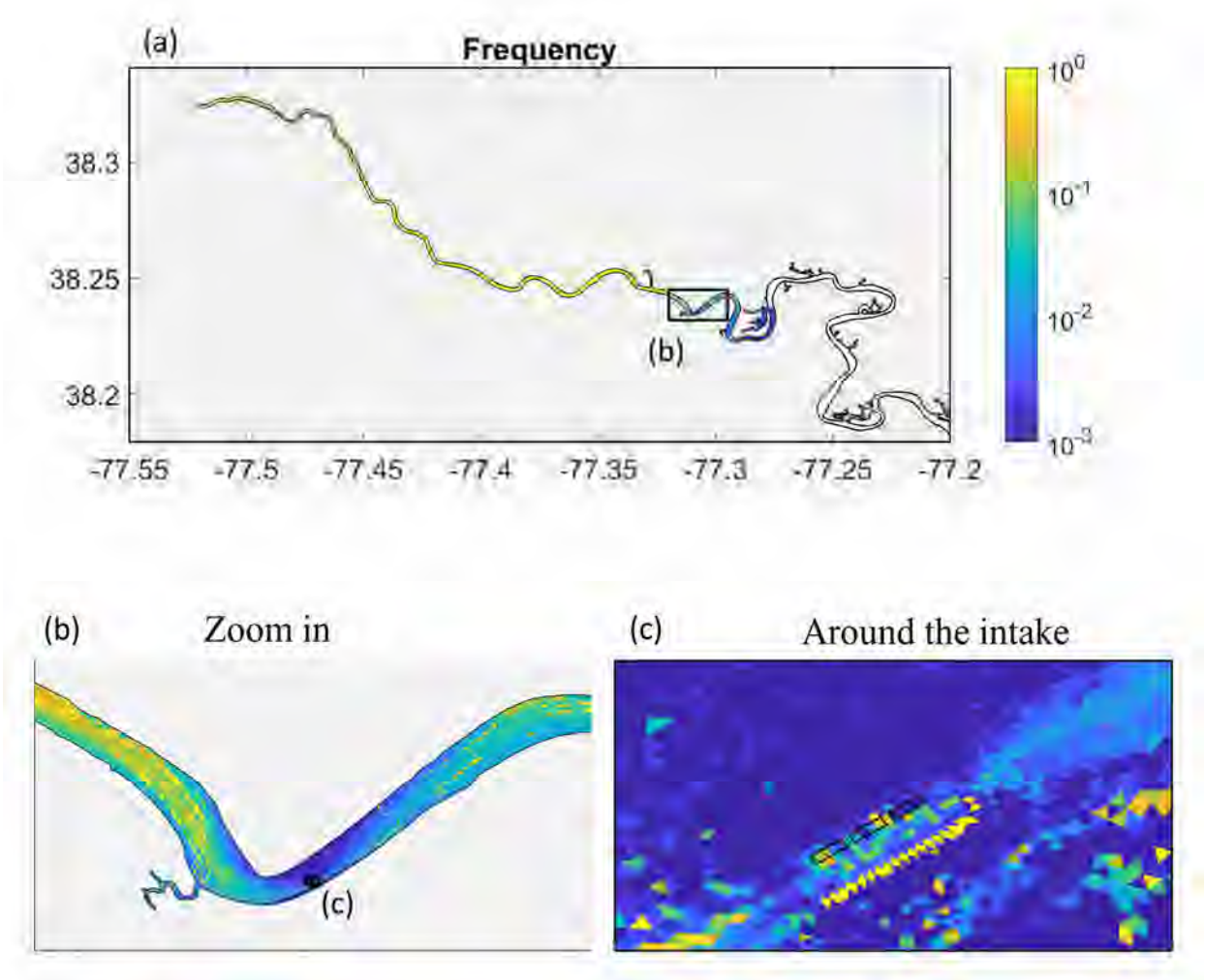


Figure 12. Computed frequency of the particle removal based on the backward-tracking results in the upper Rappahannock River (a-b), and the local area around the intake (c). The locations of the 3 intake screens are denoted by the black boxes.

3.2.2.2. Contribution

Results from the backward tracking model under moderate flow conditions show that the highest contribution was about 69% at the location where the freshwater discharge enters the Rappahannock River in the model domain (Figure 13). Because this analysis was based on the distribution of particles on 5/28/2011 in the study area, this suggests that about 69% percent of particles that were removed by the intake during the 31-day tracking period originally came from the upstream area of the Rappahannock River. Additionally, the contribution of particles from the downstream of the intake in the Rappahannock River was low or equal to zero indicating that few particles are removed by the intake under moderate flow from the downstream. Considering other locations within the Rappahannock River, the maximum contribution was about 3.7% at a location near the Virginia State Route 3 (Figure 13a). This indicates that particles appearing at

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this location contributed to about 3.7% of total particles that were removed by the intake from the entire system during the simulation period. Note that not all of the particles that appear in a particular grid cell will ultimately be removed by the intake. To compute the fraction of particles from a grid cell that are removed by the intake, the forward particle tracking model is needed.

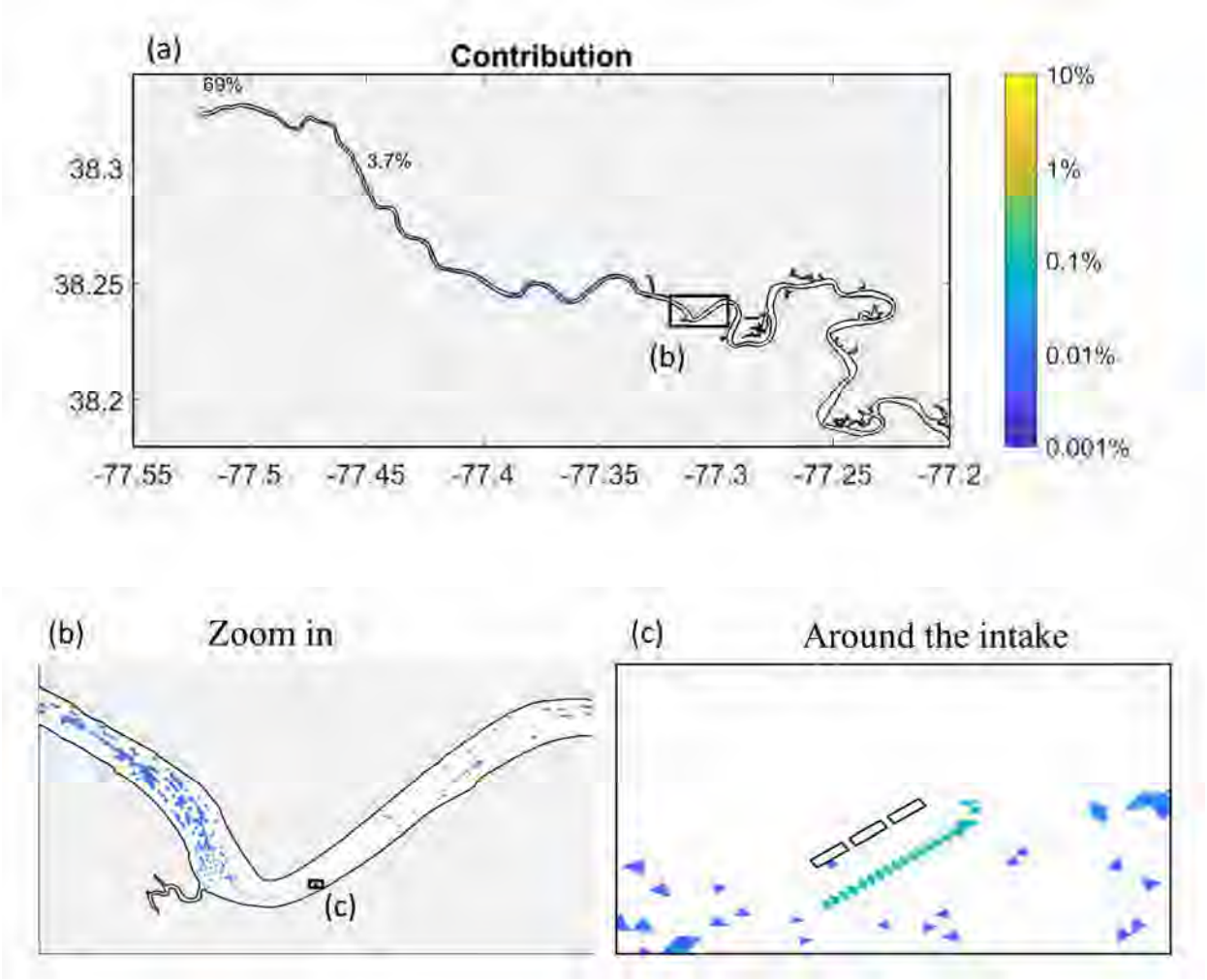


Figure 13. Computed contribution of the particles released at each location to the particles that encounter the intake during the study period, based on the backward-tracking results in the upper Rappahannock River (a-b) and the local area around the intake (c). The locations of the three intake screens are denoted by the black boxes. The red circles mark the locations with the two highest contribution (= 69% and 3.7%) in this area. Note that the location with the highest contribution marked by the red circle (in (a)) is where the freshwater discharge enters the Rappahannock River in the model.

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3.2.2. Forward tracking scenarios

Statistics of the five scenarios with around 100,000 particles are listed in Table 5. Under moderate flow conditions, Scenario 2 (one-time release upstream of the intake) resulted in the highest number of particles (n = 258) and the highest percent of particles (0.242%) that were removed by the intake (Table 5). The second most impactful scenario, Scenario 5 (continuous releases at the head of the River), resulted in the removal of 0.233% of the particles. Under Scenario 1 (one-time release near the intake), 0.065% of the particles were removed by the intake. The other two scenarios showed no loss (Table 5). These results show that particles released from locations downstream of the intake in the Rappahannock River are much less likely to be removed by the intake under moderate flow conditions compared with release locations upstream or near the intake.

Those scenarios with around 10,000 particles are presented for visual demonstrations. Under Scenario 1, particles move back and forth along the Rappahannock River by tide (Figure 14a-b). As the tides change and particles are dispersed, eight particles are removed by the intake within one day (i.e., entrained, impinged, or damaged through contact; Figure 14c-d). The major removal of particles happens within the first two days, and the number of particles that are removed by the intake reaches the maximum after 1.5 day (n = 11; Figure 14e). On the subtidal scale, the particles are either settled to the bottom or transported downstream (Figure 14f). Under Scenario 2, particles are transported from the release location to the vicinity of the intake within two days (Figure A4a-b). Tidal processes transport the particles back and forth across the location of the intake and the number of particles that are removed by the intake increases from 6 particles to 14 particles in 5 hours on May 29 (Figure A4c-d). As time continues, the number of particles that are removed by the intake increases to 18 on June 3, though most have been transported downstream (Figure A4e-f). Under Scenarios 3 and 4 where the release locations occurred downstream of the intake, the only way for particles to reach the intake is through tidal transport and the overall number of particles that are removed by the intake was zero (Figures A5 and A6). For one-time release scenarios, particles are removed by the intake within the first few days after initial release (Figure 15). Under continuous release Scenario 5 where particles are released upstream of the intake in the Rappahannock River, particles are removed by the intake over a 24-day period (Figure 15). A total of 23 particles are eventually removed by the intake for the 10,000-particle case of Scenario 5 (Figure A7).

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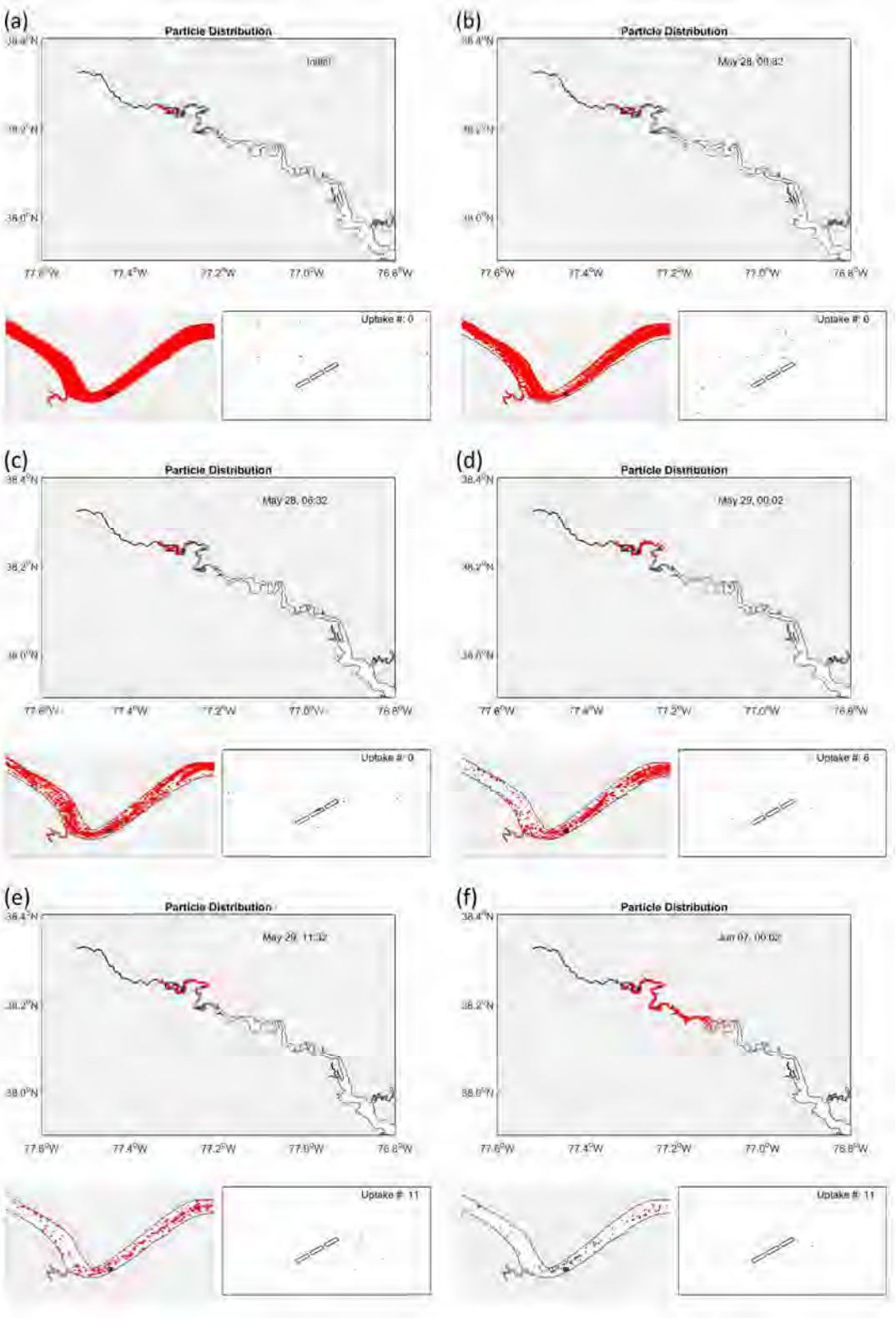


Figure 14. Distribution of particles (red dots) in Scenario 1. (a) Initial distribution at 5/28/2011. (b) After half hour. (c) After 6.5 hours. (d) After 1 day. (e) After 1 day and 11.5 hours. (f) After 10 days. Blue dots denote those particles that are eventually removed by the intake.

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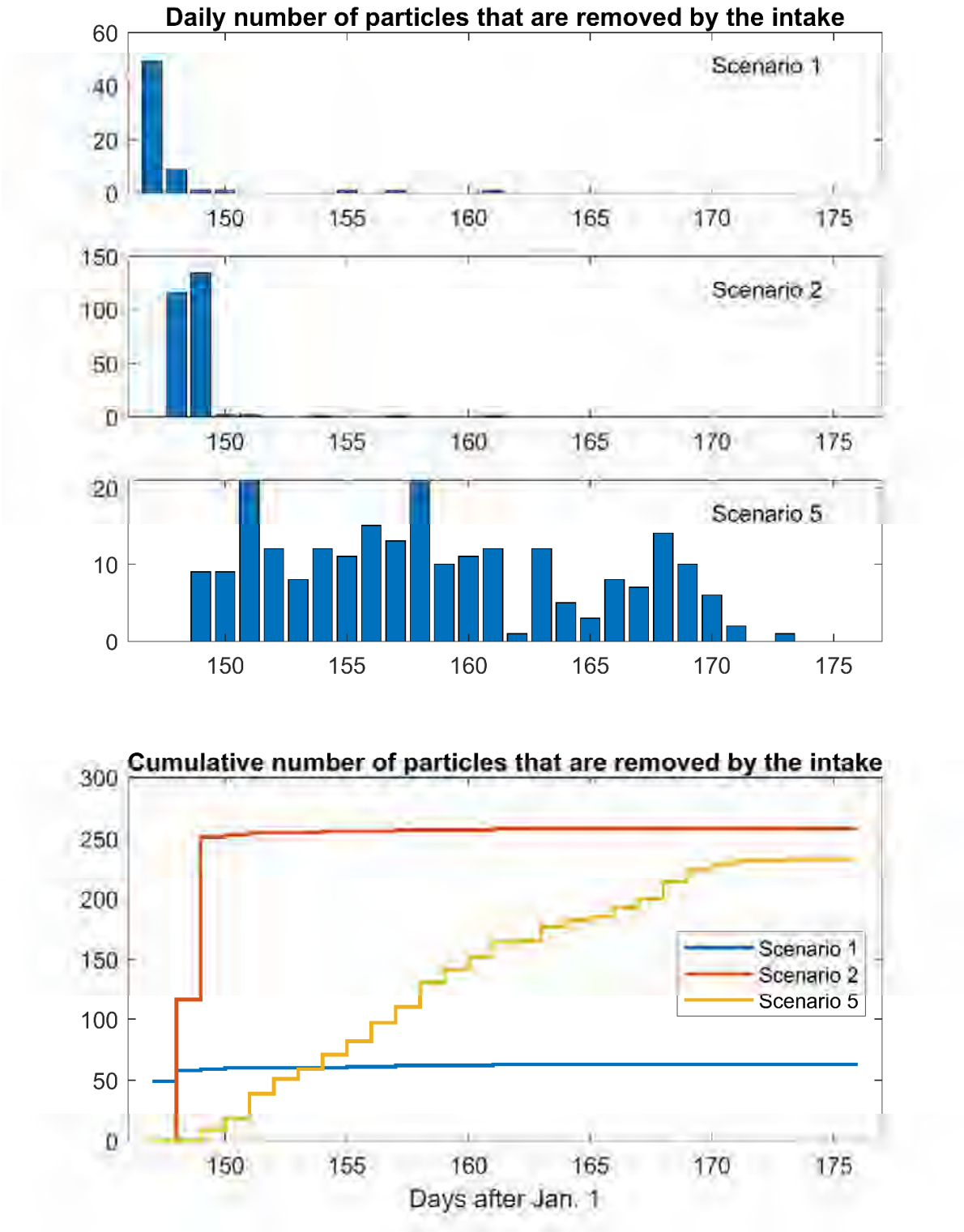


Figure 15. Daily statistics of the number of particles that are removed by the intake for Scenarios 1, 2, and 5 with about 100,000 particles released.

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Table 5. The statistics of the forward particle tracking scenarios 1-5 under moderate flow conditions.

Scenario	Release method	Total number of particles released	Number of particles that encounter the intake	Percent of particles that encounter the intake	Maximum daily percent
1	One time	97,663	63	0.065%	0.050%
2	One time	106,746	258	0.242%	0.126%
3	One time	102,040	0	0	0
4	One time	101,767	0	0	0
5	Continuously	100,005	233	0.233%	0.021%

3.2.3. Summary of passive particle simulations

Results from the forward and backward tracking models show that particles released from locations upstream of the intake are more likely to be removed than those released from downstream locations. River discharge from the Rappahannock river quickly transport particles downstream and moves them away from the intake. Whereas tidal processes disperse particles upstream and downstream, river discharge likely dominates the particle transport process when flow is moderate. Thus, only a small portion of released particles are transported upstream after their initial release and all particles are eventually transported downstream.

3.4. Scenarios that examine potential impacts of river discharge

Under one-time release scenarios, we compared the results of previous scenarios with the same release location but under different flow conditions (Scenarios 1, 6, and 7; Scenarios 2, 8, and 9; Scenarios 3, 10, and 11). We found that a lower discharge rate led to higher total removal of particles by the intake (Table 6 and Figure 16). This was expected because a lower discharge rate results in weaker downstream transport of particles and longer retention, thus increasing the probability of particles being removed. Under Scenario 9 (low flow), the highest percent of particles removed was 0.572% (Table 6). Under high flow conditions, the particles were advected outside of the study area more quickly and the particles had a lower chance to be removed by the intake.

Under continuous release scenarios 12 and 13, a greater proportion of total particles are released with the highest discharge rate and the particle number around the intake increases, however this does not increase the percent of particles that are removed by the intake, because the higher discharge rate leads to stronger advection and more particles are advected outside the study area. Scenario 13 (continuous release upstream of the Rappahannock River under low flow conditions) resulted in the high percent (0.543%) of particles that were removed. Nevertheless, the total percent removed may not only depend on the mean discharge over the tracking period, but may also depend on the location of the intake screens or the pattern of flow variability during the study period.

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Table 6. Summary of the forward particle tracking Scenarios 6-13, considering the impact of flow conditions.

Scenario	Release method	Release Location	Total number of particles released	Number of particles that encounter the intake	Percent of particles that encounter the intake	Maximum daily percent
6	One time, high flow	Vicinity of the intake	97,663	0	0	0
7	One time, low flow	Vicinity of the intake	97,663	232	0.238%	0.080%
8	One time, high flow	Upstream of the intake	106,746	158	0.148%	0.148%
9	One time, low flow	Upstream of the intake	106,746	611	0.572%	0.136%
10	One time, high flow	Downstream of the intake	102,040	0	0	0
11	One time, low flow	Downstream of the intake	102,040	0	0	0
12	Continuously, high flow	Head of the Rapp. of the model grid	100,001	210	0.210%	0.056%
13	Continuously, low flow	Head of the Rapp. of the model grid	100,001	543	0.543%	0.033%

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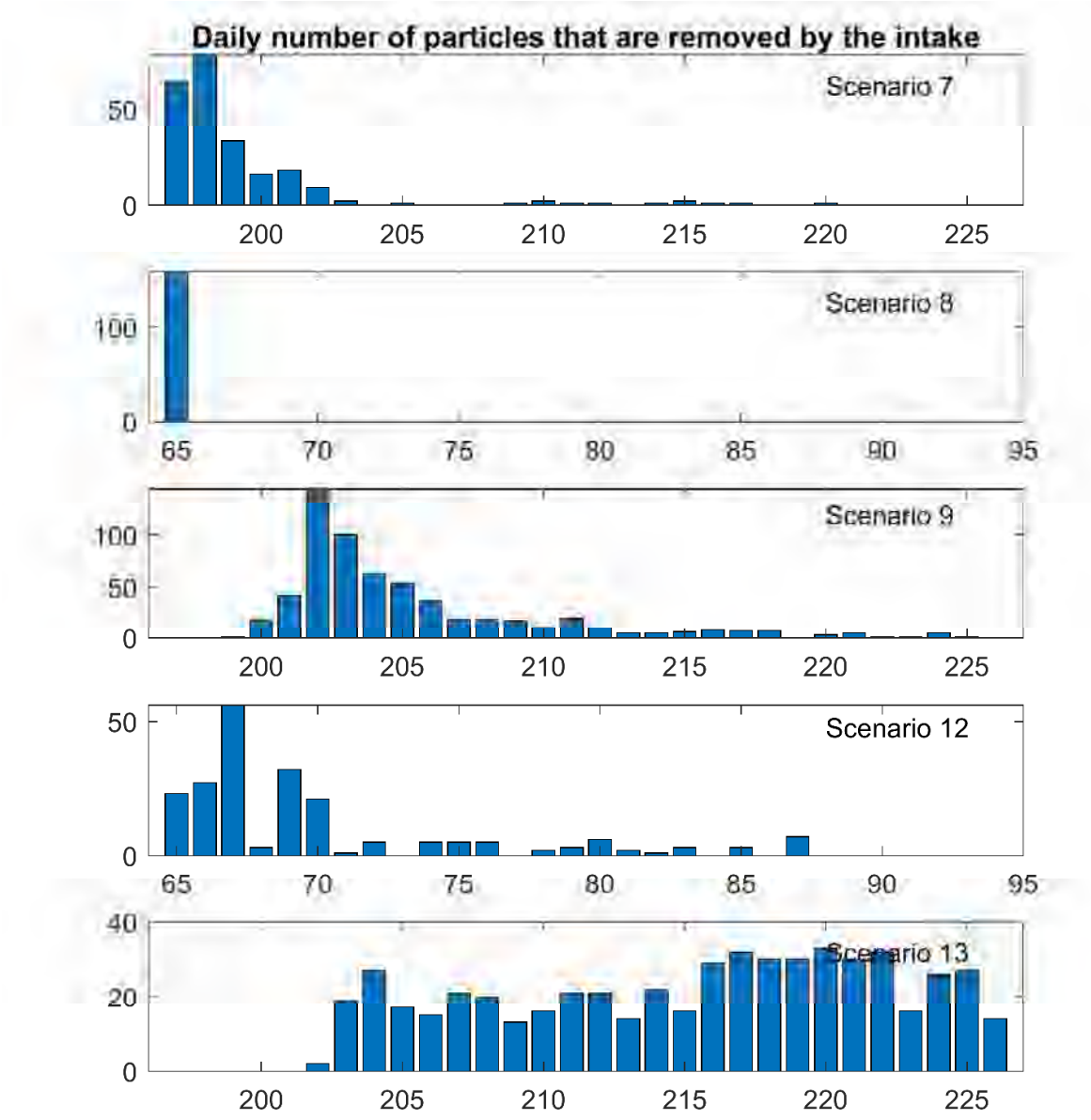


Figure 16. Daily statistics of the number of particles that are removed by the intake for Scenarios 7, 8, 9, 12, and 13.

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3.5. Scenarios investigating active particles

We conducted 21 scenarios to investigate active particles with seven different vertical velocities that represent sinking eggs and larvae with swimming behaviors. Active particles alter their position in the water column and this interacts with the hydrodynamic field and changes the potential dispersal pattern relative to passive particles.

Active particles released near the intake (Scenarios 14-18) had non-zero removal for all downward velocity scenarios (Table 7). The largest removal rate was 0.174% (Scenario 18) with a settling velocity of -0.001 cm s^{-1}, which was slightly lower than that observed for passive particles under Scenario 7 (0.238%). Particles with relatively fast settling velocities (-1, -0.3, and -0.1 cm s^{-1}) experienced higher removal rates during the first two days compared with scenarios with relatively slow settling velocities (-0.01 and -0.001 cm s^{-1}; Figure 17). The fast-settling velocities result in fewer particles in the water column that are available to the intake, so they are only vulnerable for the first few tidal cycles. Conversely, slower settling velocities increase the chance that particles encounter the intake because more particles remain in the water column, increasing the possibility of removal in subsequent tidal cycles. In the extreme case, the lowest settling velocity described by Scenario 7 (passive particle under low flow) shows that the highest daily removal rate was not until the second day (Figure 16).

This impact of downward velocity on the removal rate was even more clearly shown by Scenarios 21-25 that releases particles upstream of the intake, where all but one scenario (Scenario 25) had zero removal (Table 7). The removal rate of 0.308% with a settling velocity of -0.001 cm s^{-1} was still lower than the removal rate of 0.572% for passive particles under Scenario 9. For all one-time release scenarios with upward velocities, there was no removal of particles by the intake.

Seven continuous release scenarios with active particles were investigated and those with upward velocities or relatively fast downward settling velocities (Scenarios 28-31 and 33-34) showed no loss due to the intake, indicating the low chance for demersal eggs or larvae to encounter the intake if they are spawned at the upstream locations that are beyond the model domain. The greatest impact observed for active particles under continuous release scenarios was under Scenario 32 with a relatively slow settling velocity of -0.001 cm $s^{-1}$and a removal rate of 0.294% (Table 7).

It was interesting to find that the scenarios with particles released upstream of the intake (either one-time or continuous releases) resulted in lower removal rates compared with releases near the intake. The low removal rate for active particles suggest that downward settling particles will settle to the bottom and will end their journey before reaching the intake. Active particles with upward swimming velocities will travel a much longer distance than particles that settle, but they remain near the surface and have little chance of removal by the intake located near the riverbed.

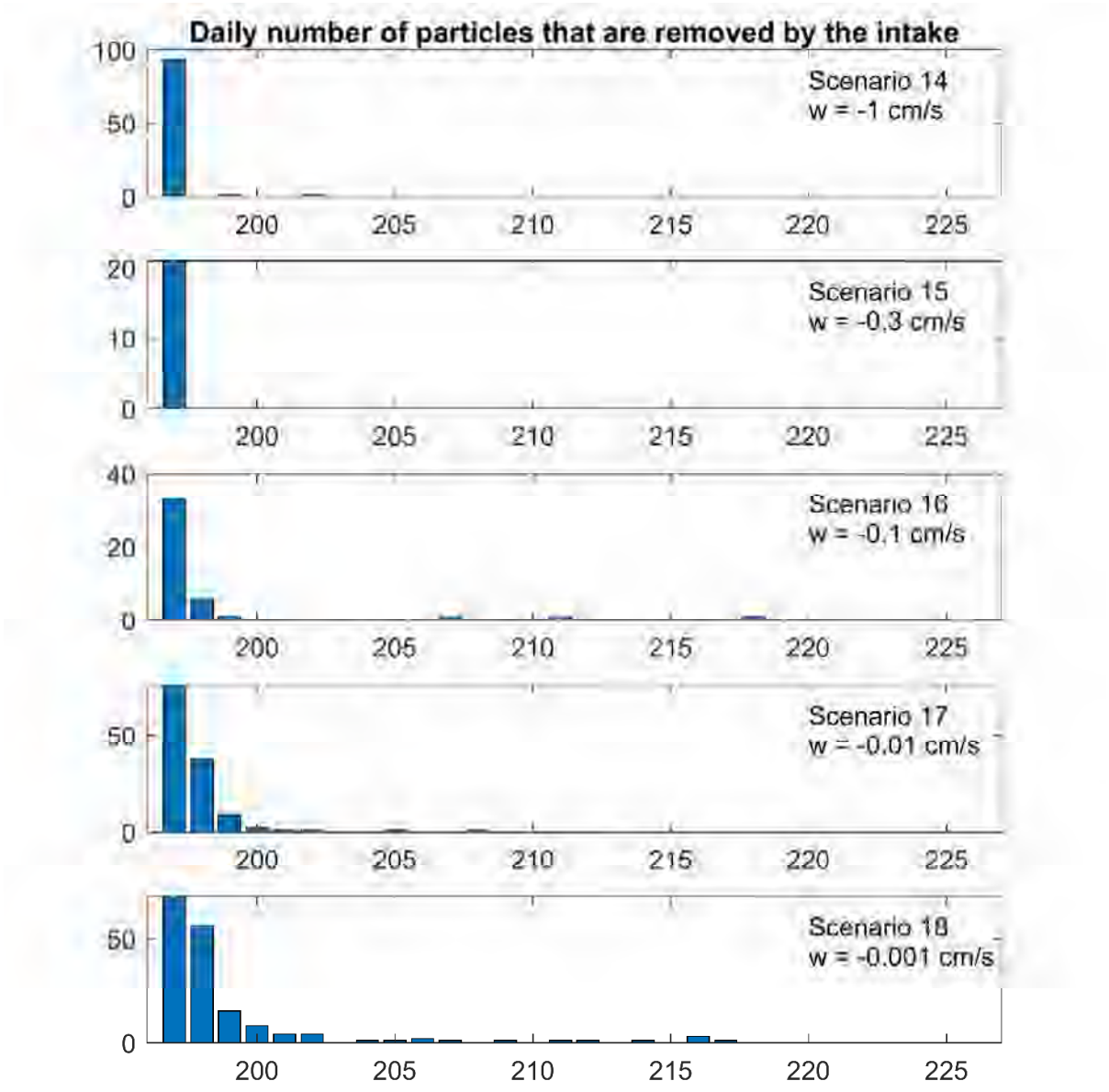
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Table 7. The statistics of the forward particle tracking scenarios 14-34. The vertical velocity of the particle can be either upward (+) or downward (-).

Scenario	Vertical velocity (cm/s)	Representative	Release method	Release Location	Total number of particles released	Number of particles that are removed by the intake	Percent of particles that are removed by the intake	Maximum daily percent
14	-1	Demersal egg	One time, low flow	Vicinity of the intake	97,663	95	0.097%	0.095%
15	-0.3	Demersal egg	One time, low flow	Vicinity of the intake	97,663	21	0.022%	0.022%
16	-0.1	Demersal egg	One time, low flow	Vicinity of the intake	97,663	43	0.044%	0.034%
17	-0.01	Demersal egg	One time, low flow	Vicinity of the intake	97,663	128	0.131%	0.078%
18	-0.001	Demersal egg	One time, low flow	Vicinity of the intake	97,663	170	0.174%	0.072%
19	1	larvae	One time, low flow	Vicinity of the intake	97,663	0	0	0
20	10	larvae	One time, low flow	Vicinity of the intake	97,663	0	0	0
21	-1	Demersal egg	One time, low flow	Upstream of the intake	106,746	0	0	0
22	-0.3	Demersal egg	One time, low flow	Upstream of the intake	106,746	0	0	0
23	-0.1	Demersal egg	One time, low flow	Upstream of the intake	106,746	0	0	0
24	-0.01	Demersal egg	One time, low flow	Upstream of the intake	106,746	0	0	0
25	-0.001	Demersal egg	One time, low flow	Upstream of the intake	106,746	329	0.308%	0.050%
26	1	larvae	One time, low flow	Upstream of the intake	106,746	0	0	0
27	10	larvae	One time, low flow	Upstream of the intake	106,746	0	0	0
28	-1	Demersal egg	Continuously, low flow	Head of the Rapp. of the model grid	100,001	0	0	0
29	-0.3	Demersal egg	Continuously, low flow	Head of the Rapp. of the model grid	100,001	0	0	0
30	-0.1	Demersal egg	Continuously, low flow	Head of the Rapp. of the model grid	100,001	0	0	0

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31	-0.01	Demersal egg	Continuously, low flow	Head of the Rapp. of the model grid	100,001	0	0	0
32	-0.001	Demersal egg	Continuously, low flow	Head of the Rapp. of the model grid	100,001	294	0.294%	0.025%
33	1	larvae	Continuously, low flow	Head of the Rapp. of the model grid	100,001	0	0	0
34	10	larvae	Continuously, low flow	Head of the Rapp. of the model grid	100,001	0	0	0



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Figure 17. Daily statistics of the number of particles that are removed by the intake for Scenarios 14-18 where the release location is around the intake.

3.6. Impact of the intake on ichthyoplankton survival

One main purpose of the present modeling effort was to examine potential impacts of the water intake on ichthyoplankton survival. In this study, the results of 34 different modeling scenarios show that the total percent of particles removed due to the intake ranged from 0 to 0.5-0.6%, and the maximum daily removal rate ranged from 0 to 0.15% per day (Figures 18 and A8; Table A1). Because the flow rate only changes in the near the intake region and it causes minor changes in velocity field away from the intake, only particles that are close to the intake have the potential to be removed. Another factor contributing to the low removal rate is that the intake is located in a high flow region where a large portion of the larvae are quickly transported out of the intake region. This suggests that even under the conservative assumption that impingement and entrainment cause 100% mortality of the ichthyoplankton that encounter with the intake, the conditional mortality rate caused by the intake is estimated to be below 0.5-0.6%. If there is potential for survival of impinged ichthyoplankton for some species, as suggested by some experimental studies (EPRI, 2000), then the conditional mortality rate would be even lower. It is known that natural mortality is typically high for ichthyoplankton and most estimates of the mortality on the order of about 20% per day (Metaxas et al., 2009; White et al., 2014). For example, among the three representative fish species in the region, larvae of striped bass have the lowest daily mortality of 10.4-32.9% while larvae of blueback herring and inland silverside have daily mortality rates of 88-99%; other fish species also have natural daily mortality rates much greater than the maximum daily removal rate of 0.15% (Abraham, 1985; Greene et al., 2009; Jenkins and Burkhead, 1993; Limburg et al., 1999; Phillips et al., 2007; Rutherford et al., 1997; Walsh et al., 2005). Thus, mortality due to the intake is orders of magnitude less than natural mortality. From this modeling study, the intake operation with a flow rate of 13.9 mgd has a low impact on ichthyoplankton survival in this area. Whereas there is increased mortality due to the intake, the increase is unlikely to cause serious harm to fish eggs and larvae.

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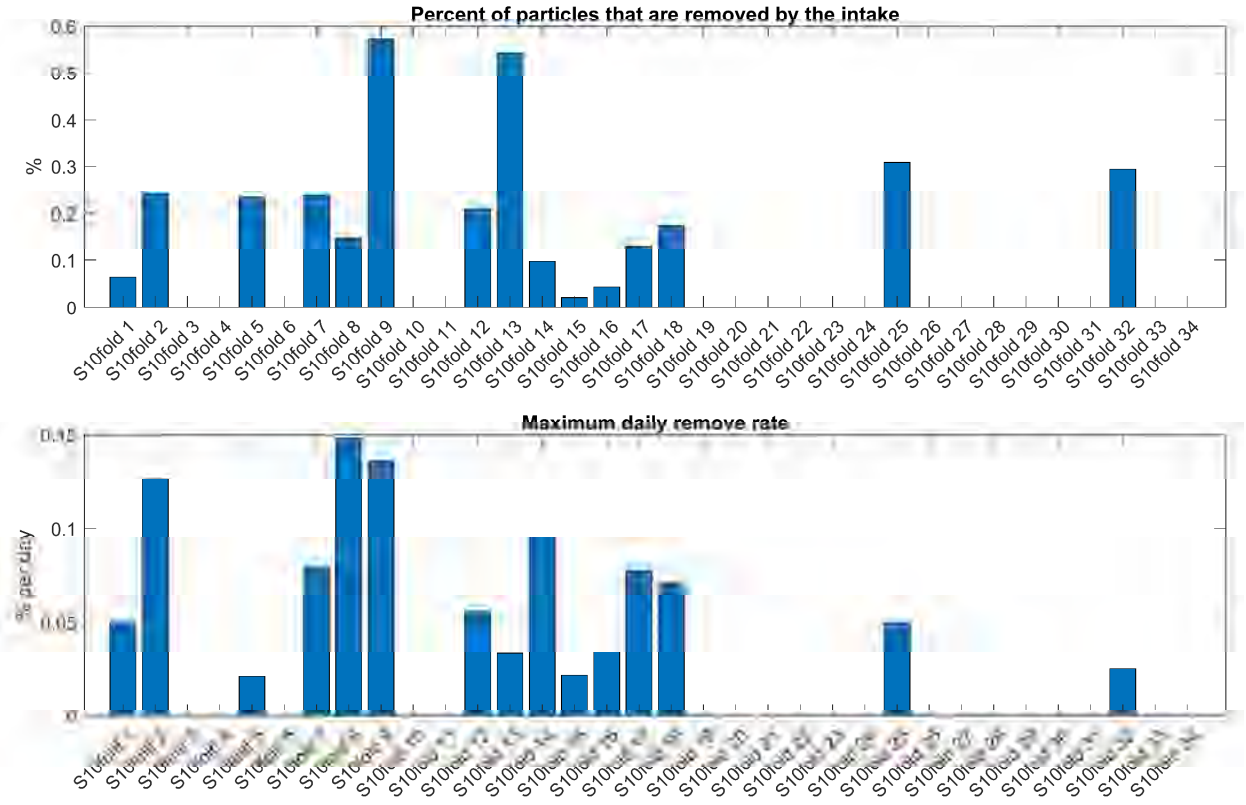


Figure 18. A summary of all of the forward-tracking scenarios showing the total number of particles removed by the intake (i.e., percent of particles that are removed by the intake) and the maximum daily removal rate, for 100,000-particle cases.

4. Conclusions

We investigated the potential impacts of a proposed municipal water intake on the survival of ichthyoplankton in a tidal freshwater estuary. We used an unstructured grid model with fine resolution in the vicinity of the intake to simulate river hydrodynamics and a particle tracking model to simulate the transport of ichthyoplankton (passive and active particles). The model results show that the intake, with a withdrawal rate of 13.9 mgd, can alter the velocity of the tidal flow near the intake, but does not have significant impacts on the hydrodynamics in the Rappahannock River.

Forward and backward particle tracking approaches were used to investigate the potential impacts of the intake. Two variables, “frequency” and “contribution”, were computed in the backward tracking scenario to identify the major sources of ichthyoplankton that were removed by the intake. Ichthyoplankton that are found in the channel have a greater probability of being removed by the intake than those found along the shoals. This is because the flushing effect is stronger in the channel created by faster currents and has the greater ability to transport particles to a larger area and increases the chance of them to be removed by the intake. Additionally,

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ichthyoplankton that originate upstream of the intake are removed to a greater extent than those originating downstream of the intake. The model results also show an increase in the percent of ichthyoplankton that are removed during dry years or seasons under low flow conditions. Since spawning seasons of other species will likely encounter low flow periods, our results suggest impacts could be more important for those species that spawn during dry summer months.

The pathways of active particles were different from passive particles, indicating that the vertical velocity of ichthyoplankton can alter the transport and distribution of eggs and larvae and hence the removal rate due to the intake. For example, particles that represent demersal eggs with negative vertical velocities had a variety of outcomes with only the slowest sinking rates resulting in removal by the intake if they were released upstream. Additionally, for particles that represent larvae with upward swimming velocities, the current location and design of the intake likely has limited impacts because the screens were located in the lower half of the water column and larvae at the surface avoided the intake. Thus, larval fish behavior can alter impacts from water intakes with those impacts determined by swimming speeds and location relative to the intake. Furthermore, other behaviors not studied here could alter impacts of water intakes, such as daily migration between surface waters at night and bottom waters during day. These different migration patterns are more complex and require additional modeling efforts.

The total removal (percent) of particles and the maximum daily removal rate in all the model scenarios was below 0.6% and 0.15%, respectively, which is two orders of magnitude lower than natural mortality rates of ichthyoplankton. It is expected that the removal rate would be lower if the proposed intake would be operated with lower withdrawal rates than the maximum withdrawal rate considered in the model scenarios. This indicates that the current design of the intake has comparatively low impacts on the ichthyoplankton in this estuary. The numerical modeling approach used here simulates ichthyoplankton dispersal and changes in mortality caused by the intake under a variety of river flow conditions (e.g., high, moderate, and low flows), which provides scientific-based assessment of potential impacts that would otherwise not be possible.

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Appendix

Table A1. The release method, location, flow condition, vertical velocity, percent of particles that are removed by the intake, and maximum daily removal rate of the 34 forward particle tracking scenarios. In those scenarios where particles are released continuously, the release period is 21 days, and the number of particles release is proportional to daily freshwater discharge. The vertical velocity of the particle can be either upward (+) or downward (-).

Scenario	Release method	Release location	Flow condition	Vertical velocity (cm s^{-1})	Percent of particles that are removed by the intake	Maximum daily removal rate
1	One time	Vicinity of the intake	Moderate	0	0.065%	0.050%
2	One time	Upstream of the intake	Moderate	0	0.242%	0.126%
3	One time	Downstream of the intake	Moderate	0	0	0
4	One time		Moderate	0	0	0
5	Continuously	Head of the Rapp. of the model grid	Moderate	0	0.233%	0.021%
6	One time	same as Scenario 1	High	0	0	0
7	One time	same as Scenario 1	Low	0	0.238%	0.080%
8	One time	same as Scenario 2	High	0	0.148%	0.148%
9	One time	same as Scenario 2	Low	0	0.572%	0.136%
10	One time	same as Scenario 3	High	0	0	0
11	One time	same as Scenario 3	Low	0	0	0
12	Continuously	same as Scenario 5	High	0	0.210%	0.056%
13	Continuously	same as Scenario 5	Low	0	0.543%	0.033%
14	One time	same as Scenario 1	Low	-1	0.097%	0.095%
15	One time	same as Scenario 1	Low	-0.3	0.022%	0.022%
16	One time	same as Scenario 1	Low	-0.1	0.044%	0.034%
17	One time	same as Scenario 1	Low	-0.01	0.131%	0.078%
18	One time	same as Scenario 1	Low	-0.001	0.174%	0.072%
19	One time	same as Scenario 1	Low	1	0	0
20	One time	same as Scenario 1	Low	10	0	0
21	One time	same as Scenario 2	Low	-1	0	0
22	One time	same as Scenario 2	Low	-0.3	0	0
23	One time	same as Scenario 2	Low	-0.1	0	0
24	One time	same as Scenario 2	Low	-0.01	0	0
25	One time	same as Scenario 2	Low	-0.001	0.308%	0.050%
26	One time	same as Scenario 2	Low	1	0	0
27	One time	same as Scenario 2	Low	10	0	0
28	Continuously	same as Scenario 5	Low	-1	0	0
29	Continuously	same as Scenario 5	Low	-0.3	0	0
30	Continuously	same as Scenario 5	Low	-0.1	0	0
31	Continuously	same as Scenario 5	Low	-0.01	0	0
32	Continuously	same as Scenario 5	Low	-0.001	0.294%	0.025%
33	Continuously	same as Scenario 5	Low	1	0	0
34	Continuously	same as Scenario 5	Low	10	0	0

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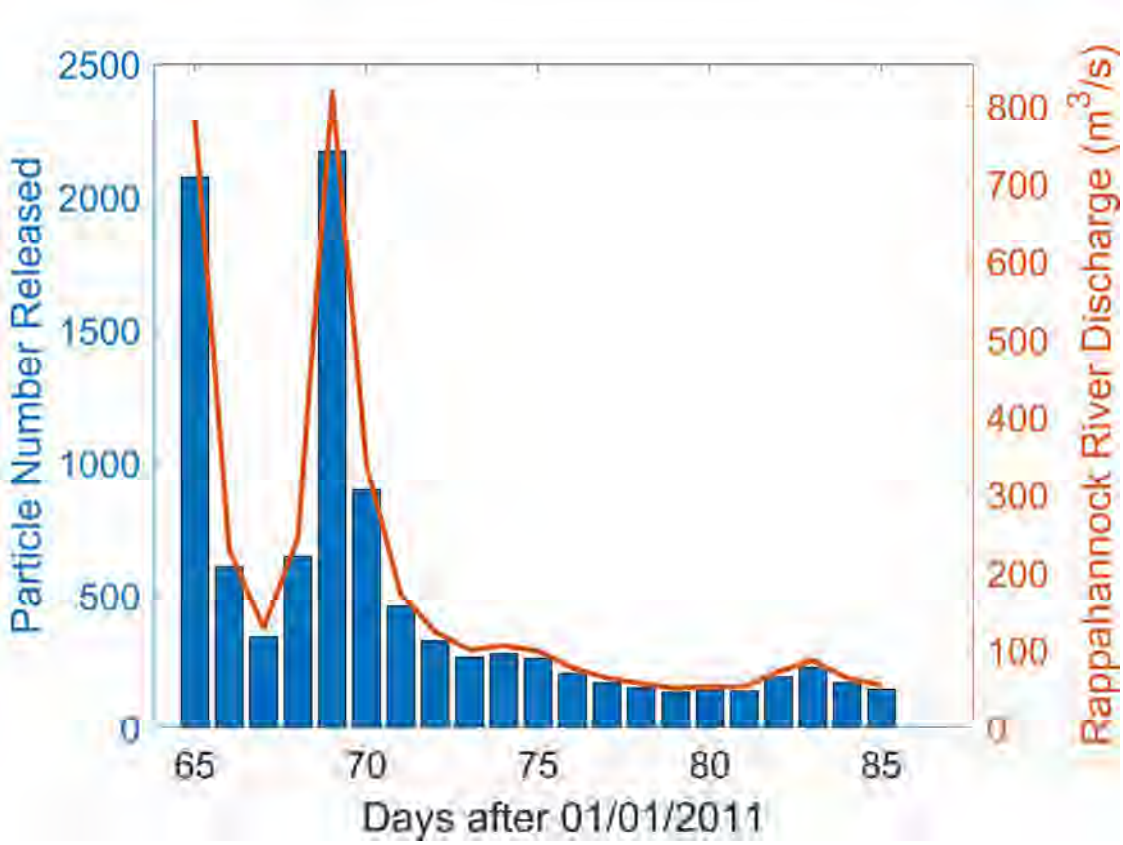


Figure A1. Particle release in Scenario 12 with 10,000 particles, at the surface of the uppermost grid cell in the Rappahannock River in the model for the 21 days (3/7/2011-3/27/2011). The number of particles released is proportional to the daily freshwater discharge of the Rappahannock River.

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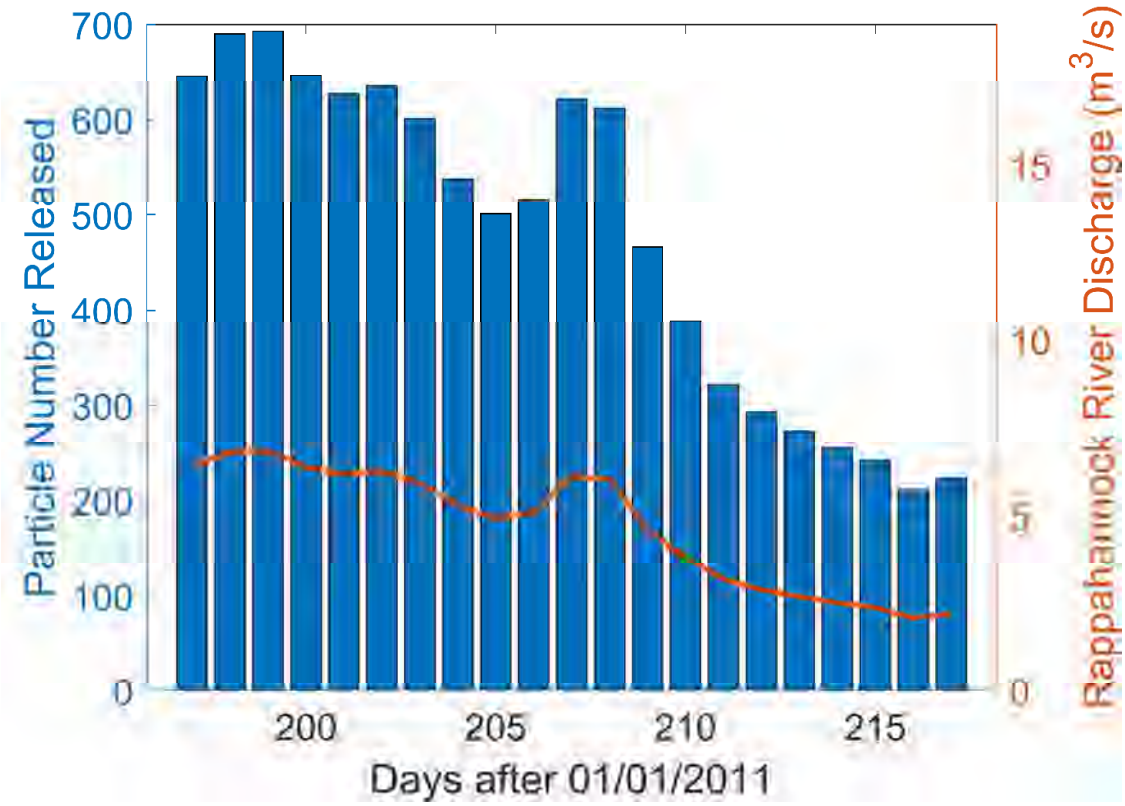


Figure A2. Particle release in Scenario 13 with 10,000 particles, at the surface of the uppermost grid cell in the Rappahannock River in the model for the 21 days (7/17/2011-8/06/2011). The number of particles released is proportional to the daily freshwater discharge of the Rappahannock River.

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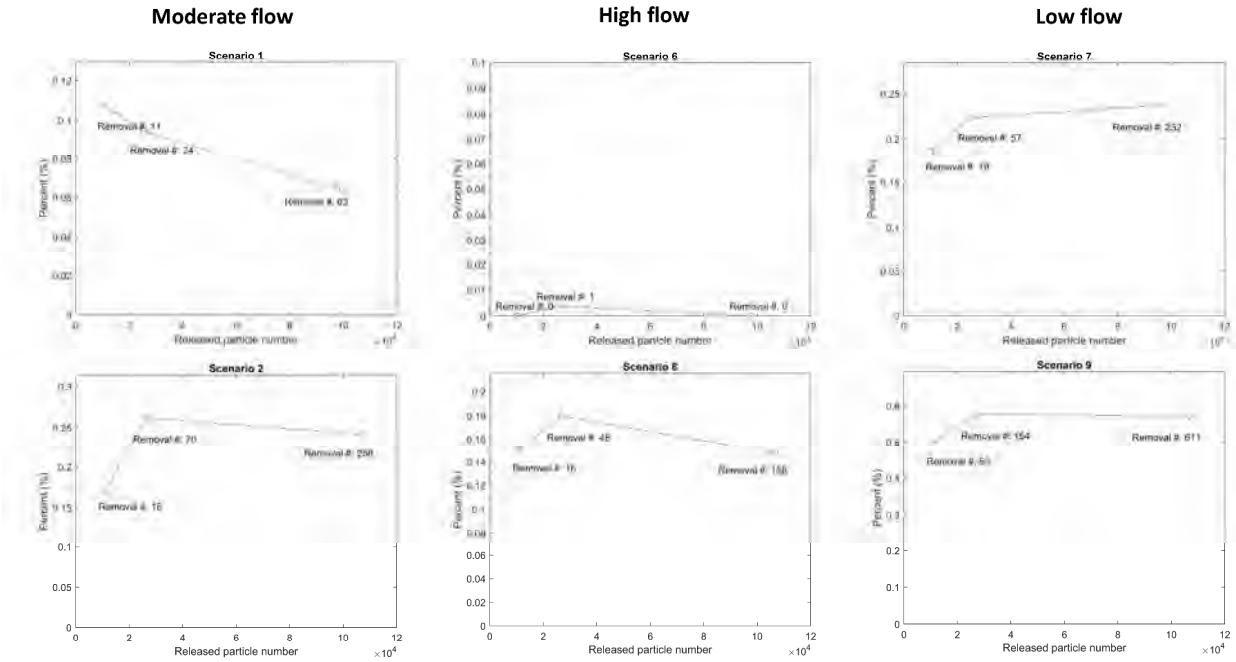


Figure A3. Comparison of the removal percent of particles by the water intake between cases of about 10,000, 25,000, and 100,000 particles for each of Scenarios 1, 6, 7, 2, 8, and 9.

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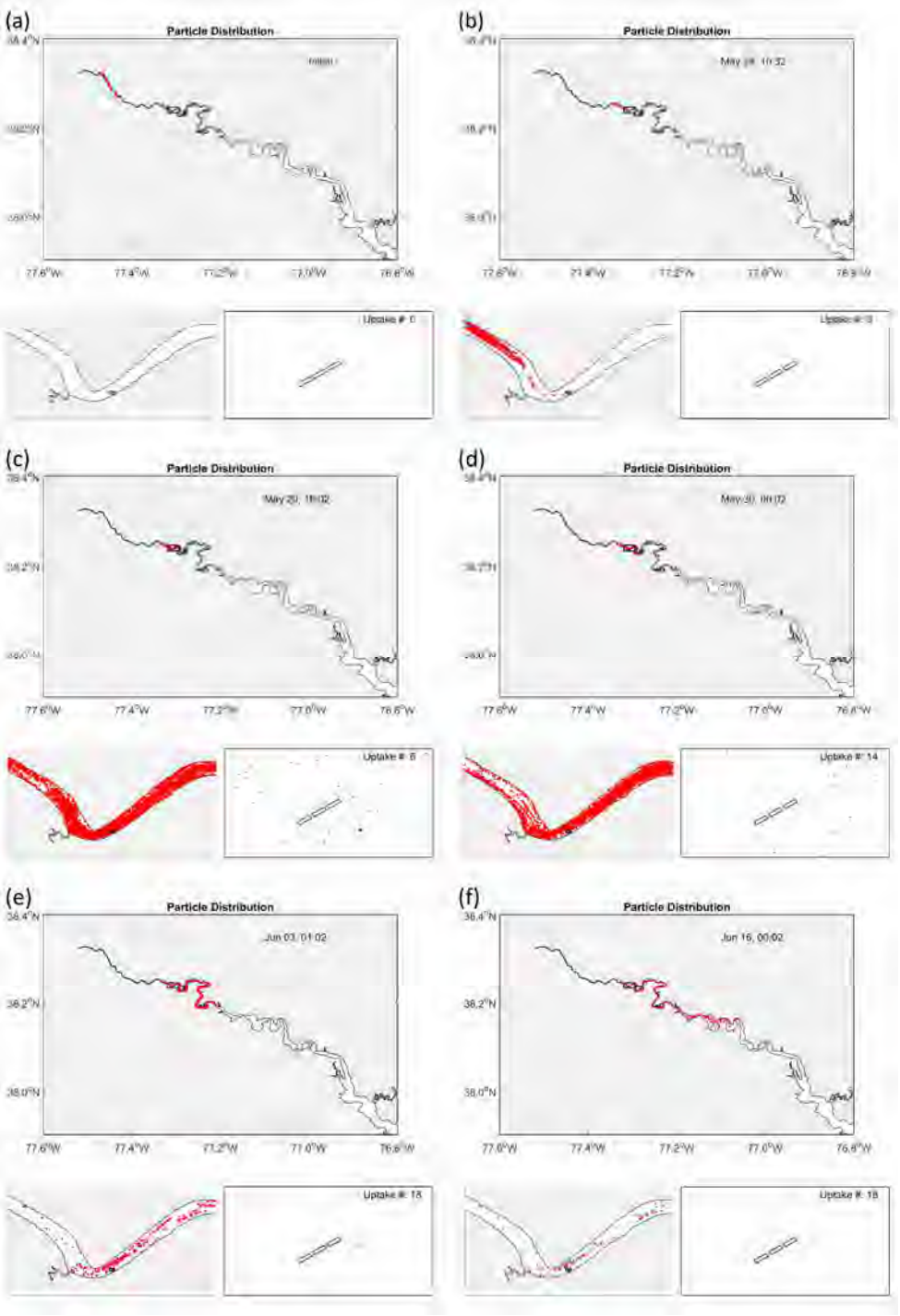


Figure A4. Distribution of particles (red dots) in Scenario 2. (a) Initial distribution at 5/28/2011. (b) After 10.5 hours. (c) After 19 hours. (d) After 1 day. (e) After 6 days and 1 hour. (f) After 19 days. Blue dots denote those particles that are eventually removed by the intake.

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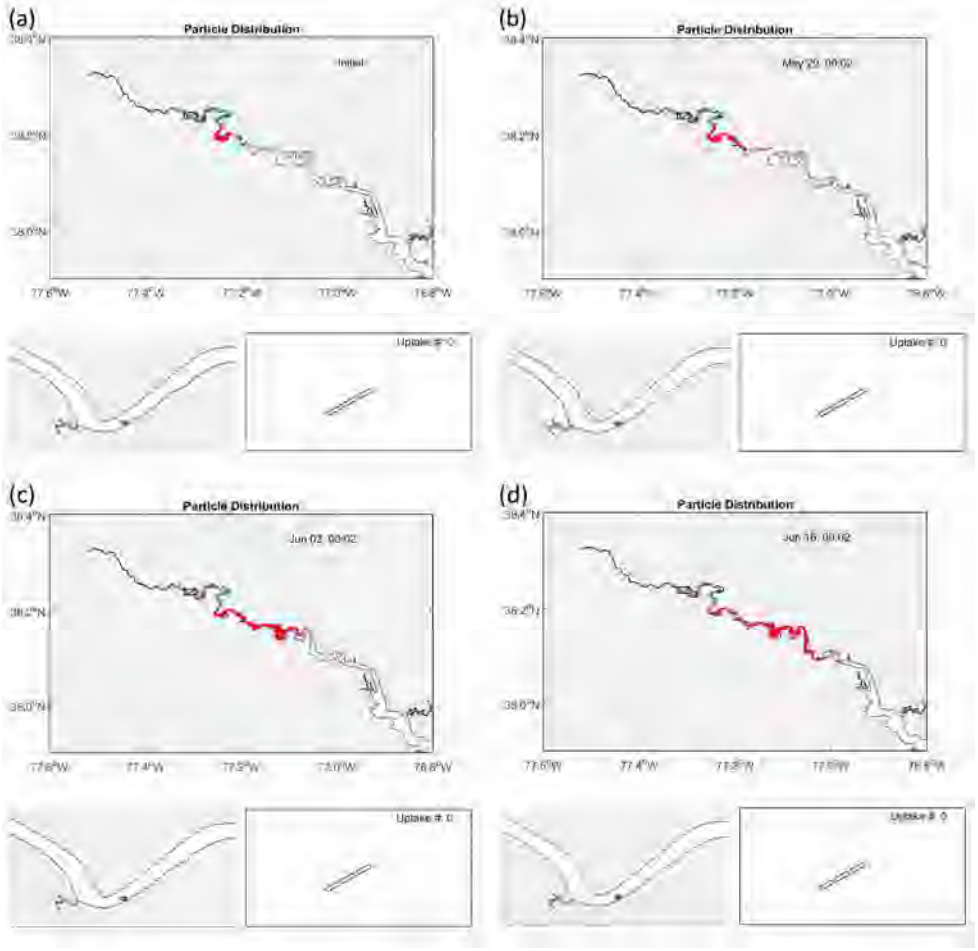


Figure A5. Distribution of particles (red dots) in Scenario 3. (a) Initial distribution at 5/28/2011. (b) After 1 day. (c) After 5 days. (d) After 19 days. Blue dots denote those particles that are eventually removed by the intake.

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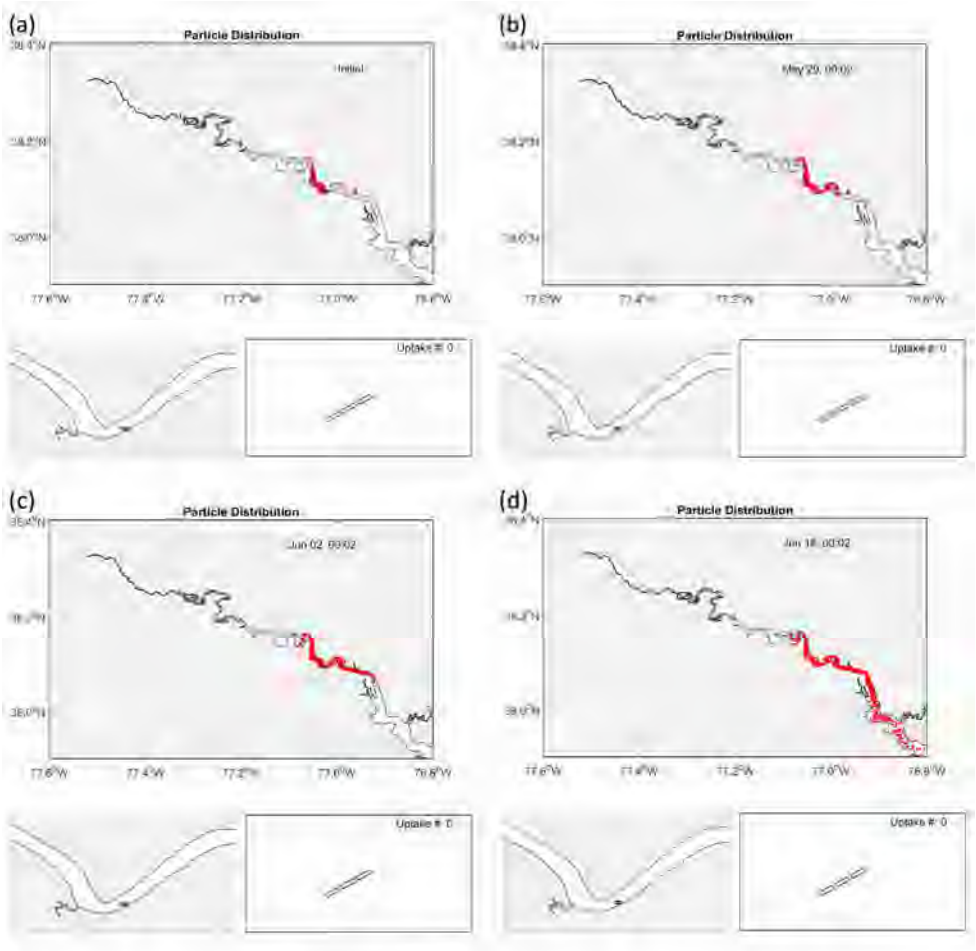


Figure A6. Distribution of particles (red dots) in Scenario 4. (a) Initial distribution at 5/28/2011. (b) After 1 day. (c) After 5 days. (d) After 19 days. Blue dots denote those particles that are eventually removed by the intake.

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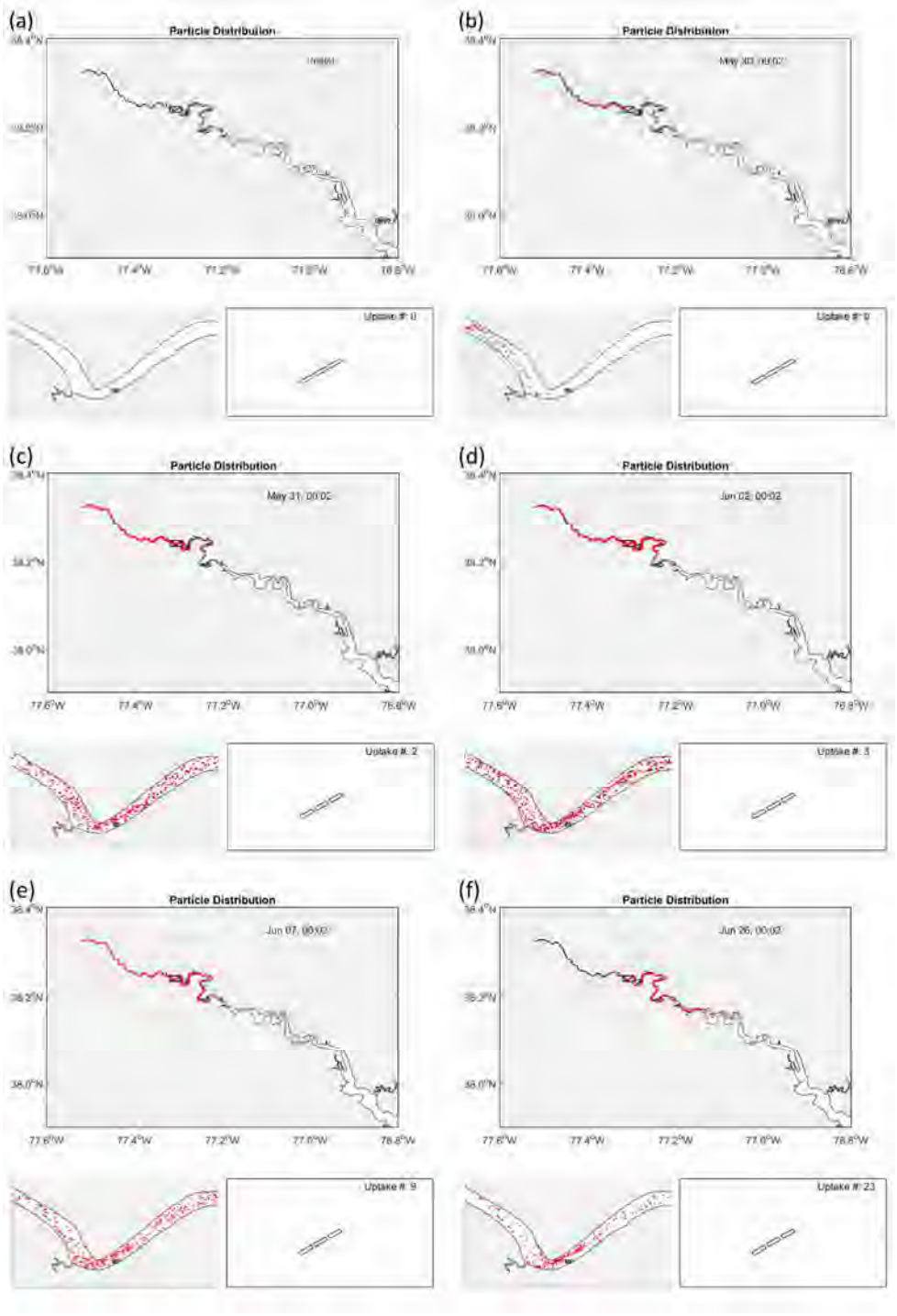


Figure A7. Distribution of particles (red dots) in Scenario 5. (a) Initial distribution at 5/28/2011. (b) After 2 days. (c) After 3 days. (d) After 5 days. (e) After 10 days. (f) After 29 days. Blue dots denote those particles that are eventually removed by the intake.

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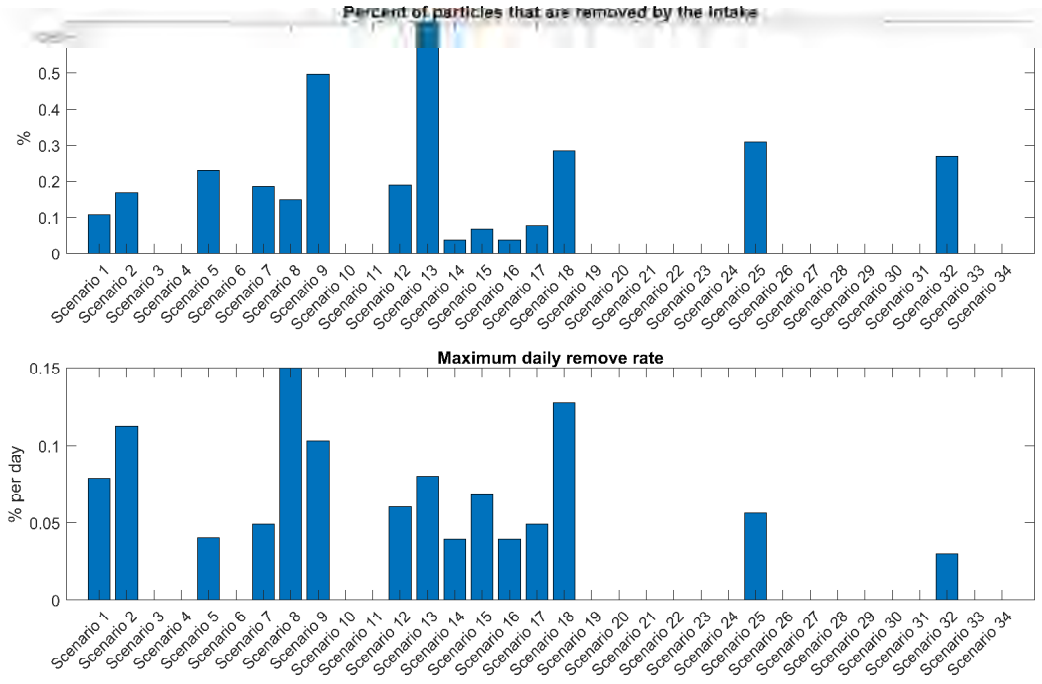


Figure A8. A summary of all of the forward-tracking scenarios showing the total number of particles removed by the intake (i.e., percent of particles that are removed by the intake) and the maximum daily removal rate, for 10,000-particle cases.

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Appendix B

Rappahannock River Hydrologic and Salinity Analysis

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Rappahannock River Hydrologic and Salinity Analysis

Caroline County Rappahannock River Water Supply Project

March 2020

Caroline County is located within the Eastern Virginia Groundwater Management Area (EVGMA). The County currently relies on groundwater for water supply, and additional groundwater withdrawals are expected to be limited due to the regulations affecting the EVGMA. The County anticipates additional population growth and increasing water demands. The Virginia General Assembly and the Department of Environmental Quality (DEQ) have recognized that the available groundwater supplies in the EVGMA are insufficient to meet the long terms demands of current and future groundwater users.

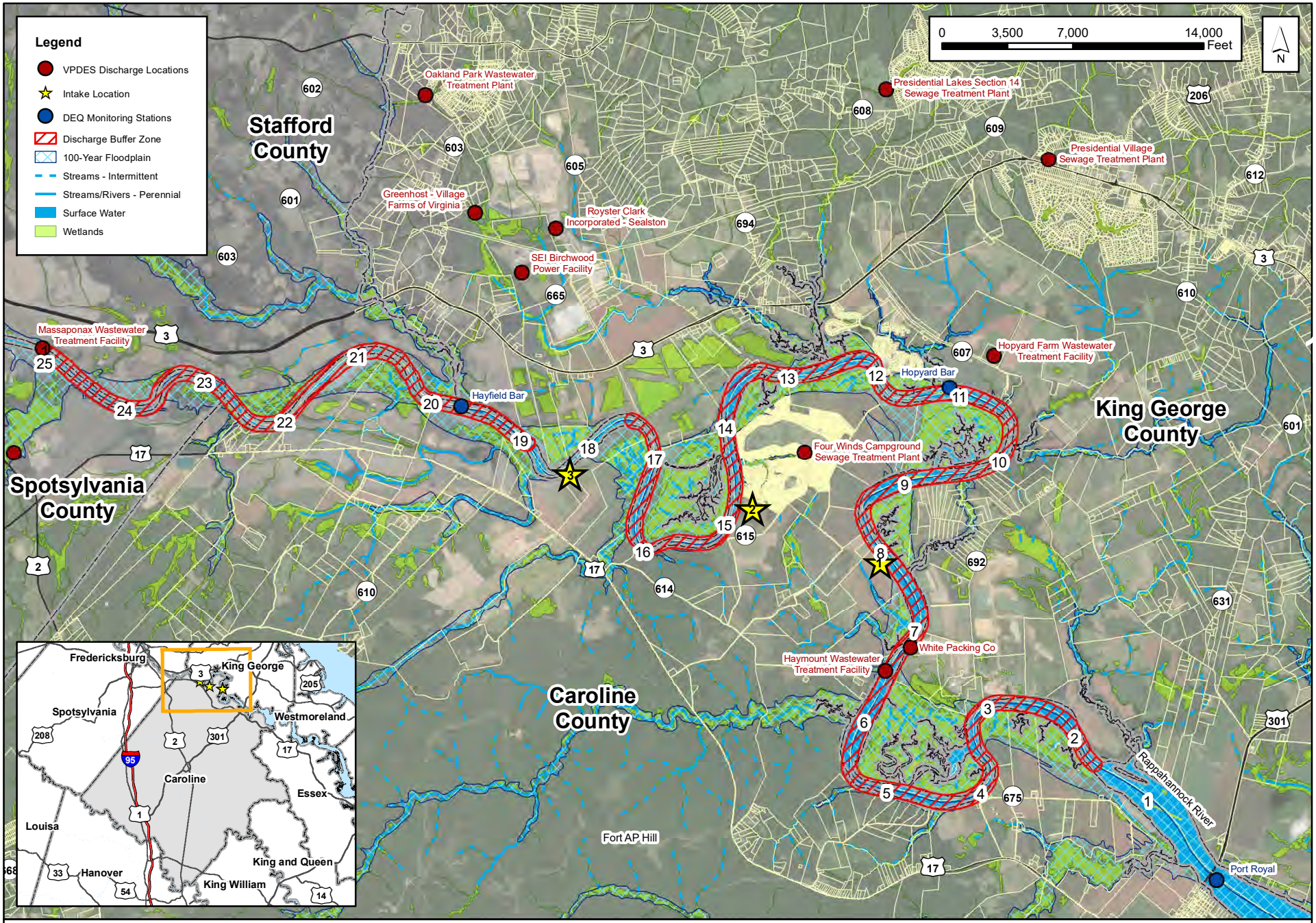
Caroline County is pursuing a Joint Permit Application (JPA) to withdraw water from the Rappahannock River. The County must submit the JPA for the construction of a new river intake, water treatment plant (WTP), and associated conveyance infrastructure. A preferred intake location was selected and water demand projections were developed for Caroline County, King George County and the Town of Bowling Green. This memorandum summarizes the hydrologic analyses used to evaluate the potential changes to the river from the proposed drinking water withdrawal.

1. Intake Location Alternatives

The Rappahannock River adjoining Caroline County was evaluated to identify potential intake locations. Three potential intake locations along the Rappahannock River were identified based on initial screening criteria. The hydrologic model described in this memo was developed for and is applicable to all three locations, which are within a 10-mile stretch of the river. The data and results presented in this memo are for the preferred location shown as Site 3 in **Figure 1-1**. Refer to the Intake Location Alternatives Analysis (Attachment J) for the details and evaluation of the three intake locations.

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Potential Intake Sites Vicinity Map

Caroline County, Virginia - Rappahannock River

DAA# R15287R-05

Figure 1-1

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2. Rappahannock River Flow Development

The Rappahannock River serves as the northeastern boundary of Caroline County. The entire reach of the river that borders the County is defined as being a tidal freshwater resource. This section of river is predominantly fresh (e.g. salinity less than 0.5 ppt) but is influenced by tidal variations from the Chesapeake Bay and Atlantic Ocean approximately 60 and 105 miles downstream, respectively. The nearest U.S .Geological Survey (USGS) flow gauge (#01668000) is located approximately 15 miles upstream at the City of Fredericksburg, VA. The Rappahannock River gauge at Fredericksburg captures approximately 90 percent of the watershed area upstream of Caroline County **(Figure 2-1**).



Figure 2-1. Map of the Rappahannock River Watershed upstream of Proposed Caroline County Intake Locations and the adjacent Mattaponi River Watershed

Flows from the contributing watershed downstream of the USGS gauge were estimated by scaling the watershed area from USGS gauge #01674000 on the Mattaponi River near Bowling Green, VA. The Mattaponi River watershed is adjacent to the Rappahannock River watershed in Caroline County (pink shaded area on **Figure 2-1**). This watershed was selected to scale flows because it is largely located in the coastal plain physiographic province, similar to the ungauged watershed area of the Rappahannock River being estimated.

The date range used for this analysis is from October 1, 1942 through May 31, 2019. The starting date is based on the earliest date available for the Mattaponi River USGS gauge. The ending date is based on the latest approved data from USGS for both gauges. Preliminary USGS data were not used for the analysis.

Natural flows in the river at Caroline County are influenced by water supply operations and wastewater discharges upstream. It is recognized that water supply withdrawals and wastewater discharges have changed over time as the upstream communities have grown. Data were not available to recreate the changes these operations have had on the river flows at Caroline County. Therefore, a number of

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assumptions were made to estimate flows in the river. Overall, wastewater flows are small compared to the river flows, even during typical dry weather conditions.

Withdrawals for Fredericksburg, Spotsylvania County and Stafford County to Hunting Run Reservoir, Motts Run Reservoir, and Rocky Pen Reservoir, occur upstream of the Rappahannock River USGS gauge at Fredericksburg. Discharges from the Fredericksburg, Spotsylvania County (Massaponax and FMC) and Stafford County (Little Falls Run) wastewater treatment plants occur downstream of the USGS gauge. Wastewater return flows from withdrawals upstream of the USGS gauge were estimated at approximately 27.4 cfs (17.7 mgd) on average and were added to the gauge flows (USEPA, 2019a, USEPA, 2019b, USEPA, 2019c, USEPA, 2019d).[1] Flow records at the Mattaponi gauge have been affected by operations of the Ni River Reservoir constructed in 1974. It is assumed that during dry periods the drainage area above the Ni River Dam will be completely captured and not contribute to flows downstream. No adjustment was made based on this condition, as the 24.5 square mile watershed area for the reservoir represents less than two percent of the calculated flows based on watershed area contributing to the Caroline County intake locations.

In summary, the freshwater flows in the Rappahannock River are estimated for points downstream of the USGS gauge at Fredericksburg based on the following formula:

*Rappahannock R. gauge #01668000 flow + Spotsylvania, Fredericksburg, and Stafford withdrawals + (ungauged Rappahannock R area / Mattaponi R. gauge #01674000 area) * Mattaponi R. gauge #01674000 flow*

The flows in the Rappahannock river follow the typical pattern in the Mid-Atlantic region with highest flows in the spring and lowest flows in the late summer (**Figure 2-2**). Large storm events can greatly increase flows to tens of thousands of cubic feet per second (cfs). Extended dry periods can result in low flows on the order of 30 cfs, which historically has occurred in 1954, 1966, 1999, and 2002. These low flow conditions typically occur in August, September, or October.

[1] Recognizing that withdrawals and wastewater return flows vary, a sensitivity analysis was conducted to confirm that variations (+/- ~5 cfs [2.7 mgd]) would have no significant effect on the salinity model.

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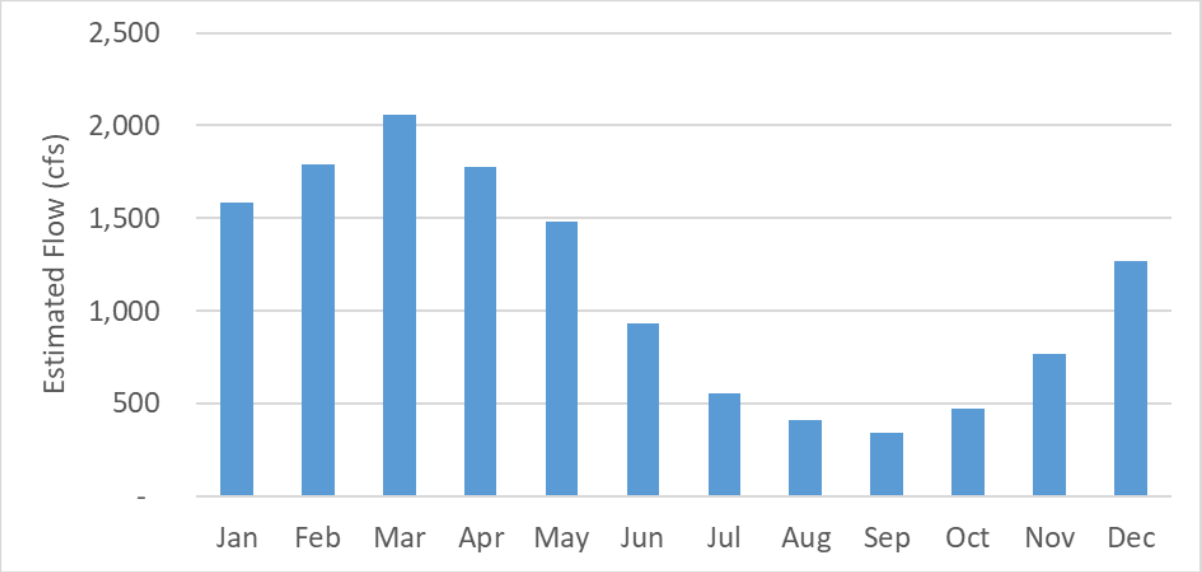


Figure 2-2: Estimated Monthly Median Freshwater Flows at the Preferred Intake Location

3. Rappahannock River Salinity Analysis

Because the County intake would be located in the tidal portion of the river, withdrawals will not affect flow depths in the river in the same manner as in a non-tidal stream. In tidal rivers, water surface elevations are driven by the tide. **Figure 3-1** presents a comparison of hourly measured tide elevations at the Rappahannock Bend Tide Station (8635257) and the corresponding hourly flow rates based on the USGS Rappahannock gauge at Fredericksburg, VA in 2007. The 10-month period had a wide range of flows from as low as 27 cfs to higher than 20,000 cfs. The data indicates that freshwater flows have minimal influence over the tidal range until flow exceeds approximately 5,000 cfs. Therefore, withdrawals on the order of approximately 10 to 20 cfs are expected to have no measurable impact on the river water surface elevations.

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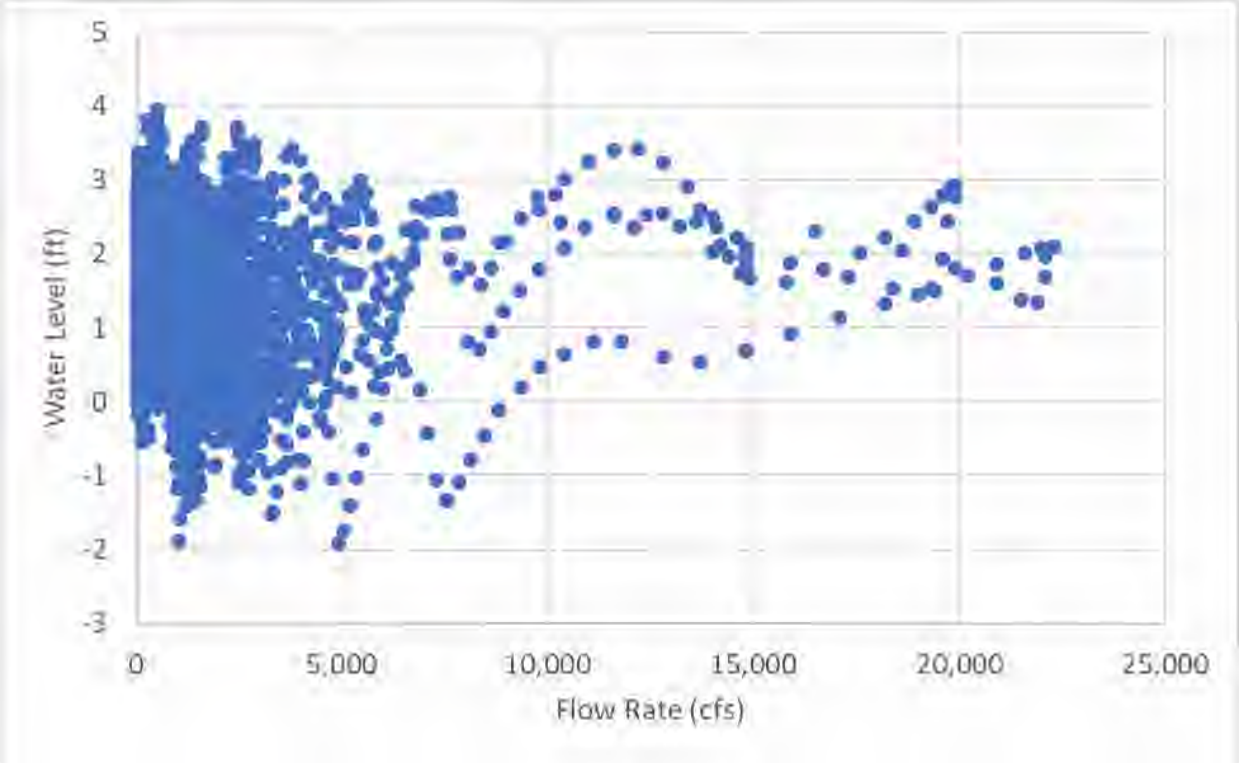


Figure 3-1. Hourly Rappahannock Bend Tide Height[2] and USGS River Flow Data from February to November 2007

While water surface elevations are not affected, withdrawals decrease freshwater flows downstream, allowing the tide to push more brackish water from the Chesapeake Bay further upstream in the river. An important consideration for the County when planning a new intake is the impact of County withdrawals on salinity in the river, both at the intake and at environmentally sensitive locations downstream.

The occurrence of high salinity conditions is important at the intake because chloride and total dissolved solids (TDS) are on the US Environmental Protection Agency (USEPA) list of secondary contaminants.[3] Elevated chloride levels above the secondary standard of 250 mg/L or elevated TDS above the above the secondary standard of 500 mg/L (approximately 1,000 uS/cm conductivity[4]) are not desirable in drinking water. In addition to high salinity at the intake, substantial changes to the salinity regime throughout the freshwater tidal portion of the river could have negative impacts on unique tidal freshwater wetlands or fish species that are sensitive to salinity. At the January 19, 2016 pre-application meeting, DGIF suggested that salinity should be modeled at multiple locations under varying flow conditions to understand the impact of the withdrawals on saltwater intrusion in the river.

[2] Mean Lower Low Water level datum
[3] Secondary standards are non-mandatory water quality standards established as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color, and odor.
[4] Units of conductivity used as a measure of TDS or salinity are microsiemens per centimeter.

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3.1 Data Analysis

Salinity data were reviewed along the length of the tidal freshwater portion[5] of the river to identify water quality monitoring locations with sufficient data to support modeling efforts. Data were collected from the USEPA STORET database[6] and the Virginia Institute of Marine Science (VIMS) Virginia Estuarine and Coastal Observing System (VECOS).[7] The following five water quality monitoring sites were identified as having sufficient data for modeling:

- Hayfield Bar is approximately one mile upstream of Intake Site #3. Data at this location consisted of grab samples collected by DEQ and is generally bimonthly from 1991 to 2003 and monthly from 2004 to 2015.
- Hop Yard Landing is approximately four miles downstream of Intake Site #2. Data at this location consisted of grab samples collected by DEQ and is generally bimonthly from 1979 to 1996 and monthly from 1997 to 2015.
- Hicks Landing is approximately two miles downstream of Intake Site #1 – Haymount. Data at this location was collected by VIMS at 15-minute intervals for the spring through fall for 2007, 2008 and 2009.
- Port Royal is approximately seven miles downstream of Intake Site #1 – Haymount. Data at this location consisted of grab samples collected by DEQ and VIMS and is generally bimonthly from 1979 to 1996, and monthly from 1997 to 2015.
- Station TF3.3 is approximately 33 miles downstream from Site #1 – Haymount. Data at this location consisted of grab samples collected by VIMS and is generally monthly from 1984 to 2016.

The data were screened for outliers and to determine the appropriate flow thresholds for analysis. Salinity data were checked for quality to remove any data that was erroneous based on comparison of salinity between stations, at different depths (where available), and with hydrology data. The data were evaluated for the presence of dry periods to assess the change in salinity based on hydrology. The drought conditions were compared with the collected data, and the years 1999, 2002, and 2007 were identified as the 2nd, 3rd, and 8th worst drought years, respectively. Therefore, the water quality data overlaps with a number of drought periods to help calibrate the modeling for changes in salinity based on low flow conditions.

The VIMS VECOS data also include water quality sampling cruises, referred to as dataflow, for the Rappahannock River. These cruises collect water quality data along a length of the river over a few hours. These data were not used in the development of the river salinity model, but were used to understand the shape of the salt wedge during dry hydrologic periods (**Figure 3-2**).

[5] The tidal freshwater section of the river is defined as the being from the fall line to the transition zone boundaries listed in 9 VAC 25-260 - Virginia Water Quality Standards.
[6] https://ofmpub.epa.gov/storpubl/dw_pages.querycriteria
[7] http://web2.vims.edu/vecos/

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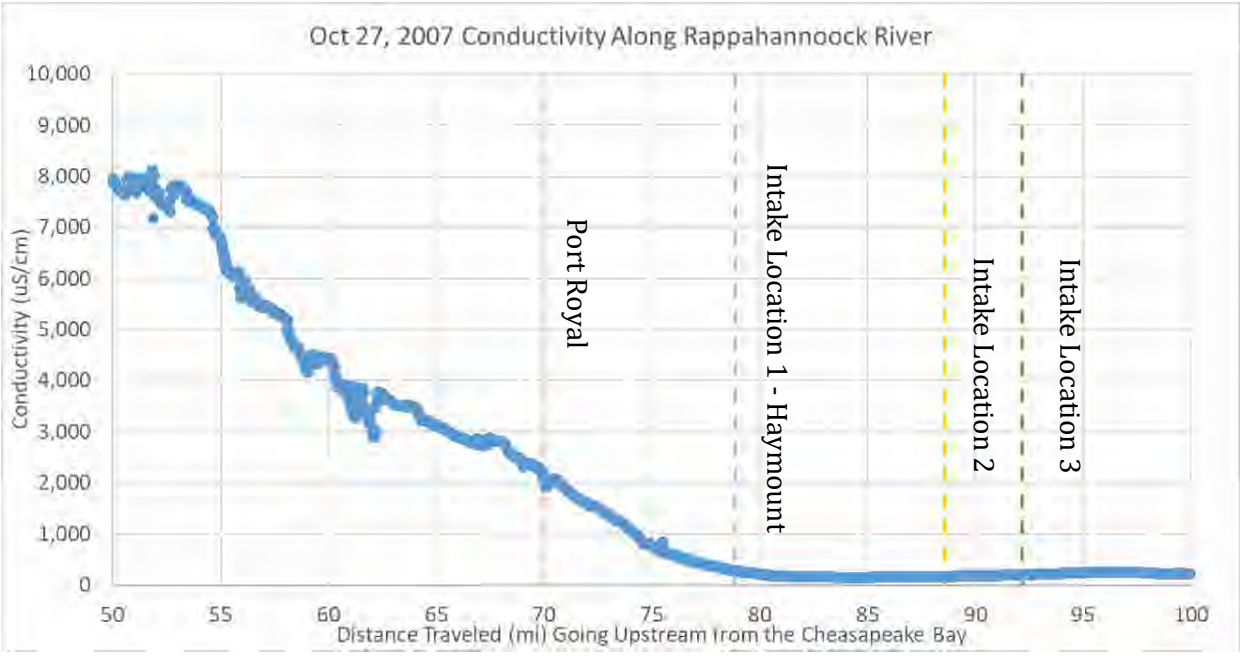


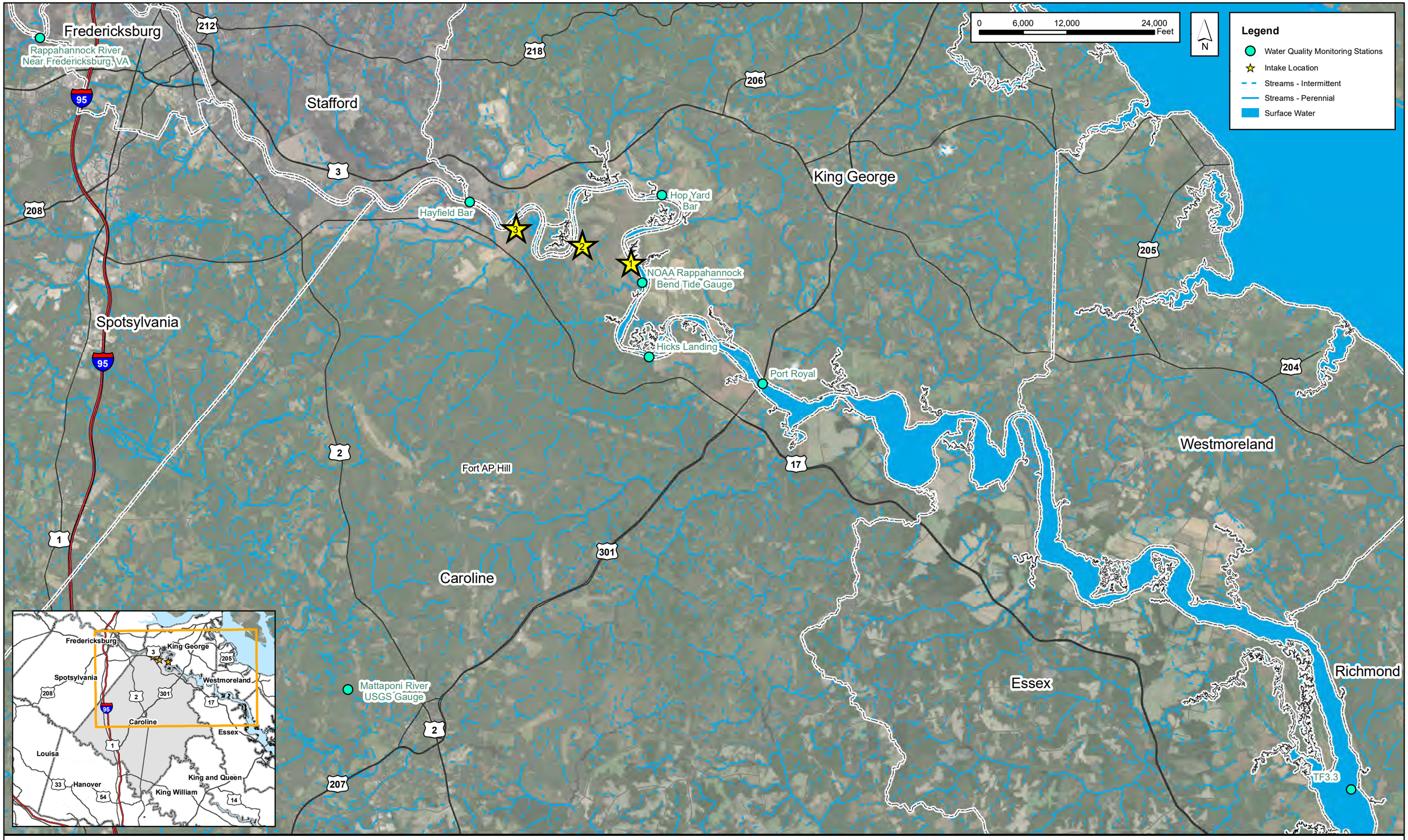
Figure 3-2. VIMS VECOS Rappahannock Dataflow Observations for Conductivity in the Vicinity of the Proposed Intakes

In addition to flow and water quality data, tide data for NOAA station 8635257 Rappahannock Bend, VA was obtained.[8] This station is located between the Hop Yard Landing and Hicks Landing water quality monitoring stations. Observations at this location were only available for 2007 and 2008. However, NOAA has developed a tide model at this location that can simulate tide height at 6-minute intervals for any date range. Refer to **Figure 3-3** for locations of all flow, tide and water quality monitoring locations used for the flow and salinity modeling.

Bay salinity data were reviewed to identify the range of salinity variation, because the Rappahannock River discharges to the Chesapeake Bay and not the open ocean. The Chesapeake Bay Interpretive Buoy System has a buoy located close to the mouth of the Rappahannock River at Stingray Point. Hourly salinity data were available at his location from 2008 through 2016. The data exhibited an intra-annual change in salinity with the highest salinity occurring in the August/September months and lowest salinity occurring in the February/March months **(Figure 3-4**). The salinity pattern is consistent with seasonal changes to inflows of fresh water to the bay, which results in the highest freshwater flow in the spring and lowest freshwater flow in the summer (Chesapeake Bay Program, 2018).

[8] https://tidesandcurrents.noaa.gov/stationhome.html?id=8635257#available

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DAA# R15287R-05

Water Quality Monitoring Stations
Caroline County, Virginia - Rappahannock River

Figure 3-3

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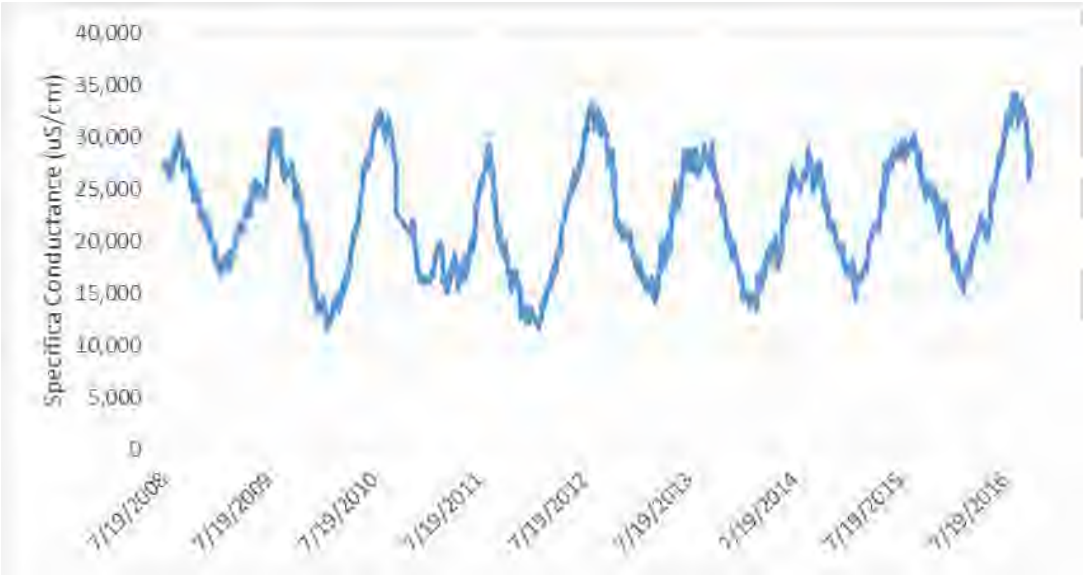


Figure 3-4. Chesapeake Bay Conductivity at the Stingray Point Observation Buoy

Data at each water quality monitoring location was combined as follows for preliminary data analysis:

- Tide projections from the Rappahannock Bend tide model was linked with the water quality monitoring data based on the closest date/time.
- Daily average flow estimates were developed for each day of the time series at each location.
- Flows were aggregated for each day based on the average of the prior seven, 30, 60, and 90 days.
- Daily average salinity at the Stingray Point buoy was added for each day of the time series.

3.2 Rappahannock River Conductivity/Salinity Model Development

The initial data analysis consisted of comparing the predictor parameters (flows, tide height and Chesapeake Bay Salinity) with the water quality data. The data comparison indicated strong relationships with flow and tide data. A freshwater threshold of 0.5 parts per thousand (ppt) or 1,000 uS/cm conductivity was used to categorize the freshwater threshold.

The Chesapeake Bay salinity dataset was ultimately not used in the modeling because the data did not extend far back enough to cover the important drought periods. Further, the bay salinity fluctuation was determined to be heavily influenced by hydrology, which was accounted for with direct flow measurements for the river.

A regression model was developed at each of the water quality monitoring stations. Model formulations were developed based on published literature and data exploration to achieve a model fit that is stable under a wide range of flow conditions (Sun and Koch, 2001: Qiu and Wan, 2013). For the model development, the data were used in the native format of either conductivity or salinity to limit potential rounding issues from unit conversions. Further, while some of the withdrawals are expected to be

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returned to the river through wastewater discharges, the modeling conservatively assumes zero return flows.

3.2.1.1 Hayfield Bar

Conductivity data for Hayfield Bar indicated that even during very dry conditions experienced during 1999 and 2002 conductivity changed minimally and did not exceed the freshwater threshold (**Figure 3-5**). Therefore, a model was not developed for this location.

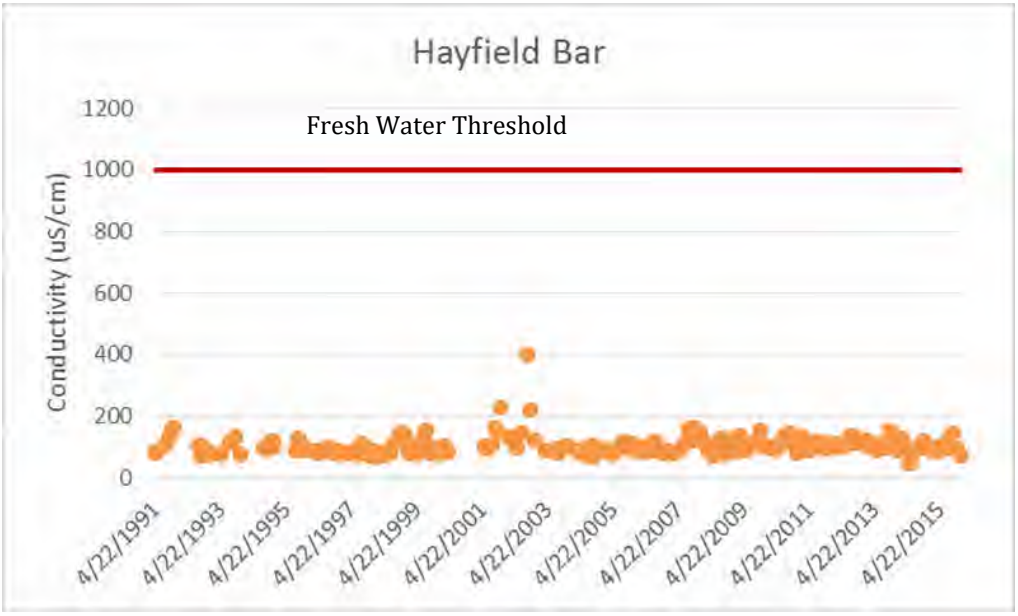


Figure 3-5. Hayfield Bar Conductivity Data

3.2.1.2 Hop Yard Landing

Conductivity data for Hop Yard Landing indicated that even during very dry conditions experienced during 1999 and 2002, conductivity changed minimally and did not exceed the freshwater threshold (**Figure 3-6**). Therefore, it is expected that conductivity would not exceed the freshwater threshold under future withdrawal scenarios, and a model was not developed for this location.

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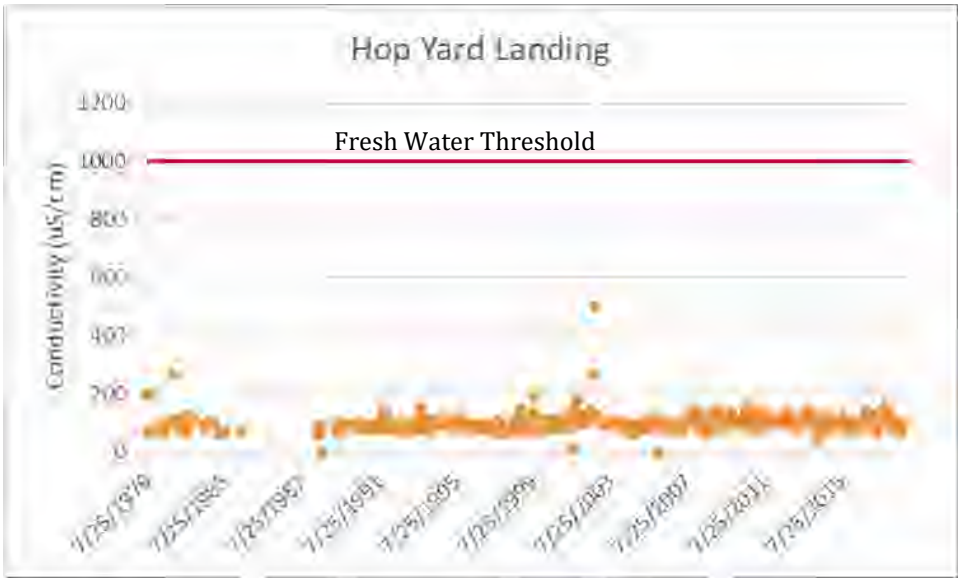


Figure 3-6. Hop Yard Landing Conductivity Data

3.2.1.3 Hicks Landing

Data at Hicks Landing indicated conductivity exceeded the freshwater threshold under moderately dry conditions in 2007 (**Figure 3-7**). Plotting flows versus conductivity indicated there was a bimodal behavior based on flow rates. Conductivity levels varied substantially when flows were low, but were relatively stable at high flow rates (**Figure 3-8**). A flow threshold of 150 cfs was selected as the transition point for these two modes based on weekly average flows for Hicks Landing.

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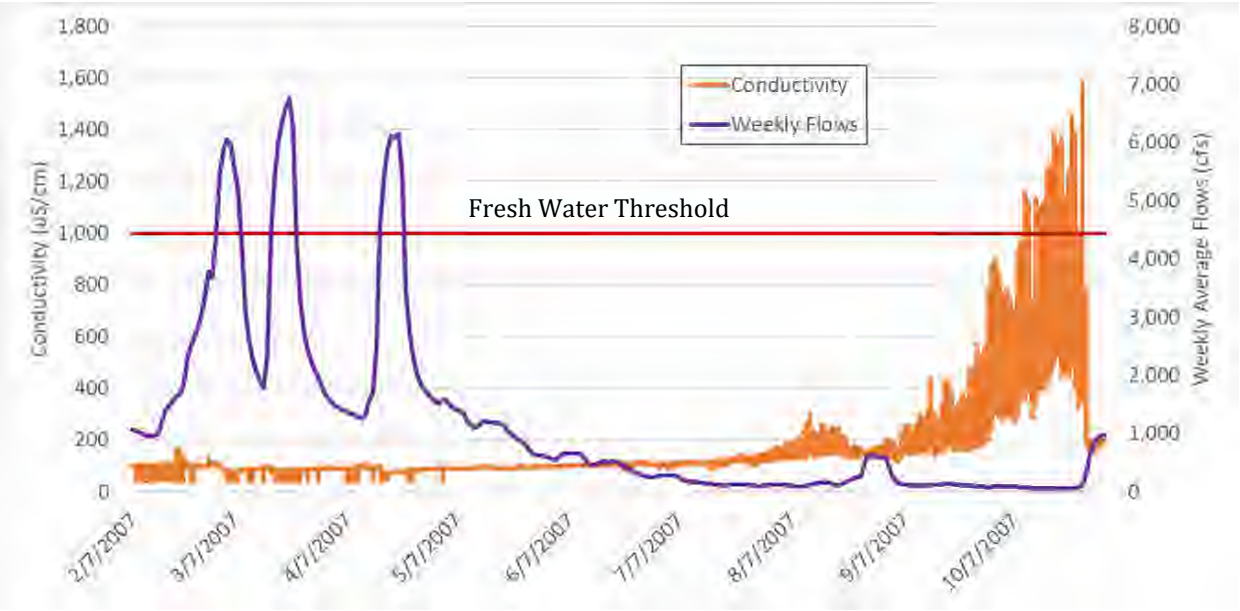


Figure 3-7. Hicks Landing Conductivity Observations and Weekly Flow Data

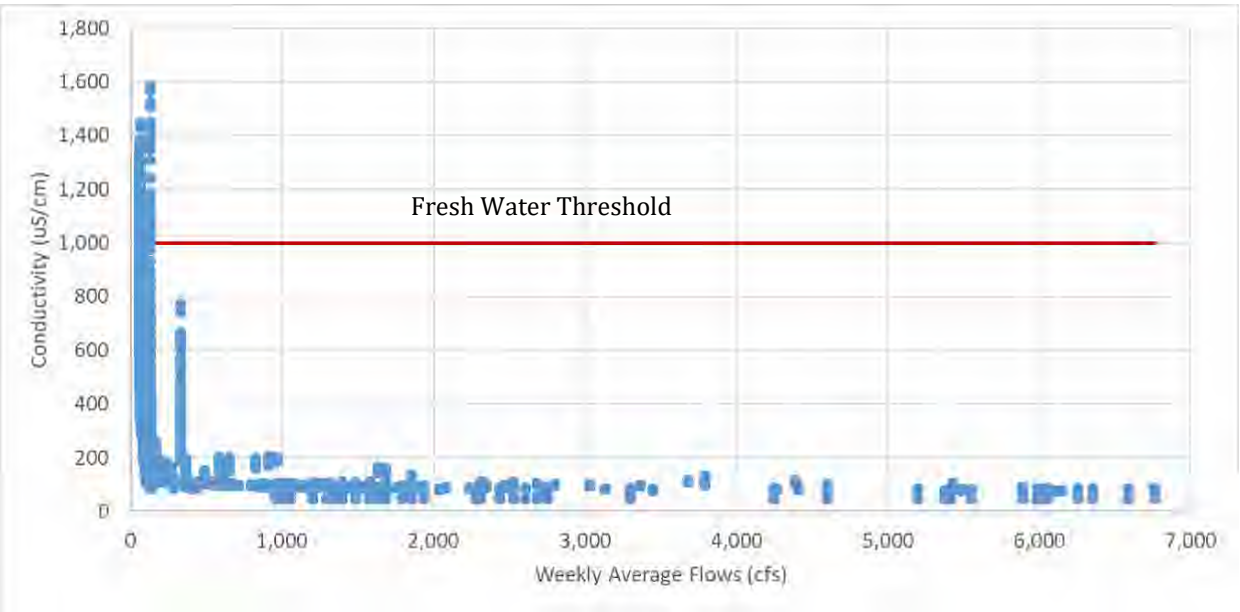


Figure 3-8. Flow vs Conductivity for Hicks Landing

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Separate models were developed for low flow/high salinity conditions and for high flow/low salinity conditions using tide height and river flows as predictors. Log transformation of the predicted variable (conductivity) was used for both models to achieve good model fit. The two models are:

- Hicks Landing Low Flow Model (less than 150 cfs, high salinity)
    - Log(Conductivity) = 2.0 – 0.26(Daily max tide) – 0.0007(Daily average flow) + 0.0027(30-day average flow) – 0.0012(60-day average flow) + 70.0(Tide/30-day average flow) – 483.4(Tide/30-day average flow)^2
    - $R^2 = 0.74$

- Hicks Landing High Flow Model (greater than 150 cfs, low salinity)
    - Log(Conductivity) = 2.1 - 0.013(Daily max tide) + 1.6E-6(Daily average flow) + 8.4E-7(30-day average flow) – 2.5E-5(60-day average flow) + 20.2(Tide/30-day average flow) – 233.8(Tide/30-day average flow)^2
    - $R^2 = 0.50$

The model fit was not as good for the low salinity model, but the variation in this range was acceptable because salinity when flows were in this range were consistently within the freshwater range.

Figure 3-9 presents the modeled and observed conductivity based on daily max tide data for Hicks Landing. While some of the variation within the freshwater threshold is not being captured by the high flow model, the model is capturing the critical high conductivity peak. **Figure 3-10** presents conductivity model projections for the full historical timeseries. These results show that 1) the model results simulate conductivity that exceeds the conductivity in the observations; and 2) the model captures the key drought periods.

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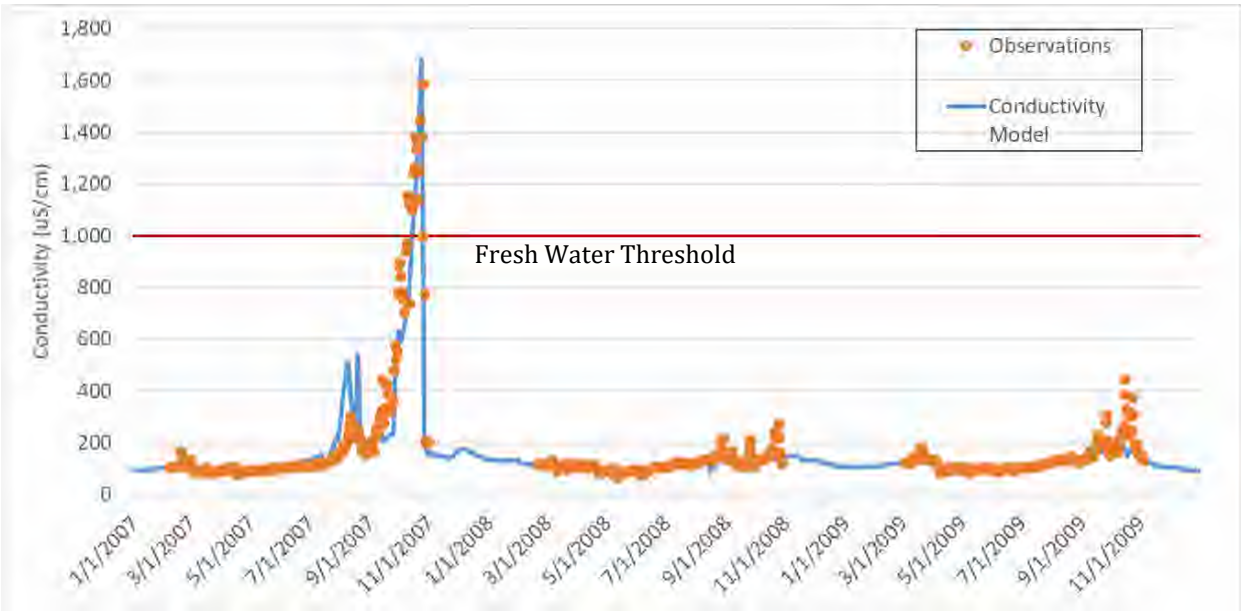


Figure 3-9. Hicks Landing Observed and Modeled Conductivity

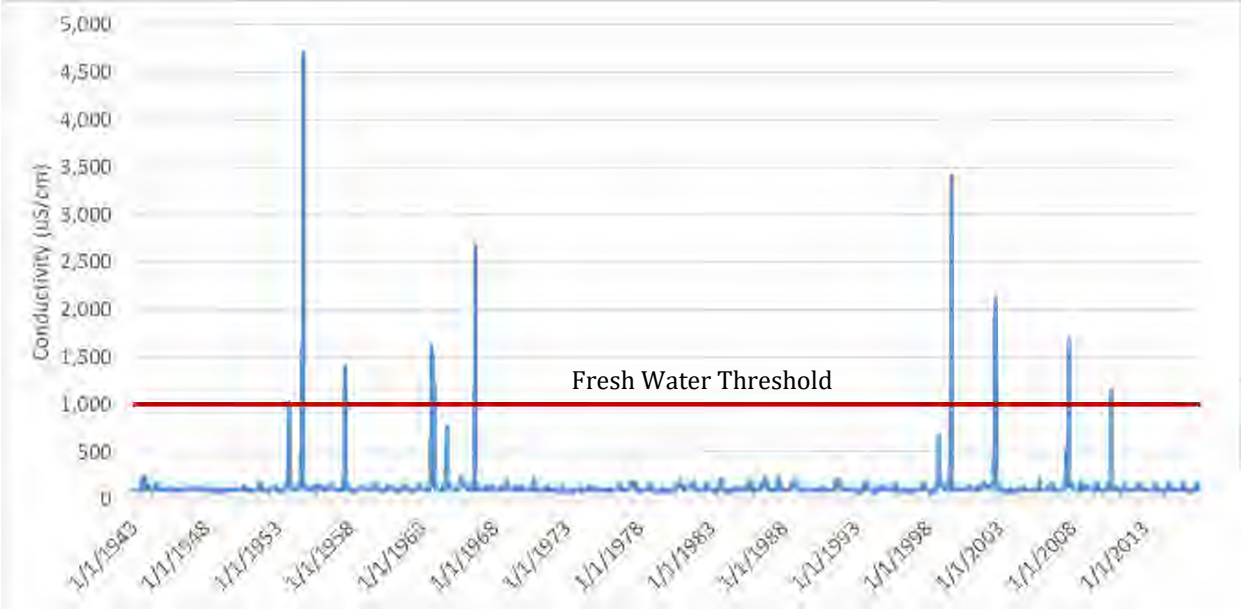


Figure 3-10. Hicks Landing Modeled Conductivity for the Full Record

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3.2.1.4 Port Royal

Conductivity data at Port Royal exceeded the freshwater threshold and exhibited a similar bimodal behavior as Hicks Landing. A flow threshold of 500 cfs was selected as the transition point for the two modes based on weekly average flows for Port Royal. The conductivity range under high flow conditions was narrow, between 44 to 243 uS/cm. Therefore, the median value of 88 uS/cm was used as a constant for high flow conditions when weekly flows were above 500 cfs.

The low flow model formulation for the Port Royal conductivity model was the same as for Hicks Landing, but with different coefficients.

- Port Royal Low Flow Model (less than 500 cfs, high salinity)
    - Log(Conductivity) = 2.01 – 0.02(Daily max tide) – 4.7E-5(Daily average flow) – 1.9E-5(30-day average flow) – 0.00023(60-day average flow) + 92.8(Tide/30-day average flow) – 1108.6(Tide/30-day average flow)^2
    - $R^2 = 0.70$

Figure 3-11 presents the modeled and observed conductivity based on daily max tide data for Port Royal. Unlike the Hicks Landing data, which consists of 15-minute data, Port Royal is limited to grab samples. Therefore, the observed data do not necessarily fall at the time of maximum tide. The model is based on maximum tide data in order to capture the daily peak conductivity. Similar to Hicks Landing, the key drought periods are represented by elevated conductivity.

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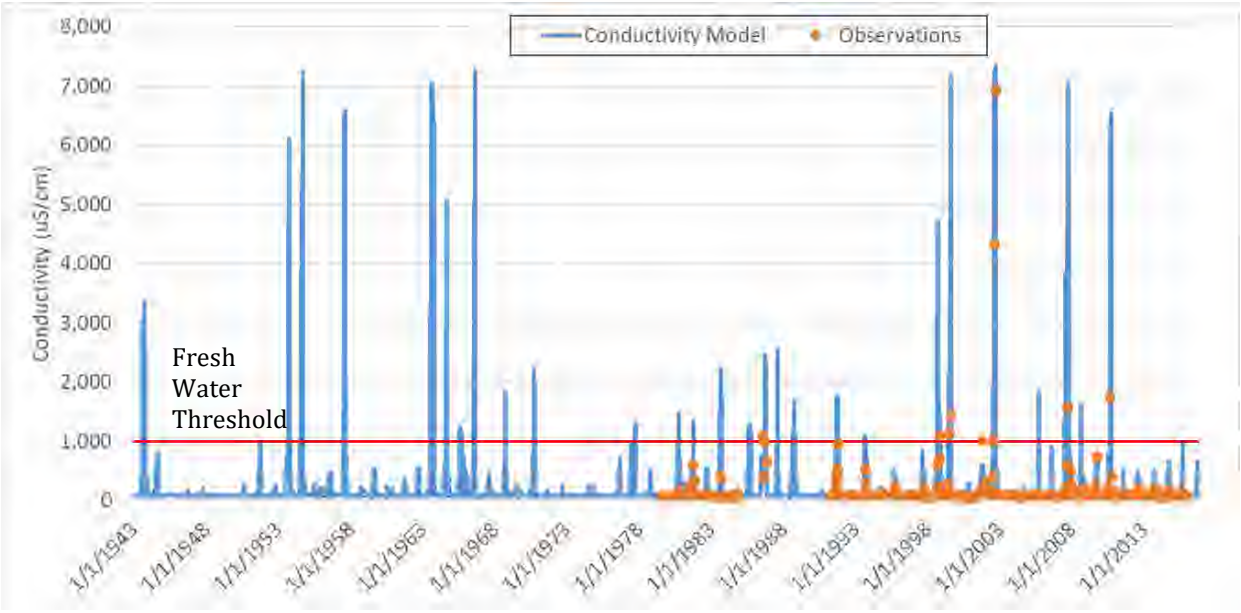


Figure 3-11. Port Royal Observed and Modeled Conductivity

3.2.1.5 Station TF3.3

Salinity data at Station TF3.3, which is within the transition zone of the tidal freshwater portion of the river,[9] has substantially higher salinity than the other stations. The data at Station TF3.3 did not exhibit bimodal behavior, and only a single model was developed for all the observed data.

The model formulation for the Station TF3.3 salinity model was similar to that for Port Royal and Hicks Landing, but with different coefficients.

- Station TF3.3 Salinity Model
    - Log(Conductivity) = 0.63 + 0.006(Daily max tide) – 7.8E-5(Daily average flow) – 1.37E-4(30-day average flow) + 8.12E-5(60-day average flow) – 2.39E-4(90-day average flow) + 54.0(Tide/30-day average flow) – 1688.3(Tide/30-day average flow)^2
    - $R^2 = 0.65$

Figure 3-12 presents the modeled and observed conductivity based on daily maximum tide data for Station TF3.3. As with Port Royal, the TF3.3 model is based on grab samples that occurred at various tide stages, while the modeled salinity is based on daily max tide to capture the daily highest tide. A few of the very highest salinity measurements have not been captured by the model. This is believed to be because 1) approximately 25% of the salinity data did not have sample time, which made it difficult to correlate with tide height, and 2) the Rappahannock Bend tide station is located further from TF3.3 than for Port Royal or Hicks Landing, which may affect the timing and tide height of the tide data relative to this

[9] Per 9 VAC 25-260 - Virginia Water Quality Standards

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location. Despite these limitations, the model performs well, capturing a large range of salinity variation at this location that correlates with known drought conditions.

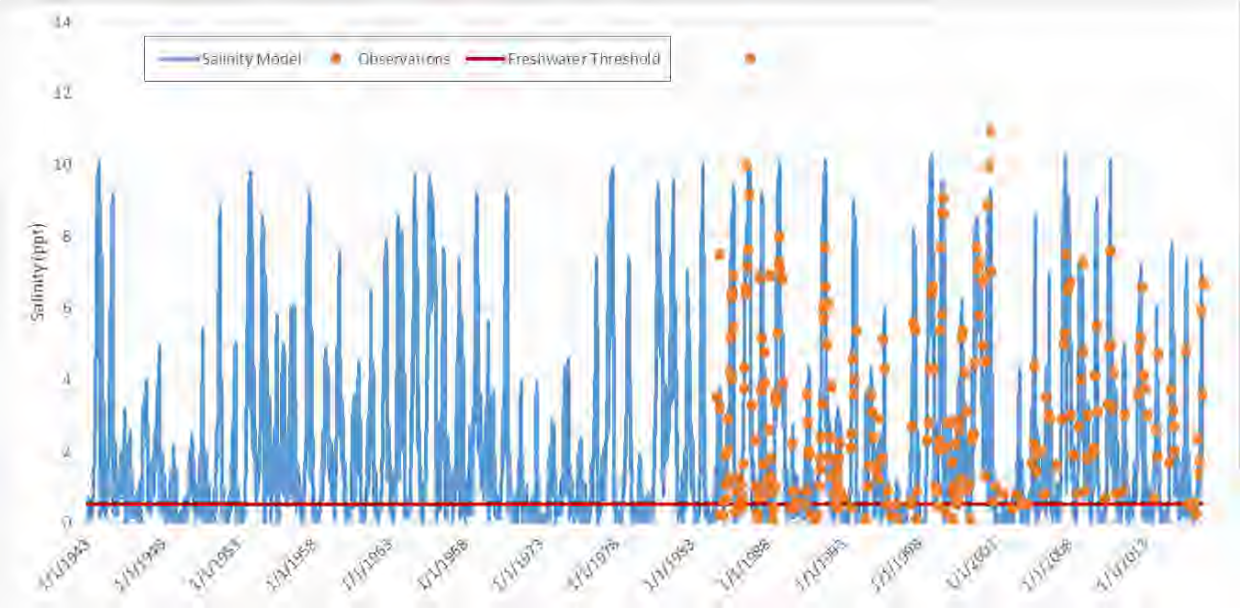


Figure 3-12. Station TF3.3 Observed and Modeled Conductivity

4. River Withdrawal Scenarios

The goal of the County is to obtain a permit for withdrawals needed to satisfy demands over a 15-year VWP permit term. The projected average day withdrawal for 2035 is 12.2 cfs (7.9 mgd). The estimated maximum day withdrawal is 21.4 cfs (13.9 mgd), approximately 1.76 times the average day value. Further, an estimated range of monthly withdrawal multipliers (ranging from 0.7 to 1.35) were used to simulate that typical changes in seasonal demands (**Figure 4-1**).[10] It is difficult to predict when the maximum day withdrawals can occur within a system. In order to evaluate the potential effect on salinity from maximum day withdrawals, the salinity model was evaluated with just the monthly withdrawal variations and the single highest salinity value was identified for each year. The model was re-run with the max day multiplier of 1.76 applied to demands on those days. The resulting river salinity based on these withdrawal values were compared to the baseline salinity estimates described previously at the water quality monitoring stations (Hicks Landing, Port Royal, and TF3.3).

Data are presented below comparing differences for the over 76 years of available data (January 1, 1943 to May 31, 2019, total number of days of 27,910).[11]

[10] Monthly factors were derived from data for other utilities in the Mid-Atlantic region and were selected to be conservative with high summer withdrawals.
[11] Because the salinity the model uses antecedent river flows, the first few months of available flow data do not have a salinity estimate.

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Figure 4-1: Estimated Monthly Demand Multipliers used in Salinity Modeling

4.1 Overall Differences in Salinity Regime

Figure 4-2 provides a snapshot for the overall changes in conductivity at Hicks Landing and Port Royal under baseline and projected conditions given a 12.22 cfs (7.9 mgd) average day withdrawal in 2035. Since these two locations are predominantly freshwater under most flow conditions, days with max conductivity above and below the freshwater threshold of 1,000 uS/cm were tabulated. The results indicate there is a small decrease in the number of freshwater days and a corresponding increase in days above the freshwater threshold.

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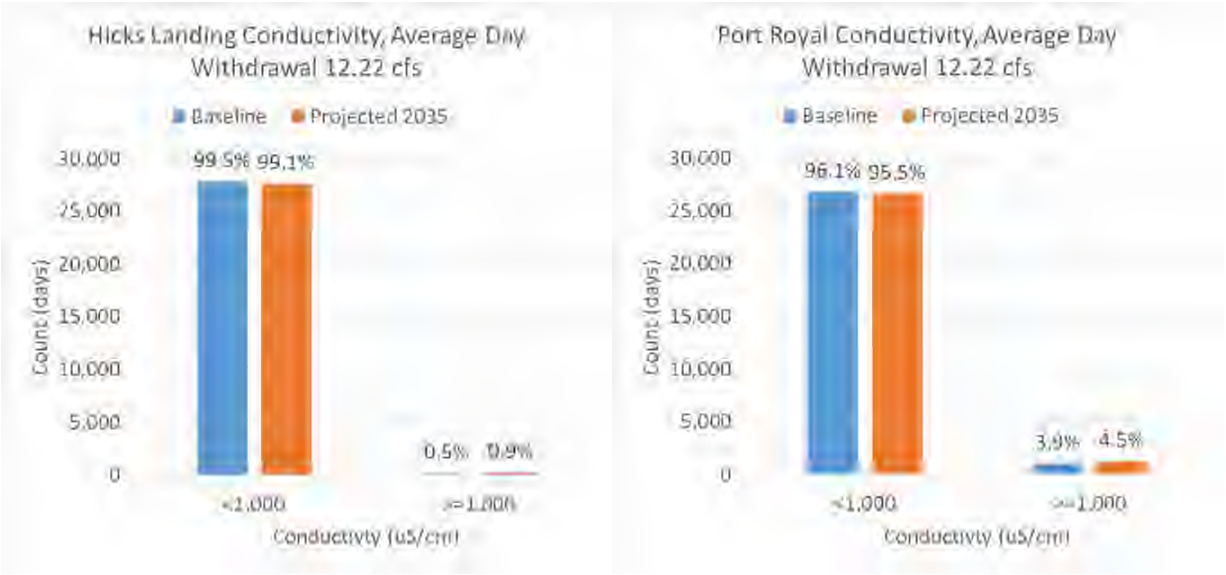


Figure 4-2. Modeled Baseline and Projected Change in Days Above and Below the Freshwater Threshold (1,000 uS/cm) for Hicks Landing and Port Royal (Total number of days = 27,910)

DEQ staff provided a representative threshold value for the change in salinity of 0.5 parts per thousand (ppt) between baseline and future conditions. Comparing the daily magnitude of conductivity for these two locations results in the following observations:

- Hicks Landing had a total of 54 days (0.2%) that exceeded the baseline conductivity value by the equivalent of 0.5 ppt with the largest difference being approximately 0.8 ppt and the longest event lasting 13 days.
- Port Royal had a total of 123 (0.5%) days that exceeded the baseline conductivity value by the equivalent of 0.5 ppt with the largest difference being approximately 0.6 ppt and the longest event lasting 29 days.

Figure 4-3 presents the changes in salinity at Station TF3.3 between baseline and 12.2 cfs (7.9 mgd) average day withdrawals with monthly and max day peaking factors. This location is substantially downstream from Hicks Landing and Port Royal and has naturally higher salinity. Therefore, additional salinity ranges were used to divide the data based on a wider range of salinity concentrations. The results of the withdrawals have a similar effect at this location as with Hicks Landing and Port Royal. There is a small decrease in the number of freshwater days and a corresponding increase in days at the higher salinity levels. With respect to the 0.5 ppt threshold for salinity increase, none of the days shift more than 0.35 ppt between baseline and future conditions based on the model.

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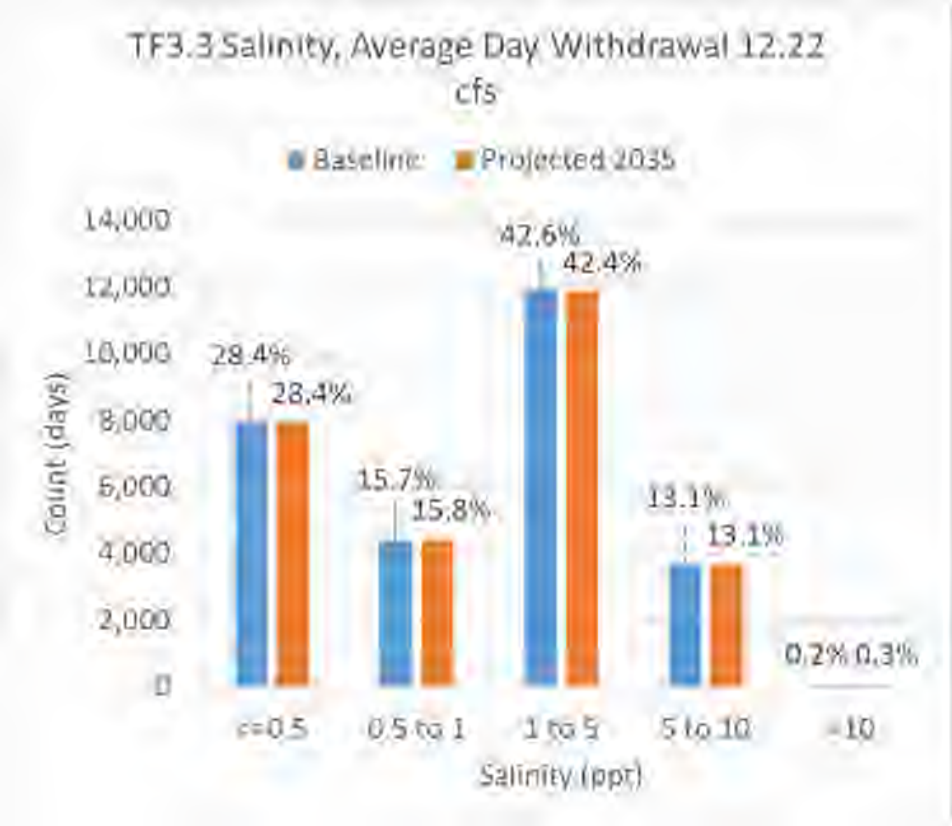


Figure 4-3. Modeled Baseline and Projected Change in Days Above and Below Various Salinity Ranges for Station TF3.3 (Total number of days = 27,910)

The relatively small shift in salinity is consistent with the fact that the overall withdrawal is small compared to the flow in the river during most days. Over the course of the simulation, the withdrawals are below 10% of the river flow in more than 95% of days.

5. Conclusion

The following conclusions were drawn from this evaluation to assess the hydrology and salinity in the river in the vicinity and downstream of the proposed drinking water intake for Caroline County.

- Freshwater inflows are reliable and sufficient to supply the anticipated withdrawals for Caroline County.
- Salinity in the vicinity of the proposed intake would be in the range of fresh water, even during typical low flow conditions.
- Salinity levels downstream of the proposed intake would not change appreciably at the proposed withdrawals rates for Caroline County. Therefore, salinity impacts are not expected to occur for freshwater wetlands or aquatic species downstream of the proposed intake.

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Hazen

Rappahannock River and Mattaponi River Hydrologic and Salinity Analysis

Caroline County Rappahannock River Water Supply Project

May 2025

Caroline County is located within the Eastern Virginia Groundwater Management Area (EVGMA). The County currently relies on groundwater for water supply, and additional groundwater withdrawals are expected to be limited due to the regulations affecting the EVGMA. The County anticipates additional population growth and increasing water demands. The Virginia General Assembly and the Department of Environmental Quality (DEQ) have recognized that the available groundwater supplies in the EVGMA are insufficient to meet the long term demands of current and future groundwater users.

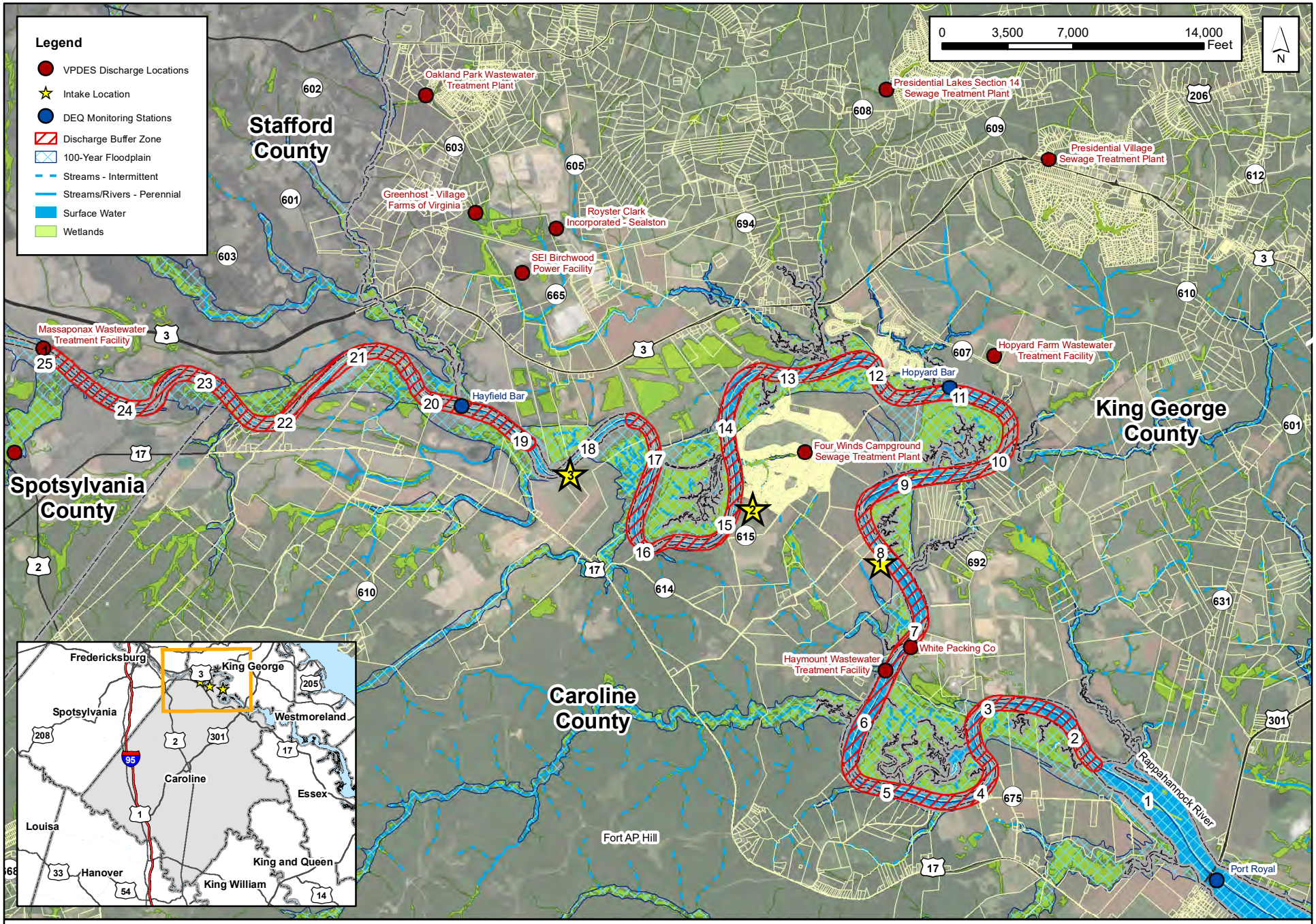
Caroline County is pursuing a Joint Permit Application (JPA) to withdraw water from the Rappahannock River. The County must submit the JPA for the construction of a new river intake, water treatment plant (WTP), and associated conveyance infrastructure. A preferred intake location was selected, and water demand projections were developed for Caroline County and the Town of Bowling Green. This memorandum summarizes the hydrologic analyses used to evaluate the potential changes to the Rappahannock River and the Mattaponi River from the proposed drinking water withdrawal.

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1. Intake Location Alternatives

The Rappahannock River adjoining Caroline County was evaluated to identify potential intake locations. Three potential intake locations along the Rappahannock River were identified based on initial screening criteria. The hydrologic model described in this memo was developed for and is applicable to all three locations, which are within a 10-mile stretch of the river. The data and results presented in this memo are for the preferred location shown as Site 3 in **Figure 1-1**. Refer to the Intake Location Alternatives Analysis (Attachment J) for the details and evaluation of the three intake locations.



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Potential Intake Sites Vicinity Map

Caroline County, Virginia - Rappahannock River

DAA# R15287R-05

Figure 1-1

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2. Rappahannock River Flow Development

The Rappahannock River serves as the northeastern boundary of Caroline County. The entire reach of the river that borders the County is defined as being a tidal freshwater resource. This section of river is predominantly fresh (e.g. salinity less than 0.5 parts per thousand) but is influenced by tidal variations from the Chesapeake Bay and Atlantic Ocean approximately 60 and 105 miles downstream, respectively. The nearest U.S. Geological Survey (USGS) flow gauge (#01668000) is located approximately 15 miles upstream at the City of Fredericksburg, VA. The Rappahannock River gauge at Fredericksburg captures approximately 90 percent of the watershed area upstream of Caroline County **(Figure 2-1**).

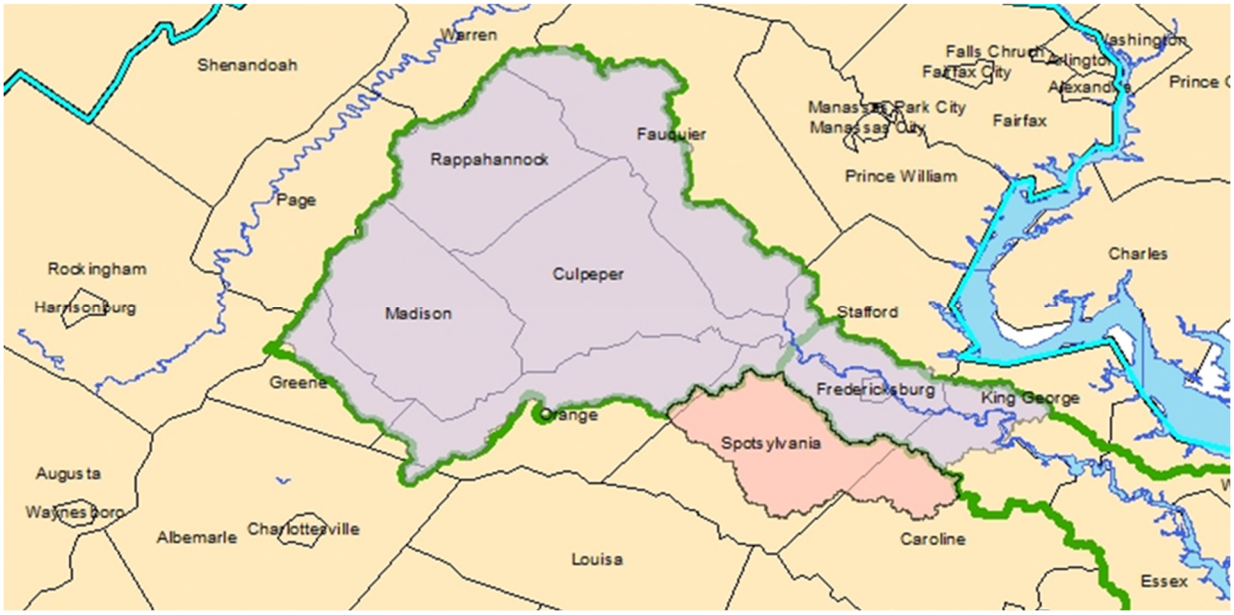


Figure 2-1. Map of the Rappahannock River Watershed upstream of Proposed Caroline County Intake Locations and the adjacent Mattaponi River Watershed

Flows from the contributing watershed downstream of the USGS gauge were estimated by scaling the watershed area from USGS gauge #01674000 on the Mattaponi River near Bowling Green, VA. The Mattaponi River watershed is adjacent to the Rappahannock River watershed in Caroline County (pink shaded area on **Figure 2-1**). This watershed was selected to scale flows because it is largely located in the coastal plain physiographic province, similar to the ungauged watershed area of the Rappahannock River being estimated.

The date range used for this analysis is from October 1, 1942 through May 31, 2019.[1] The starting date is based on the earliest date available for the Mattaponi River USGS gauge. The ending date is based on the latest approved data from USGS for both gauges. Preliminary USGS data were not used for the analysis.

[1] While there is more recent river flow data for the period 2019 to 2025, there has not been a drought period that exceeds what is currently in the model (i.e. major droughts during 1966, 1999, 2002, and 2007). Therefore, the model period remains October 1942 through May 2019 in the revised memo.

Natural flows in the river at Caroline County are influenced by water supply operations and wastewater discharges upstream. It is recognized that water supply withdrawals and wastewater discharges have changed over time as the upstream communities have grown. Data were not available to recreate the changes these operations have had on the river flows at Caroline County. Therefore, a number of assumptions were made to estimate flows in the river. Overall, wastewater flows are small compared to the river flows, even during typical dry weather conditions.

Withdrawals for Fredericksburg, Spotsylvania County and Stafford County to Hunting Run Reservoir, Motts Run Reservoir, and Rocky Pen Reservoir, occur upstream of the Rappahannock River USGS gauge at Fredericksburg. Discharges from the Fredericksburg, Spotsylvania County (Massaponax and FMC) and Stafford County (Little Falls Run) wastewater treatment plants occur downstream of the USGS gauge. Wastewater return flows from withdrawals upstream of the USGS gauge were estimated at approximately 27.4 cfs (17.7 mgd) on average and were added to the gauge flows (USEPA, 2019a, USEPA, 2019b, USEPA, 2019c, USEPA, 2019d).[2] Flow records at the Mattaponi gauge have been affected by operations of the Ni River Reservoir constructed in 1974. It is assumed that during dry periods the drainage area above the Ni River Dam will be completely captured and not contribute to flows downstream. No adjustment was made based on this condition, as the 24.5 square mile watershed area for the reservoir represents less than two percent of the calculated flows based on watershed area contributing to the Caroline County intake locations.

In summary, the freshwater flows in the Rappahannock River are estimated for points downstream of the USGS gauge at Fredericksburg based on the following formula:

*Rappahannock R. gauge #01668000 flow + Spotsylvania, Fredericksburg, and Stafford return flows + (ungauged Rappahannock R area / Mattaponi R. gauge #01674000 area) * Mattaponi R. gauge #01674000 flow*

The flows in the Rappahannock River follow the typical pattern in the Mid-Atlantic region with highest flows in the spring and lowest flows in the late summer (**Figure 2-2**). Large storm events can greatly increase flows to tens of thousands of cubic feet per second (cfs). Extended dry periods can result in low flows on the order of 30 cfs, which historically has occurred in 1954, 1966, 1999, and 2002. These low flow conditions typically occur in August, September, or October.

[2] Recognizing that withdrawals and wastewater return flows vary, a sensitivity analysis was conducted to confirm that variations (+/- ~5 cfs [2.7 mgd]) would have no significant effect on the salinity model.

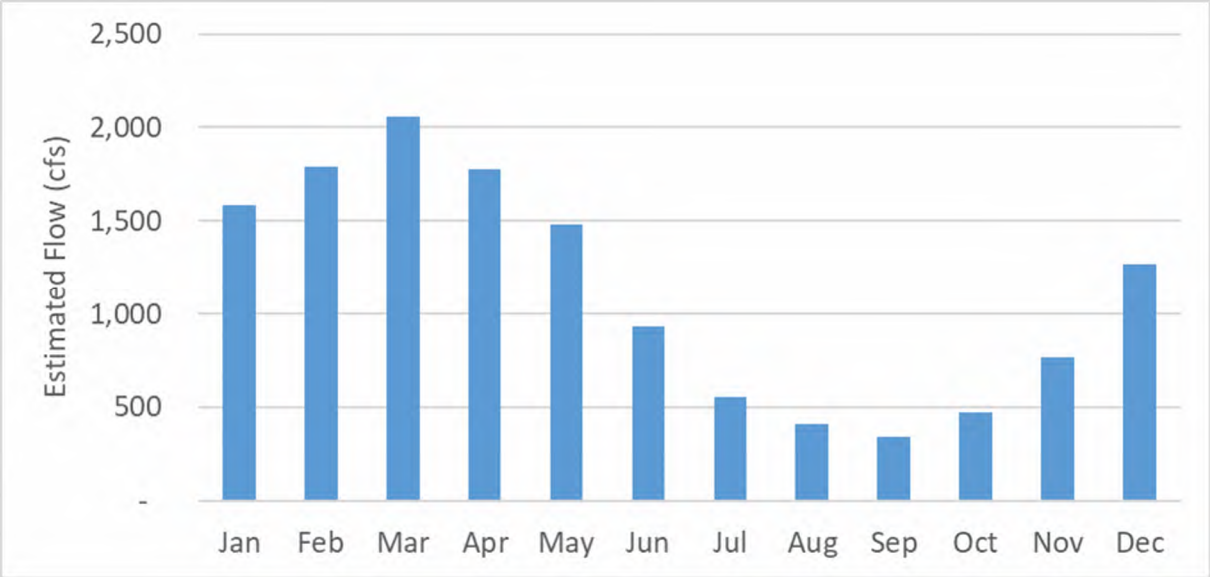


Figure 2-2: Estimated Monthly Median Freshwater Flows at the Preferred Intake Location

3. Rappahannock River Salinity Analysis

The Rappahannock River begins as a non-tidal stream and transitions to tidal downstream of the falls at Fredericksburg, VA. The Rappahannock River continues for approximately 100 miles downstream from Fredericksburg, VA to its confluence with the Chesapeake Bay. The tidal section of the river is divided into three segments based on salinity levels: tidal fresh, oligohaline, and mesohaline. Salinity ranges for the different salinity regimes are provided in **Table 3-1**. A salinity of less than 0.5 ppt (500 mg/L) or, equivalently, a specific conductance of less than approximately 1,000 uS/cm, was used as the threshold to categorize freshwater conditions.

Table 3-1: General Description of Salinity Ranges for Waterbodies

Salinity Regime	Salinity Range (ppt)	Specific Conductance Range (µS/cm)
Freshwater and Tidal Freshwater	less than 0.5	less than 1,000
Oligohaline	0.5 to 5.0	1,000 to 9,000
Mesohaline	5.0 to 18.0	9,000 to 29,000
Polyhaline	18.0 to 30.0	29,000 to 46,000
Seawater	greater than 30.0	greater than 46,000

Because the County intake would be located in the tidal portion of the river, withdrawals will not affect flow depths in the river in the same manner as in a non-tidal stream. In tidal rivers, water surface elevations are driven by the tide. **Figure 3-1** presents a comparison of hourly measured tide elevations at the NOAA Rappahannock Bend Tide Station (8635257) and the corresponding hourly flow rates based on the USGS Rappahannock gauge at Fredericksburg, VA in 2007. The 10-month period had a wide range of

flows from as low as 27 cfs to higher than 20,000 cfs. The data indicates that freshwater flows have minimal influence over the tidal range until flow exceeds approximately 5,000 cfs. Therefore, daily withdrawals of less than 15 cfs are expected to have no measurable impact on the river water surface elevations.

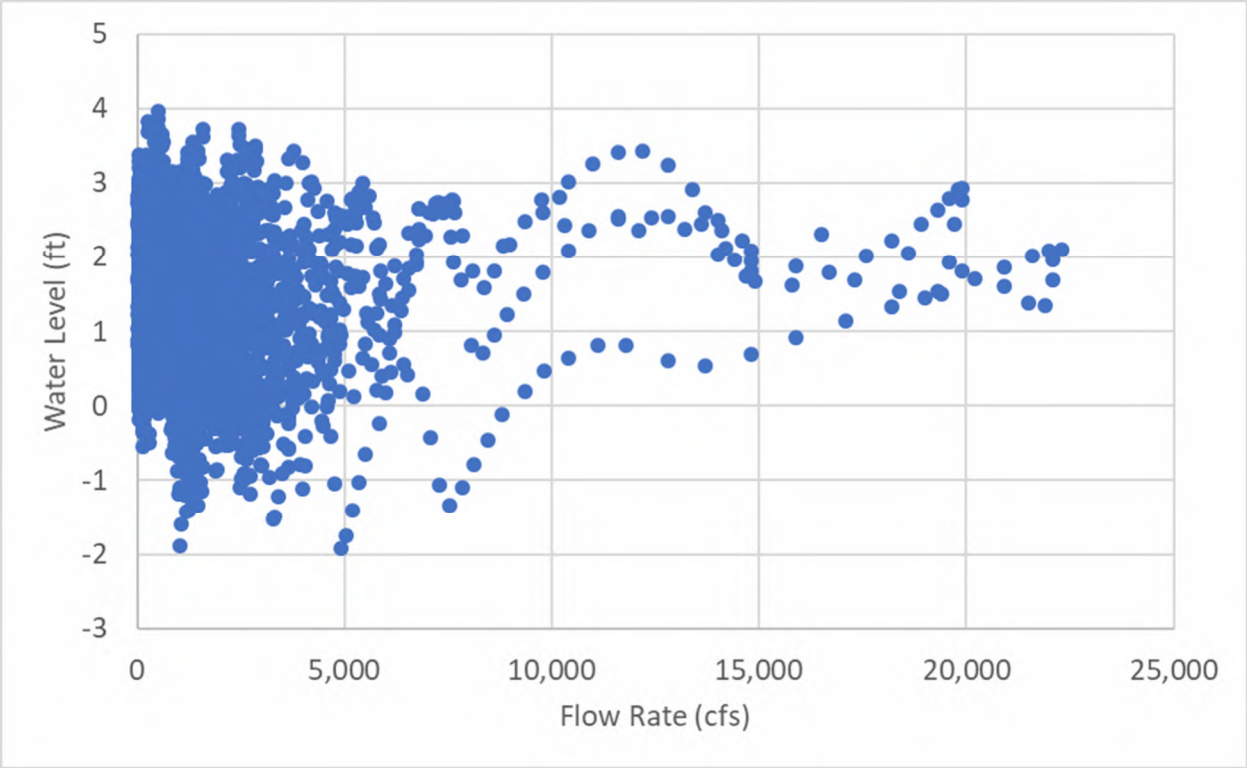


Figure 3-1. Hourly Rappahannock Bend Tide Height[3] and USGS River Flow Data from February to November 2007

While water surface elevations are not affected, withdrawals decrease freshwater flows downstream, allowing the tide to push more brackish water from the Chesapeake Bay further upstream in the river. An important consideration for the County when planning a new intake is the impact of County withdrawals on salinity in the river, both at the intake and at environmentally sensitive locations downstream.

The occurrence of high salinity conditions is important at the intake because chloride and total dissolved solids (TDS) are on the US Environmental Protection Agency (USEPA) list of secondary contaminants.[4] Elevated chloride levels above the secondary standard of 250 mg/L or elevated TDS above the above the secondary standard of 500 mg/L (approximately 1,000 uS/cm conductivity[5]) are not desirable in drinking water. In addition to high salinity at the intake, substantial changes to the salinity regime throughout the

[3] Mean Lower Low Water level datum
[4] Secondary standards are non-mandatory water quality standards established as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color, and odor.
[5] Conductivity is typically used as a measure of TDS or salinity in freshwater zones, which are reported in units microsiemens per centimeter (uS/cm). Salinity reported in parts per thousand (ppt) is more common in areas of higher salinity (oligohaline, mesohaline, etc.).

freshwater tidal portion of the river could have negative impacts on unique tidal freshwater wetlands or fish species that are sensitive to salinity. At the January 19, 2016 pre-application meeting, the Department of Wildlife Resources (DWR) suggested that salinity should be modeled at multiple locations under varying flow conditions to understand the impact of the withdrawals on saltwater intrusion in the river.

3.1 Data Analysis

Salinity data were reviewed along the length of the tidal freshwater portion[6] of the river to identify water quality monitoring locations with sufficient data to support modeling efforts. Data were collected from the USEPA STORET database[7] and the Virginia Institute of Marine Science (VIMS) Virginia Estuarine and Coastal Observing System (VECOS).[8] The following five water quality monitoring sites were identified as having sufficient data for modeling:

- Hayfield Bar is approximately one mile upstream of Intake Site #3. Data at this location consisted of grab samples collected by DEQ and is generally bimonthly from 1991 to 2003 and monthly from 2004 to 2015.
- Hop Yard Bar is approximately four miles downstream of Intake Site #2. Data at this location consisted of grab samples collected by DEQ and is generally bimonthly from 1979 to 1996 and monthly from 1997 to 2015.
- Hicks Landing is approximately two miles downstream of Intake Site #1 – Haymount. Data at this location was collected by VIMS at 15-minute intervals for the spring through fall for 2007, 2008 and 2009.
- Port Royal is approximately seven miles downstream of Intake Site #1 – Haymount. Data at this location consisted of grab samples collected by DEQ and VIMS and is generally bimonthly from 1979 to 1996, and monthly from 1997 to 2015.
- Station TF3.3 is approximately 33 miles downstream from Site #1 – Haymount. Data at this location consisted of grab samples collected by VIMS and is generally monthly from 1984 to 2016.

The data were screened for outliers and to determine the appropriate flow thresholds for analysis. Salinity data were checked for quality to remove any data that was erroneous based on comparison of salinity between stations, at different depths (where available), and with hydrology data. The data were evaluated for the presence of dry periods to assess the change in salinity based on hydrology. The drought conditions were compared with the collected data, and the years 1999, 2002, and 2007 were identified as the 2nd, 3rd, and 8th worst drought years, respectively. Therefore, the water quality data overlaps with a number of drought periods to help calibrate the modeling for changes in salinity based on low flow conditions.

[6] The tidal freshwater section of the river is defined as the being from the fall line to the transition zone boundaries listed in 9 VAC 25-260 - Virginia Water Quality Standards.
[7] https://ofmpub.epa.gov/storpubl/dw_pages.querycriteria
[8] http://web2.vims.edu/vecos/

The VIMS VECOS data also include water quality sampling cruises, referred to as dataflow, for the Rappahannock River. These cruises collect water quality data along a length of the river over a few hours. These data were not used in the development of the river salinity model, but were used to understand the shape of the salt front during dry hydrologic periods (**Figure 3-2**). These data indicate there is a strong linear trend for salinity from upstream to downstream. This salt "wedge" moves upstream and downstream based on freshwater flow into the tidal zone.

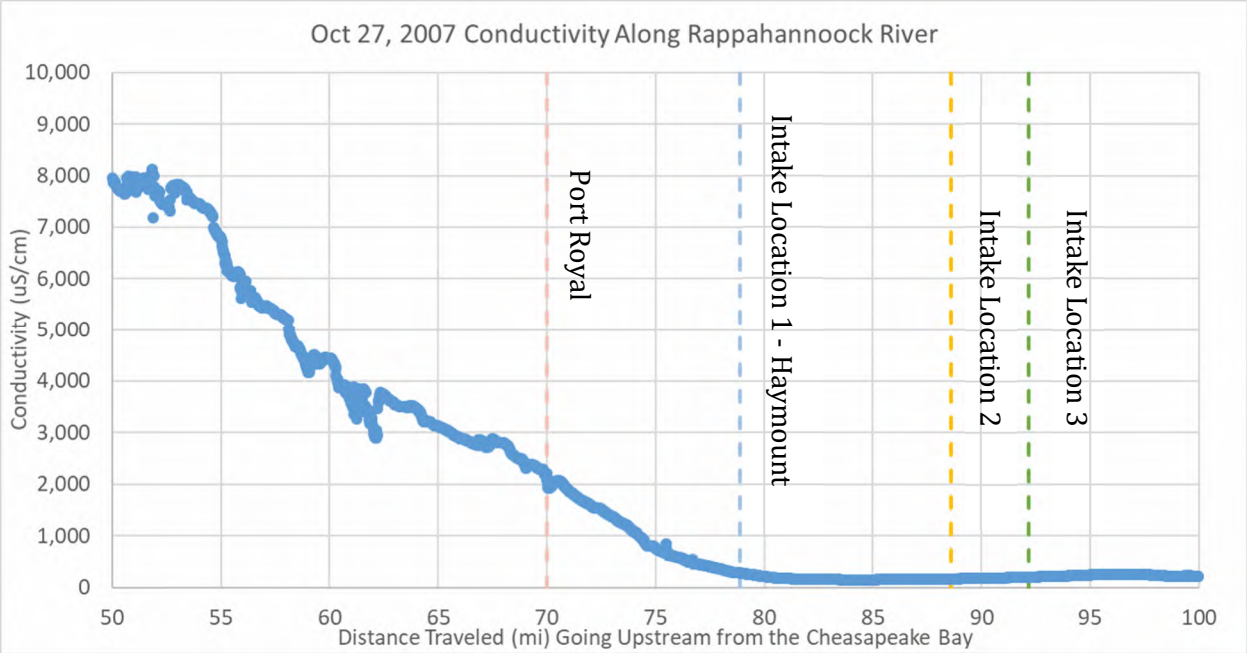
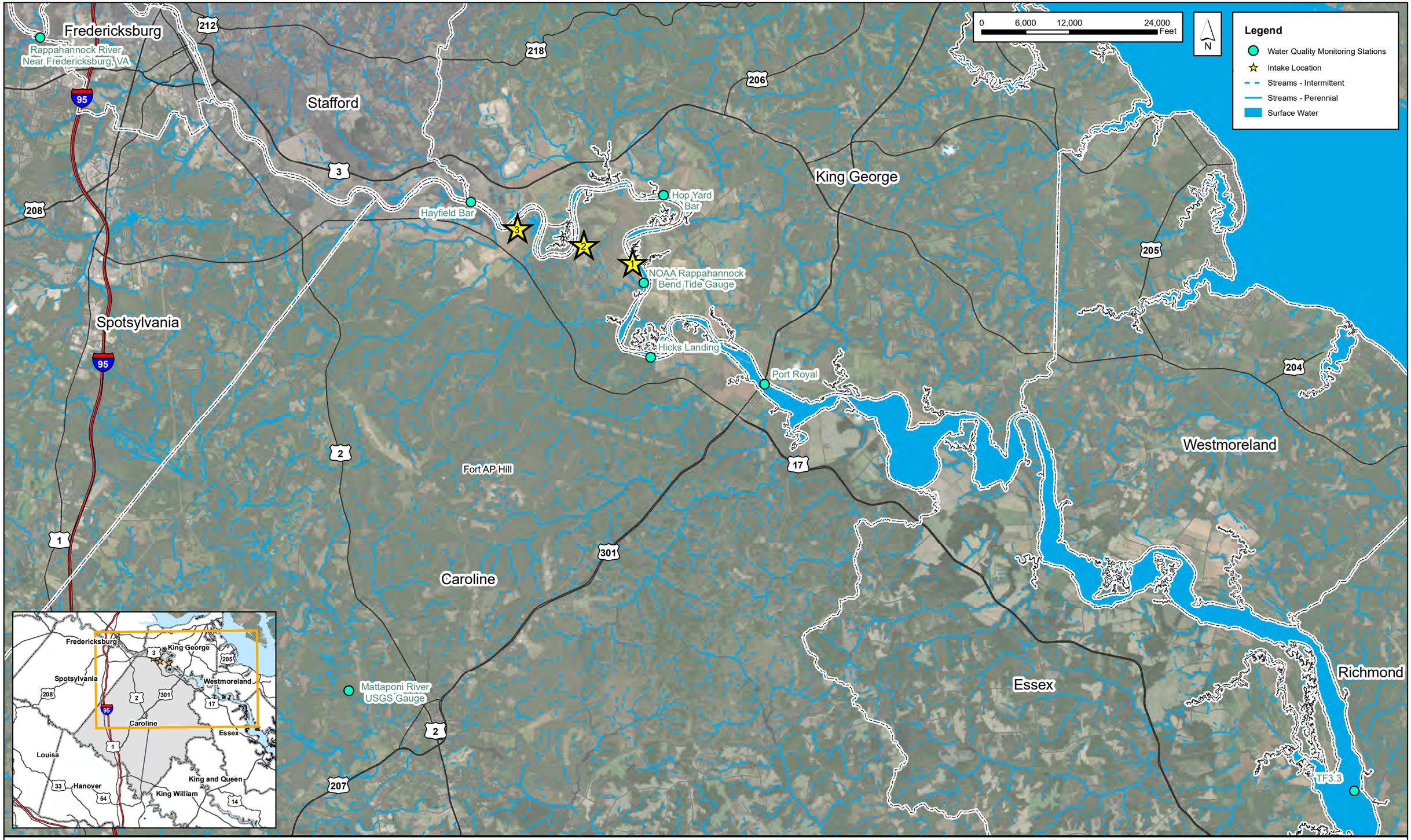


Figure 3-2. VIMS VECOS Rappahannock Dataflow Observations for Conductivity

In addition to flow and water quality data, tide data for NOAA station 8635257 Rappahannock Bend, VA was obtained.[9] This station is located between the Hop Yard Bar and Hicks Landing water quality monitoring stations. Observations at this location were only available for 2007 and 2008. However, NOAA has developed a tide model at this location that can simulate tide height at 6-minute intervals for any date range. Refer to **Figure 3-3** for locations of all flow, tide and water quality monitoring locations used for the flow and salinity modeling.

Bay salinity data were reviewed to identify the range of salinity variation, because the Rappahannock River discharges to the Chesapeake Bay and not the open ocean. The Chesapeake Bay Interpretive Buoy System has a buoy located close to the mouth of the Rappahannock River at Stingray Point. Hourly salinity data were available at his location from 2008 through 2016. The data exhibited an intra-annual change in salinity with the highest salinity occurring in the August/September months and lowest salinity occurring in the February/March months **(Figure 3-4**). The salinity pattern is consistent with seasonal changes to inflows of fresh water to the bay, which results in the highest freshwater flow in the spring and lowest freshwater flow in the summer (Chesapeake Bay Program, 2018).

[9] https://tidesandcurrents.noaa.gov/stationhome.html?id=8635257#available



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DAA# R15287R-05

Water Quality Monitoring Stations
Caroline County, Virginia - Rappahannock River

Figure 3-3

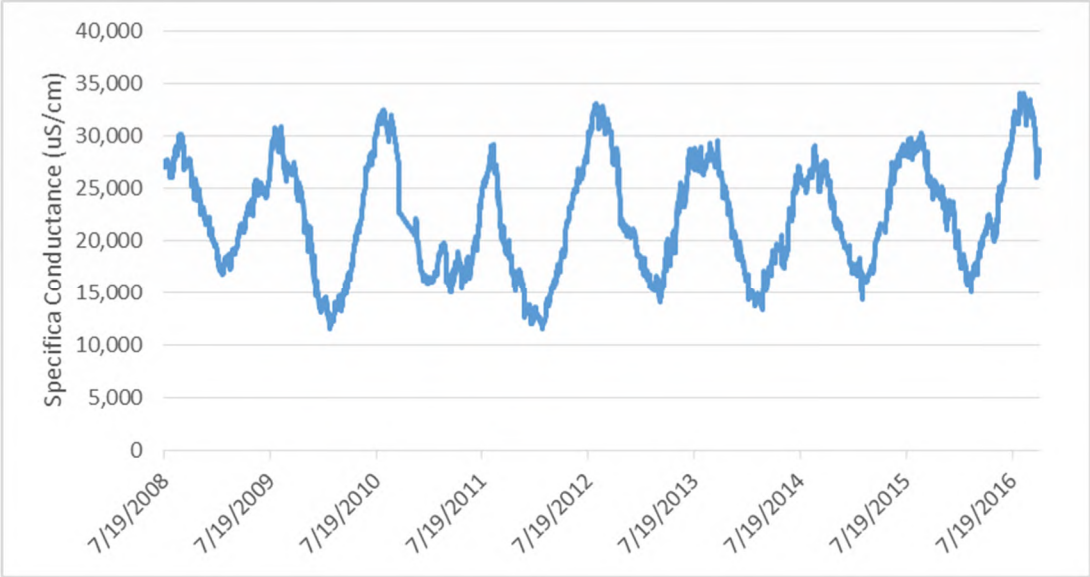


Figure 3-4. Chesapeake Bay Conductivity at the Stingray Point Observation Buoy

Data at each water quality monitoring location was combined as follows for preliminary data analysis:

- Tide projections from the Rappahannock Bend tide model were linked with the water quality monitoring data based on the closest date/time.
- Daily average flow estimates were developed for each day of the time series at each location.
- Flows were aggregated for each day based on the average of the prior seven, 30, 60, and 90 days.
- Daily average salinity at the Stingray Point buoy was added for each day of the time series.

3.2 Rappahannock River Conductivity/Salinity Model Development

The initial data analysis consisted of comparing the predictor parameters (flows, tide height and Chesapeake Bay Salinity) with the water quality data. The data comparison indicated strong relationships with flow and tide data. A freshwater threshold of 0.5 parts per thousand (ppt) or 1,000 uS/cm conductivity was used to categorize the freshwater threshold.

The Chesapeake Bay salinity dataset was ultimately not used in the modeling because the data did not extend far back enough to cover the important drought periods. Further, the bay salinity fluctuation was determined to be heavily influenced by hydrology, which was accounted for with direct flow measurements for the river.

A regression model was developed at each of the water quality monitoring stations. Model formulations were developed based on published literature and data exploration to achieve a model fit that is stable under a wide range of flow conditions (Sun and Koch, 2001: Qiu and Wan, 2013). For the model development, the data were used in the original units of either conductivity or salinity to limit potential rounding issues from unit conversions. Further, while some of the withdrawals are expected to be

returned to the river through wastewater discharges, the modeling conservatively assumes zero return flows.

3.2.1.1 Hayfield Bar

Conductivity data for Hayfield Bar indicated that even during very dry conditions experienced during 1999 and 2002 conductivity changed minimally and did not exceed the freshwater threshold (**Figure 3-5**). Therefore, a model was not developed for this location.

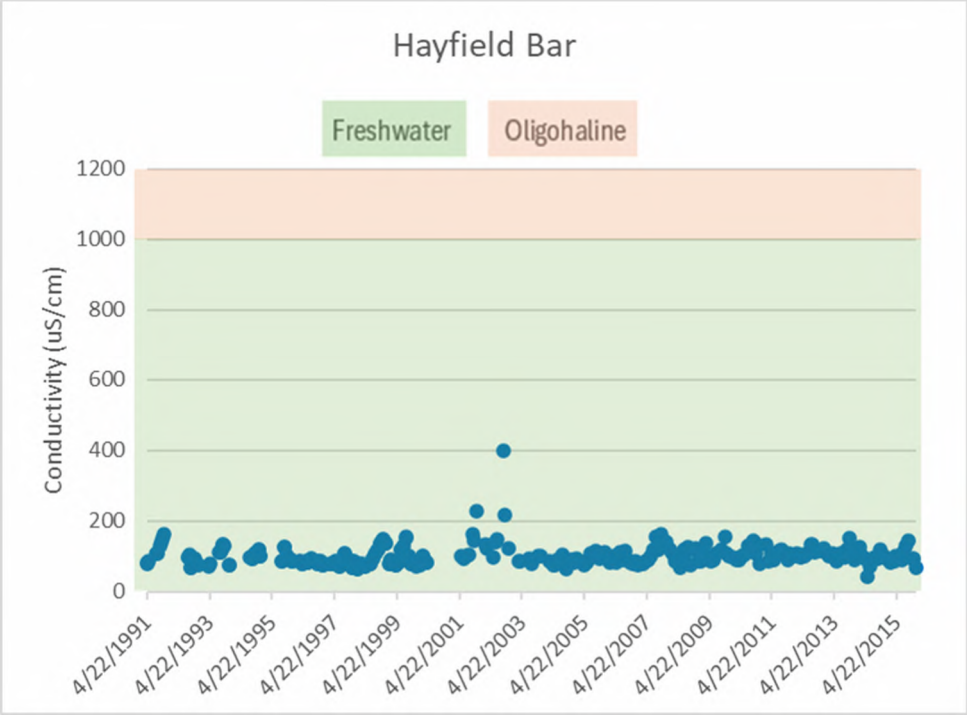


Figure 3-5. Hayfield Bar Conductivity Data

3.2.1.2 Hop Yard Bar

Conductivity data for Hop Yard Bar indicated that even during very dry conditions experienced during 1999 and 2002, conductivity changed minimally and did not exceed the freshwater threshold (**Figure 3-6**). Therefore, it is expected that conductivity would not exceed the freshwater threshold under future withdrawal scenarios, and a model was not developed for this location.

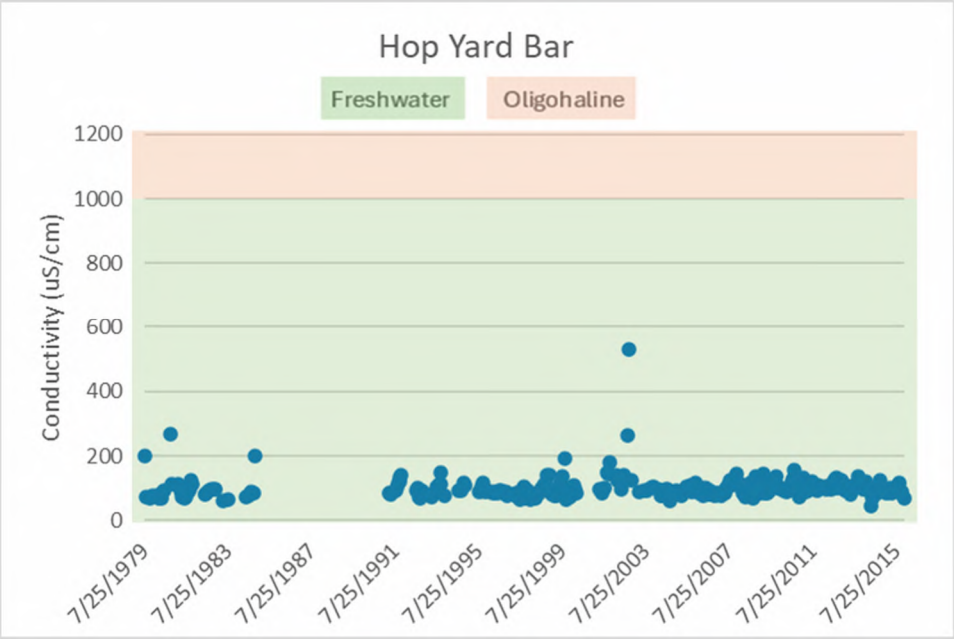


Figure 3-6. Hop Yard Bar Conductivity Data

3.2.1.3 Hicks Landing

Data at Hicks Landing indicated conductivity exceeded the freshwater threshold under moderately dry conditions in 2007 (**Figure 3-7**). Plotting flows versus conductivity indicated there was a bimodal behavior based on flow rates. Conductivity levels varied substantially when flows were low, but were relatively stable at high flow rates (**Figure 3-8**). A flow threshold of 150 cfs was selected as the transition point for these two modes based on weekly average flows for Hicks Landing.

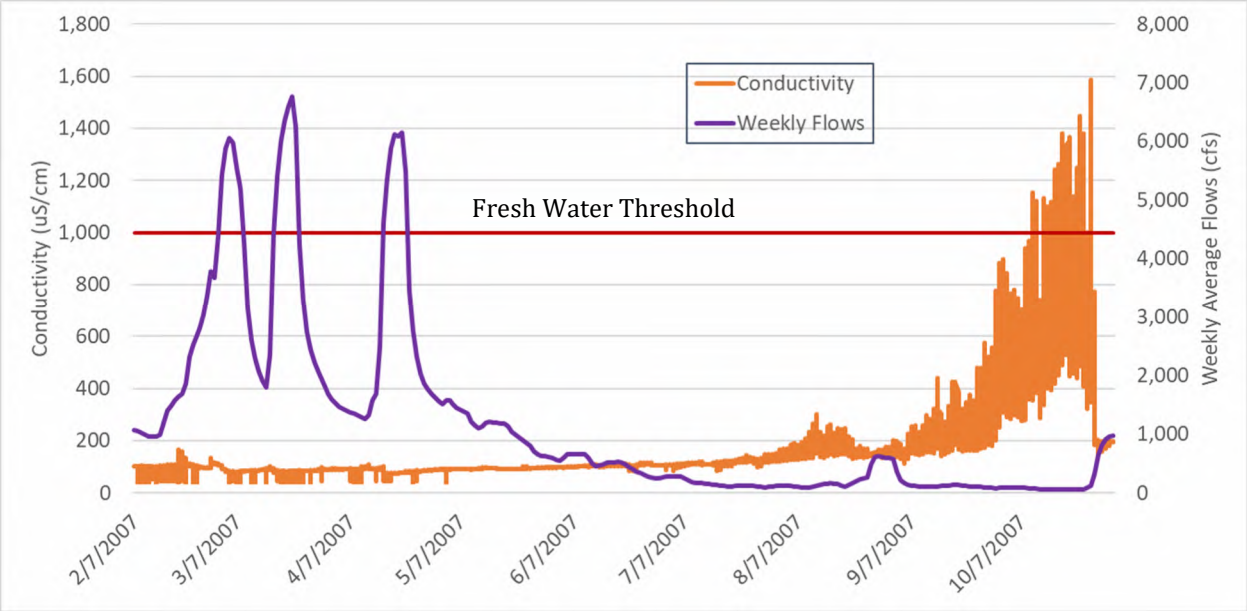


Figure 3-7. Hicks Landing Conductivity Observations and Weekly Flow Data

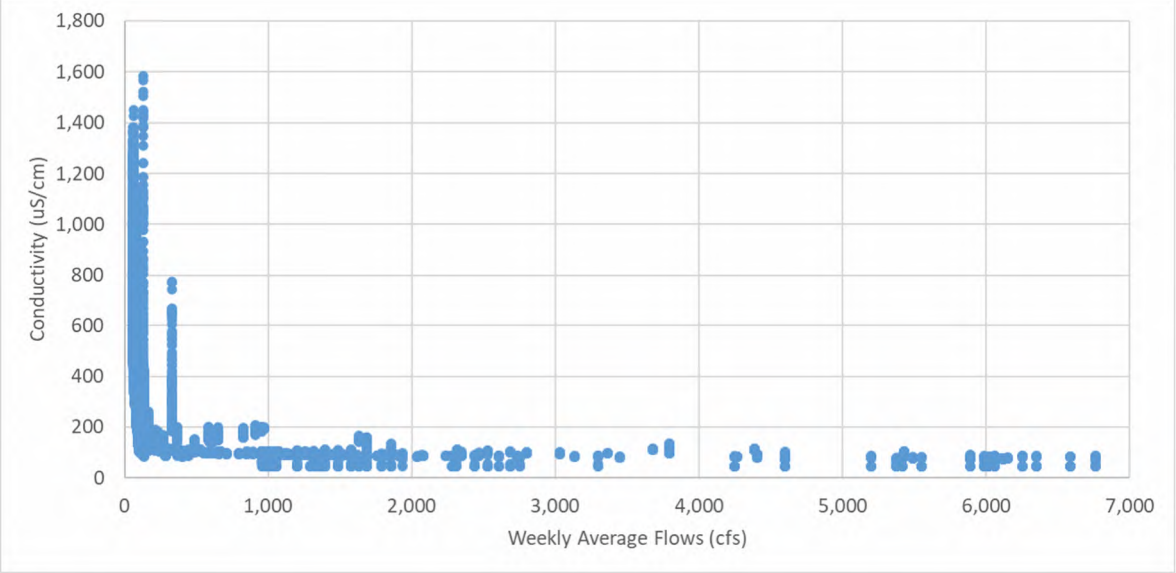


Figure 3-8. Flow vs Conductivity for Hicks Landing

Separate models were developed for low flow/high salinity conditions and for high flow/low salinity conditions using tide height and river flows as predictors. Log transformation of the predicted variable (conductivity) was used for both models to achieve good model fit. The two models are:

- Hicks Landing Low Flow Model (less than 150 cfs, high salinity)
    - Log(Conductivity) = 2.0 – 0.26(Daily max tide) – 0.0007(Daily average flow) + 0.0027(30-day average flow) – 0.0012(60-day average flow) + 70.0(Tide/30-day average flow) – 483.4(Tide/30-day average flow)^2
    - $R^2 = 0.74$

- Hicks Landing High Flow Model (greater than 150 cfs, low salinity)
    - Log(Conductivity) = 2.1 - 0.013(Daily max tide) + 1.6E-6(Daily average flow) + 8.4E-7(30-day average flow) – 2.5E-5(60-day average flow) + 20.2(Tide/30-day average flow) – 233.8(Tide/30-day average flow)^2
    - $R^2 = 0.50$

The model fit was not as good for the low salinity model, but the variation in this range was acceptable because salinity when flows were in this range were consistently within the freshwater range.

Figure 3-9 presents the modeled and observed conductivity based on daily max tide data for Hicks Landing. While some of the variation within the freshwater threshold is not being captured by the high flow model, the model is capturing the critical high conductivity peak. **Figure 3-10** presents conductivity model projections for the full historical timeseries. These results show that 1) the model results simulate conductivity that exceeds the conductivity in the observations; and 2) the model captures the known drought periods.

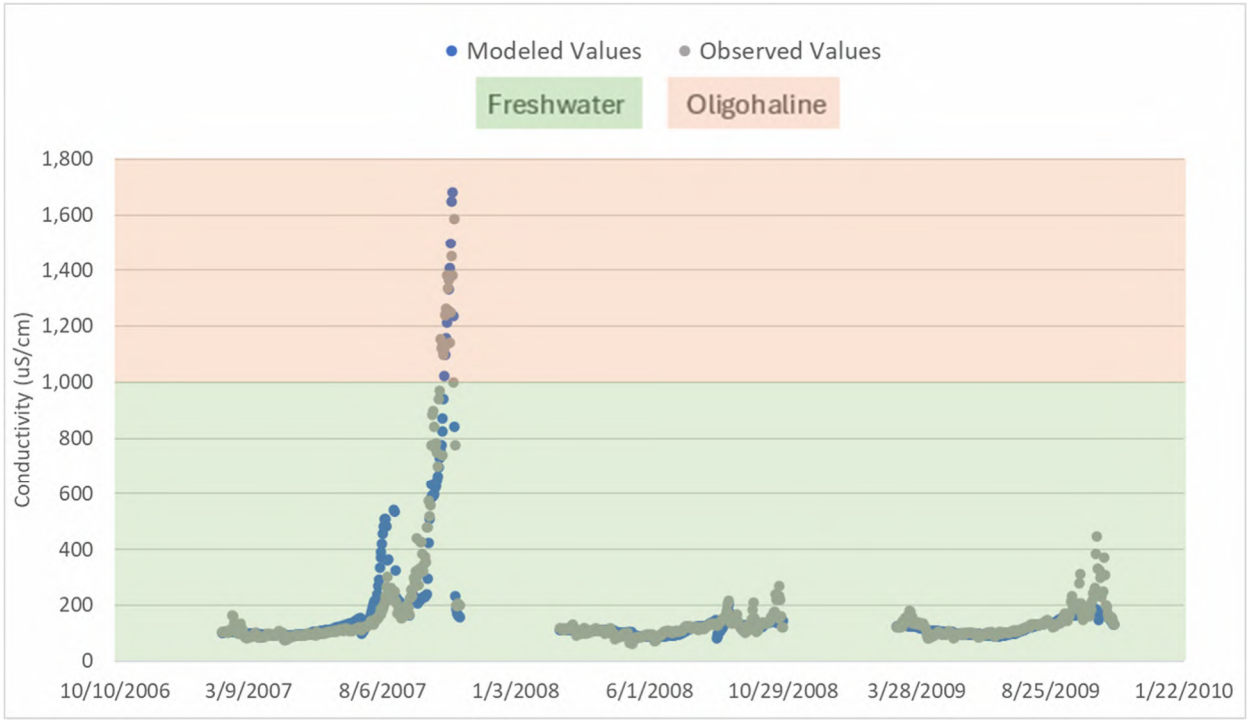


Figure 3-9. Hicks Landing Observed and Modeled Conductivity

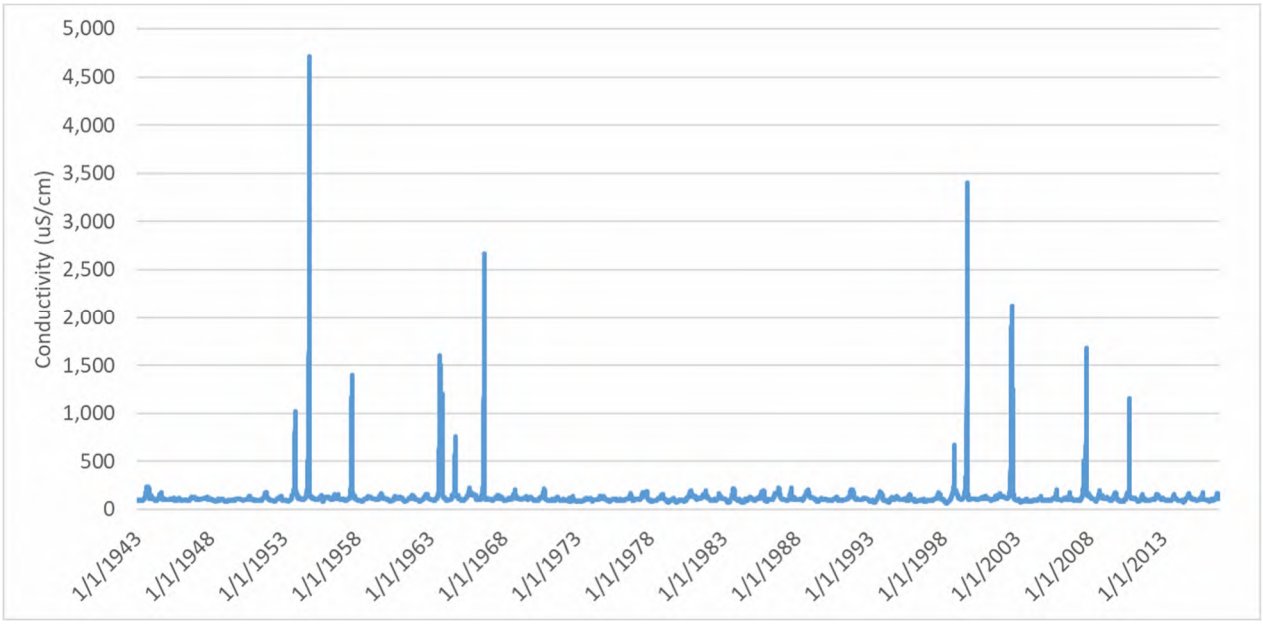


Figure 3-10. Hicks Landing Modeled Conductivity for the Full Record

3.2.1.4 Port Royal

Conductivity data at Port Royal exceeded the freshwater threshold and exhibited a similar bimodal behavior as Hicks Landing (**Figure 3-11**). A flow threshold of 500 cfs was selected as the transition point for the two modes based on weekly average flows for Port Royal. The conductivity range under high flow conditions was narrow, between 44 to 243 uS/cm. Therefore, the median value of 88 uS/cm was used as a constant for high flow conditions when weekly flows were above 500 cfs.

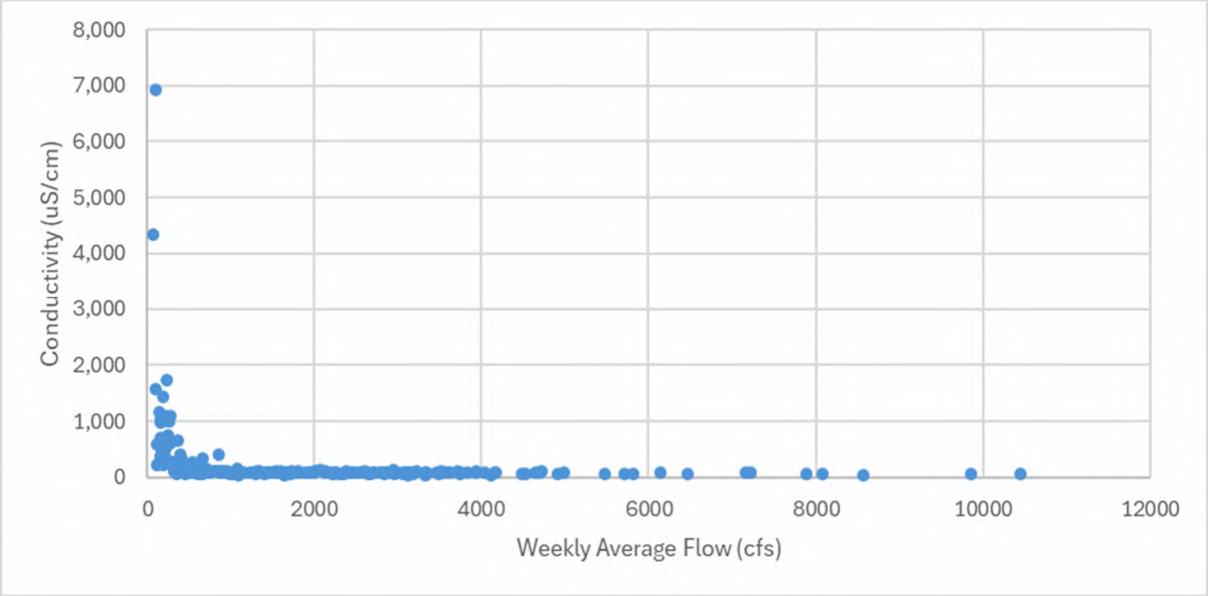


Figure 3-11: Flow vs Conductivity for Port Royal

The low flow model formulation for the Port Royal conductivity model was the same as for Hicks Landing, but with different coefficients.

- Port Royal Low Flow Model (less than 500 cfs, high salinity)
    - Log(Conductivity) = 2.01 – 0.02(Daily max tide) – 4.7E-5(Daily average flow) – 1.9E-5(30-day average flow) – 0.00023(60-day average flow) + 92.8(Tide/30-day average flow) – 1108.6(Tide/30-day average flow)^2
    - $R^2 = 0.70$

Figure 3-12 presents the modeled and observed conductivity based on daily max tide data for Port Royal. Unlike the Hicks Landing data, which consists of 15-minute data, Port Royal is limited to grab samples. Therefore, the observed data do not necessarily fall at the time of maximum tide. The model is based on maximum tide data in order to capture the daily peak conductivity. Similar to Hicks Landing, the key drought periods are represented by elevated conductivity.

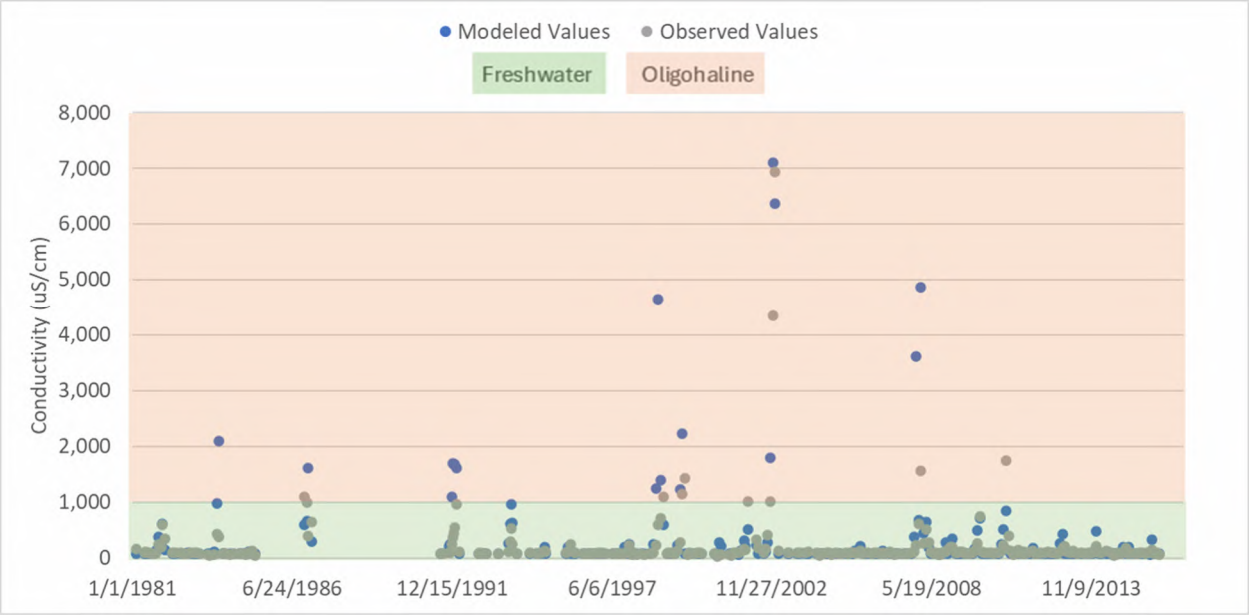


Figure 3-12. Port Royal Observed and Modeled Conductivity

3.2.1.5 Station TF3.3

Salinity data at Station TF3.3, which is within the transition zone of the tidal freshwater portion of the river,[10] has substantially higher salinity than the other stations. Salinity measurements at this location are collected in units of parts per thousand (ppt). The data at Station TF3.3 did not exhibit bimodal behavior, and only a single model was developed for all the observed data (**Figure 3-13**). Station TF3.3 is more heavily influenced by tidal flows and has substantially fewer days with freshwater conditions. Of the 286 salinity observations for this location, only 39 (13.6%) were below the freshwater threshold of 0.5 ppt. Further, freshwater inflows have a lower influence on the salinity at this location as exhibited in a wider range of salinity at any given flow rate in **Figure 3-13**. For example, when weekly average flows are at the low end of the range (approximately 100 cfs), salinity can range from 2 ppt to over 10 ppt. Even at higher weekly average flows in the range of 1,000 cfs, salinity can range from less than 0.5 ppt (freshwater) to over 7 ppt. This variation indicates that tidal flows typically supersede the influence of river flows at this location.

[10] Per 9 VAC 25-260 - Virginia Water Quality Standards

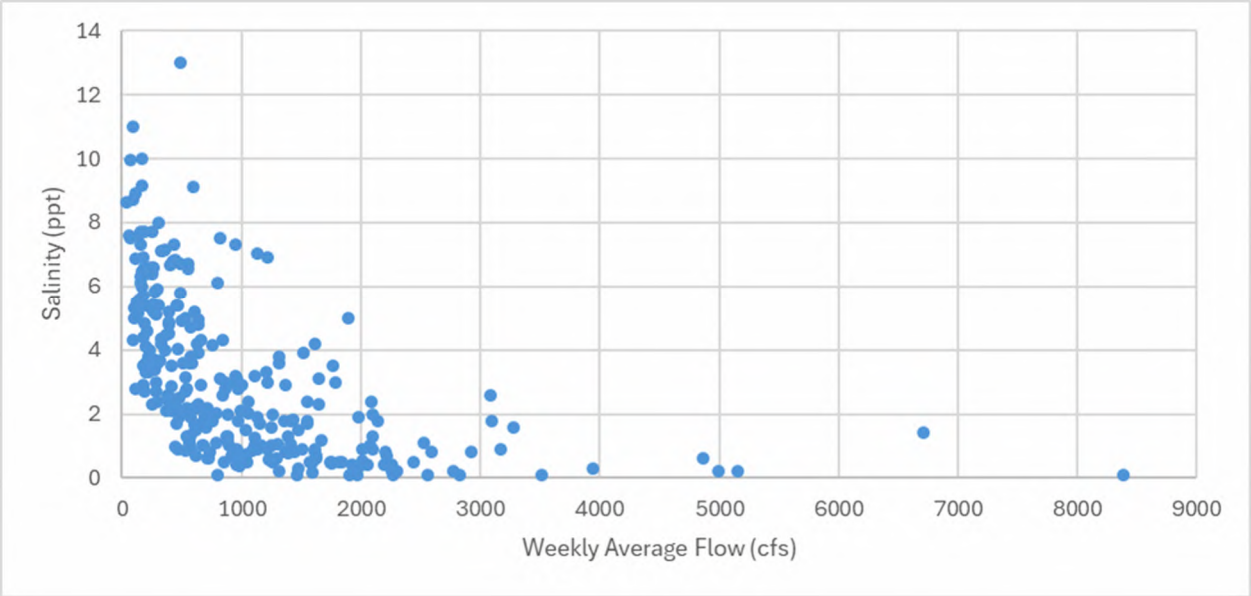


Figure 3-13: Flow vs Conductivity for TF3.3

The model formulation for the Station TF3.3 salinity model was similar to that for Port Royal and Hicks Landing, but with different coefficients.

- Station TF3.3 Salinity Model
    - Log(Conductivity) = 0.63 + 0.006(Daily max tide) – 7.8E-5(Daily average flow) – 1.37E-4(30-day average flow) + 8.12E-5(60-day average flow) – 2.39E-4(90-day average flow) + 54.0(Tide/30-day average flow) – 1688.3(Tide/30-day average flow)^2
    - $R^2 = 0.65$

Figure 3-14 presents the modeled and observed conductivity based on daily maximum tide data for Station TF3.3. As with Port Royal, the TF3.3 model is based on grab samples that occurred at various tide stages, while the modeled salinity is based on daily max tide to capture the daily highest tide. A few of the very highest salinity measurements have not been captured by the model. This is believed to be because 1) approximately 25% of the salinity data did not have sample time, which made it difficult to correlate with tide height, and 2) the Rappahannock Bend tide station is located further from TF3.3 than for Port Royal or Hicks Landing, which may affect the timing and tide height of the tide data relative to this location. Despite these limitations, the model performs well, capturing a large range of salinity variation at this location that correlates with observed peaks in salinity.

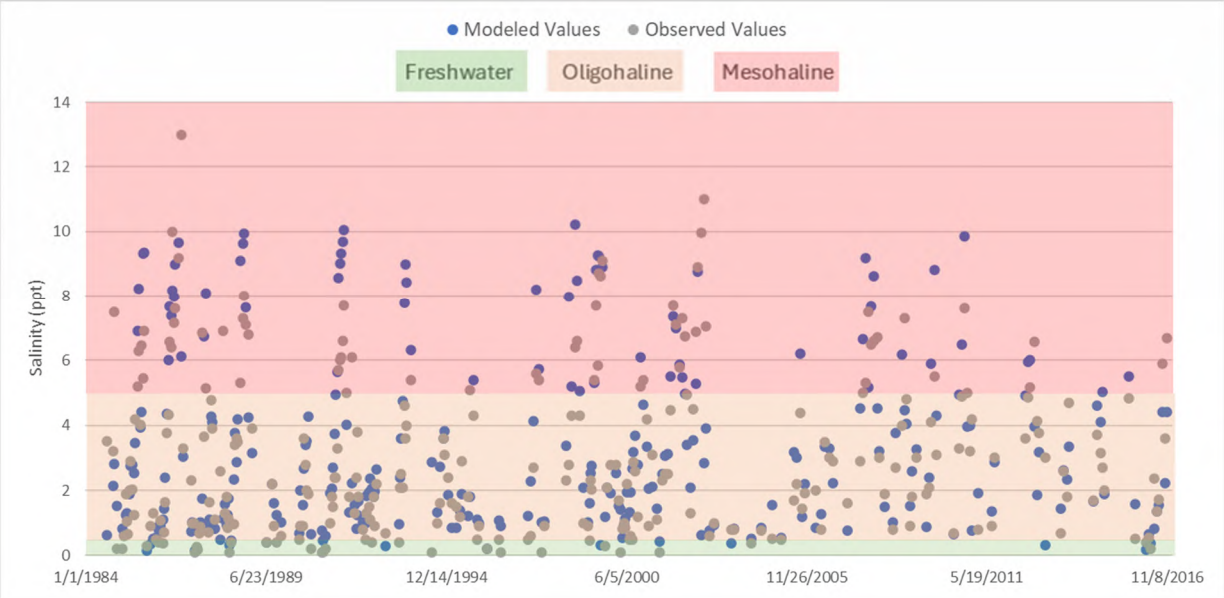


Figure 3-14. Station TF3.3 Observed and Modeled Conductivity

4. River Salinity Assessment

The goal of the County is to obtain a permit for withdrawals needed to satisfy demands over a 15-year VWP permit term. The projected average day withdrawal is 7.89 cfs (5.1 mgd). The estimated maximum day withdrawal is 13.9 cfs (9.0 mgd), approximately 1.76 times the average day value. Further, an estimated range of monthly withdrawal multipliers (ranging from 0.7 to 1.35) were used to simulate the typical changes in seasonal demands (**Figure 4-1**).[11] It is difficult to predict when the maximum day withdrawals can occur within a system. In order to evaluate the potential effect on salinity from maximum day withdrawals, the salinity model was evaluated with just the monthly withdrawal variations and the single highest salinity value was identified for each year. The model was re-run with the max day multiplier of 1.76 applied to demands on those days. The resulting river salinity based on these withdrawal values were compared to the baseline salinity estimates described previously at the water quality monitoring stations (Hicks Landing, Port Royal, and TF3.3).

Data are presented below comparing differences for the over 76 years of available data (January 1, 1943 to May 31, 2019, total number of days of 27,910).[12]

[11] Monthly factors were derived from data for other utilities in the Mid-Atlantic region and were selected to be conservative with high summer withdrawals.
[12] Because the salinity the model uses antecedent river flows, the first few months of available flow data do not have a salinity estimate.

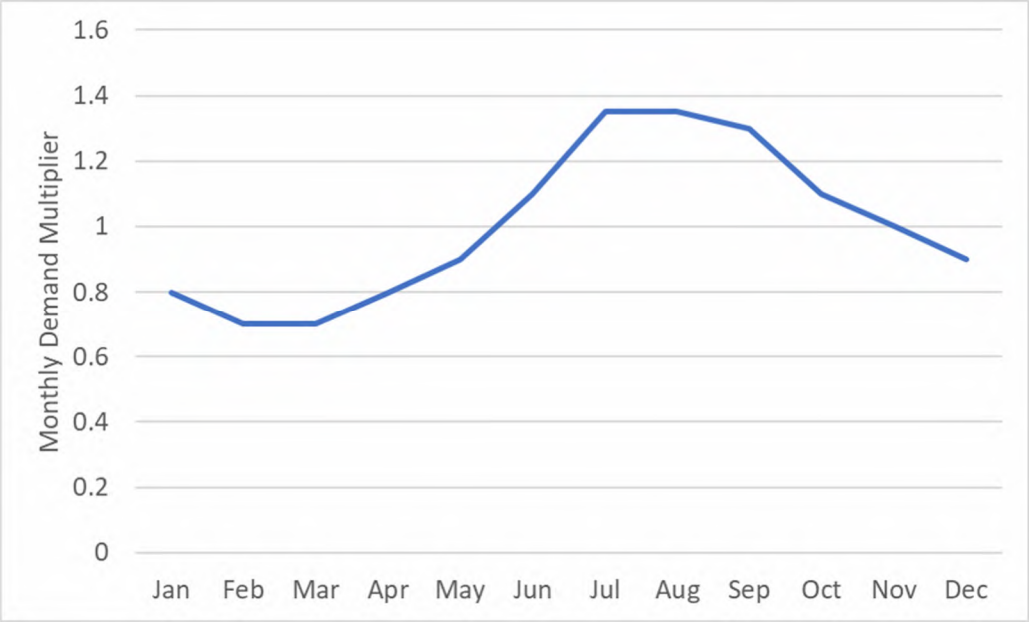


Figure 4-1: Estimated Monthly Demand Multipliers used in Salinity Modeling

4.1 Overall Differences in Salinity Regime

Figure 4-2 provides a snapshot for the overall changes in conductivity at Hicks Landing and Port Royal under baseline and projected conditions given a 7.89 cfs (5.1 mgd) average day withdrawal. Since these two locations are predominantly freshwater under most flow conditions, days with max conductivity above and below the freshwater threshold of 1,000 uS/cm were tabulated. The results indicate there is a small decrease in the number of freshwater days and a corresponding increase in days above the freshwater threshold.

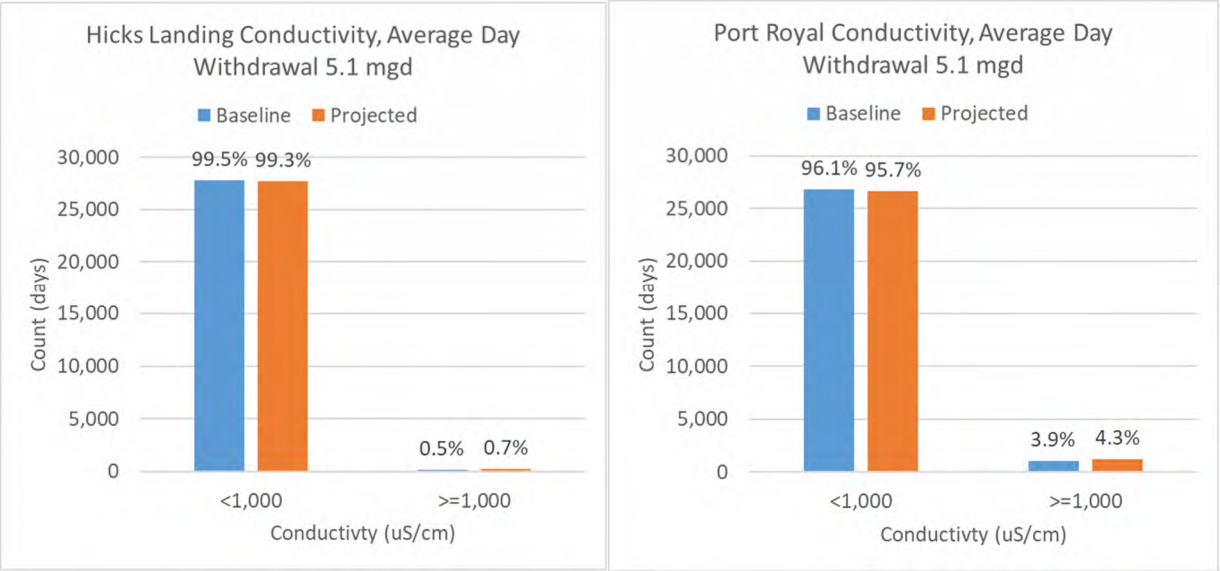


Figure 4-2. Modeled Baseline and Projected Change in Days Above and Below the Freshwater Threshold (1,000 uS/cm) for Hicks Landing and Port Royal (Total number of days = 27,910)

Figure 4-3 presents the changes in salinity at Station TF3.3 between baseline and 12.2 cfs (7.9 mgd) average day withdrawals with monthly and max day peaking factors. This location is substantially downstream from Hicks Landing and Port Royal and has naturally higher salinity. Therefore, additional salinity ranges were used to divide the data based on a wider range of salinity concentrations. The results of the withdrawals have a similar effect at this location as with Hicks Landing and Port Royal. There is a small decrease in the number of freshwater days and a corresponding increase in days at the higher salinity levels.

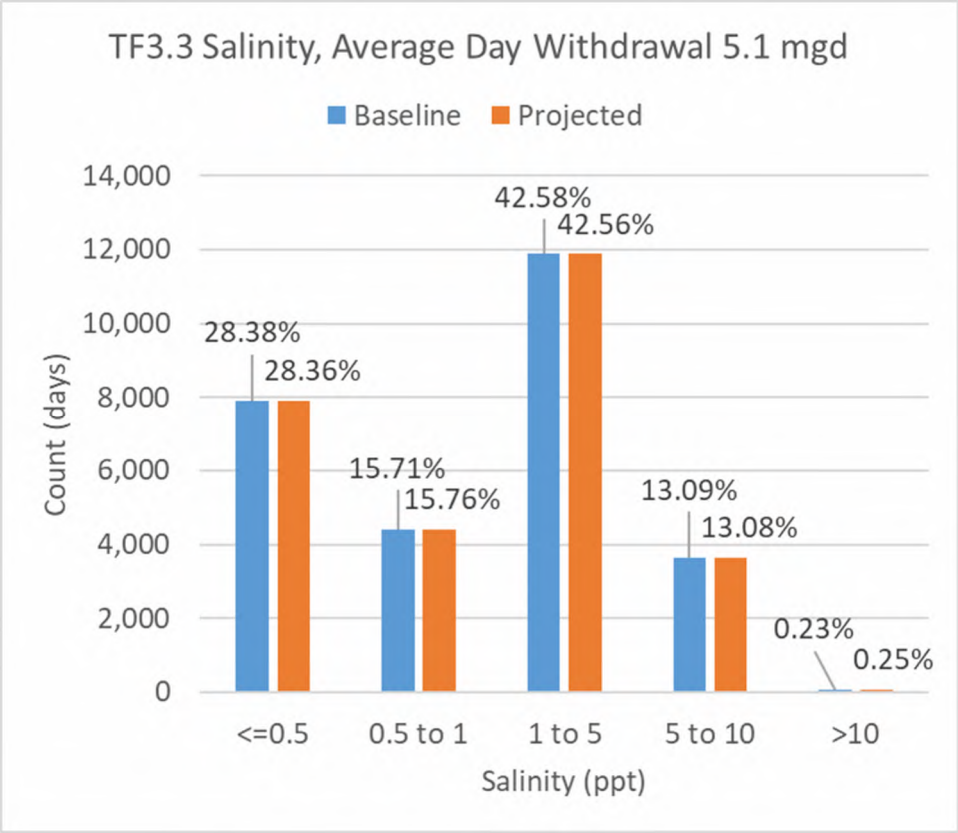


Figure 4-3. Modeled Baseline and Projected Change in Days Above and Below Various Salinity Ranges for Station TF3.3 (Total number of days = 27,910)

The relatively small shift in salinity is consistent with the fact that the overall withdrawal is small compared to the flow in the river during most days. Over the course of the simulation, the withdrawals are below 10% of the river flow in more than 95% of days.

4.2 Virginia Institute of Marine Science Model Results

In addition to the regression model, the Virginia Institute of Marine Science (VIMS) developed a fine-resolution model to simulate tidal flow and larval transport processes in the Rappahannock River to assess impacts to fish larva and ichthyoplankton. This model was calibrated for the Rappahannock River for both surface elevation and salinity. The calibration results show that the model simulated tidal range and salinity intrusion along the Rappahannock River and is capable of conducting accurate simulations of the river (Qin, Shen, Tuckey, 2023).

Figure 4-4 presents the results from the VIMS model indicating salinity levels with and without the proposed Caroline County withdrawal during a period of low river discharge on July 2, 2011.[13] The results indicate that the salinity change is expected to be less than 0.01 ppt for most of the

[13] July 2, 2011 was selected for the VIMS model to represent low flow condition, which had flow lower than the 10th percentile for the river.

river, with a maximum salinity difference was in the range of 0.02 to 0.03 ppt for the section of the river downstream of the intake, primarily from Tappahannock to Saluda. This difference was consistent with the results of the regression model.

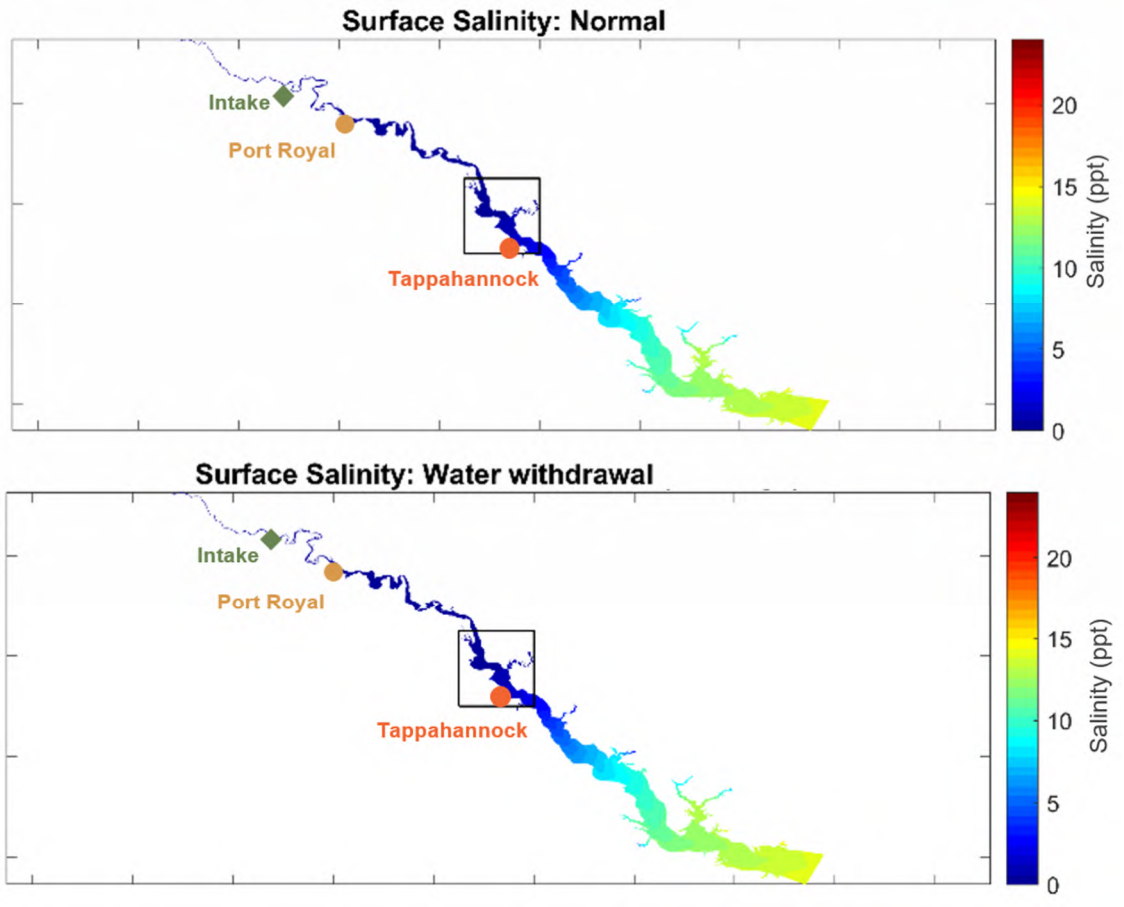


Figure 4-4: VIMS Modeled Salinity along the Rappahannock River With and Without the Proposed Withdrawal during a Period of Low River Discharge on July 2, 2011 (Qin, Shen, Tuckey, 2022)

Figure 4-5 illustrates the salinity difference between baseline and proposed conditions from the VIMS model. Salinity changes throughout most of the river upstream of Tappahannock are expected to be less than 0.01 ppt (i.e., less than approximately 20 uS/cm). Downstream of Tappahannock, where baseline salinity levels are naturally higher, the modeled salinity increase is up to approximately 0.03 ppt (i.e., less than 60 uS/cm).

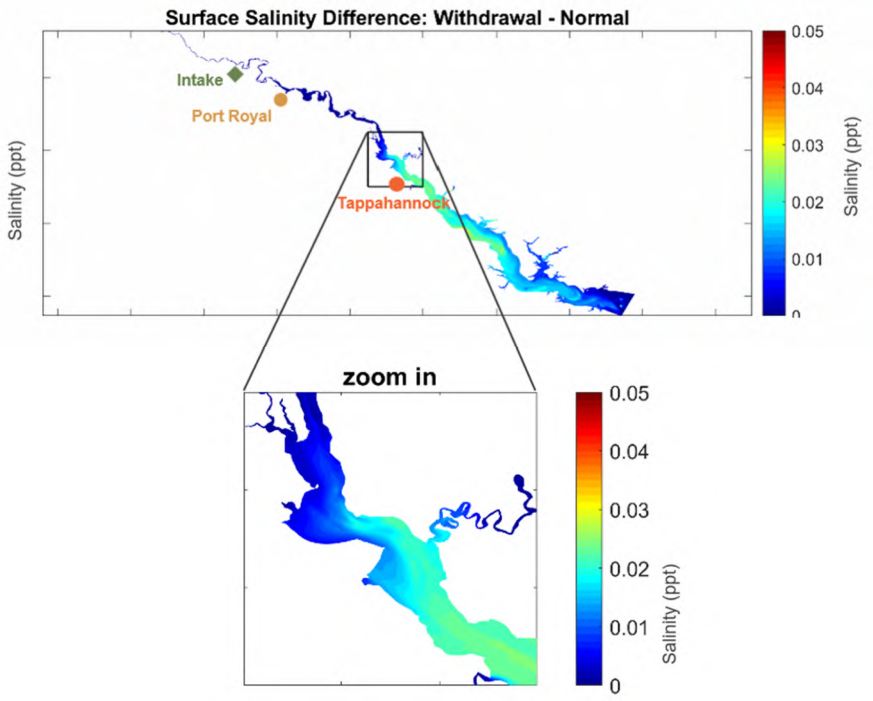


Figure 4-5: Salinity Difference along the Rappahannock River from the VIMS Model during a Period of Low River Discharge on July 2, 2011 (Qin, Shen, Tuckey, 2022)

VIMS concluded based on their salinity model that "the small difference in salinity indicates that the existence of the intake with a withdrawal rate of 13.9 mgd will not cause significant changes in the salinity distribution, even in the period of low river discharges in 2011." It should be noted this VIMS model was conducted at a higher average day withdrawal rate of 7.9 million gallons per day (mgd) and a maximum daily withdrawal rate of 13.9 mgd based on an earlier estimate of demands for Caroline County. With the currently-proposed lower withdrawals, the salinity difference is expected to be even smaller.

4.3 Salinity Changes at Agricultural Intakes

There are a number of agricultural intakes located along the Rappahannock River downstream of the proposed Caroline County intake (**Figure 4-6**). While the incremental change in salinity is negligible at the four monitoring locations utilized in this assessment, DEQ has requested additional analysis of salinity levels at the specific agricultural intake locations.

DEQ provided data on the locations of known agricultural surface water withdrawals along the Rappahannock River. These locations were reviewed and screened to identify withdrawals directly from the river rather than adjacent surface water sources (e.g., farm ponds).

Table 4-1 provides a list of agricultural intakes on the mainstem of the Rappahannock River from data provided by DEQ. The intakes fall into four location zones along the river relative to the available monitoring stations. Assessment of salinity changes at each location was estimated using linear interpolation based on the modeled data at the available monitoring locations.

- Between the Proposed Intake and Hop Yard Bar – 3 agricultural withdrawals
- Between Hop Yard Bar and Hicks Landing – 2 agricultural withdrawals
- Between Hicks Landing and Port Royal – 1 agricultural withdrawal
- Between Port Royal and TF3.3 – 8 agricultural withdrawals

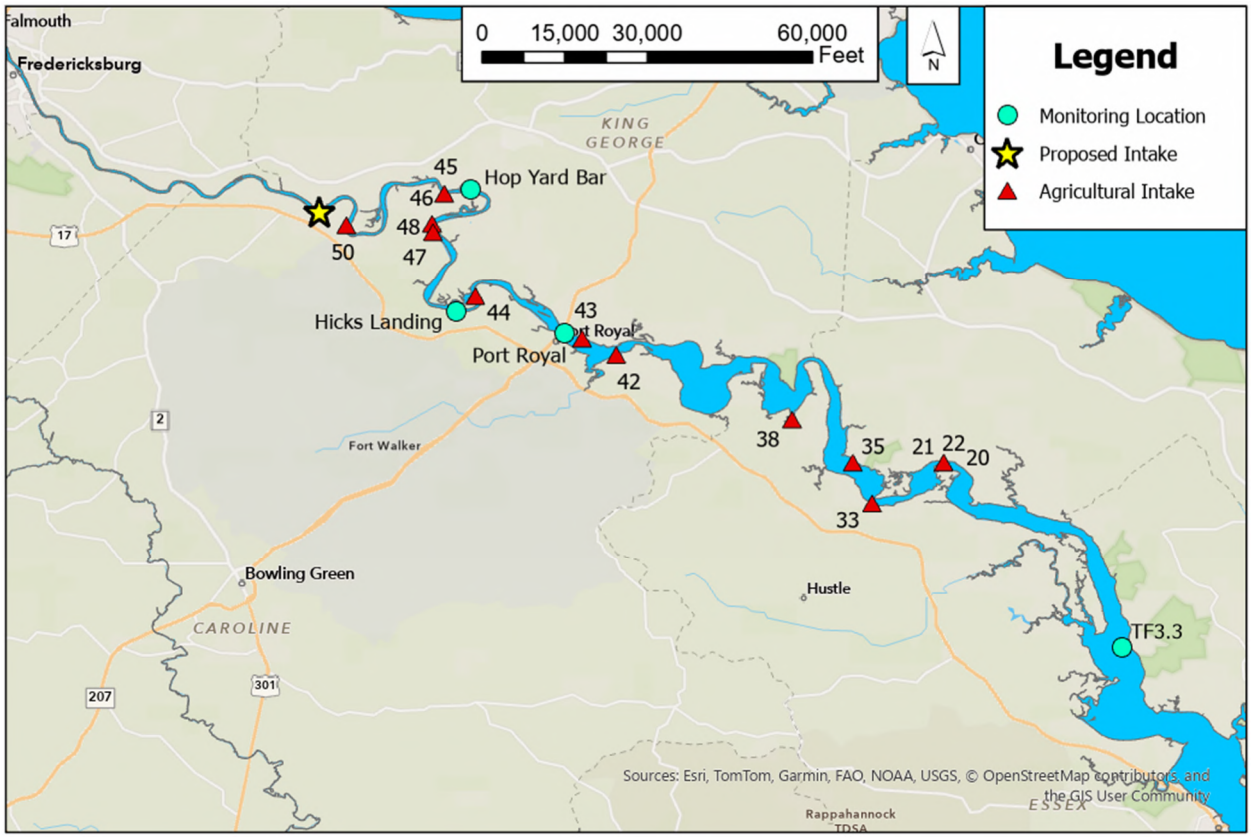


Figure 4-6: Map of Agricultural Intakes along the Mainstem of the Rappahannock River in Relation to Monitoring Locations and the Proposed Intake

Table 4-1: Agricultural Intakes on the Mainstem Rappahannock River Downstream of the Proposed Caroline County Intake

No.	Name[1]	Location Relative to Upstream Monitoring Station	Facility	County
50	Rappahannock River Pump #4	Between Proposed Intake and Hop Yard Bar	Black Marsh Farm	Caroline
45	Rappahannock River Pump #1	Between Proposed Intake and Hop Yard Bar	Black Marsh Farm	Caroline
46	Rappahannock River Pump #2	Between Proposed Intake and Hop Yard Bar	Black Marsh Farm	Caroline
48	Rappahannock River Pump #3	2.5 mi Downstream of Hop Yard Bar	Black Marsh Farm	Caroline
47	Rappahannock River	2.8 mi Downstream of Hop Yard Bar	Racefield Farm	Caroline
44	Rappahannock R - Hazelwood Ln	1.11 Mi Downstream of Hicks Landing	Davis And Pratt Farms	Caroline
43	Rappahannock River - Walsinghm	0.5 Mi Downstream of Port Royal	Woodlawn \ Walsingham Farms	King George
42	Rappahannock R - Camden Rd	1.6 Mi Downstream of Port Royal	Davis And Pratt Farms	Caroline
38	Rappahannock River	8.0 Mi Downstream of Port Royal	Cloverfield Farm	Essex
35	Rappahannock River	13.5 Mi Downstream of Port Royal	Ingleside Plantation and Liberty Farm	Westmoreland
33	Rappahannock River	14.6 Mi Downstream of Port Royal	F L Dickinson Farm	Essex
20	Rappahannock #1 Eagle Tree	17.5 Mi Downstream of Port Royal	Eagle Tree	Westmoreland
21	Rappahannock #3 South	17.5 Mi Downstream of Port Royal	Eagle Tree	Westmoreland
22	Rappahannock #2 Grigsby	17.5 Mi Downstream of Port Royal	Eagle Tree	Westmoreland

1. Withdrawal numbers and names are listed as reported in DEQ records.

4.3.1 Agricultural Irrigation Salinity Thresholds

DEQ requested that the salinity tolerance of common crops in the vicinity of the Rappahannock River be used to establish thresholds for assessing salinity impacts. Based on the County profiles for Caroline, Essex, King George, and Westmoreland Counties from the USDA Census of Agriculture (2022), corn, soybeans and wheat are the most common crops across the counties (**Table 4-2**).

Table 4-2: Top Five Crops in Acres by County per the 2022 USDA Census of Agriculture

Crop	Caroline	Essex	King George	Westmoreland
Soybeans for beans	19,800	25,648	4,969	11,571
Corn for grain	13,092	16,851	4,150	8,553
Wheat for grain, all	5,615	7,507	1,721	4,850
Forage (hay/haylage), all	3,513	638	1,382	1,871
Vegetables harvested, all	436	NA	NA	1,409

Salinity tolerance for these crops was adapted from the Viginia Cooperative Extension bulletin BSE-348P *Managing Irrigation with Saline Water* (**Table 4-3**).

Table 4-3: Excerpt from Table 2. Relationship between crop yield and irrigation water salinity for common crops in Virginia (All conductivity values are in uS/cm)

Crop	Relative Yield Reduction				Maximum Tolerable Conductivity
	0%	10%	25%	50%	
Corn	1,100	1,700	2,500	3,900	6,700
Soybean	3,300	3,700	4,200	5,000	7,000
Wheat	4,000	4,900	6,300	8,700	13,000

Corn is the most sensitive to salinity of the major crops in the counties adjacent to the Rappahannock River. The yield reduction rates and maximum tolerable salinity level for corn are used to tabulate the number of days over the 76-year data period in each conductivity range using baseline and projected conductivity model data to assess the changes for each range of salinity. While corn is used to tabulate the data, any given field in any given year may have any one of these crops because they are often rotated from year to year. Further, changes in salinity are a short-term occurrence during a drought condition. Therefore, higher levels of salinity would be a temporary condition and would not be expected to harm crops long-term through a build up of salinity in the soil. The region receives sufficient rainfall so that any salt build-up in the soil would be flushed out through typical precipitation (Virginia Cooperative Extension).

4.3.2 Agricultural Irrigation Location Salinity Estimates

The tables below summarize the change in number of days within each conductivity range for corn estimated at each agricultural intake location. Monthly plots of the number of days in each conductivity range modeled for baseline and projected withdrawal scenarios are provided in **Appendix A**.

4.3.2.1 Between the Proposed Intake and Hop Yard Bar

As stated previously, conductivity data for Hop Yard Bar indicated that even during very dry conditions experienced during 1999 and 2002, conductivity changed minimally and did not exceed the freshwater threshold. Therefore, it is expected that conductivity for intakes upstream of Hop Yard Bar would not exceed the freshwater threshold under future withdrawal scenarios. Therefore, there are no anticipated impacts to salinity in agricultural irrigation water within this segment of the river.

4.3.2.2 Between Hop Yard Bar and Hicks Landing

As stated previously, a salinity model is not required for Hop Yard Bar because all the available historical data is in the freshwater range. Therefore, to interpolate between Hop Yard Bar and Hicks Landing

(approximately 6.5 river miles), an average value of 150 uS/cm was used for Hop Yard Bar based on observed data.

Table 4-4 and Table 4-5 present the data across the specified conductivity ranges. Consistent with the monitoring locations, the model predicts a small shift in days (<0.2%) from lower to higher salinity ranges. Additionally, salinity levels in this segment of the river are predicted to remain consistently within a tolerable range for corn (i.e., less than 6,700 µS/cm) and other common crops.

Table 4-4: Black Marsh Farm Rappahannock River Pump #3 - 2.5 mi Downstream of Hop Yard Bar

Conductivity Range (uS/cm)	Baseline (days)	Projected (days)	Difference (days)	Difference (%)
0 to 1100	27891	27856	-35	-0.12%
1100 to 1700	11	41	30	0.11%
1700 to 2500	8	13	5	<0.01%
2500 to 3900	0	0	0	0%
3900 to 6700	0	0	0	0%
Over 6700	0	0	0	0%

Table 4-5: Racefield Farm Rappahannock River - 2.8 mi Downstream of Hop Yard Bar

Conductivity Range (uS/cm)	Baseline (days)	Projected (days)	Difference (days)	Difference (%)
0 to 1100	27890	27850	-40	-0.14%
1100 to 1700	10	41	31	0.11%
1700 to 2500	10	19	9	<0.01%
2500 to 3900	0	0	0	0%
3900 to 6700	0	0	0	0%
Over 6700	0	0	0	0%

4.3.2.3 Between Hicks Landing and Port Royal

Table 4-6 presents interpolated model data between Hicks Landing and Port Royal (approximately 4.6 river miles). Consistent with the modeling at the monitoring locations, the model predicts a small shift in days (<0.23%) from lower to higher salinity. Maximum salinity levels would remain within the tolerable range for corn and other common crops.

Table 4-6: Davis And Pratt Farms Rappahannock R - Hazelwood Ln 1.11 Mi Downstream Of Hicks Landing

Conductivity Range (uS/cm)	Baseline (days)	Projected (days)	Difference (days)	Difference (%)
0 to 1100	27555	27499	-56	-0.20%
1100 to 1700	133	124	-9	-0.03%
1700 to 2500	130	134	4	0.01%
2500 to 3900	83	138	55	0.20%
3900 to 6700	9	15	6	0.02%
Over 6700	0	0	0	0

4.3.2.4 Between Port Royal and TF3.3

Table 4-7 through **Table 4-12** present interpolated model data for the agricultural intakes between Port Royal and TF3.3, a distance of over 26 miles. Salinity data in units of ppt for data collected at TF3.3 were converted to uS/cm using the conversion factor of 1 mg/L is equivalent to 640 mS/cm from the Virginia Cooperative Extension bulletin BSE-348P *Managing Irrigation with Saline Water*.[14] The regression model linear interpolation approach utilized for the other stations is less consistent in this zone of the river. The reason for this is this section of river transitions from a predominantly freshwater location to an oligohaline location over a substantial distance. Further, as stated previously, Station TF3.3 is more influenced by tidal flows and freshwater inflows can have less of an influence on salinity levels than the upstream stations. While the conductivity differences are not consistent at each conductivity range, the overall number of days affected across the modeling remains small (<0.3%).

The number of days salinity is expected to be in a range that impacts crops under baseline conditions increases substantially the closer the intake is to monitoring station TF3.3. Historical baseline salinity levels at monitoring station TF3.3 regularly exceed the maximum tolerable salinity level for corn (i.e., 6,700 µS/cm); the model indicates that the proposed withdrawal would not further increase the occurrence of salinity levels above this threshold and is not likely to impact the use of the river for agricultural irrigation.

Table 4-7: Woodlawn \ Walsingham Farms Rappahannock River – Walsinghm 0.5 Mi Downstream Of Port Royal

Conductivity Range (uS/cm)	Baseline (days)	Projected (days)	Difference (days)	Difference (% of days)
0 to 1100	26649	26649	0	0%
1100 to 1700	472	472	0	0%
1700 to 2500	295	300	5	0.02%
2500 to 3900	170	170	0	0%
3900 to 6700	262	260	-2	-0.01%
Over 6700	62	59	-3	-0.01%

[14] Converting to typical units used in this report yields a conversion factor of 1 ppt is equivalent to 1562 uS/cm. Note that the conversion of salinity to conductivity is not a constant because conductivity varies with ionic composition.

Table 4-8: Davis And Pratt Farms Rappahannock R - Camden Rd 1.6 Mi Downstream Of Port Royal

Conductivity Range (uS/cm)	Baseline (days)	Projected (days)	Difference (days)	Difference (% of days)
0 to 1100	25706	25670	-36	-0.13%
1100 to 1700	1030	1054	24	0.09%
1700 to 2500	547	574	27	0.10%
2500 to 3900	274	276	2	<0.01%
3900 to 6700	314	303	-11	-0.04%
Over 6700	39	33	-6	-0.02%

Table 4-9: Cloverfield Farm Rappahannock River 8.0 Mi Downstream Of Port Royal

Conductivity Range (uS/cm)	Baseline (days)	Projected (days)	Difference (days)	Difference (% of days)
0 to 1100	18591	18512	-79	-0.28%
1100 to 1700	3147	3147	0	0%
1700 to 2500	2270	2275	5	0.02%
2500 to 3900	1988	1968	-20	-0.07%
3900 to 6700	1914	2008	94	0.33%
Over 6700	0	0	0	0%

Table 4-10: Ingleside Plantation And Liberty Farm Rappahannock River 13.5 Mi Downstream Of Port Royal

Conductivity Range (uS/cm)	Baseline (days)	Projected (days)	Difference (days)	Difference (% of days)
0 to 1100	14359	14302	-57	-0.20%
1100 to 1700	3802	3780	-22	-0.08%
1700 to 2500	2824	2824	0	0%
2500 to 3900	2826	2873	47	0.17%
3900 to 6700	2727	2864	137	0.49%
Over 6700	1372	1267	-105	-0.38%

Table 4-11: F L Dickinson Farm Rappahannock River 14.6 Mi Downstream Of Port Royal

Conductivity Range (uS/cm)	Baseline (days)	Projected (days)	Difference (days)	Difference (% of days)
0 to 1100	13824	13768	-56	-0.20%
1100 to 1700	3719	3696	-23	-0.08%
1700 to 2500	2942	2917	-25	-0.09%
2500 to 3900	2974	3050	76	0.27%
3900 to 6700	2774	2855	81	0.29%
Over 6700	1677	1624	-53	-0.19%

Table 4-12: Eagle Tree Rappahannock #1, #2, #3 17.5 Mi Downstream Of Port Royal (9.2 Miles Upstream Of TF3.3)

Conductivity Range (uS/cm)	Baseline (days)	Projected (days)	Difference (days)	Difference (% of days)
0 to 1100	12591	12526	-65	-0.23%
1100 to 1700	3523	3517	-6	-0.02%
1700 to 2500	3067	3063	-4	-0.01%
2500 to 3900	3183	3263	80	0.29%
3900 to 6700	3072	3116	44	0.16%
Over 6700	2474	2425	-49	-0.18%

4.3.3 Findings from VIMS Salinity Model

Figure 4-7 presents the modeled salinity change in the river from the VIMS model during a period of low river discharge. Modeled salinity changes throughout the river are low (i.e., less than 0.03 ppt or 60 µS/cm). The VIMS model indicates that the portion of the river expected to experience slight salinity changes is located primarily from Tappahannock to Saluda. The existing known agricultural withdrawals reported by DEQ are located upstream of the region of the river predicted in the VIMS model to have slight salinity increases (i.e., from Tappahannock to Saluda). Baseline salinity levels in this portion of the river downstream of Tappahannock are generally higher, likely limiting the use of water from the river in this area for agricultural irrigation.

Based on the VIMS model, the salinity change, during low river discharge conditions, is expected to be less than 0.01 ppt (i.e., less than approximately 20 µS/cm) throughout the portion of the river with known agricultural withdrawals. The VIMS model indicates that salinity changes throughout the portion of the river currently used for agricultural irrigation would be negligible and would not impact agriculture.

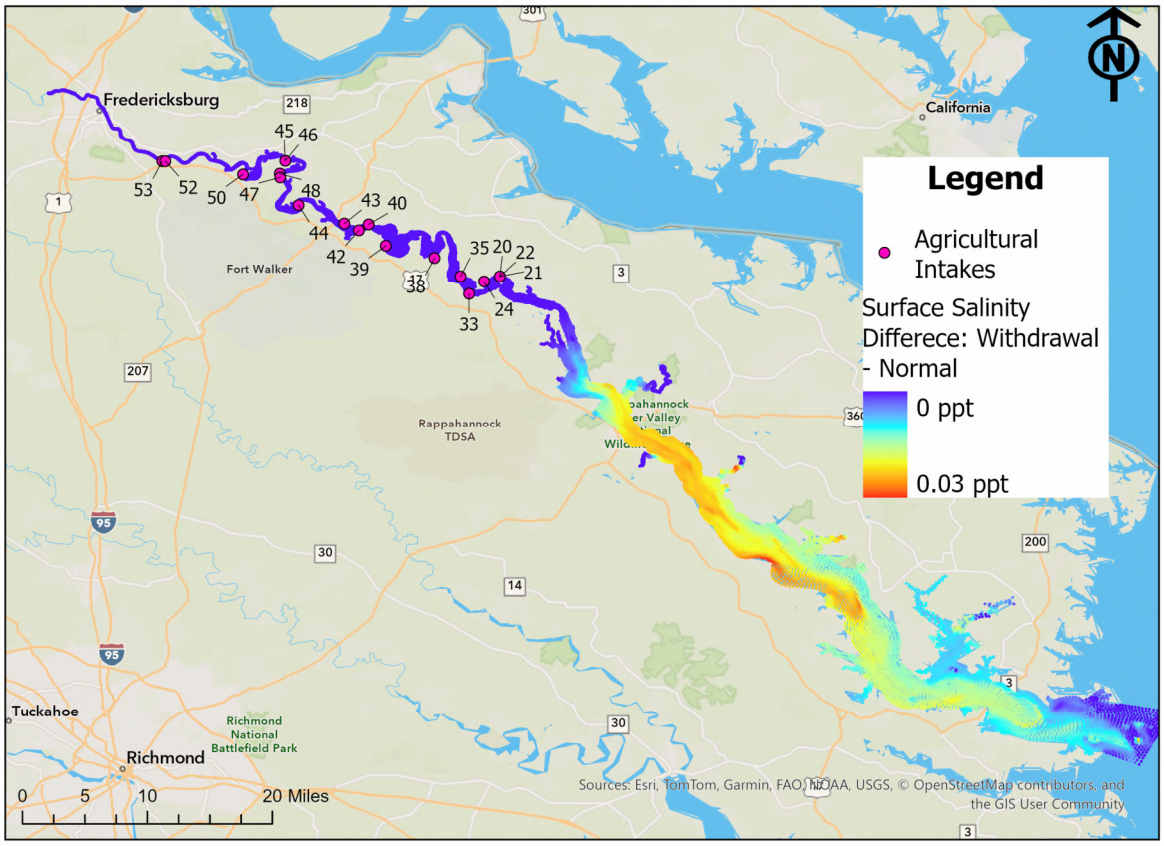


Figure 4-7: Salinity Difference along the Rappahannock River from the VIMS Model during a Period of Low River Discharge on July 2, 2011 Compared to Agricultural Withdrawals

4.3.4 Summary of Agricultural Withdrawal Analysis

Table 4-13 summarizes the results of the salinity model analysis for known agricultural withdrawals. The number of days with salinity levels above the most conservative salinity level for irrigation of corn (i.e., 1,100 uS/cm) is predicted to increase by up to 0.28% at these locations. Salinity levels would not increase above the maximum tolerable salinity level for irrigation of corn (i.e., 6,700 uS/cm) at any known irrigation withdrawal locations. Other common crops in the area (e.g., soybeans, wheat, etc) are more tolerant of salinity, and the potential for impacts to irrigation of these crops is even lower.

Table 4-13: Summary of Salinity Model for Agricultural Intakes on the Mainstem Rappahannock River

No.	Name	Facility	Increase Above Lowest Salinity Threshold for Corn (Percent of Days)	Increase Above Maximum Tolerable Salinity Level for Corn (Percent of Days)
50	Rappahannock River Pump #4	Black Marsh Farm	0%	0%
45	Rappahannock River Pump #1	Black Marsh Farm	0%	0%
46	Rappahannock River Pump #2	Black Marsh Farm	0%	0%
48	Rappahannock River Pump #3	Black Marsh Farm	0.12%	0%
47	Rappahannock River	Racefield Farm	0.14%	0%
44	Rappahannock R - Hazelwood Ln	Davis And Pratt Farms	0.23%	0%
43	Rappahannock River - Walsinghm	Woodlawn / Walsingham Farms	0%	0%
42	Rappahannock R - Camden Rd	Davis And Pratt Farms	0.13%	0%
38	Rappahannock River	Cloverfield Farm	0.28%	0%
35	Rappahannock River	Ingleside Plantation And Liberty Farm	0.20%	0%
33	Rappahannock River	F L Dickinson Farm	0.20%	0%
20	Rappahannock #1 Eagle Tree	Eagle Tree	0.23%	0%
21	Rappahannock #3 South	Eagle Tree	0.23%	0%
22	Rappahannock #2 Grigsby	Eagle Tree	0.23%	0%

Hazen

5. Mattaponi River Analysis

Water withdrawn from the Rappahannock River and used within Caroline County and the Town of Bowling Green will be returned to the Mattaponi River, constituting an interbasin transfer from the Rappahannock River Basin to the York River Basin. The *Beneficial Use and Aquatic Life Evaluation* (April 2025) describes the beneficial uses of the Rappahannock River and the Mattaponi River, and it assesses the potential impacts of additional return flows. To supplement the evaluation of beneficial uses of the Mattaponi River basin, a hydrology and salinity assessment was conducted to evaluate the possibility of changes to flow and salinity regimes in the Mattaponi River resulting from increased return flows associated with this project.

Caroline County is providing this memorandum to support the evaluation of potential impacts to beneficial uses of the Mattaponi River in accordance with 9VAC25-210-340 Part B.5. The water quality of discharges is governed by the Virginia Pollutant Discharge Elimination System (VPDES) permits and is outside the scope of the Virginia Water Protection (VWP) permit program. This document presents the findings of the Mattaponi River assessment, providing supplemental information to support Caroline County's Joint Permit Application. The quality of return flows and level of treatment will meet permitted requirements through a future VPDES process and will protect instream water quality.

5.1 Mattaponi River Hydrologic Analysis

The Mattaponi River is a tributary of the York River that flows through Caroline County. The river's lower reach serves as the boundary between King William and King and Queen Counties. The nearest U.S. Geological Survey (USGS) flow gage on the Mattaponi River (Gage ID 01674500) is located near Beulahville, VA. Historical flows at this gage from January 1984 to July 2024 are presented in **Figure 5-1**. Large storm events can greatly increase flows to thousands of cubic feet per second (cfs). Extended dry periods can result in low flows under 1 cfs, which historically occurred in 1999 and 2002.

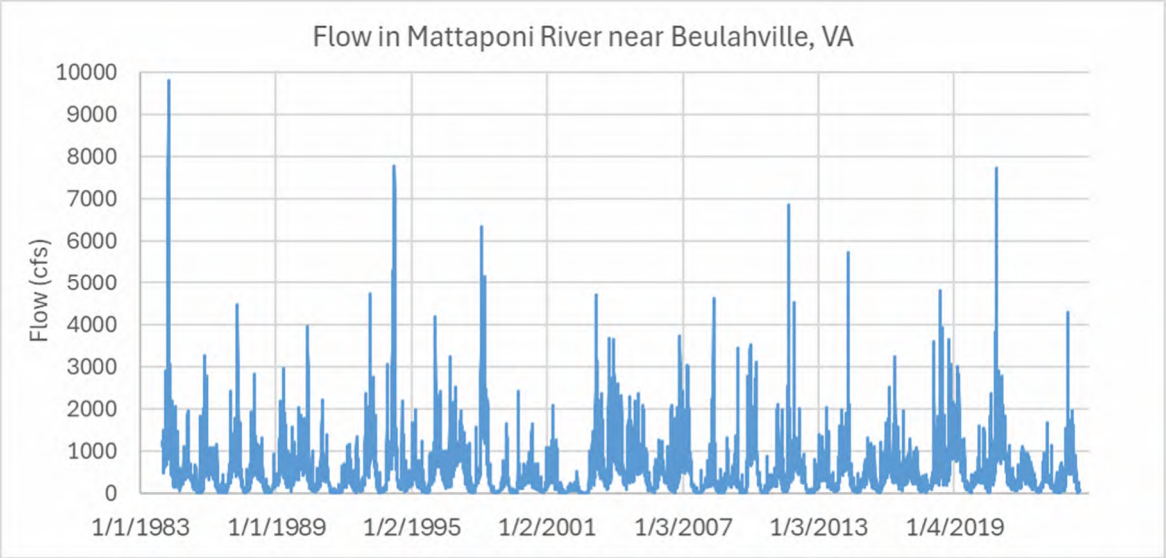


Figure 5-1: Mattaponi River Flow from USGS Gage 01674500

5.2 Mattaponi River Salinity Analysis

The Mattaponi River begins as a non-tidal stream and transitions to tidal just upstream of Aylett, VA.[15] The Mattaponi River continues for approximately 30 miles downstream of Aylett and then joins with the Pamunkey River to form the York River. The upper reach of the tidal Mattaponi River is considered tidal fresh, and the river shifts into oligohaline towards the confluence with the York River. The York River has higher salinity, and transitions from mesohaline to polyhaline. Salinity ranges for the different salinity regimes are provided in **Table 3-1**.

5.2.1 Modeling Approach

The objective of this analysis is to estimate the impact of increased return flows from the proposed Rappahannock River water supply project on salinity levels in the Mattaponi River. The modeling approach consisted of developing a relationship between freshwater inflows at each monitoring location and measured salinity; this is similar to the modeling approach used to evaluate the effects of the proposed withdrawal on salinity levels in the Rappahannock River.

Data were reviewed along the length of the Mattaponi River to identify water quality monitoring locations with sufficient salinity data to support modeling efforts. Data were collected from the US National Water Quality Monitoring Council Water Quality Portal database,[17] the Virginia Institute of Marine Science (VIMS) Virginia Estuarine and Coastal Observing System (VECOS),[18] and the Chesapeake Bay Program DataHub.[19]

[15] https://dwr.virginia.gov/waterbody/mattaponi-river/
[17] https://www.waterqualitydata.us/
[18] http://web2.vims.edu/vecos/
[19] https://datahub.chesapeakebay.net/

The following four water quality monitoring sites were identified for further analysis based on the availability of historical salinity data, and their locations are shown in **Figure 5-2:**

- **Aylett**: Data at this location consisted of grab samples collected by DEQ and is generally monthly since 1997.
- **Walkerton**: Data at this location consisted of grab samples collected by DEQ and is generally monthly since 1984.
- **Wakema**: Data at this location consisted of grab samples collected by DEQ since 1994.
- **Muddy Point**: Data at this location consisted of grab samples collected by DEQ and is generally monthly since 1985.

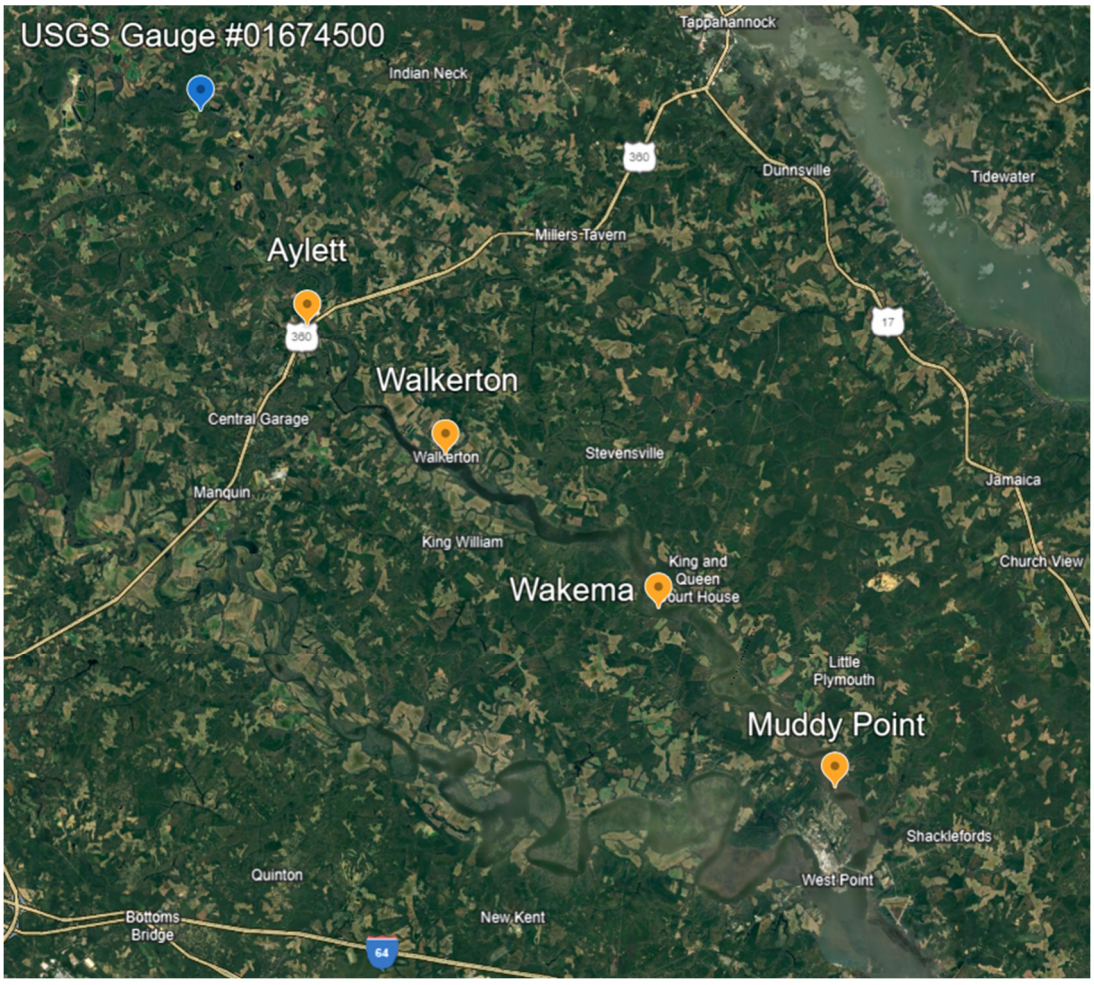


Figure 5-2: Map of Water Quality Monitoring Sites

The scope of this salinity analysis is focused on the freshwater transition zone in the Mattaponi River where increased return flows could influence salinity levels. Monitoring stations further upstream than Aylett were not included in this salinity analysis because the river is non-tidal and remains freshwater

regardless of flow conditions; increased return flows would not affect salinity in this region. Further downstream in the York River, salinity levels are higher and directly influenced by the Chesapeake Bay. The watershed area of the York River Basin increases with the addition of 1,470 square miles[20] from the Pamunkey River Basin at the confluence with the Mattaponi River. Further, the York River salinity is significantly influenced by the Chesapeake Bay. York River salinity ranges from mesohaline (5,000 to 18,000 mg/L) in the upper reach to polyhaline (18,000 to 30,000 mg/L) at the confluence with the bay. Given the substantial increase in watershed area and higher salinity of the York River, hydrology and salinity were not evaluated in the York River.

5.2.2 Baseline Salinity Levels

The VIMS VECOS data include water quality sampling cruises, referred to as dataflow, that collect water quality data along a length of the river over a few hours. For the Mattaponi River, these cruises began at the mouth of the Mattaponi River at the Lord Delaware Bridge in West Point and finished in the upper tidal reach about 800 feet past the Rt 360 bridge at Aylett. These data were not used in the development of the river salinity model, but they were used to understand the transition from fresh to brackish water along the length of the river during different hydrologic conditions. **Figure 5-3** shows salinity levels along the length of the Mattaponi River under average and low flow conditions.

- **Low River Flow Conditions** – On October 5, 2005, the flow at the USGS gage was 21.3 cfs, which is the 3rd percentile meaning that 97% of the time the flow is greater.
- **Average River Flow Conditions** – On May 11, 2005, the flow was 345 cfs which is the 52nd percentile, representing average conditions.

During the dry conditions on October 5, 2005, salinity moved further upstream than it was on May 11, 2005, when there was greater freshwater flow. Specifically, at Muddy Point, a freshwater flow increase of 324 cfs decreased the salinity by approximately 84%.

[20] Foster, B. M., Lopez, R., Crawford, E. R., Cook, W., Krigsvold, J., Langston, J. H., ... & Jastram, J. D. (2024). Characterization of the water resources of the Pamunkey River watershed in Virginia—A review of water science, management, and traditional ecological knowledge. Scientific Investigations Report, (2024-5024).

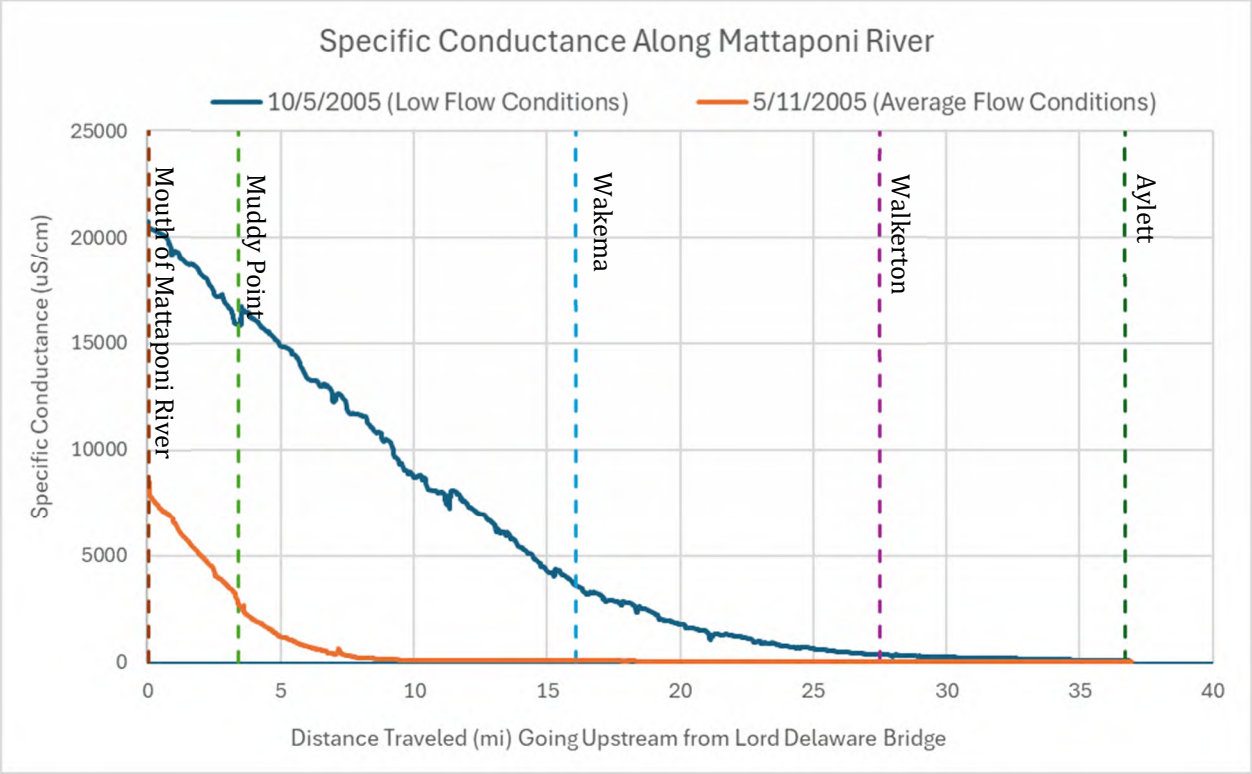


Figure 5-3: VIMS VECOS Mattaponi River Dataflow Observations for Specific Conductance

These naturally-occurring variations in freshwater flow rates significantly affect salinity level in the Mattaponi River. By contrast, the estimated return flows associated with this project are minimal.

The following subsections describe the baseline salinity levels in the Mattaponi River based on historical data at each primary water quality monitoring station.

5.2.2.1 Aylett

Specific conductance measurements at Aylett are shown in **Figure 5-4**. The median conductance is 61 uS/cm. All values are below the freshwater threshold of 1,000 uS/cm, even during 1999 and 2002 when extended dry periods resulted in low flows. No further analysis was conducted for this location because increased freshwater flows resulting from the County's discharge would not affect the tidal freshwater status at this location.

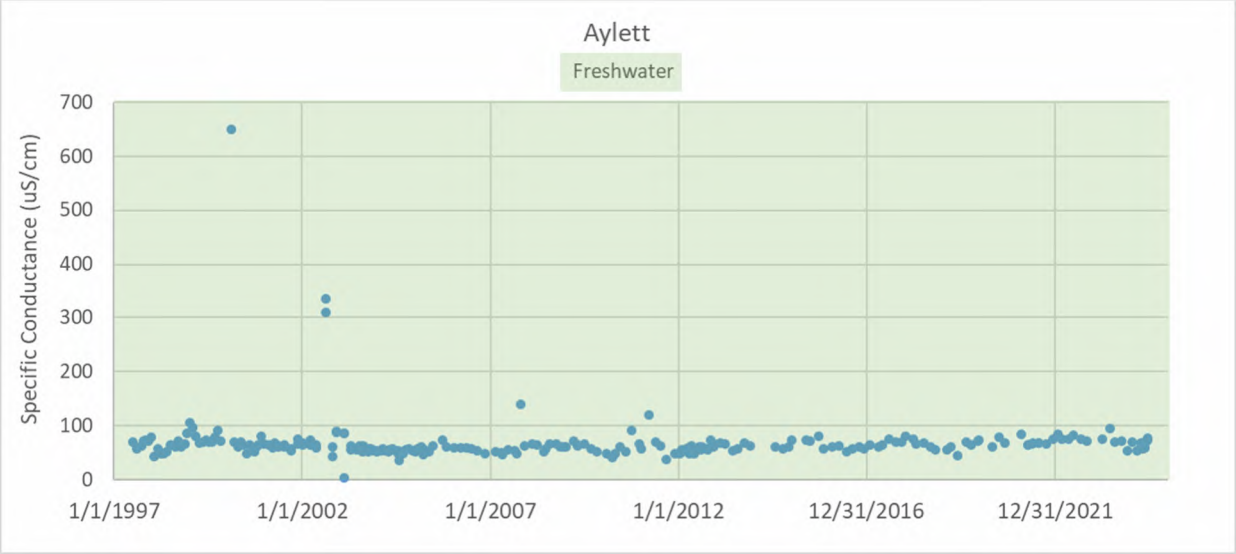


Figure 5-4: Specific Conductance at Aylett Monitoring Station

5.2.2.2 *Walkerton*

Figure 5-5 shows specific conductance measurements at Walkerton. The median conductance is 64 uS/cm, indicating that flow is typically freshwater at this location. The location is classified as tidal freshwater per VIMS VECOS. However, in 2002, some conductance values surpassed 4,000 uS/cm. Additional analysis was conducted at this location to determine the influence of the County's discharge to the river (see Section 5.2.5.1).

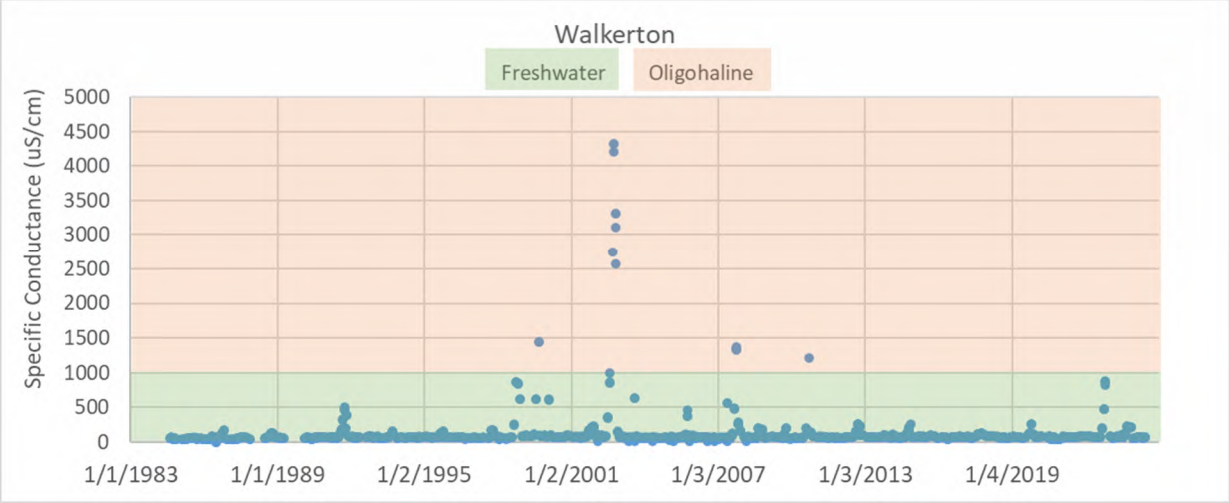


Figure 5-5: Specific Conductance at Walkerton Monitoring Station

5.2.3.1 Wakema

Specific conductance measurements at Wakema are shown in **Figure 5-6**. The median conductance is 99 uS/cm, so flow is also typically freshwater at this location. However, there are many measurements of conductance values exceeding the freshwater threshold, with values as high as 13,000 uS/cm. Wakema is classified as oligohaline per VIMS VECOS. Additional analysis was conducted at this location to determine the influence of the County's discharge to the river (see Section 5.2.5.2).

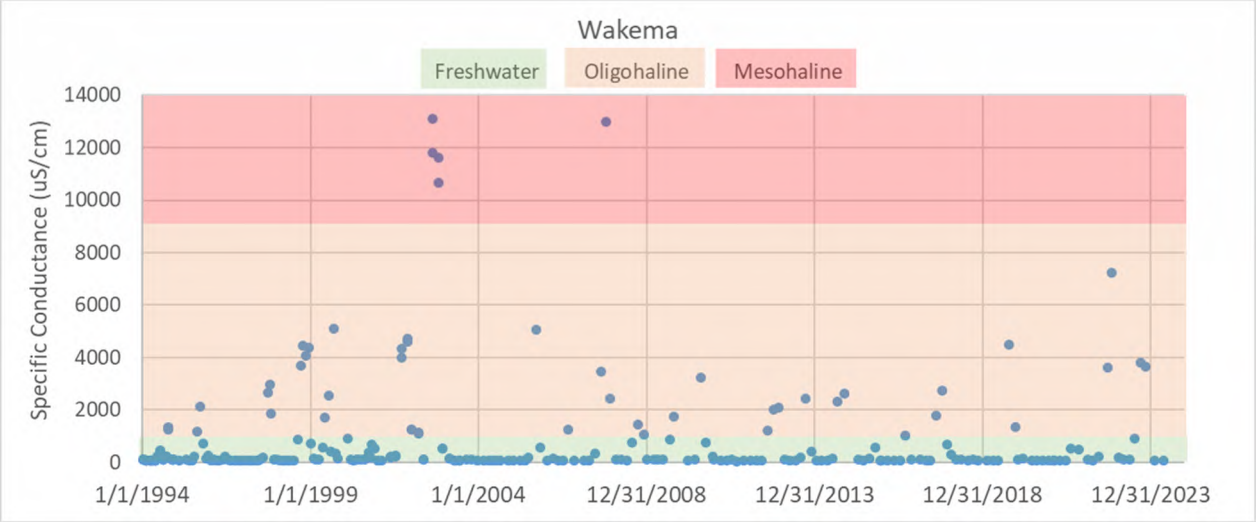


Figure 5-6: Specific Conductance at Wakema Monitoring Station

5.2.3.2 Muddy Point

Muddy Point is classified by VIMS VECOS as oligohaline, but salinity levels frequently reach the mesohaline range. The station is located about five miles upstream of the York River, which is classified as mesohaline to polyhaline. **Figure 5-7** depicts specific conductance measurements at Muddy Point that range from 58 to 30,000 uS/cm with a median of 6,500 uS/cm. Specific conductance at this location is frequently high, even outside of drought years (e.g., 1999 and 2002) when freshwater flow was greatly reduced. Additional analysis was conducted at this location to determine the influence of the County's discharge on the river (see Section 5.2.5.3).

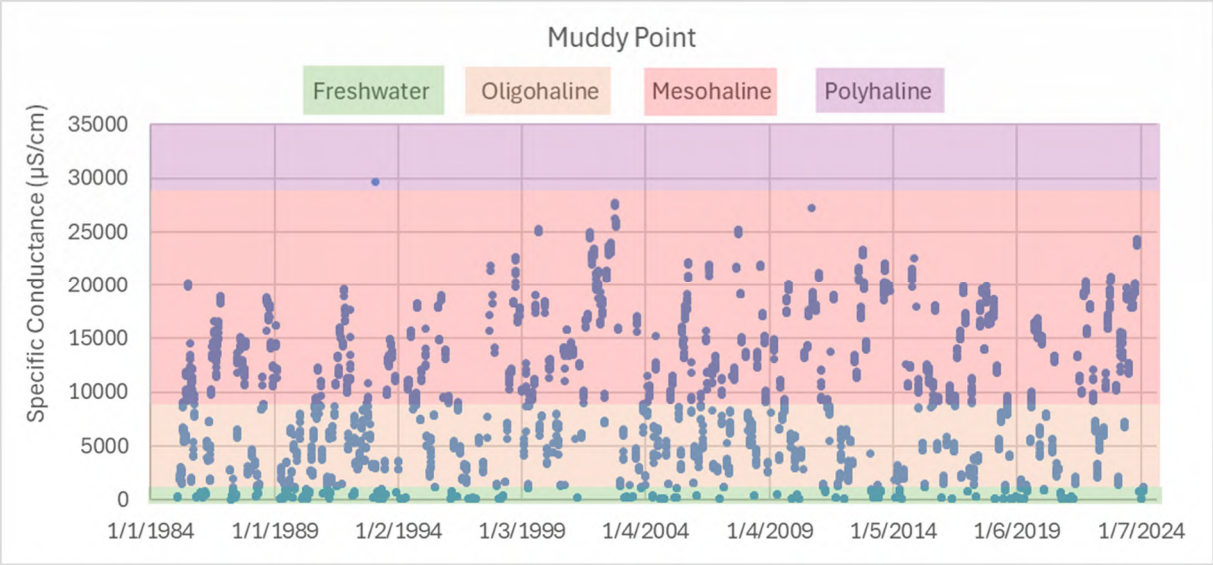


Figure 5-7: Specific Conductance at Muddy Point Monitoring Station

5.2.4 Salinity Model Development

Stream flow data were compared to specific conductance measurements to identify the relationship between flow and salinity at select locations along the tidal Mattaponi River. As noted previously, Aylett remains freshwater regardless of flow, so no analysis was conducted for this location. If multiple specific conductance measurements were collected on the same day, then they were averaged to create one daily value.

Flow data from USGS gage #01674500 was scaled by watershed area to estimate flows at the monitoring station locations. The USGS gage has a drainage area of 603 square miles. USGS StreamStats[21] was used to estimate drainage areas of 745, 819 and 878 square miles for Walkerton, Wakema and Muddy Point, respectively. Therefore, flow at Walkerton was estimated as equal to 1.235 (i.e., 745/603) times the flow at the USGS gage, flow at Wakema was estimated as equal to 1.358 (i.e., 819/603) times the flow at the USGS gage, and flow at Muddy Point was estimated as equal to 1.456 (i.e., 878/603) times the flow at the USGS gage.

Specific conductance was compared to daily, weekly, and 30-day rolling average scaled flows. The 30-day averages were found to result in the best fit of the models, so these flows were selected for the final models. By taking flow averages, short-term variability from sudden peaks in flow from storm events was reduced.

For Caroline County's Rappahannock River water supply project, the estimated average transferred flow rate to the Mattaponi River basin is projected at 4.1 mgd (6.4 cfs) with the proposed withdrawal in place.

[21] https://streamstats.usgs.gov/ss/

An analysis of estimated consumptive use and return flows is presented in the *Beneficial Use and Aquatic Life Evaluation* (April 2025).

5.2.5 Salinity Model Results

The following subsections present the salinity model results for each primary water quality monitoring station on the Mattaponi River. The chosen models were used to estimate specific conductance based on daily historical flows going back to 1984 (baseline conditions) and under the conditions with a return flow of 6.4 cfs (projected conditions). The number of days above and below the freshwater threshold were compared between the baseline condition and with the proposed additional flow as a metric for the potential change in salinity in the river at the following locations.

5.2.5.1 Walkerton

Figure 5-8 presents the flow and specific conductance data at the Walkerton monitoring station. Flows above 250 cfs were always below the freshwater threshold, so they were not considered in the model to improve the fit of the data.

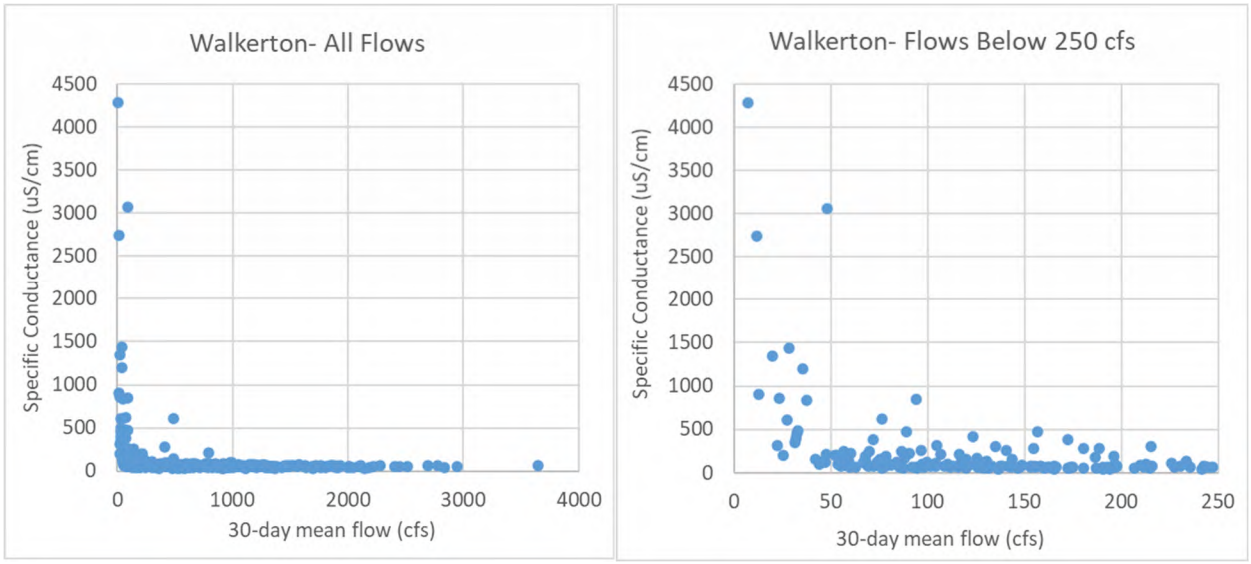


Figure 5-8: Walkerton Station Specific Conductance vs Flow

The following equation fits the data for flow values below 250 cfs with an R-squared of 0.60:

$$\text{Specific Conductance} = 11{,}138\ (\text{30-day average flow})^{-0.985}$$

Figure 5-9 shows the measured specific conductance values along with the modeled values corresponding to the same days as the measured values for the Walkerton monitoring station.

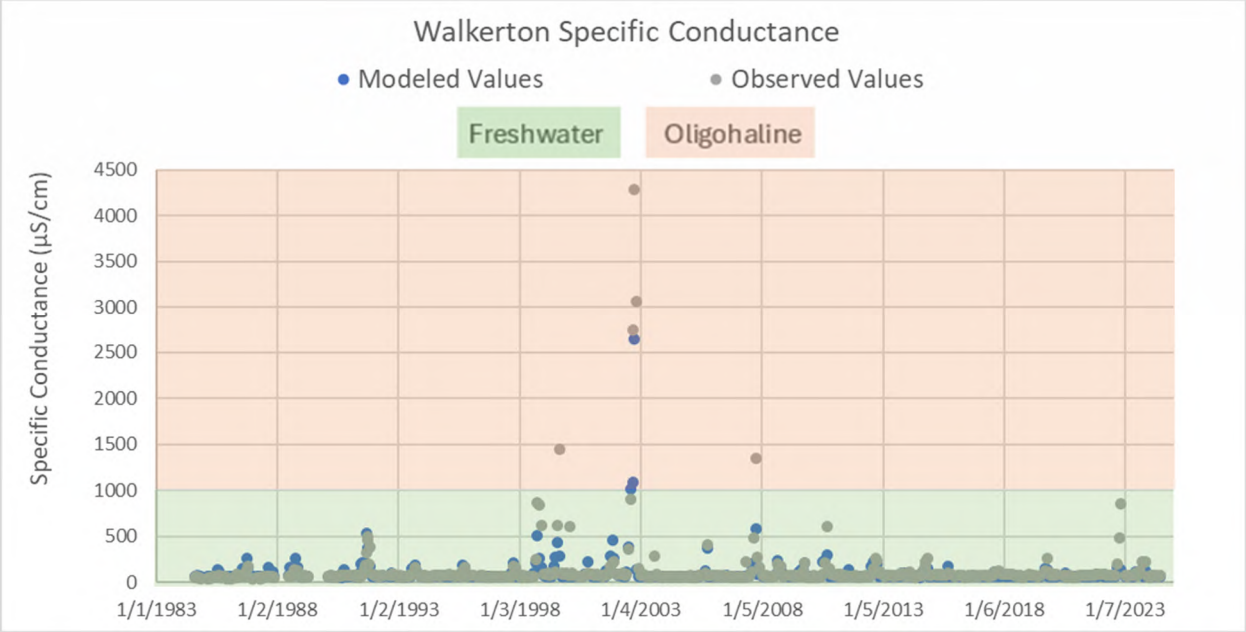


Figure 5-9: Walkerton Measured vs Modeled Specific Conductance

Comparing the model over the entire 40-year historical hydrologic record, baseline conditions resulted in an estimated 0.3% of days (45 days) above the freshwater threshold at Walkerton. This value is reduced to almost 0% (6 days) under the proposed conditions as shown in **Figure 5-10**. Therefore, the additional return flows would have a minimal effect on salinity levels at Walkerton.

The Walkerton monitoring station is in the freshwater tidal zone of the Mattaponi River. The additional discharges from Caroline County would support the freshwater tidal zone by providing additional low-salinity water that reduces the incursion of high-salinity water from further downstream during low flow conditions. This would have a slight effect of preserving freshwater conditions in this region of the river.

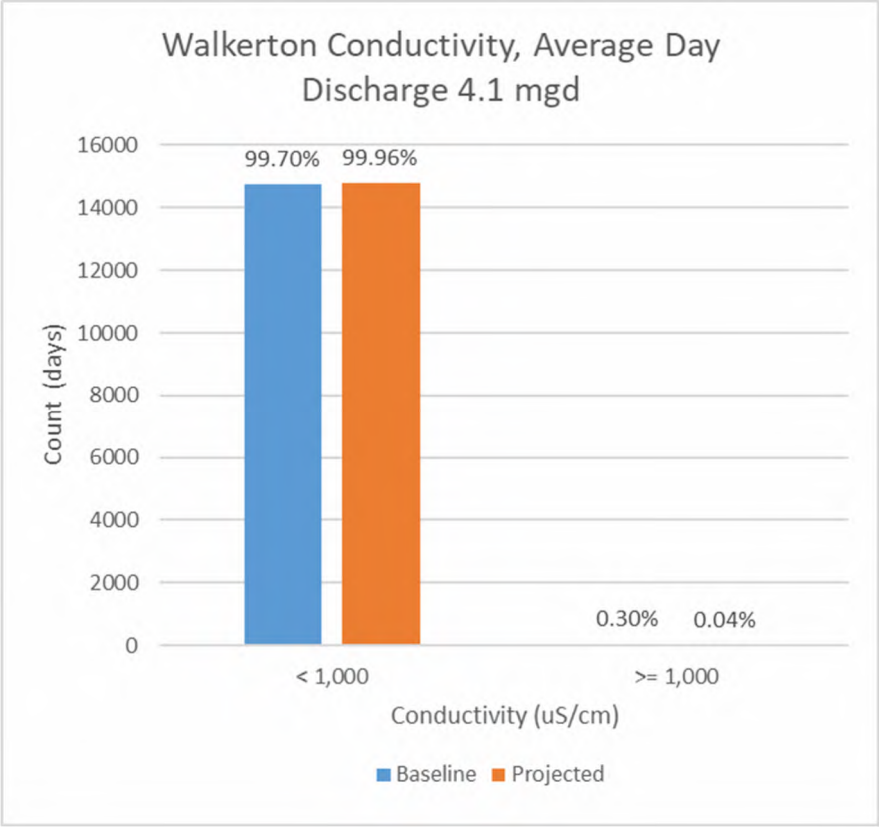


Figure 5-10: Walkerton Estimated Specific Conductance Under Baseline and Proposed Conditions

5.2.5.2 Wakema

Figure 5-11 presents the flow and specific conductance data at the Wakema monitoring station. All historical flow data were considered in the model. The following equation fits the data with an R-squared of 0.62:

$$\text{Specific Conductance} = 237{,}890\ (\text{30-day average flow})^{-1.159}$$

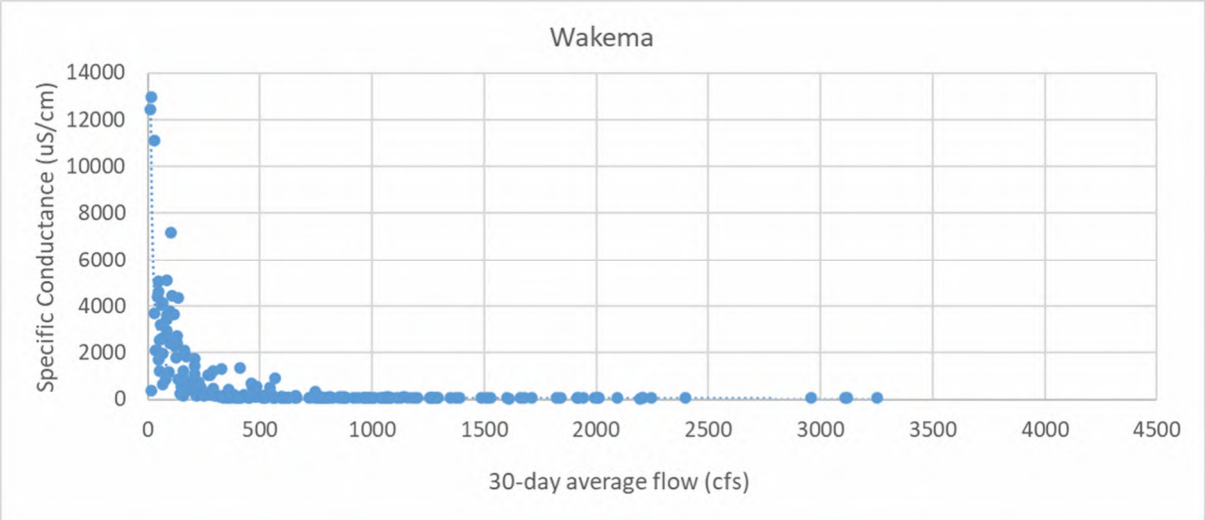


Figure 5-11: Wakema Station Specific Conductance vs Flow

Figure 5-12 shows the measured specific conductance values along with the modeled values corresponding to the same days as the measured values for the Wakema monitoring station.

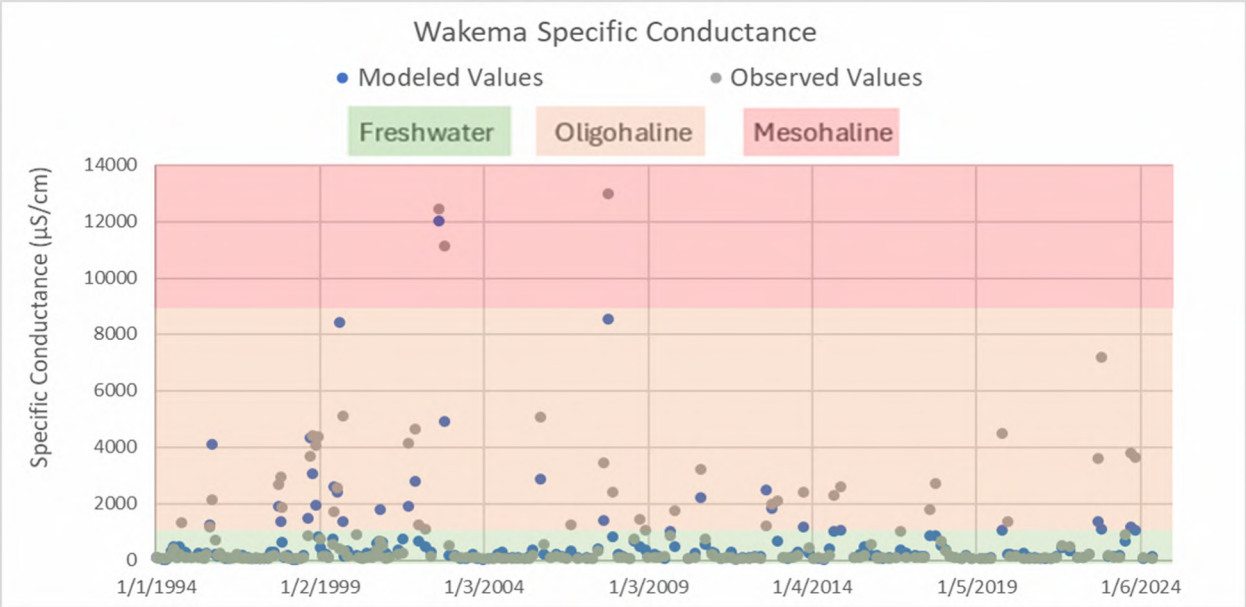


Figure 5-12: Wakema Measured vs Modeled Specific Conductance

Comparing the modeling over the 40-year historical hydrologic record, baseline conditions resulted in an estimated 12.1% of days above the freshwater threshold (11.4% as oligohaline and 0.7% as mesohaline); this percentage is reduced to 11.4% (11.2% as oligohaline and 0.2% as mesohaline) under the proposed conditions as shown in **Figure 5-13**. Specific conductance values under baseline conditions range from 12 to 20,800 uS/cm with a median value of 163 uS/cm. With the additional discharge flow, the estimated range of specific conductance values is 12 to 10,700 uS/cm with a median value of 160 uS/cm.

The Wakema monitoring station is in the oligohaline zone of the Mattaponi River, which is defined by salinity in the range of 1,000 to 9,000 uS/cm. While salinity would be reduced on 107 days over the 40-year modeling period (i.e., approximately 3 days per year) from above to below the freshwater zone, this limited change would have no effect on the salinity regime in this section of the river.

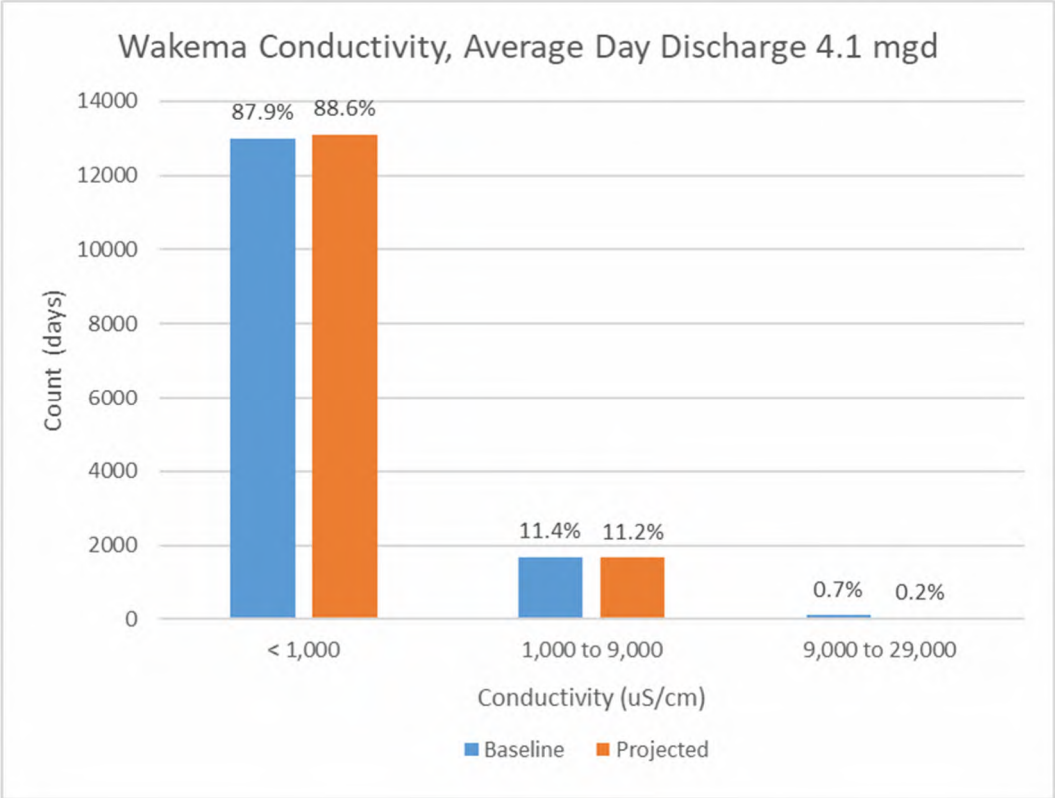


Figure 5-13: Wakema Estimated Specific Conductance Under Baseline and Proposed Conditions

5.2.5.3 Muddy Point

Figure 5-14 presents specific conductance versus flow at the Muddy Point monitoring station location. The relationship between flow and conductivity at this location is less defined, and there is substantially more variability in the historical salinity observations. Salinity at this location is predominantly above the freshwater threshold of 1,000 uS/cm. Salinity levels were within the freshwater zone only when river flows were sustained above 4,000 cfs. The approximately 6.4 cfs of return flow from the County's

WWTP is unlikely to have a measurable effect on salinity at this location. Therefore, a model was not developed at this location.

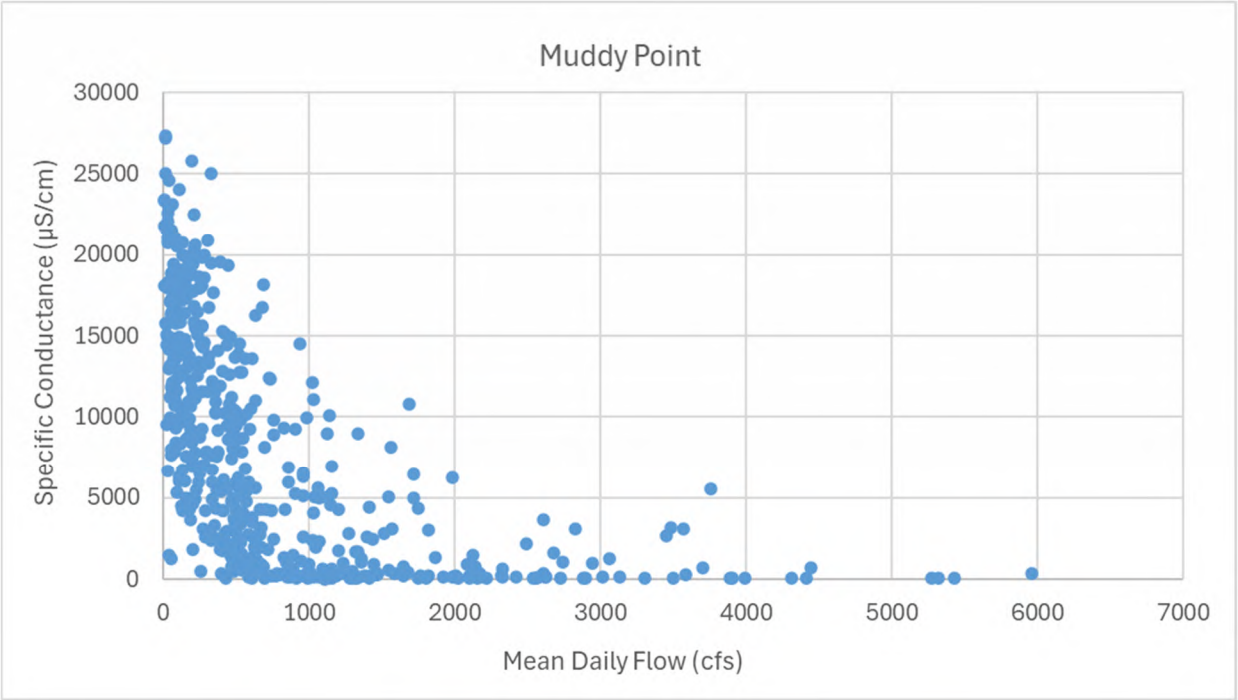


Figure 5-14: Muddy Point Station Specific Conductance vs Flow

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6. Conclusion

The salinity models for the Rappahannock River and the Mattaponi River use a regression model based upon historical salinity data to estimate the impacts of flow changes on salinity levels in the river. Due to the relatively low water withdrawal and transfer flow rates, salinity changes in both rivers are predicted to be minimal. In addition, a VIMS model of the Rappahannock River also concluded that salinity changes are expected to be minimal. Specific findings for both rivers are summarized in the following sections.

6.1 Rappahannock River

The following conclusions were drawn from this evaluation to assess the hydrology and salinity in the river in the vicinity and downstream of the proposed drinking water intake for Caroline County.

- Freshwater inflows are reliable and sufficient to supply the anticipated withdrawals for Caroline County.
- Salinity in the vicinity of the proposed intake would be in the range of fresh water, even during typical low flow conditions.
- Salinity levels downstream of the proposed intake are driven by river hydrology and tidal conditions. The minor increase in withdrawals from the river would result in a negligible change in conductivity in the river. Therefore, proposed withdrawals are not expected to affect natural resources or beneficial uses (e.g., freshwater wetlands, aquatic species or irrigation withdrawals) downstream of the proposed intake.
- Salinity changes at specific locations of known agricultural withdrawals on the Rappahannock River are minimal, with slight increases in salinity levels on less than 0.3% of days. At locations which have historically had salinity levels within the acceptable ranges for irrigation of corn and other common crops in the area, the proposed withdrawal would not increase salinity levels above tolerable levels. The model results indicate that the proposed withdrawal will not impact agricultural irrigation.

6.2 Mattaponi River

The Rappahannock River Water Supply Project is expected to result in a transfer of flow to the Mattaponi River basin as overall water use in Caroline County increases. This evaluation of salinity levels was performed to support the evaluation of beneficial uses of the Mattaponi River. Key findings and conclusions regarding the effects of the increased return flows on salinity levels in the Mattaponi River include the following:

- Salinity levels in tidal portions of the Mattaponi River between Aylett and Muddy Point range from freshwater to mesohaline, and salinity levels vary significantly depending on natural variations in freshwater flows.

- Salinity levels in the Mattaponi River would not change appreciably with the estimated discharge rates for Caroline County's proposed water supply project. The model indicates that the estimated return flows would not change the salinity regimes within the Mattaponi River.
- Return flows associated with the Rappahannock River water supply project are small relative to the natural range of freshwater stream flows. During periods of high streamflow, the estimated return flow is approximately 0.1% to 0.2% of the natural Mattaponi River flow. The additional return flows would have minimal effect on river hydrology.
- Any change in salinity levels in the Mattaponi River would be towards maintaining freshwater conditions, which would not contribute to salinity stress on freshwater wetlands or aquatic species in the freshwater tidal zone, helping to preserve this sensitive habitat and protect other beneficial uses.

The results of this analysis indicate that no significant impacts to hydrology or salinity levels in the Mattaponi River are expected as a result of the Rappahannock River Water Supply Project.

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7. References

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Appendix A: Agricultural Irrigation Intakes Salinity Estimate Figures

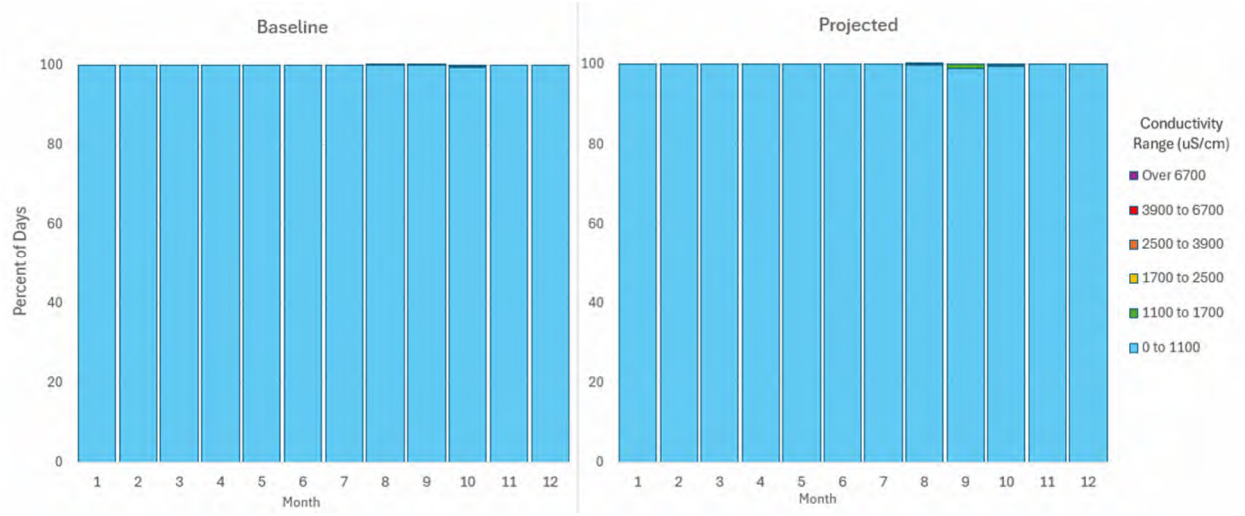


Figure A-1. Black Marsh Farm Rappahannock River Pump #3 - 2.5 mi Downstream of Hop Yard Bar

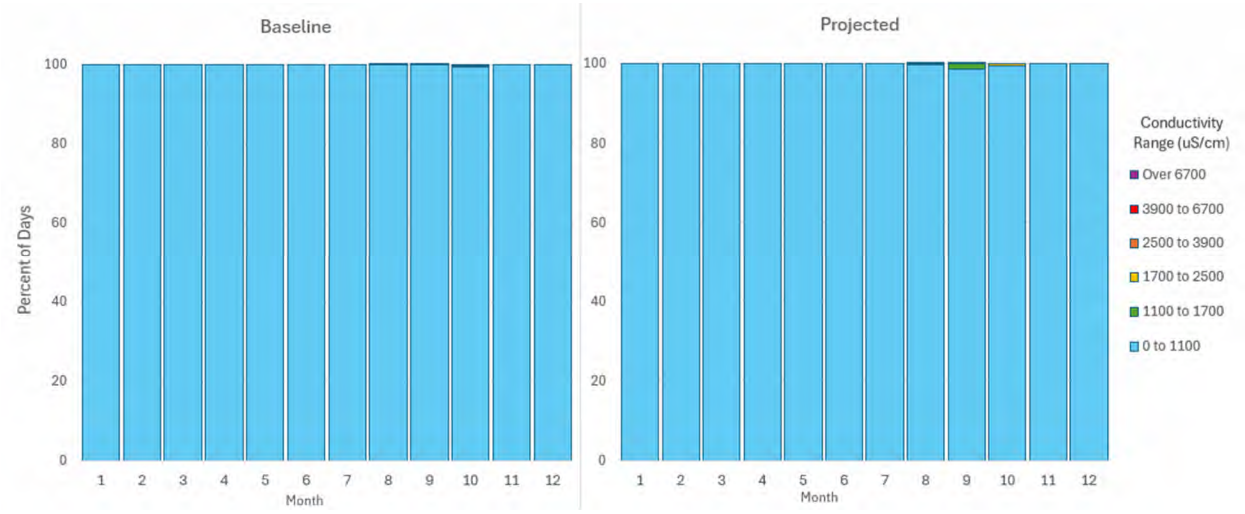


Figure A-2. Racefield Farm Rappahannock River - 2.8 mi Downstream of Hop Yard Bar

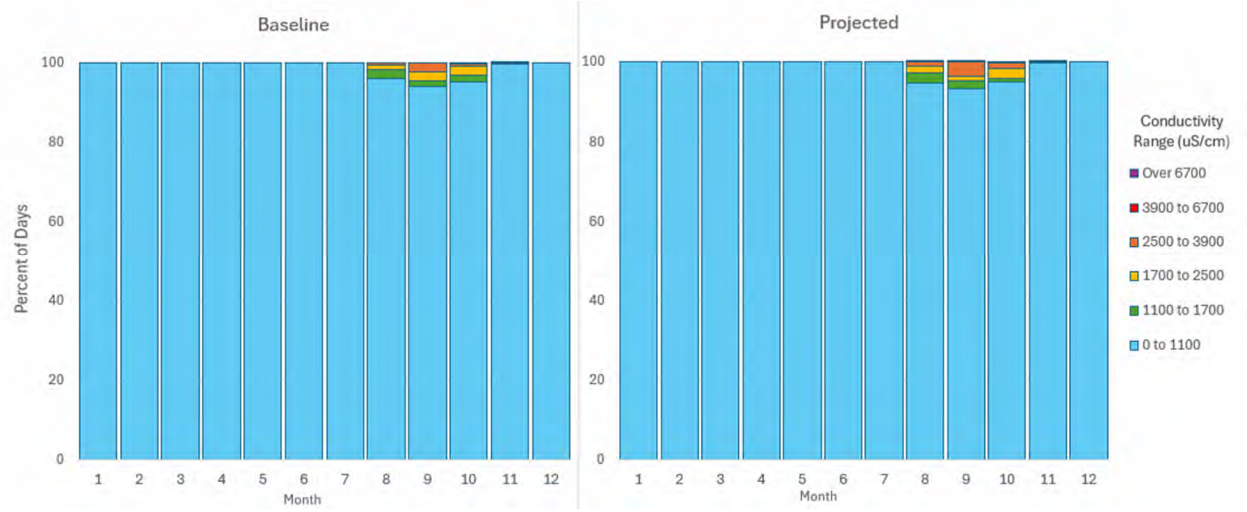


Figure A-3. Davis and Pratt Farms Rappahannock R - Hazelwood Ln 1.11 Mi Downstream of Hicks Landing

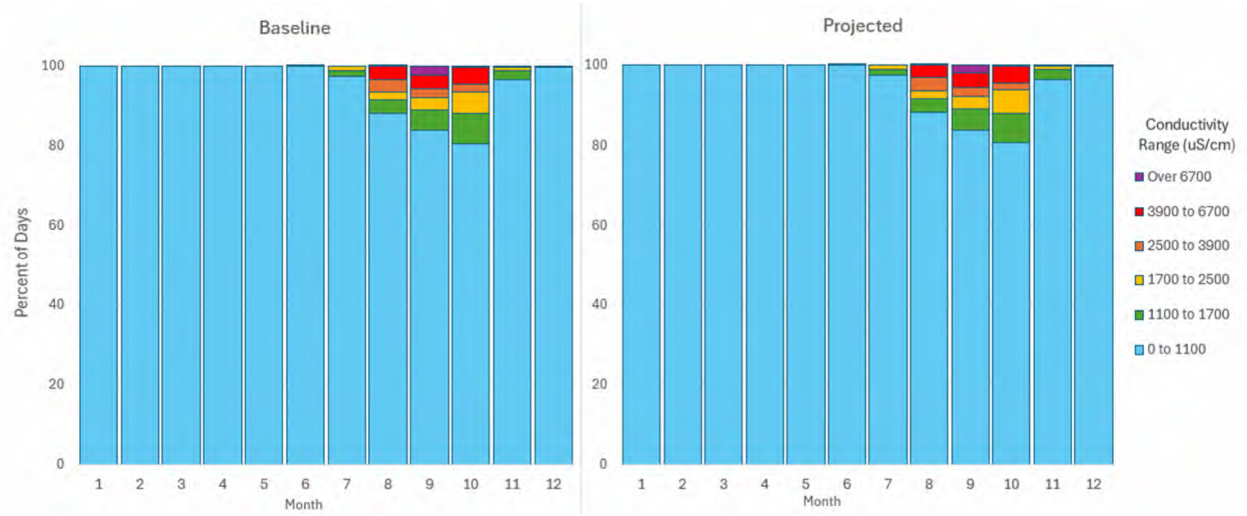


Figure A-4. Woodlawn \ Walsingham Farms Rappahannock River – Walsinghm 0.5 Mi Downstream of Port Royal

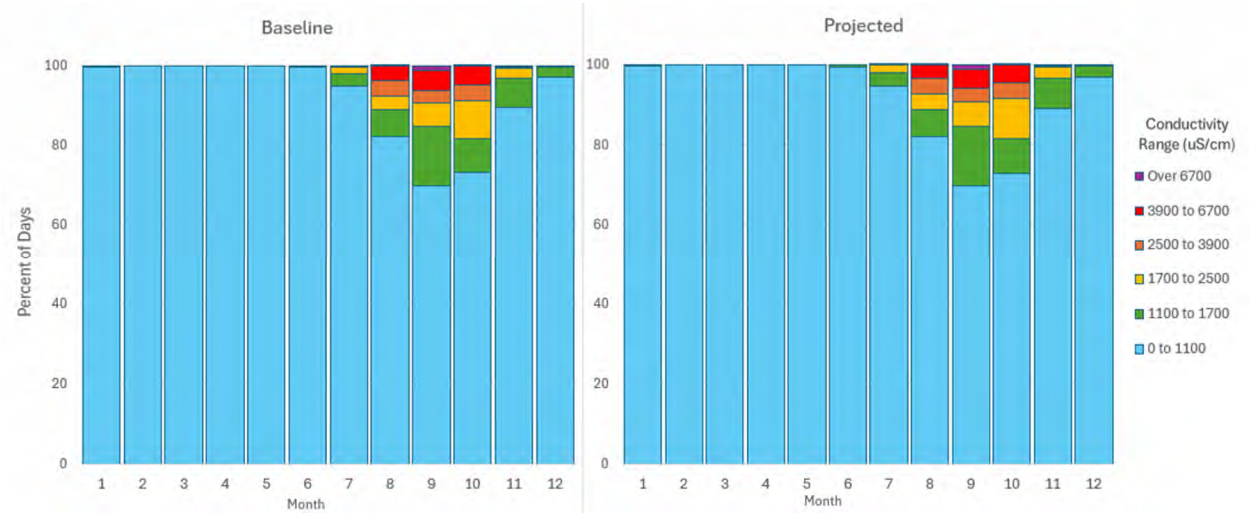


Figure A-5. Davis and Pratt Farms Rappahannock R - Camden Rd 1.6 Mi Downstream of Port Royal

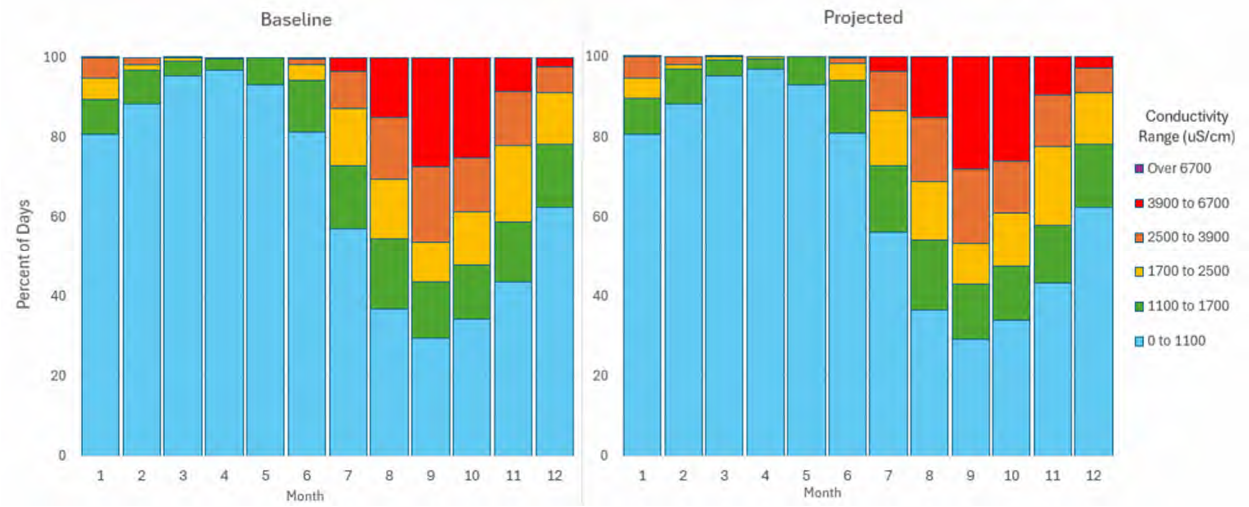


Figure A-6. Cloverfield Farm Rappahannock River 8.0 Mi Downstream of Port Royal

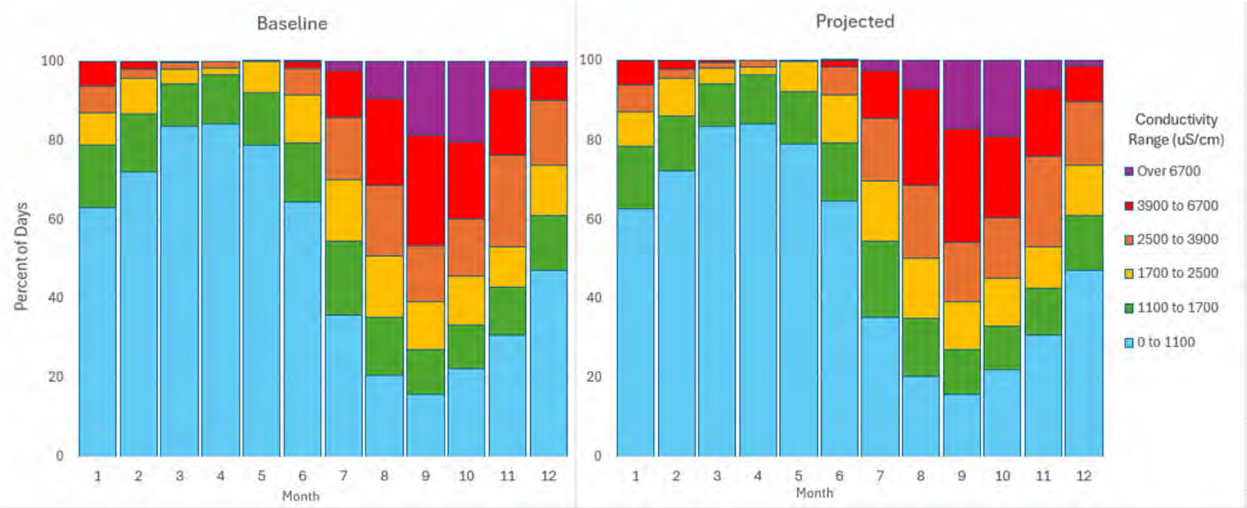


Figure A-7. Ingleside Plantation and Liberty Farm Rappahannock River 13.5 Mi Downstream of Port Royal

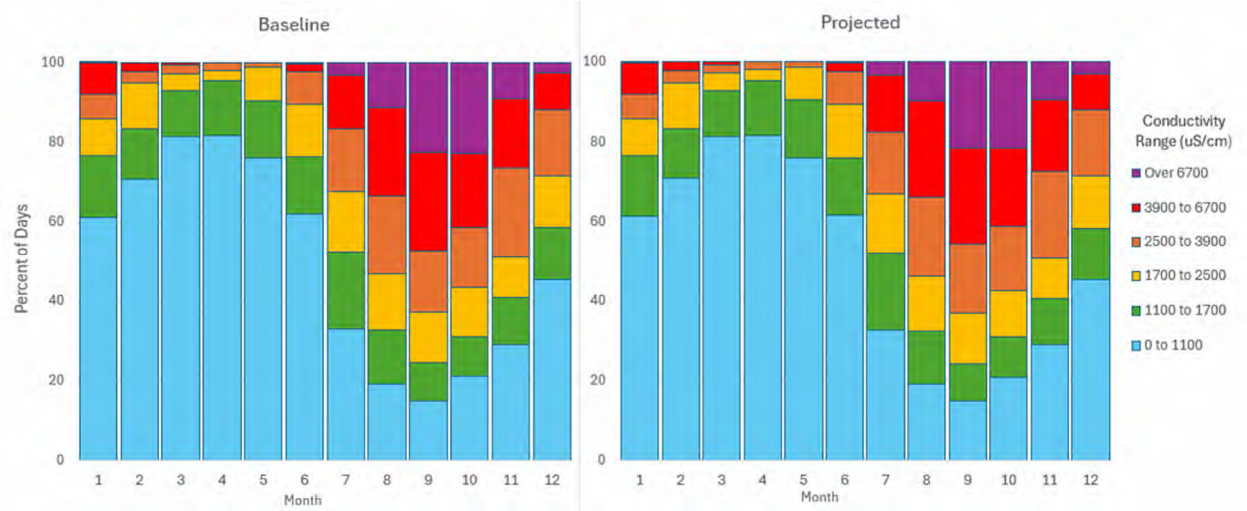


Figure A-8. F L Dickinson Farm Rappahannock River 14.6 Mi Downstream of Port Royal

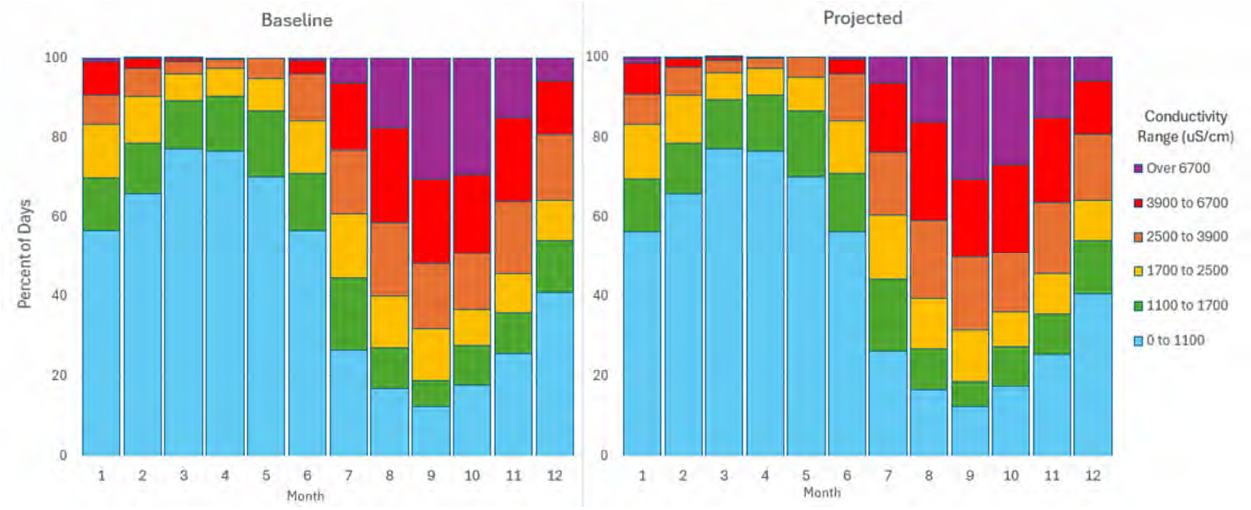


Figure A-9. Eagle Tree Rappahannock #1, #2, #3 17.5 Mi Downstream of Port Royal (9.2 Miles Upstream of TF3.3)

Appendix B: Incremental Conductivity Changes at Agricultural Irrigation Intakes

The following figures provide the incremental change in conductivity by month and year at each of the main stem Rappahannock River agricultural intake locations. The values in the figures represent the change in number of days above 1,100 uS/cm from modeled baseline to projected conditions with the proposed intake in operation.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1943	0	0	0	0	0	0	0	0	0	0	0	0
1944	0	0	0	0	0	0	0	0	0	0	0	0
1945	0	0	0	0	0	0	0	0	0	0	0	0
1946	0	0	0	0	0	0	0	0	0	0	0	0
1947	0	0	0	0	0	0	0	0	0	0	0	0
1948	0	0	0	0	0	0	0	0	0	0	0	0
1949	0	0	0	0	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0	0	0	0	0
1951	0	0	0	0	0	0	0	0	0	0	0	0
1952	0	0	0	0	0	0	0	0	0	0	0	0
1953	0	0	0	0	0	0	0	0	0	0	0	0
1954	0	0	0	0	0	0	0	0	2	1	0	0
1955	0	0	0	0	0	0	0	0	0	0	0	0
1956	0	0	0	0	0	0	0	0	0	0	0	0
1957	0	0	0	0	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	0	0	0	0	0	0
1959	0	0	0	0	0	0	0	0	0	0	0	0
1960	0	0	0	0	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0	0	3	0	0	0
1967	0	0	0	0	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1982	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	3	1	0	0	0
2000	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	2	23	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0	0	0	0	0

Figure B-1 Black Marsh Farm Rappahannock River Pump #3 - 2.5 mi Downstream of Hop Yard Bar

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1943	0	0	0	0	0	0	0	0	0	0	0	0
1944	0	0	0	0	0	0	0	0	0	0	0	0
1945	0	0	0	0	0	0	0	0	0	0	0	0
1946	0	0	0	0	0	0	0	0	0	0	0	0
1947	0	0	0	0	0	0	0	0	0	0	0	0
1948	0	0	0	0	0	0	0	0	0	0	0	0
1949	0	0	0	0	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0	0	0	0	0
1951	0	0	0	0	0	0	0	0	0	0	0	0
1952	0	0	0	0	0	0	0	0	0	0	0	0
1953	0	0	0	0	0	0	0	0	0	0	0	0
1954	0	0	0	0	0	0	0	0	3	1	0	0
1955	0	0	0	0	0	0	0	0	0	0	0	0
1956	0	0	0	0	0	0	0	0	0	0	0	0
1957	0	0	0	0	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	0	0	0	0	0	0
1959	0	0	0	0	0	0	0	0	0	0	0	0
1960	0	0	0	0	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0	0	1	0	0	0
1964	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0	0	3	0	0	0
1967	0	0	0	0	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1982	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	3	1	0	0	0
2000	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	3	24	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0	0	1	0	0
2008	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0	0	0	0	0

Figure B-2 Racefield Farm Rappahannock River - 2.8 mi Downstream of Hop Yard Bar

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1943	0	0	0	0	0	0	0	0	0	4	0	0
1944	0	0	0	0	0	0	0	0	0	0	0	0
1945	0	0	0	0	0	0	0	0	0	0	0	0
1946	0	0	0	0	0	0	0	0	0	0	0	0
1947	0	0	0	0	0	0	0	0	0	0	0	0
1948	0	0	0	0	0	0	0	0	0	0	0	0
1949	0	0	0	0	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0	0	0	0	0
1951	0	0	0	0	0	0	0	0	0	0	0	0
1952	0	0	0	0	0	0	0	0	0	0	0	0
1953	0	0	0	0	0	0	0	0	0	2	0	0
1954	0	0	0	0	0	0	0	12	3	0	0	0
1955	0	0	0	0	0	0	0	0	0	0	0	0
1956	0	0	0	0	0	0	0	0	0	0	0	0
1957	0	0	0	0	0	0	0	2	0	0	0	0
1958	0	0	0	0	0	0	0	0	0	0	0	0
1959	0	0	0	0	0	0	0	0	0	0	0	0
1960	0	0	0	0	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0	3	0	0	0	0
1964	0	0	0	0	0	0	0	0	8	0	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0	2	0	0	0	0
1967	0	0	0	0	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1982	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0	4	2	0	0
1999	0	0	0	0	0	0	0	3	0	0	0	0
2000	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	1	0	1	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	7	1	0	0	0
2008	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0	1	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0	0	0	0	0

Figure B-3 Davis and Pratt Farms Rappahannock R - Hazelwood Ln 1.11 Mi Downstream of Hicks Landing

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1943	0	0	0	0	0	0	0	0	0	0	0	0
1944	0	0	0	0	0	0	0	0	0	0	0	0
1945	0	0	0	0	0	0	0	0	0	0	0	0
1946	0	0	0	0	0	0	0	0	0	0	0	0
1947	0	0	0	0	0	0	0	0	0	0	0	0
1948	0	0	0	0	0	0	0	0	0	0	0	0
1949	0	0	0	0	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0	0	0	0	0
1951	0	0	0	0	0	0	0	0	0	0	0	0
1952	0	0	0	0	0	0	0	0	0	0	0	0
1953	0	0	0	0	0	0	0	0	0	0	0	0
1954	0	0	0	0	0	0	0	0	0	0	0	0
1955	0	0	0	0	0	0	0	0	0	0	0	0
1956	0	0	0	0	0	0	0	0	0	0	0	0
1957	0	0	0	0	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	0	0	0	0	0	0
1959	0	0	0	0	0	0	0	0	0	0	0	0
1960	0	0	0	0	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1982	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0	2	0	0	0
2000	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0	0	0	0	0

Figure B-4 Woodlawn \ Walsingham Farms Rappahannock River – Walsinghm 0.5 Mi Downstream of Port Royal

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1943	0	0	0	0	0	0	0	0	0	0	0	0
1944	0	0	0	0	0	0	0	0	0	0	0	0
1945	0	0	0	0	0	0	0	0	0	0	0	0
1946	0	0	0	0	0	0	0	0	0	0	0	0
1947	0	0	0	0	0	0	0	0	0	0	0	0
1948	0	0	0	0	0	0	0	0	0	0	0	0
1949	0	0	0	0	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0	0	0	0	0
1951	0	0	0	0	0	0	0	0	0	0	0	0
1952	0	0	0	0	0	0	0	0	0	0	0	0
1953	0	0	0	0	0	0	0	1	0	0	0	0
1954	0	0	0	0	0	0	0	0	0	0	0	0
1955	0	0	0	0	0	0	0	0	0	0	0	0
1956	0	0	0	0	0	0	0	0	0	0	0	0
1957	0	0	0	0	0	0	1	0	0	0	0	0
1958	0	0	0	0	0	0	0	0	0	0	0	0
1959	0	0	0	0	0	0	0	0	0	0	0	0
1960	0	0	0	0	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	0	0	1	4	1	0
1963	0	0	0	0	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	1	0	0
1966	0	0	0	0	0	0	1	0	0	0	0	0
1967	0	0	0	0	0	0	0	2	0	0	0	0
1968	0	0	0	0	0	0	0	0	0	0	2	0
1969	0	0	0	0	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0	1	0	0	0
1971	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	1	3	0
1979	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	1	0
1981	0	0	0	0	0	0	0	0	0	0	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1982	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	1	1	0	0	0
1986	0	0	0	0	0	0	0	1	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	1	0
1989	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	1	0	0	1	1
1992	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	2	0
1994	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	1	0	0
1998	0	0	0	0	0	0	0	0	0	0	0	1
1999	0	0	0	0	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	1	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	1	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	1	0	0	0
2010	0	0	0	0	0	0	1	1	0	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0	0	0	0	0

Figure B-5 Davis and Pratt Farms Rappahannock R - Camden Rd 1.6 Mi Downstream of Port Royal

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1943	0	0	0	0	0	0	2	0	0	0	0	0
1944	0	0	0	0	0	1	0	0	1	0	0	0
1945	0	0	0	0	0	0	0	0	0	0	1	0
1946	0	0	0	0	0	0	0	0	0	0	0	0
1947	0	0	0	0	0	0	2	0	0	0	0	0
1948	0	0	0	0	0	0	0	0	0	0	0	0
1949	0	0	0	0	0	0	0	0	0	0	0	2
1950	0	0	0	0	0	0	0	0	0	0	0	0
1951	0	0	0	0	0	0	0	1	0	0	0	0
1952	0	0	0	0	0	0	0	1	0	0	0	0
1953	0	0	0	0	0	0	0	0	0	0	0	0
1954	0	0	0	0	0	1	0	0	0	3	0	0
1955	0	1	0	0	0	1	1	0	0	0	0	0
1956	0	0	0	0	0	0	0	0	0	0	0	0
1957	0	0	0	0	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	0	0	0	0	0	0
1959	0	2	1	0	0	0	1	0	0	0	0	0
1960	0	0	0	0	0	0	1	1	0	0	0	0
1961	2	1	0	0	0	0	0	0	1	0	0	0
1962	0	0	0	0	0	0	0	0	0	0	1	0
1963	0	0	0	0	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	0	0	1	0	0	0
1968	0	0	0	0	0	0	0	0	0	0	0	0
1969	1	0	0	0	1	0	0	0	0	0	0	0
1970	0	0	0	0	0	1	1	0	0	0	0	0
1971	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	1	0
1974	0	0	0	0	0	0	1	0	0	0	0	0
1975	0	0	0	0	0	0	0	1	0	0	0	0
1976	0	0	0	0	0	0	2	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	1	0	0	0	1
1979	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1982	3	0	0	0	0	0	0	0	0	0	0	0
1983	0	1	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	1	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	2	0
1988	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	1	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	2	0	0
1993	0	0	0	0	0	0	1	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	1	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	1	0	0	0	0	0
1999	0	0	0	0	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	1	0	0	0	0	0	0
2001	0	0	3	0	0	0	2	1	0	0	0	0
2002	0	0	0	0	1	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	1	0	0	0
2005	0	0	0	0	0	0	5	0	0	0	1	0
2006	0	0	0	0	1	0	1	0	1	0	0	0
2007	0	0	0	0	0	1	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	1	0	0	0	0
2009	0	0	0	0	0	0	0	1	0	0	0	0
2010	0	0	0	0	0	1	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	1	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	1	0	1	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0	0	0	0	0

Figure B-6 Cloverfield Farm Rappahannock River 8.0 Mi Downstream of Port Royal

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1943	0	0	0	0	0	0	0	0	0	0	0	0
1944	0	0	1	0	0	0	0	0	0	0	0	0
1945	0	0	0	0	1	0	0	0	0	1	0	0
1946	0	0	0	0	0	0	0	0	0	0	0	0
1947	0	1	0	1	0	0	0	0	0	0	0	0
1948	1	0	0	0	0	0	1	0	1	0	0	0
1949	0	0	0	0	0	0	0	0	0	0	1	0
1950	0	0	0	0	0	0	0	0	0	0	0	0
1951	0	0	0	0	0	0	0	0	0	0	0	0
1952	0	0	0	0	0	0	1	0	0	0	0	0
1953	0	0	0	0	0	0	0	0	0	0	0	0
1954	0	0	0	0	0	0	0	0	0	5	0	0
1955	0	0	0	0	0	0	0	0	0	0	0	0
1956	0	0	0	1	0	0	0	0	0	0	0	0
1957	0	0	0	0	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	1	0	0	0	0	0
1959	0	0	2	0	0	0	0	0	0	0	0	0
1960	0	0	0	0	0	0	0	0	0	0	0	0
1961	1	0	0	0	0	0	1	0	0	0	0	0
1962	0	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	2	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	0
1966	0	0	1	0	0	0	0	0	0	0	0	0
1967	1	0	0	0	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0	0	0	0	0
1969	0	0	0	1	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	1
1974	0	0	0	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	1	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0
1977	1	0	0	0	0	0	0	0	0	0	0	1
1978	0	0	0	0	0	0	1	1	0	0	0	0
1979	0	0	0	0	0	0	1	0	0	0	0	0
1980	0	0	0	0	0	0	1	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1982	0	0	0	0	1	0	1	0	0	0	0	0
1983	0	1	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0
1988	1	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	2	0	0	0	0	1	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	1	0	0	0
1995	0	0	1	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0	0	2	0	0
2000	0	0	0	0	0	0	1	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	1	0
2003	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	1	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	2	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0	0	0	0	1
2011	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	1
2013	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0
2015	1	0	0	0	0	1	1	0	0	0	0	0
2016	0	0	0	0	0	0	0	1	0	0	0	0
2017	1	0	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0	0	0	0	0

Figure B-7 Ingleside Plantation and Liberty Farm Rappahannock River 13.5 Mi Downstream of Port Royal

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1943	0	0	0	0	0	1	0	0	0	0	0	0
1944	0	0	0	0	0	0	0	0	0	1	0	0
1945	0	0	1	0	0	0	0	0	0	0	0	2
1946	0	0	0	0	0	0	0	0	0	0	0	0
1947	0	1	0	0	0	1	0	0	0	0	0	0
1948	0	0	0	0	0	0	1	0	0	0	0	0
1949	0	0	0	0	0	0	0	0	0	1	0	0
1950	0	0	0	0	0	1	0	0	0	0	0	0
1951	0	0	0	0	0	0	0	0	0	0	0	0
1952	0	0	0	0	0	0	0	0	0	0	0	0
1953	0	0	0	0	0	0	0	0	0	0	0	0
1954	0	0	0	0	0	0	0	0	0	5	0	0
1955	0	0	0	0	1	0	0	0	0	0	0	0
1956	0	1	0	0	0	0	0	0	0	0	0	1
1957	0	0	0	0	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	0	0	0	0	0	0
1959	0	0	0	0	0	0	0	0	0	0	0	1
1960	0	0	0	0	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	1	0	0	0	0	0
1963	0	0	0	1	1	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0	0	0	0	0	1
1967	0	1	0	0	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0	0	0	0	1
1970	0	0	0	0	0	2	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	1	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	1	0	0	0	0	0	0
1976	0	0	0	0	1	1	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	1	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1982	0	0	0	0	1	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	1	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	1	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0
1988	1	0	0	1	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	1	0
1991	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	1	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	1	0	0	0	0	0	0
1995	0	0	0	0	1	0	0	0	0	1	0	0
1996	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	1	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	0	0	2	0	1	0
2005	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	1	0	0	0	0	0
2007	0	0	0	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	1	0
2010	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	1	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	1	0
2013	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	1	0	0	0	1	1	0
2016	0	0	0	0	0	0	1	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	0	2	0	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0	0	0	0	0

Figure B-8 F L Dickinson Farm Rappahannock River 14.6 Mi Downstream of Port Royal

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1943	0	0	0	0	0	0	0	0	0	0	0	0
1944	0	0	0	0	0	0	0	0	0	0	0	0
1945	0	0	0	0	0	0	0	0	0	0	0	1
1946	0	0	0	0	0	0	1	1	0	0	0	0
1947	0	0	0	1	0	0	0	0	0	0	0	0
1948	0	0	0	0	0	0	1	0	0	0	1	0
1949	0	0	0	0	0	0	0	0	0	0	0	0
1950	0	0	1	0	0	0	0	0	0	0	1	0
1951	0	0	0	0	0	0	0	0	0	0	0	0
1952	0	0	0	0	0	0	0	0	0	0	0	0
1953	0	0	0	0	0	0	0	0	0	0	0	0
1954	0	0	1	0	0	0	0	0	0	6	0	0
1955	0	0	0	0	0	0	0	0	0	0	0	0
1956	0	0	0	0	0	0	0	0	0	0	0	0
1957	1	0	0	0	1	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	2	0	0	0	0	0
1959	0	0	0	0	0	0	0	0	0	0	0	0
1960	0	1	0	0	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	0	0	0	0	0	0
1962	2	0	0	0	0	0	0	0	0	0	0	0
1963	0	1	0	0	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	0	0	0
1966	0	0	0	0	1	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	0	0	0	0	0	0
1968	0	0	1	0	0	1	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	1	0	0	0	0
1970	0	0	0	0	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	1	0	0
1973	0	0	0	0	0	0	1	0	0	0	0	0
1974	0	0	0	0	1	2	0	0	0	0	0	1
1975	1	0	0	0	0	0	0	1	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	1	1	0	0	0	0	0
1979	1	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1982	0	0	0	0	1	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	1	0	0	0	0
1985	1	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	1	0	0	0
1988	0	0	0	1	0	0	0	0	0	0	0	0
1989	0	0	1	0	0	0	0	0	0	0	0	1
1990	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	1	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0	1	0	0	0	0
1997	0	0	0	0	1	0	0	0	0	0	2	1
1998	0	0	0	0	0	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0	0	0	0	0	1
2000	0	0	0	0	0	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0	0	0	0	0	0
2002	0	0	0	0	0	0	0	0	0	0	0	0
2003	0	0	0	0	0	0	0	0	0	0	0	0
2004	0	0	0	0	0	0	1	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	2	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	0	0
2010	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	2	0	0	0	0	0	0
2012	0	0	0	1	1	0	0	0	0	0	1	0
2013	1	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	1	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	1	0	0	0	0	0	0
2017	0	0	0	1	0	0	1	0	0	0	0	0
2018	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0	0	0	0	0

Figure B-9 Eagle Tree Rappahannock #1, #2, #3 17.5 Mi Downstream of Port Royal (9.2 Miles Upstream of TF3.3)

Hazen

Mattaponi River Hydrologic and Salinity Analysis

Caroline County Rappahannock River Water Supply Project

September 2024

Caroline County is located within the Eastern Virginia Groundwater Management Area (EVGMA). The County currently relies on groundwater for water supply, and additional groundwater withdrawals are expected to be limited due to the regulations affecting the EVGMA. The County anticipates additional population growth and increasing water demands. The Virginia General Assembly and the Department of Environmental Quality (DEQ) have recognized that the available groundwater supplies in the EVGMA are insufficient to meet the long terms demands of current and future groundwater users.

Caroline County is pursuing a Virginia Water Protection (VWP) permit to withdraw water from the Rappahannock River. The County submitted a Joint Permit Application (JPA) for the construction of a new river intake, raw water pipeline, water treatment plant (WTP), and associated conveyance infrastructure. A preferred intake location was selected, and water demand projections were developed for Caroline County and the Town of Bowling Green. Water will be transferred to the Mattaponi River basin via effluent discharge from two existing Wastewater Treatment Plants (WWTPs).

Water withdrawn from the Rappahannock River and used within Caroline County and the Town of Bowling Green will be returned to the Mattaponi River, constituting an interbasin transfer from the Rappahannock River Basin to the York River Basin. Per 9VAC25-210-340 Part B.5., an assessment of the beneficial uses of both the source and receiving basins is required. Beneficial uses of the source basin were documented in the Joint Permit Application. The *Beneficial Use and Aquatic Life Evaluation* (September 2023)[1] describes the beneficial uses of the Rappahannock River and the Mattaponi River, and it assesses the potential impacts of additional return flows. To supplement this prior evaluation of beneficial uses of the Mattaponi River, a salinity model was performed to evaluate the possibility of changes to salinity regimes in the Mattaponi River resulting from increased return flows associated with this project.

Caroline County is providing this memorandum to support the evaluation of potential impacts to beneficial uses of the Mattaponi River in accordance with 9VAC25-210-340 Part B.5. The water quality of discharges is governed by the Virginia Pollutant Discharge Elimination System (VPDES) permits and is outside the scope of the Virginia Water Protection (VWP) permit program. This document presents the findings of the Mattaponi River salinity model, providing supplemental information to support Caroline County's Joint Permit Application.

32380-002

[1] https://webapps.mrc.virginia.gov/public/habitat/

Hazen

1. Mattaponi River Hydrologic Analysis

The Mattaponi River is a tributary of the York River that flows through Caroline County. The river's lower reach serves as the boundary between King William and King and Queen Counties. The nearest U.S. Geological Survey (USGS) flow gage on the Mattaponi River (Gage ID 01674500) is located near Beulahville, VA. Historical flows at this gage from January 1984 to July 2024 are presented in **Figure 1**. Large storm events can greatly increase flows to thousands of cubic feet per second (cfs). Extended dry periods can result in low flows under 1 cfs, which historically occurred in 1999 and 2002.

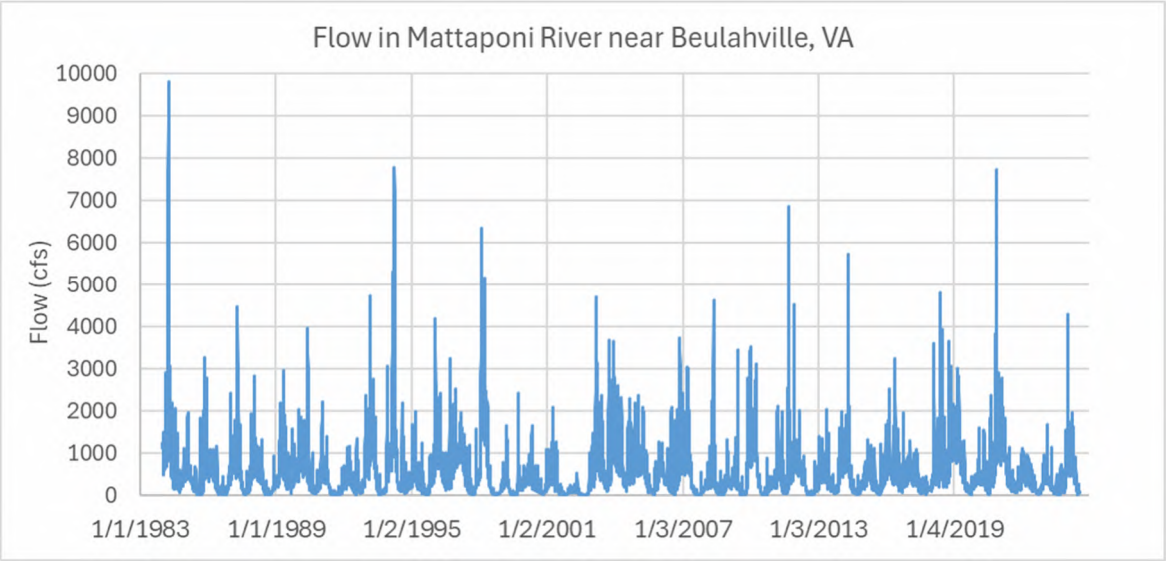


Figure 1: Mattaponi River Flow from USGS Gage 01674500

2. Mattaponi River Salinity Analysis

The Mattaponi River begins as a non-tidal stream and transitions to tidal just upstream of Aylett, VA.[2] The Mattaponi River continues for approximately 30 miles downstream of Aylett and then joins with the Pamunkey River to form the York River. The upper reach of the tidal Mattaponi River is considered tidal fresh, and the river shifts into oligohaline towards the confluence with the York River. The York River has higher salinity, and transitions from mesohaline to polyhaline. Salinity ranges for the different salinity regimes are provided in **Table 1**. A salinity of less than 500 mg/L or, equivalently, a specific conductance of less than approximately 1,000 uS/cm, was used as the threshold to categorize freshwater conditions.

[2] https://dwr.virginia.gov/waterbody/mattaponi-river/

Table 1: General Description of Salinity Ranges for Waterbodies

Salinity Regime	Salinity Range (mg/L)	Specific Conductance Range (uS/cm)
Freshwater and Tidal Freshwater	less than 500	less than 1,000
Oligohaline	500 to 5,000	1,000 to 9,000
Mesohaline	5,000 to 18,000	9,000 to 29,000
Polyhaline	18,000 to 30,000	29,000 to 46,000
Seawater	greater than 30,000	greater than 46,000

2.1 Modeling Approach

The objective of this analysis is to estimate the impact of increased return flows from the proposed Rappahannock River water supply project on salinity levels in the Mattaponi River. The modeling approach consisted of developing a relationship between freshwater inflows at each monitoring location and measured salinity; a similar modeling approach was used to evaluate the effects of the proposed withdrawal on salinity levels in the Rappahannock River (refer to the *Rappahannock River Hydrologic and Salinity Analysis*, March 2020[3]).

Data were reviewed along the length of the Mattaponi River to identify water quality monitoring locations with sufficient salinity data to support modeling efforts. Data were collected from the US National Water Quality Monitoring Council Water Quality Portal database,[4] the Virginia Institute of Marine Science (VIMS) Virginia Estuarine and Coastal Observing System (VECOS),[5] and the Chesapeake Bay Program DataHub.[6]

The following four water quality monitoring sites were identified for further analysis based on the availability of historical salinity data, and their locations are shown in **Figure 2**:

- **Aylett**: Data at this location consisted of grab samples collected by DEQ and is generally monthly since 1997.
- **Walkerton**: Data at this location consisted of grab samples collected by DEQ and is generally monthly since 1984.
- **Wakema**: Data at this location consisted of grab samples collected by DEQ since 1994.
- **Muddy Point**: Data at this location consisted of grab samples collected by DEQ and is generally monthly since 1985.

[3] https://webapps.mrc.virginia.gov/public/habitat/
[4] https://www.waterqualitydata.us/
[5] http://web2.vims.edu/vecos/
[6] https://datahub.chesapeakebay.net/



Figure 2: Map of Water Quality Monitoring Sites

The scope of this salinity analysis is focused on the freshwater transition zone in the Mattaponi River where increased return flows could influence salinity levels. Monitoring stations further upstream than Aylett were not included in this salinity analysis because the river is non-tidal and remains freshwater regardless of flow conditions; increased return flows would not affect salinity in this region. Further downstream in the York River, salinity levels are higher and directly influenced by the Chesapeake Bay. The watershed area of the York River Basin increases with the addition of 1,470 square miles[7] from the Pamunkey River Basin at the confluence with the Mattaponi River. Further, the York River salinity is significantly influenced by the Chesapeake Bay. York River salinity ranges from mesohaline (5,000 to 18,000 mg/L) in the upper reach to polyhaline (18,000 to 30,000 mg/L) at the confluence with the bay. Given the substantial increase in watershed area and higher salinity of the York River, hydrology and salinity were not evaluated in the York River.

[7] Foster, B. M., Lopez, R., Crawford, E. R., Cook, W., Krigsvold, J., Langston, J. H., ... & Jastram, J. D. (2024). Characterization of the water resources of the Pamunkey River watershed in Virginia—A review of water science, management, and traditional ecological knowledge. Scientific Investigations Report, (2024-5024).

2.2 Baseline Salinity Levels

The VIMS VECOS data include water quality sampling cruises, referred to as dataflow, that collect water quality data along a length of the river over a few hours. For the Mattaponi River, these cruises began at the mouth of the Mattaponi River at the Lord Delaware Bridge in West Point and finished in the upper tidal reach about 800 feet past the Rt 360 bridge at Aylett. These data were not used in the development of the river salinity model, but they were used to understand the transition from fresh to brackish water along the length of the river during different hydrologic conditions. **Figure 3** presents salinity levels along the length of the Mattaponi River under average and low flow conditions.

- **Low River Flow Conditions** – On October 5, 2005, the flow at the USGS gage was 21.3 cfs, which is the 3rd percentile meaning that 97% of the time the flow is greater.
- **Average River Flow Conditions** – On May 11, 2005, the flow was 345 cfs which is the 52nd percentile, representing average conditions. that during the dry conditions on October 5, 2005, salinity moved further upstream than it was on May 11, 2005 when there was greater freshwater flow. Specifically, at Muddy Point, a freshwater flow increase of 324 cfs decreased the salinity by approximately 84%.

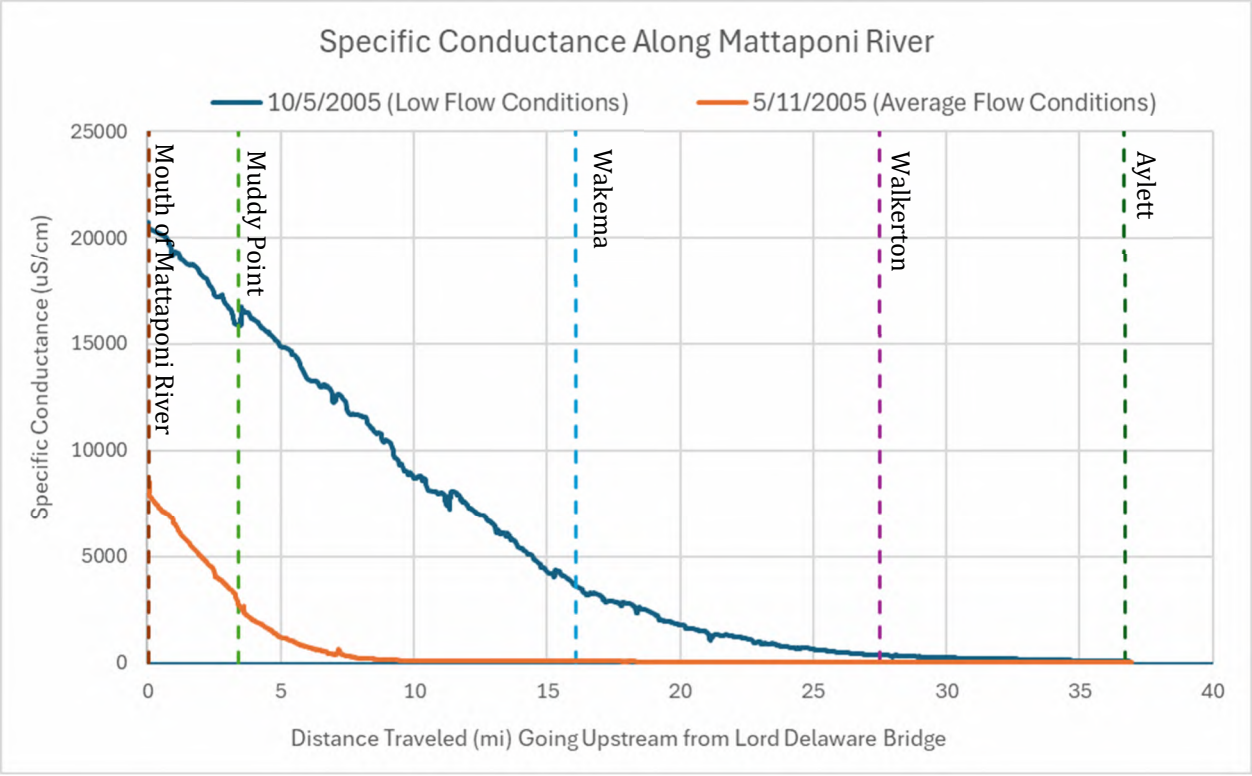


Figure 3: VIMS VECOS Mattaponi River Dataflow Observations for Specific Conductance

These naturally-occurring variations in freshwater flow rates significantly affect salinity level in the Mattaponi River. By contrast, the estimated return flows associated with this project are minimal.

The following subsections describe the baseline salinity levels in the Mattaponi River based on historical data at each primary water quality monitoring station.

2.2.1 Aylett

Specific conductance measurements at Aylett are shown in **Figure 4**. The median conductance is 61 uS/cm. All values are below the freshwater threshold of 1,000 uS/cm, even during 1999 and 2002 when extended dry periods resulted in low flows. No further analysis was conducted for this location because increased freshwater flows resulting from the County's discharge would not affect the tidal freshwater status at this location.

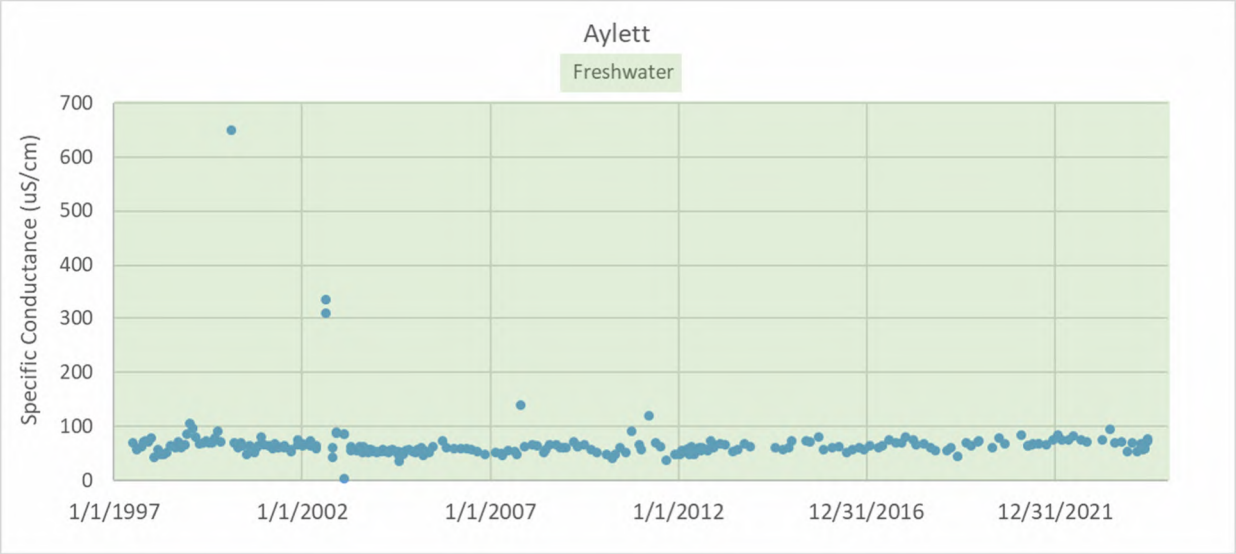


Figure 4: Specific Conductance at Aylett Monitoring Station

2.2.2 Walkerton

Figure 5 shows specific conductance measurements at Walkerton. The median conductance is 64 uS/cm, indicating that flow is typically freshwater at this location. The location is classified as tidal freshwater per VIMS VECOS. However, in 2002, some conductance values surpassed 4,000 uS/cm. Additional analysis was conducted at this location to determine the influence of the County's discharge to the river (see Section 2.2).

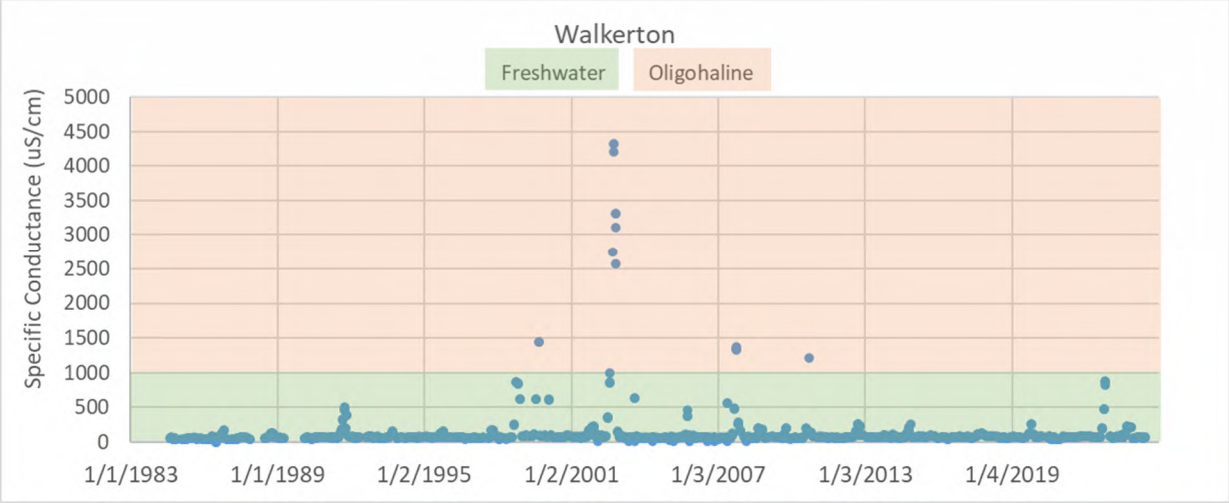


Figure 5: Specific Conductance at Walkerton Monitoring Station

2.2.4 Wakema

Specific conductance measurements at Wakema are shown in **Figure 6**. The median conductance is 99 uS/cm, so flow is also typically freshwater at this location. However, there are many measurements of conductance values exceeding the freshwater threshold, with values as high as 13,000 uS/cm. Wakema is classified as oligohaline per VIMS VECOS. Additional analysis was conducted at this location to determine the influence of the County's discharge to the river (see Section 2.2).

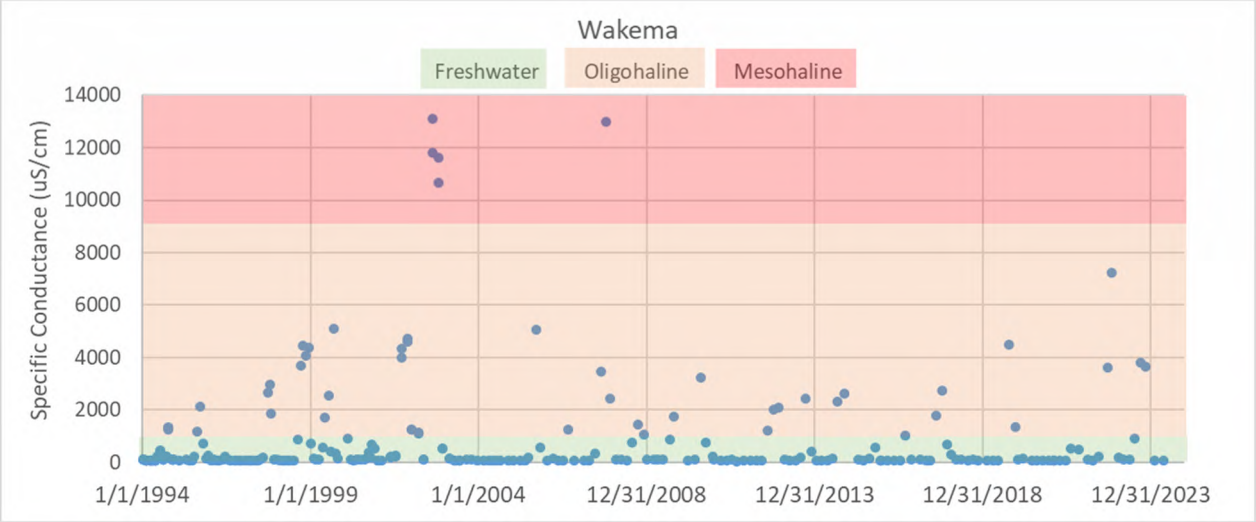


Figure 6: Specific Conductance at Wakema Monitoring Station

2.2.5 Muddy Point

Muddy Point is classified by VIMS VECOS as oligohaline, but salinity levels frequently reach the mesohaline range. The station is located about five miles upstream of the York River, which is classified as mesohaline to polyhaline. **Figure 7** depicts specific conductance measurements at Muddy Point that range from 58 to 30,000 uS/cm with a median of 6,500 uS/cm. Specific conductance at this location is frequently high, even outside of drought years (e.g., 1999 and 2002) when freshwater flow was greatly reduced. Additional analysis was conducted at this location to determine the influence of the County's discharge to the river (see Section 2.2).

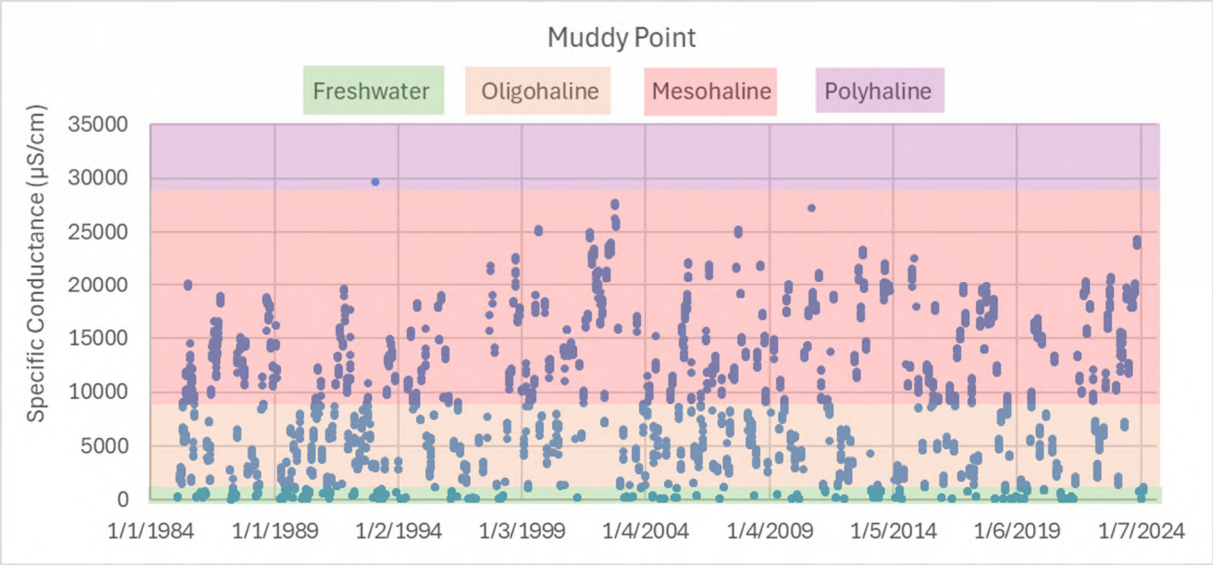


Figure 7: Specific Conductance at Muddy Point Monitoring Station

2.3 Salinity Model Development

Stream flow data were compared to specific conductance measurements to identify the relationship between flow and salinity at select locations along the tidal Mattaponi River. As noted previously, Aylett remains freshwater regardless of flow, so no analysis was conducted for this location. If multiple specific conductance measurements were collected on the same day, then they were averaged to create one daily value.

Flow data from the USGS gage was scaled by watershed area to estimate flows at the monitoring station locations. The USGS gage has a drainage area of 603 square miles. USGS StreamStats[8] was used to estimate drainage areas of 745, 819 and 878 square miles for Walkerton, Wakema and Muddy Point, respectively. Therefore, flow at Walkerton was estimated as equal to 1.235 (i.e., 745/603) times the flow at the USGS gage #01674500, flow at Wakema was estimated as equal to 1.358 (i.e., 819/603) times the flow at the USGS gage, and flow at Muddy Point was estimated as equal to 1.456 (i.e., 878/603) times the flow at the USGS gage.

Specific conductance was compared to daily, weekly, and 30 day rolling average scaled flows. The 30-day averages were found to result in the best fit of the models, so these flows were selected for the final models. By taking flow averages, short-term variability from sudden peaks in flow from storm events was reduced.

For Caroline County's Rappahannock River water supply project, the estimated average return flow discharge rate for the year 2038 is 5.6 mgd (8.66 cfs) with the proposed withdrawal in place. An analysis

[8] https://streamstats.usgs.gov/ss/

of estimated consumptive use and return flows is presented in the *Beneficial Use and Aquatic Life Evaluation* (September 2023).

2.4 Salinity Model Results

The following subsections present the salinity model results for each primary water quality monitoring station on the Mattaponi River. The chosen models were used to estimate specific conductance based on daily historical flows going back to 1984 (baseline conditions) and under the conditions with a return flow of 8.66 cfs (projected conditions). The number of days above and below the freshwater threshold were compared between the baseline condition and with the proposed additional flow as a metric for the potential change in salinity in the river at the following locations.

2.4.1 Walkerton

Figure 8 presents the flow and specific conductance data at the Walkerton monitoring station. Flows above 250 cfs were always below the freshwater threshold, so they were not considered in the model to improve the fit of the data.

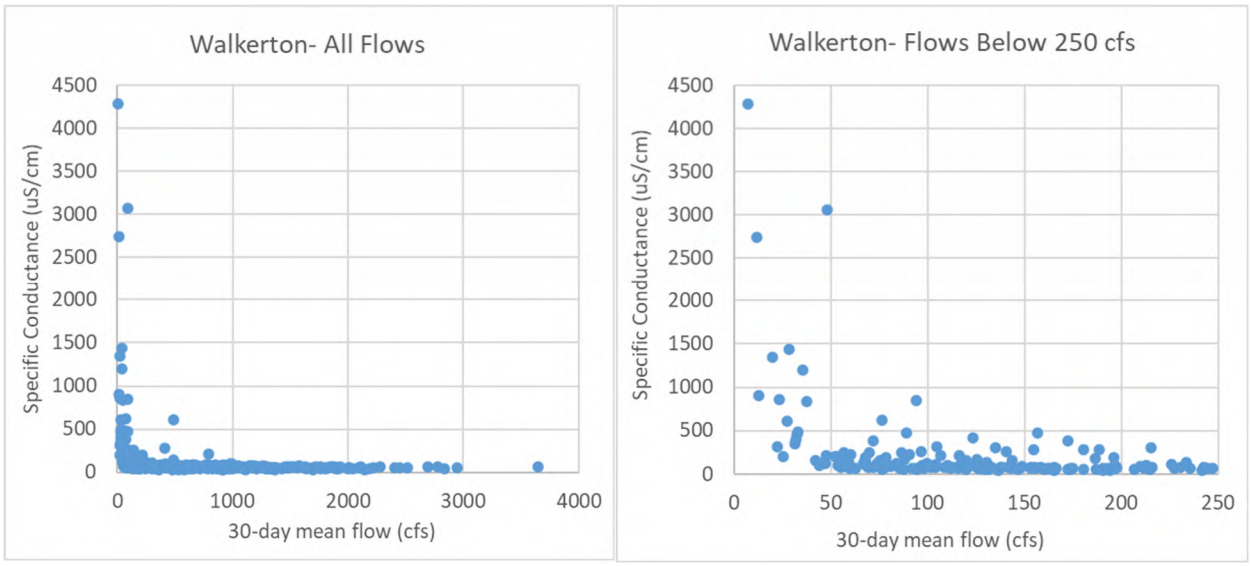


Figure 8: Walkerton Station Specific Conductance vs Flow

The following equation fits the data for flow values below 250 cfs with an R-squared of 0.60:

$$\text{Specific Conductance} = 11{,}138\ (\text{30-day average flow})^{-0.985}$$

Figure 9 shows the measured specific conductance values along with the modeled values corresponding to the same days as the measured values for the Walkerton monitoring station.

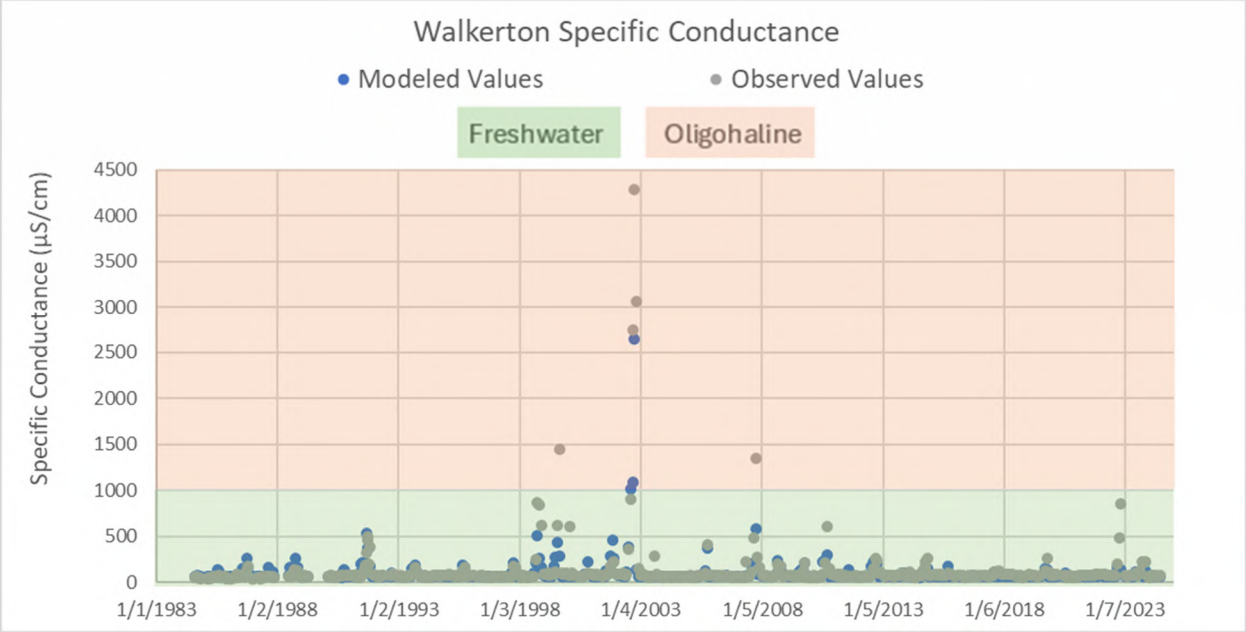


Figure 9: Walkerton Measured vs Modeled Specific Conductance

Comparing the model over the entire 40-year historical hydrologic record, baseline conditions resulted in an estimated 0.3% of days (45 days) above the freshwater threshold at Walkerton. This value is reduced to almost 0% (3 days) under the proposed conditions as shown in **Figure 10**. Therefore, the additional return flows would have a minimal effect on salinity levels at Walkerton.

The Walkerton monitoring station is in the freshwater tidal zone of the Mattaponi River. The additional discharges from Caroline County would support the freshwater tidal zone by providing additional low-salinity water that reduces the incursion of high-salinity water from further downstream during low flow conditions. This would have a slight effect of preserving freshwater conditions in this region of the river.

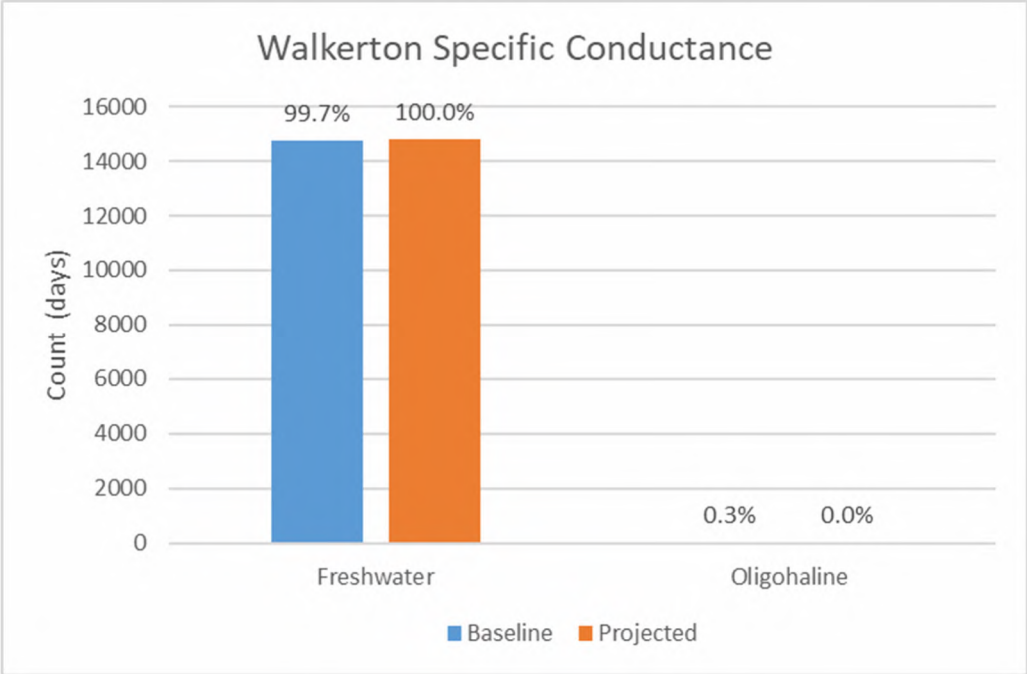


Figure 10: Walkerton Estimated Specific Conductance Under Baseline and Proposed Conditions

2.4.2 Wakema

Figure 11 presents the flow and specific conductance data at the Wakema monitoring station. All historical flow data were considered in the model. The following equation fits the data with an R-squared of 0.62:

$$\text{Specific Conductance} = 237{,}890\ (\text{30-day average flow})^{-1.159}$$

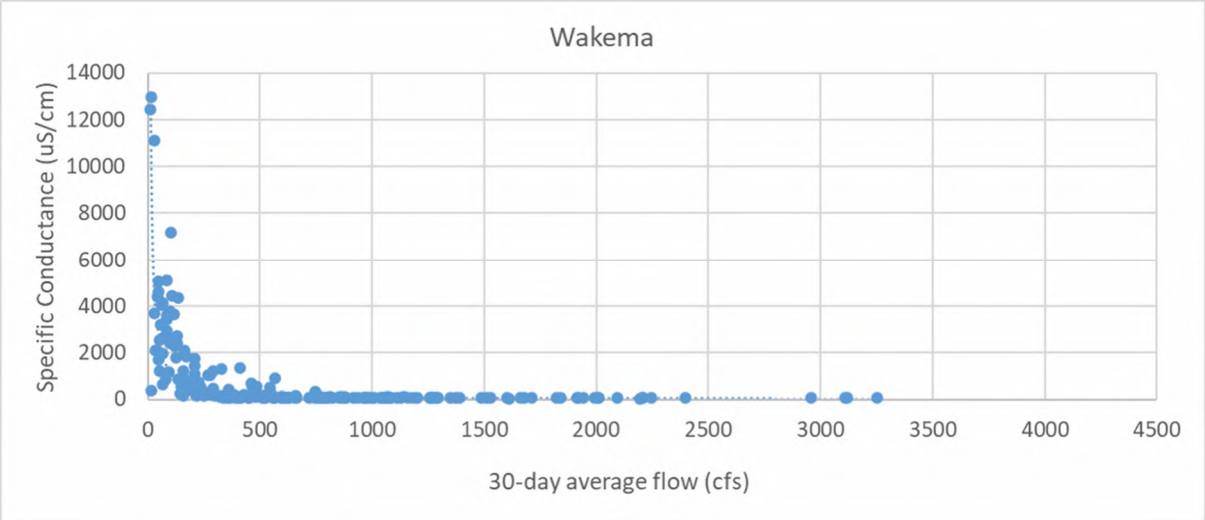


Figure 11: Wakema Station Specific Conductance vs Flow

Figure 12 shows the measured specific conductance values along with the modeled values corresponding to the same days as the measured values for the Wakema monitoring station.

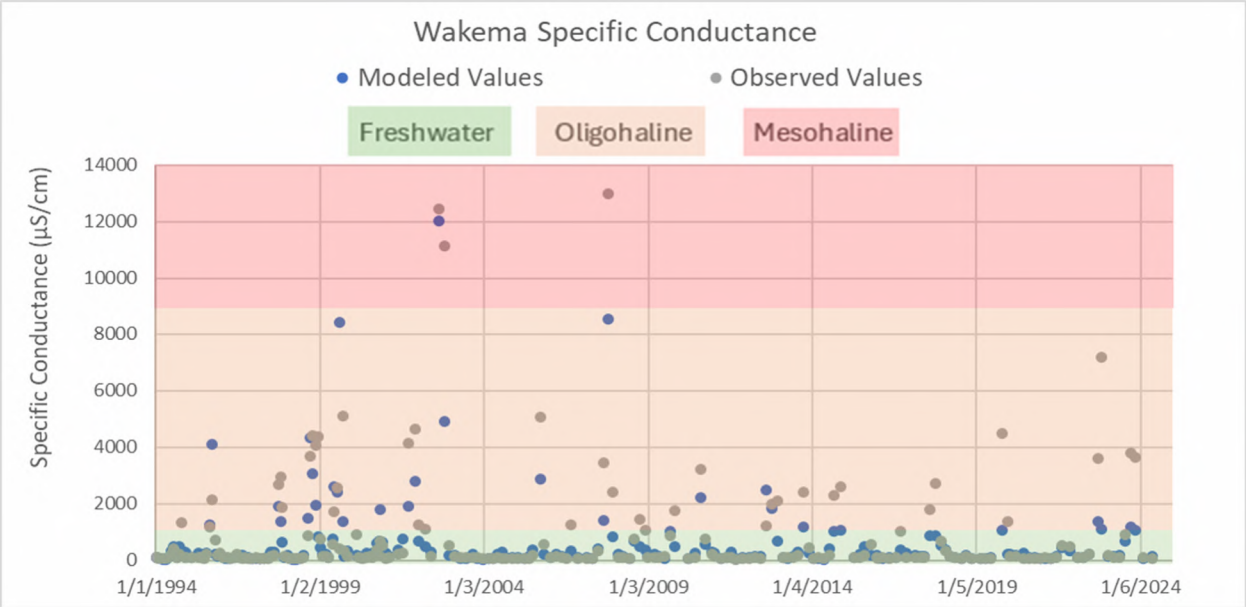


Figure 12: Wakema Measured vs Modeled Specific Conductance

Comparing the modeling over the 40-year historical hydrologic record, baseline conditions resulted in an estimated 12.1% of days above the freshwater threshold (11.4% as oligohaline and 0.7% as mesohaline); this percentage is reduced to 11.1% (11.0% as oligohaline and 0.1% as mesohaline) under the proposed conditions as shown in **Figure 13**. Specific conductance values under baseline conditions range from 12 to 20,800 uS/cm with a median value of 163 uS/cm. With the additional discharge flow, the estimated range of specific conductance values is 12 to 13,500 uS/cm with a median value of 160 uS/cm.

The Wakema monitoring station is in the oligohaline zone of the Mattaponi River, which is defined by salinity in the range of 1,000 to 9,000 uS/cm. While salinity would be reduced by 151 days over the 40-year modeling period (i.e., approximately 4 days per year) from above to below the freshwater zone, this limited change would have no effect on the salinity regime in this section of the river.

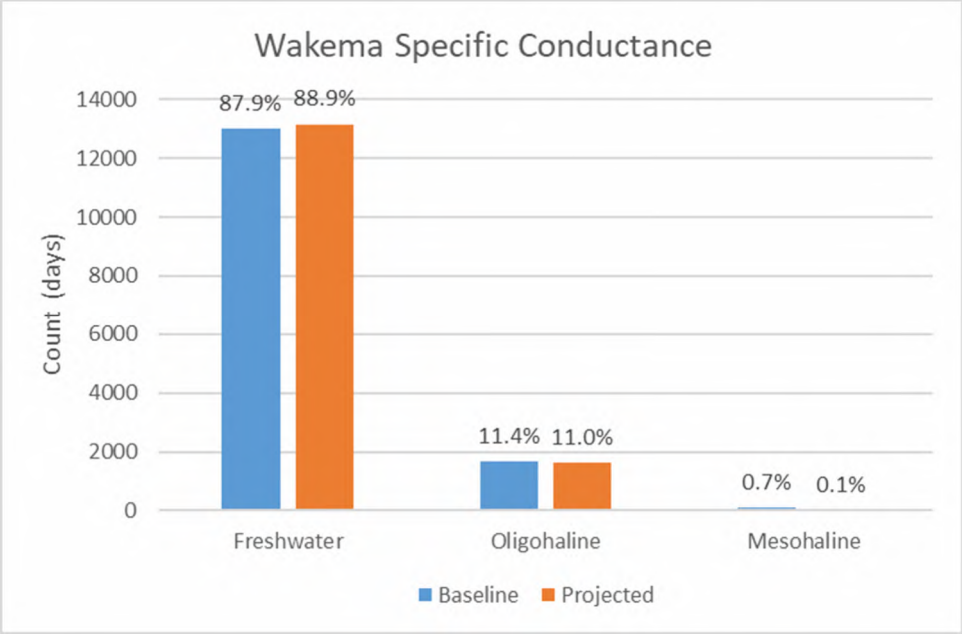


Figure 13: Wakema Estimated Specific Conductance Under Baseline and Proposed Conditions

2.4.3 Muddy Point

Figure 14 presents specific conductance versus flow at the Muddy Point monitoring station location. The relationship between flow and conductivity at this location is less defined, and there is substantially more variability in the historical salinity observations. Salinity at this location is predominantly above the freshwater threshold of 1,000 uS/cm. Salinity levels were within the freshwater zone only when river flows were sustained above 4,000 cfs. The approximately 8.66 cfs of return flow from the County's WWTP is unlikely to have a measurable effect on salinity at this location. Therefore, a model was not developed at this location.

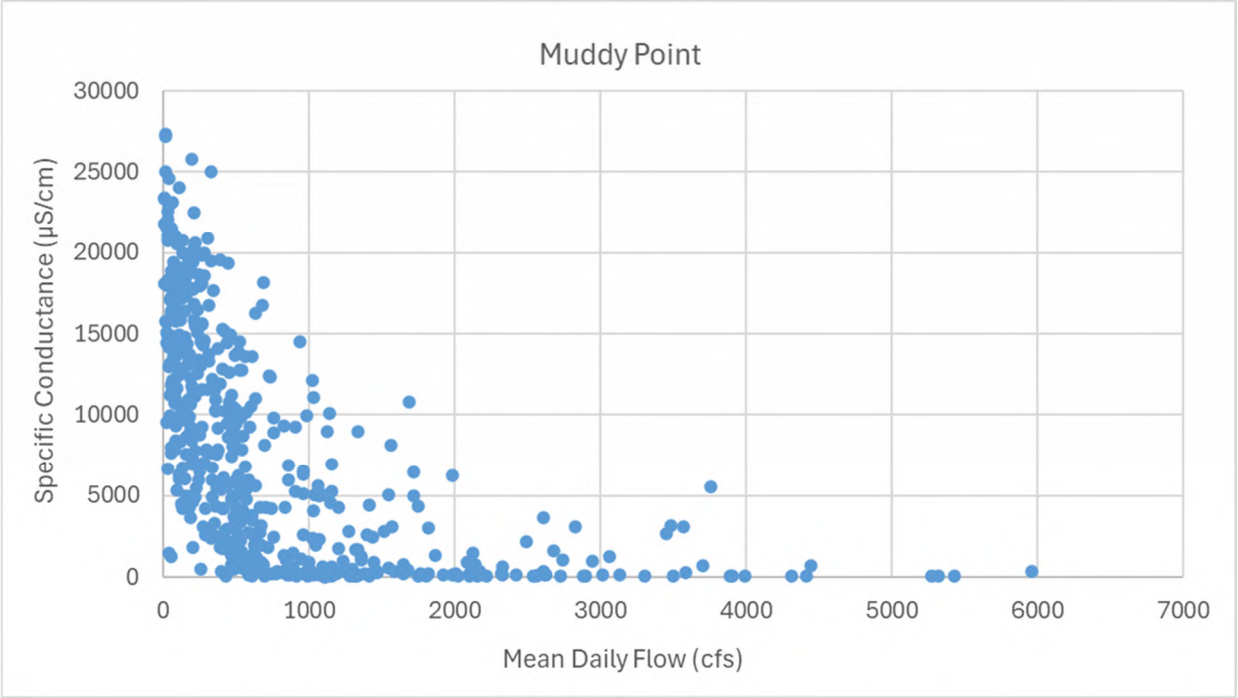


Figure 14: Muddy Point Station Specific Conductance vs Flow

3. Flooding Risk Evaluation

At the closest USGS flow gage (#01674500) near Beulahville, VA, flood categories of action and minor flooding are defined at stage values of 16 ft and 20 ft, respectively. According to the current USGS stage-discharge rating for the gage, these stage values correspond to discharges of 4,088 cfs and 8,350 cfs, respectively. The proposed average discharge rate for the year 2038 is 5.6 mgd (8.66 cfs) – equivalent to only 0.1% to 0.2% of the river flow at flood stage. Hence, the proposed additional flow will have no observable impact on flood conditions in times of high flow.

Additional details on the volumetric flow impacts of the additional return flows on the Mattaponi River and Polecat Creek are presented in the *Beneficial Use and Aquatic Life Evaluation* (September 2023).

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4. Conclusion

The Rappahannock River Water Supply Project is expected to increase return flows to the Mattaponi River as overall water use in Caroline County increases. This evaluation of salinity levels was performed to support the evaluation of beneficial uses of the Mattaponi River. Key findings and conclusions regarding the effects of the increased return flows on salinity levels in the Mattaponi River include the following:

- Salinity levels in tidal portions of the Mattaponi River between Aylett and Muddy Point range from freshwater to mesohaline, and salinity levels vary significantly depending on natural variations in freshwater flows.
- Salinity levels in the Mattaponi River would not change appreciably with the estimated discharge rates for Caroline County's proposed water supply project. The model indicates that the estimated return flows would not change the salinity regimes within the Mattaponi River.
- Return flows associated with the Rappahannock River water supply project are small relative to the natural range of freshwater stream flows. During periods of high streamflow, the estimated return flow is approximately 0.1% to 0.2% of the natural Mattaponi River flow. The additional return flows would have minimal effect on river hydrology.
- Any change in salinity levels in the Mattaponi River would be towards maintaining freshwater conditions, which would not contribute to salinity stress on freshwater wetlands or aquatic species in the freshwater tidal zone, helping to preserve this sensitive habitat and protect other beneficial uses.
- The proposed additional discharge flows are much smaller than total flows during times of flooding, so the effects on flooding risk are negligible.

The results of this analysis indicate that no significant impacts to hydrology or salinity levels in the Mattaponi River are expected as a result of the Rappahannock River Water Supply Project.

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5. References

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Beneficial Use and Aquatic Life Evaluation

Caroline County Rappahannock River Water Supply Project

May 2025

1. Introduction

Caroline County seeks to develop a new water supply source on the Rappahannock River that will include construction of a new water intake, a raw water pump station, a raw water pipeline, a water treatment plant (WTP), and a finished water pipeline connecting the WTP to the County's existing distribution system. Water withdrawn from the Rappahannock River will be conveyed to consumers in Caroline County (including the Town of Bowling Green and the Town of Port Royal). For the majority of current and anticipated water consumers in Caroline County, water will be returned to the wastewater treatment plants located in Caroline County that discharge to the Mattaponi River basin. As shown in **Figure 1-1**, the County's existing wastewater treatment plant is located on Polecat Creek, a tributary to the Mattaponi River, and the Town of Bowling Green's wastewater treatment plant discharges to the Mattaponi River. As a result, a net transfer of water from the Rappahannock River basin to the Mattaponi River basin is anticipated.

This memorandum presents an assessment of beneficial uses of the Rappahannock River (withdrawal basin) and Mattaponi River (receiving basin). The assessment considers river flow impacts, instream beneficial uses, and offstream beneficial uses. In addition, this memo presents an analysis of consumptive water loss (i.e., water withdrawn and not directly returned to a surface water source) and estimated transferred flows discharged to the Mattaponi River.

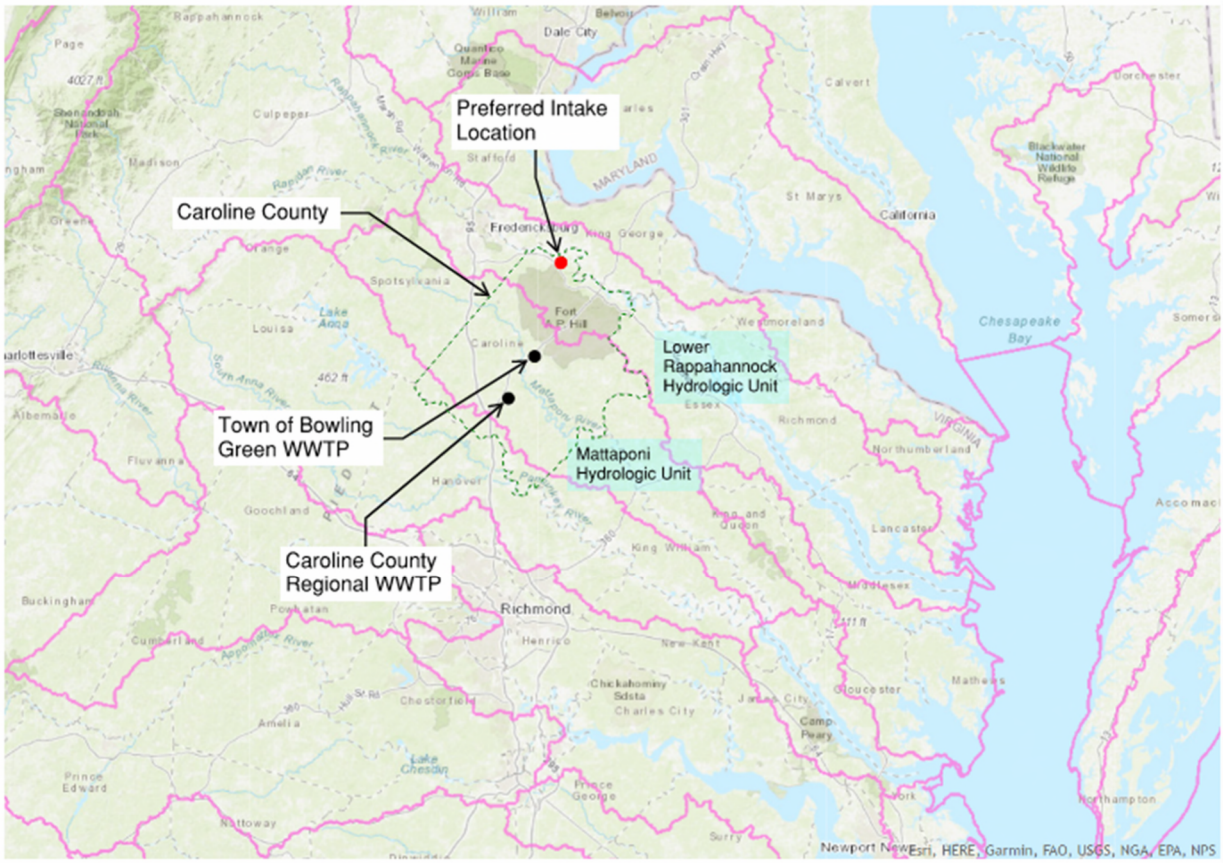


Figure 1-1: Regional Map Showing Hydrologic Units
(Adapted from Virginia Hydrologic Unit Explorer)

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2. Beneficial Uses and Aquatic Life of the Rappahannock River

An analysis of the existing uses of the Rappahannock River was conducted as part of planning for the proposed construction and operation of a raw water intake. The Rappahannock River provides public water supply, irrigation water supply, serves as a cultural and aesthetic resource, and supports aquatic habitat and resources. This section describes the instream and offstream beneficial uses of the river.

To minimize impacts on the Rappahannock River during construction, the raw water intake pipe entering the river will be constructed using tunneling construction techniques with limited disturbance from temporary installation of a cofferdam, which limits the potential for impacts to beneficial uses of the river. As described in the following subsections, installation and operation of the proposed raw water intake in the Rappahannock River is not anticipated to have a significant negative impact on the existing and post-construction flow-dependent instream or off-stream beneficial uses along the affected stream reach.

2.1 Public Water Supply

The proposed water withdrawal from the Rappahannock River will be used to meet the water supply demands of Caroline County. Caroline County is located within the Eastern Virginia Groundwater Management Area (EVGMA) and is currently reliant on groundwater resources to meet its needs for drinking water. The available groundwater supplies in the EVGMA are insufficient to meet the long term demands of current and future groundwater users; therefore, Caroline County is proposing a new withdrawal from the Rappahannock River. Caroline County proposes to withdraw an average daily withdrawal of 5.1 mgd and maximum daily withdrawal of 9.0 mgd.

The nearest existing public water supply intake on the Rappahannock River is for the City of Fredericksburg, which is located on the Rappahannock River upstream of Caroline County. No public water supply intakes are located downstream of the preferred intake site. Therefore, the project will not impact existing public water supplies.

2.2 Cultural Resources

The Rappahannock River is classified by the Virginia Department of Conservation and Recreation (DCR) as a Scenic River from its headwaters to the Lancaster County line, as depicted on the Virginia Outdoors Plan mapper. Vegetation along the slope of the riverbank will not be removed or disturbed as part of this project, and the existing vegetated buffer area along the river will be maintained. The intake screens and raw water pipes will be submerged in the river and will not be visible to recreational users or other boaters on the river, or visible from the banks of the river. The aid to navigation marker will be visible in the river. Therefore, changes to the current aesthetics and aesthetic experience of the river from implementation of this project will be negligible.

The Phase IA survey of archaeological and architectural resources identified three architectural resources within a 500-foot buffer of the intake parcel that are eligible or potentially eligible for listing with the

National Register of Historic Places (NRHP). However, the intake is proposed to be constructed at the center of the 25-acre parcel along the river, which increases the buffer distance by 500 to 1,000 feet from these resources. The Phase IA survey found no archaeological resources in the project area; however, a Phase IB survey was recommended. The results of the Phase IB survey identified one archaeological site consisting of a scatter of lithic debitage dating to an unknown prehistoric period. As a result of the site's low artifact density and disturbance of the deposits by plowing, the site was determined to be not eligible for inclusion in the NRHP. Therefore, the project is not expected to adversely affect architectural or archaeological resources in the vicinity of the Rappahannock River. Refer to the Historical and Archaeological Evaluation (Attachment E of the JPA) for additional information on cultural and historic resources within the project area.

2.3 Aquatic Habitat and Resources

Aquatic species of concern that are known or likely to be within a two-mile radius of the proposed intake site are presented in **Table 2-1**, as identified by the Virginia Department of Wildlife Resources (DWR) Fish and Wildlife Information Service (VaFWIS). The species list is based on review of the VaFWIS database on August 17, 2023.

Table 2-1: VaFWIS Aquatic Species Designated for Conservation Known or Likely to Occur within a 2-mile Radius of the Caroline County Raw Water Intake Site

Common Name	Scientific Name	Conservation Status	VA Wildlife Action Plan Tier*
Atlantic sturgeon	*Acipenser oxyrinchus*	Federal Endangered; State Endangered	I
Dwarf wedgemussel	*Alasmidonta heterodon*	Federal Endangered; State Endangered	I
Yellow lance	*Elliptio lanceolata*	Federal Threatened; State Threatened	II
Spotted turtle	*Clemmys guttata*	Collection Concern	III
Bridle shiner	*Notropis bifrenatus*	None Listed	I
Yellow lampmussel	*Lampsilis cariosa*	None Listed	II

*Tier I – Critical Conservation Need; Tier II – Very High Conservation Need; Tier III – High Conservation Need

Descriptions of federally protected species identified in the project area, including the Atlantic sturgeon, dwarf wedgemussel, and yellow lance, are included in Attachment D of the JPA. The analysis for these species concludes that no impacts are anticipated as a result of operation of the intake to these three species. Time of year restrictions for construction activities can be implemented to further reduce the potential for impacts to Atlantic sturgeon, if warranted.

DWR noted that the segment of the Rappahannock River in which the intake is located is known to be highly productive for freshwater mussels, particularly for alewife floaters and tidewater muckets. The green floater may also be present in the project area. However, these specific mussel species are not currently listed by VaFWIS as known or likely to occur within a two-mile radius of the intake site, as of August 17, 2023. The effects of construction and operation of the proposed intake on fish and mussels in the Rappahannock River are expected to be minimal due to the limit on flow velocities and limited area required for construction of the intake.

River herring, including alewife and blueback herring, are migratory fish that spend most of their lifecycle in the marine environment, returning every four to five years to their natal rivers to spawn. River herring typically spawn in the spring. Potential impacts of the intake on fish eggs and larvae are determined by the size of the openings in the intake screen and the velocity of the intake. The intake screens will be designed according to industry best practices with a wedge-wire design, a slot opening width of 1 millimeter, and a maximum through-slot velocity of 0.25 feet per second during maximum instantaneous withdrawal conditions.

Table 2-2 includes species with Essential Fish Habitat (EFH) designations in the project area per the National Ocean and Atmospheric Administration's (NOAA) Essential Fish Habitat Tool (Tool), most recently reviewed on August 17, 2023. The intake screen size and velocity will limit impacts to aquatic life in the project area.

Table 2-2: Species with Essential Fish Habitat (EFH) Designations in the Project Area

Common Name	Scientific Name
Atlantic herring	*Clupea harengus*
Red hake	*Urophycis chuss*
Clearnose skate	*Raja eglanteria*
Windowpane flounder	*Scophthalmus aquosus*
Bluefish	*Pomatomus saltatrix*
Summer flounder	*Paralichthys dentatus*

An Ichthyoplankton Impact Analysis was prepared by Versar in February 2010 in the Rappahannock River in the vicinity of the proposed intake location. **Table 2-3** summarizes the species and life stages found during the study. The screen size and intake velocity of the proposed project have been designed to minimize impacts on these species (Gowan and Garman, 2002).

Table 2-3: Predominant Ichthyoplankton Species and Life Stages Found in the Rappahannock River Near Caroline County's Proposed Intake - Spring 2007*

Species	Life Stages[1]
Yellow perch	YS, PS
American shad	EG, YS, PS
River herring	EG, YS, PS
Hickory shad	EG, YS, PS
Gizzard shad	EG, YS, PS
Unknown alosid	YS, PS
Striped bass	YS, PS
White perch	EG, YS, PS

[1] EG = egg; YS = yolk sac larvae; PS = post yolk sac larvae
*From the Caroline County Water Intake - Ichthyoplankton Population Impact Analysis; Prepared by Versar; Revised February 2010

To further evaluate the potential for impacts to ichthyoplankton in the Rappahannock River, the County contracted with the Virginia Institute of Marine Science (VIMS) to conduct a hydrodynamic model of the Rappahannock River (Qin et al, 2023). VIMS developed a fine-resolution model to simulate tidal flow and larval transport processes in the Rappahannock River. The model evaluated hydrodynamic conditions (i.e., flow currents and water exchange) and impacts of intake on ichthyoplankton transport and the living resources in the river. VIMS used a particle tracking model to simulate fish egg and larval movement and

to evaluate probabilistic increases of mortality due to the intake under different hydrological conditions. The VIMS model concluded that the maximum daily removal of modeled particles (representing ichthyoplankton) was less than 0.15% and that the intake would have “low impacts” on ichthyoplankton in the river. The VIMS model concluded that the withdrawal "does not have significant impacts on the hydrodynamics in the Rappahannock River.”

2.4 Agricultural Uses

The tidal freshwater portion of the Rappahannock River is currently used for agricultural irrigation. The Virginia State Water Resources Plan (DEQ, 2022) describes agricultural withdrawals in the Rappahannock River basin. Salinity levels in the river potentially affect agricultural uses. Attachment G “Rappahannock River Hydrologic and Salinity Analysis” includes an analysis of modeled salinity changes in the river and a focused review of salinity levels at locations of known agricultural withdrawals (based on information provided by DEQ). The analysis indicates there will be a negligible change in the number of days with elevated salinity, which will not result in significant effects on the river’s use for agricultural purposes such as irrigation. In addition, results of the hydrodynamic model of the Rappahannock River performed by VIMS concluded the withdrawal "does not have significant impacts on the hydrodynamics in the Rappahannock River". As a result, the withdrawal is not expected to have adverse effects for agricultural uses of the river.

2.5 Recreation

The Rappahannock River is used for recreational paddling, fishing, and boating. The proposed intake is located within the Rappahannock River Water Trail. The river intake structure will be clearly marked as required by the U.S. Coast Guard for recreational safety. The proposed intake structure will not alter the recreational use of the river.

2.6 Navigation

The Rappahannock River is used by recreational boaters. The intake structure will be located below the water surface in the river and will be marked by signage as required by the U.S. Coast Guard. The Rappahannock River is fed by a large drainage basin with substantial flow. The river is 10 to 25 feet deep in the location of the preferred intake site, as determined through the bathymetric survey conducted in 2018. As the river at the intake location is tidal, water withdrawals will not affect the water depth in the river, which is controlled by tidal influence. Therefore, the proposed project is not anticipated to alter or adversely affect recreational navigation.

2.7 Aesthetic Value

The aesthetic value of Rappahannock River derives from the forests and marshes that flank the waterways, providing natural scenery and wildlife viewing opportunities. The water withdrawal from the Rappahannock River is not anticipated to impact the rates or pattern of erosion, water surface elevations, and aesthetic value of the basin. As the river flow rate will be within normal range of natural fluctuations

of the river flows, erosion rates and water surface elevations will remain within the river's normal range and will therefore not alter the natural beauty of the river through degradation of the channel.

2.8 Waste Assimilation

Several wastewater treatment plants discharge to the Rappahannock River upstream and downstream of the preferred intake site (refer to Attachment M of the JPA), and the river provides beneficial dilution and waste assimilation. The withdrawal is not expected to impact the overall ability of the river to dilute and/or assimilate wastewater discharges.

3. Transfer of Water to the Mattaponi River Basin

Water withdrawal from the Rappahannock River will be conveyed and distributed to consumers in Caroline County before flowing to the Mattaponi River basin. The majority of existing and anticipated water demands to be supplied by this project are primarily located in the western portion of the County and in the Town of Bowling Green. Non-consumptive water use in this area will be transferred to the Mattaponi River basin via wastewater treatment plants (WWTPs) owned and operated by Caroline County and the Town of Bowling Green.

This section presents an analysis of consumptive use and transferred flows to the Mattaponi River. In addition, this section describes Mattaponi River flow impacts.

3.1 Consumptive Loss and Transfer of Flows

To estimate future transferred flows to the Mattaponi River basin associated with the Rappahannock River Water Supply Project, existing water demand data, future water demand projections and consumptive losses were analyzed. The preferred raw water intake site is located on the Rappahannock River in the northeastern portion of Caroline County. Water will be transferred to the Mattaponi River basin via effluent discharge from the WWTPs. The Caroline County Regional Wastewater Treatment Plant (WWTP) is located in the southwestern portion of the County and discharges to Polecat Creek, which flows into the Mattaponi River approximately 5 miles east of the WWTP. The Town of Bowling Green WWTP discharges to an unnamed tributary of the Mattaponi River, eventually flowing into the Mattaponi River approximately 1 mile west of the Caroline County WWTP. The locations of each WWTP, as well as the preferred Rappahannock River intake location and nearby USGS monitoring gages are shown in **Figure 3-1.**

Existing flows to the Mattaponi River Basin were estimated based on the Caroline County Regional WWTP and the Town of Bowling Green WWTP permitted capacities of 1.5 and 0.25 mgd, respectively. Caroline County and the Town of Bowling Green will apply for new discharge permits in the future as the plants are expanded in order to remain protective of water quality in the basin.

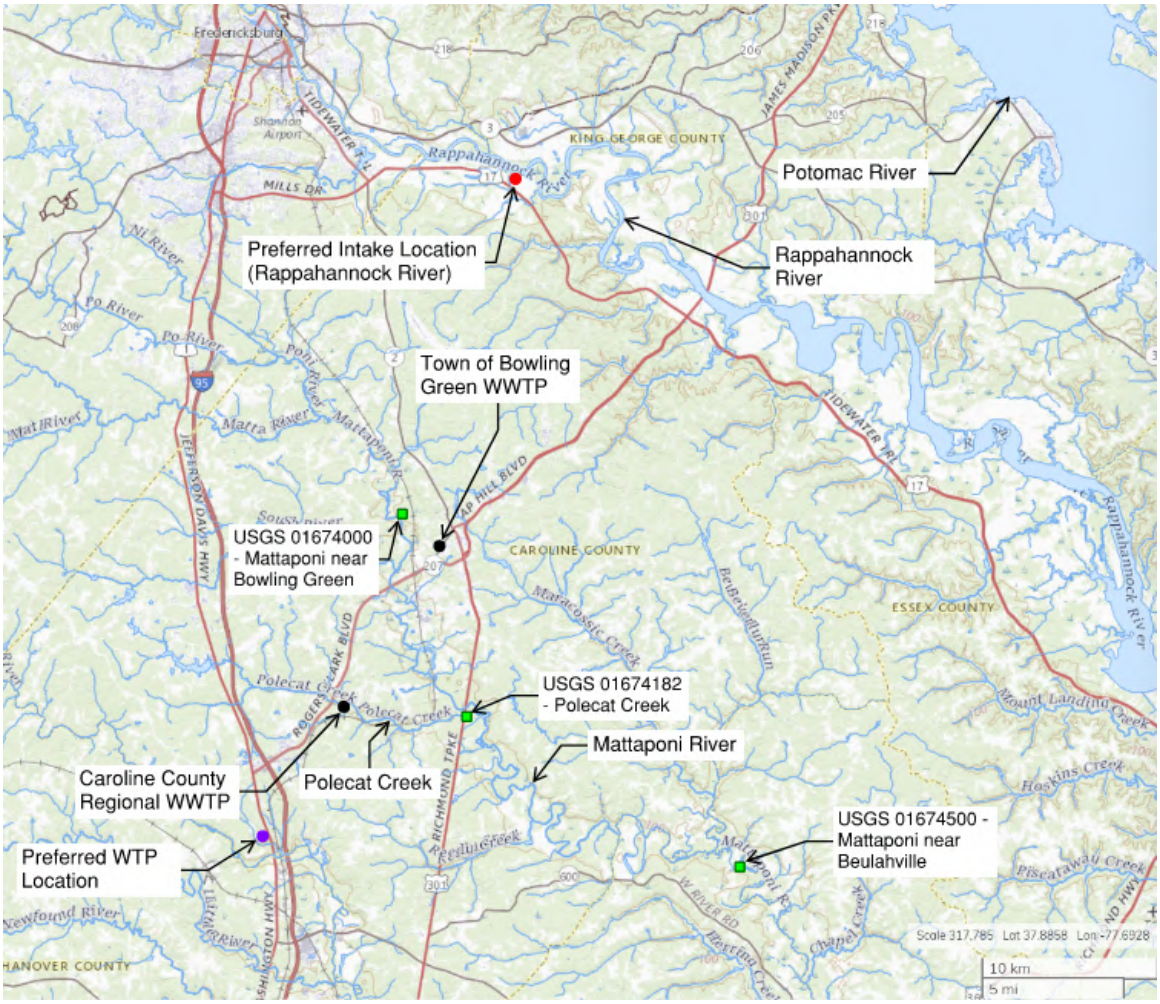


Figure 3-1: Locations of Water Withdrawal and Discharge Locations

Future water demand projections were examined based on the Caroline County Water Master Plan and presented in the *Summary of Water Demand Projections* memorandum (December 2024). To estimate future transferred flows discharged to the Mattaponi River basin, consumptive water loss was estimated for water uses in the County. Consumptive loss represents the percentage of the water withdrawn from the Rappahannock River that is consumed (e.g., evaporation, transpiration, incorporated into products or crops, consumed by humans or animals, or otherwise removed from the immediate water environment) and therefore does not contribute to additional discharge to the Mattaponi River basin. Examples of consumptive uses include irrigation, residents served by septic systems, and outdoor water use such as washing of cars or watering of plants. **Table 3-2** summarizes the water demand projections for the 15-year permit term.

Table 3-2: Water Demand Projections and Withdrawal Rates

Category	Flow Rate (mgd)
Caroline County: [1]	
Caroline County total average day water demand	4.4
Caroline County total average day withdrawal	4.6
Caroline County total max day withdrawal	8.1
Town of Bowling Green:	
Town of Bowling Green average day water demand	0.5
Town of Bowling Green average day withdrawal	0.5
Town of Bowling Green max day withdrawal	0.9
Total Withdrawals: [2]	
Total average day withdrawal	5.1
Total maximum day withdrawal	9.0

[1] Caroline County water demand projections include the Town of Port Royal.
[2] Water withdrawals include a 5% increase to account for water treatment plant process water.

To estimate the consumptive use in the County's water system, groundwater well production records, monthly customer meter data, and Polecat Creek WWTP flow rate data were analyzed. **Table 3-3** summarizes average flow rates for the County's water system from 2022 through 2024. Approximately 8% of the water supplied to the system is lost due to leaks and other unmetered losses, contributing to consumptive loss. Overall, the flow rate returned to the WWTP is approximately 20.3% less than the flow rate supplied into the distribution system. During the summer, consumptive use rates up to approximately 40% have been observed in the County's system, likely due to increased outdoor water use for irrigation.

Table 3-3: Historical Consumptive Use in Caroline County's Water System (2022-2024)

Demand Category	Average Monthly Flow (millions of gallons per month)
Groundwater Well Production	18.07
Customer Water Consumption	16.60
WWTP Influent Flow Rate	14.41
Consumptive Use [1]	**20.3%**

[1] Consumptive use represents the difference between the average groundwater well production rate and the WWTP influent flow rate.

Figure 3-2 and Figure 3-3 summarize the water balance for the water supply project. These values include existing WWTP return flows to the Mattaponi River basin (e.g., 0.5 mgd average at the Caroline County WWTP). It was assumed that the average consumptive use rate observed in the County's system is also representative for customers in the Town of Bowling Green's system. Additionally, WTP process water use will be returned to the Polecat Creek WWTP and discharged to the Mattaponi River basin, and thus does not contribute to consumptive use. **Table 3-4** summarizes the consumptive use and return flow to each basin; the total of flow values in this table equal the proposed withdrawal rate.

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Key findings of this analysis include the following:

- The estimated average daily water consumptive use for the water supply project is 1.0 mgd, and the maximum day consumptive use is estimated to be 1.8 mgd.
- The estimated average daily discharges transferred to Polecat Creek, which flows into the Mattaponi River, is approximately 3.7 mgd, and the maximum day discharges transferred is estimated to be 6.5 mgd.
- The estimated average daily discharges transferred to the Mattaponi River via the Bowling Green WWTP is approximately 0.4 mgd, and the maximum day discharges transferred is estimated to be 0.7 mgd.
- The total average daily discharges transferred to the Mattaponi River basin is 4.1 mgd, and the maximum day discharges transferred is 7.2 mgd.

Table 3-4: Summary of Consumptive Use and Flow Discharges

Category	Average Day Flow (mgd)	Maximum Day Flow (mgd)
Consumptive Use:		
Caroline County Consumptive Use	0.9	1.6
Town of Bowling Green Consumptive Use	0.1	0.2
Total Consumptive Use	**1.0**	**1.8**
Flow Discharged to Polecat Creek and Mattaponi River:		
WTP Process Water	0.2	0.4
Caroline County Flow to Polecat Creek WWTP	3.5	6.1
Total Flow Discharged to Polecat Creek WWTP	**3.7**	**6.5**
Flow Discharged to Mattaponi River via Bowling Green WWTP:		
Town of Bowling Creek Flow to WWTP	0.4	0.7
Total Flow Discharged to Bowling Green WWTP	**0.4**	**0.7**
Total Withdrawal	**5.1**	**9.0**

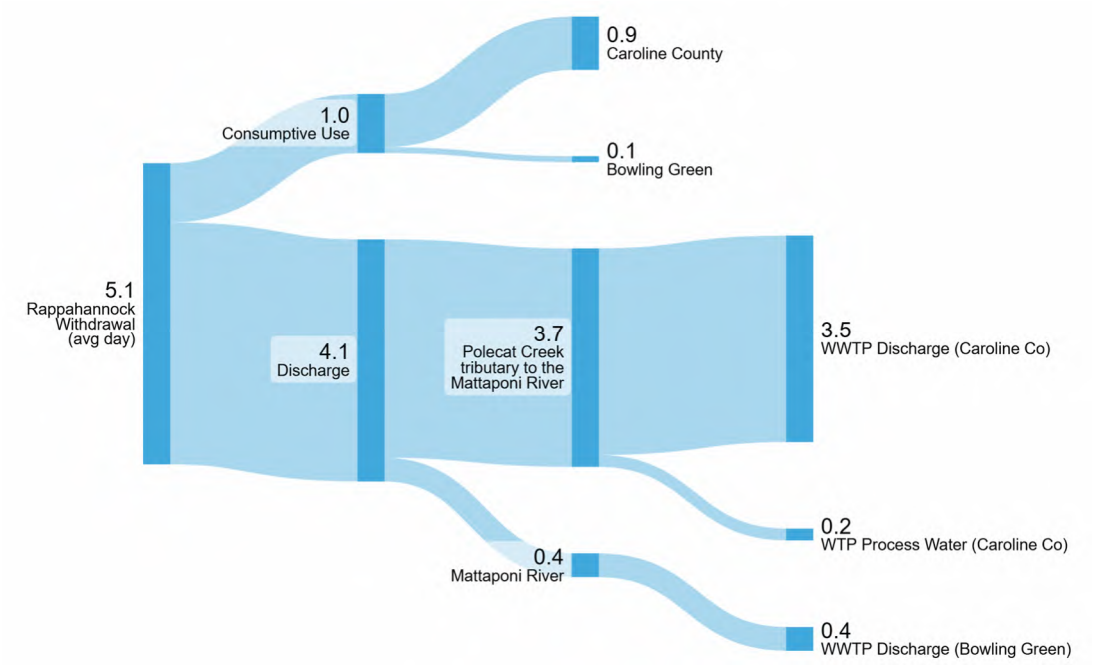


Figure 3-2: Breakdown of Estimated Consumptive Use and River Discharges for Average Day Withdrawals (all values in mgd)

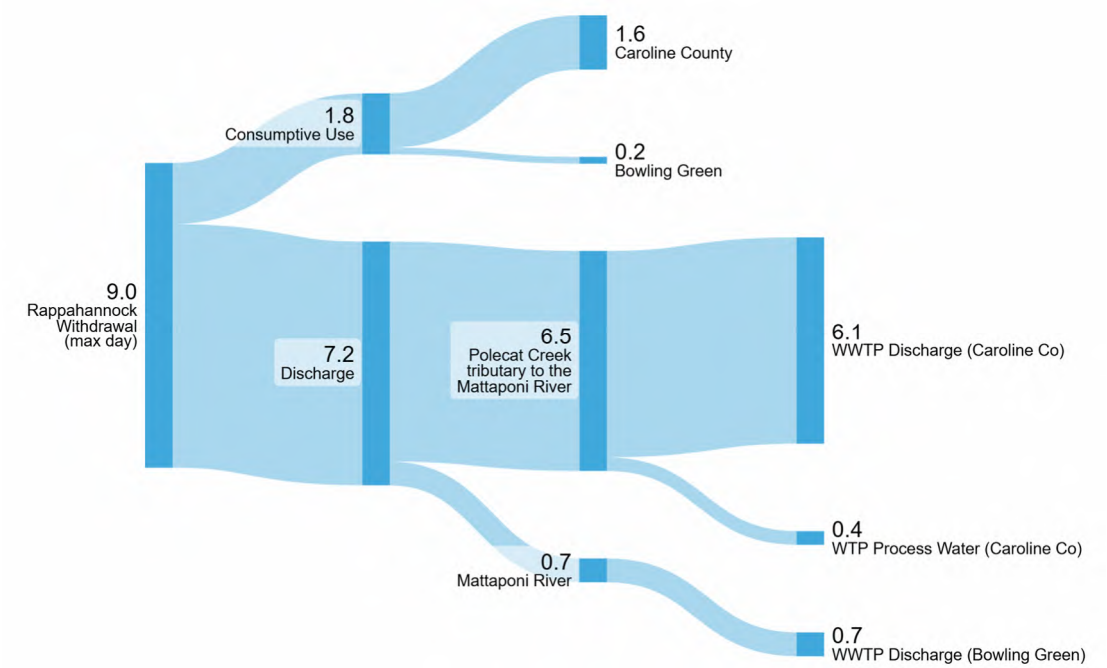


Figure 3-3: Breakdown of Estimated Consumptive Use and River Discharges for Max Day Withdrawals (all values in mgd)

3.2 Effects of Transferred Water Discharges on Polecat Creek

The potential effects on river flow rates of receiving waters was evaluated by analyzing the USGS monitoring data at USGS Monitoring Gage 01674182 - Polecat Creek (refer to **Figure 3-1** for gauge location). Approximately 3.7 mgd, on average, is expected to flow through the Caroline County Regional WWTP.

The USGS Monitoring Gage at Polecat Creek is located between the Caroline County Regional WWTP discharge and the confluence of Polecat Creek with the Mattaponi River. **Figure 3-4** presents historical flow data at this location. Historical flow data over the past 10 years indicates the average flow rate of Polecat Creek is 45.56 cfs. During high flow events in November 2020 and May 2018, the creek flow was as high as 3,230 cfs and 1,720 cfs. Historically, the average discharge flow rate is approximately 12.6% of the average flow in Polecat Creek.

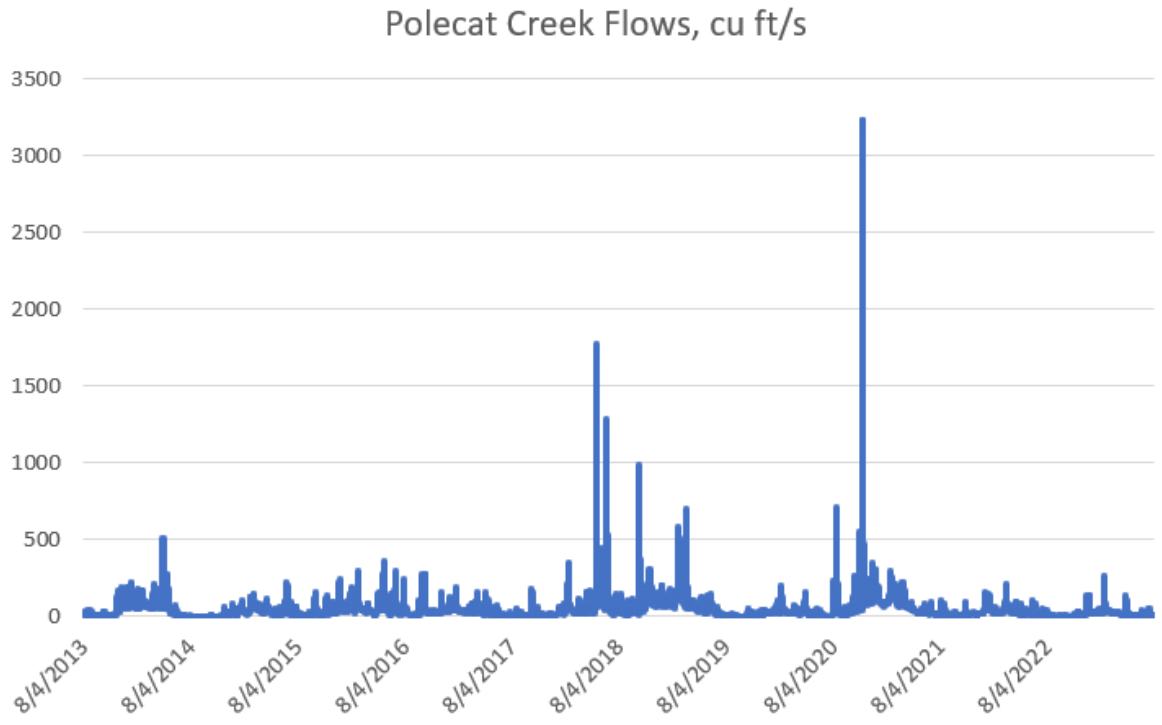
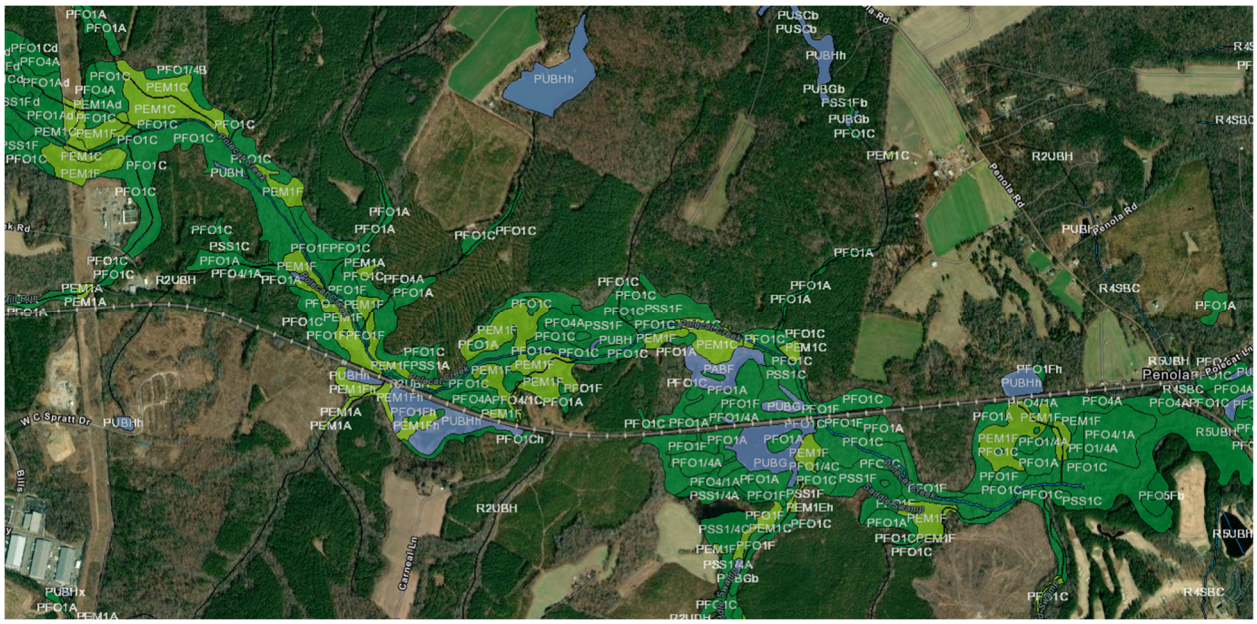


Figure 3-4: Polecat Creek USGS Stream Flow Data, 10 Years

Polecat Creek has significant, connected wetland resources throughout its length (**Figure 3-5**). Additional flow from the Caroline Co WWTP would help to support these wetlands during drought conditions. Further, these wetlands help to distribute flow across a wide floodplain and minimize flow velocity during high stream flow events.


PFO1A
PFO1C
PEM1C
PUBHh
PUSCb
PUBGb
PSS1Fb
R2UBH
R4SBC
PEM1A
PEM1F
PSS1C
PFO1F
PFO4A
PFO4/1A
PFO1/4B
PEM1Ad
PEM1Cd
PFO1Cd
PFO4A
PFO1Ad
PEM1Ad
PEM1Fd
PSS1Fd
PUBH
PUBHx
R5UBH
PFO1Fh
PEM1Fh
PFO1/4A
PFO4/1C
PFO1Ch
PEM1Ch
PSS1/4A
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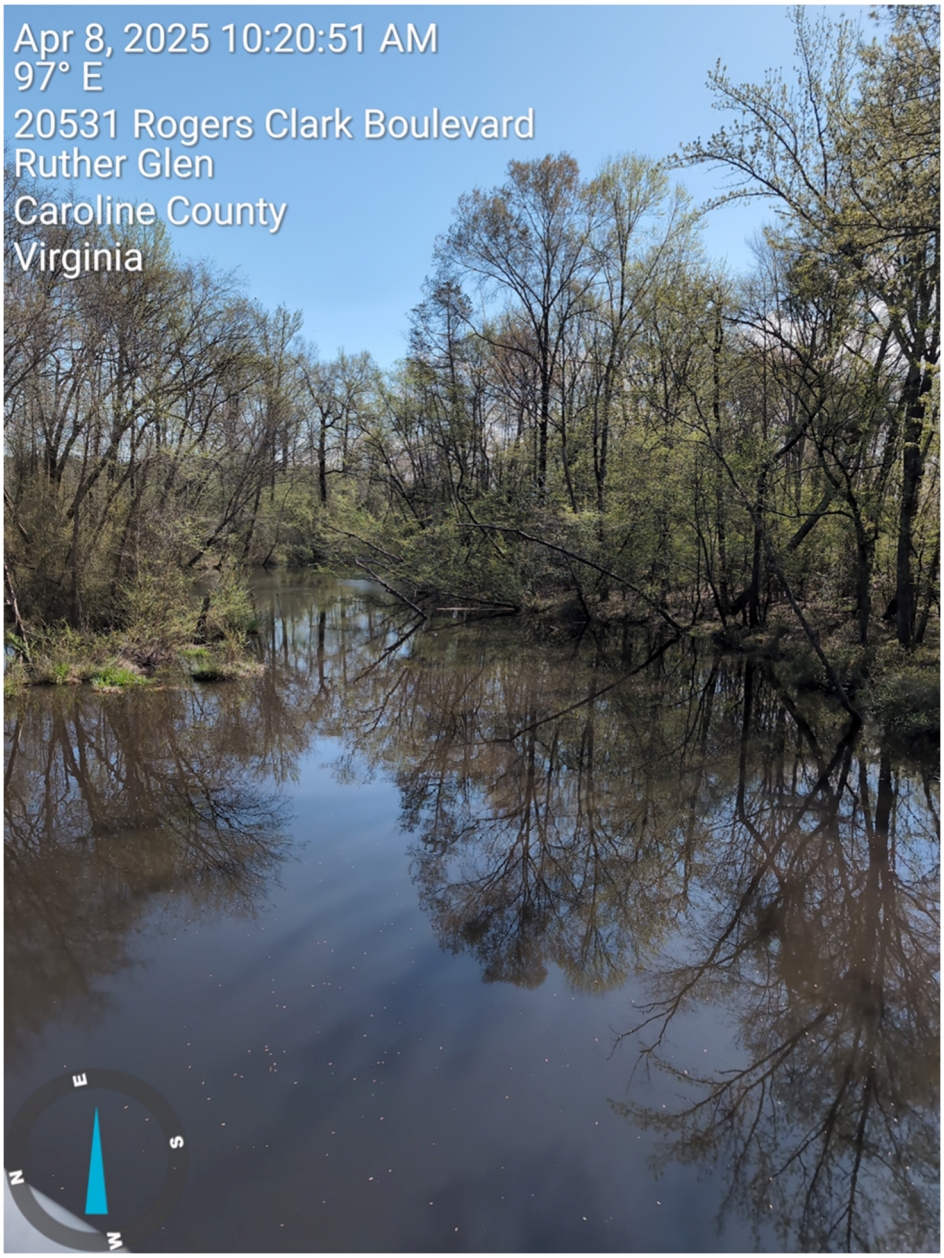


Figure 3-6: Polecat Creek looking downstream from State Route 207 (Rogers Clark Boulevard)

An overview of the study reach is shown in **Figure 3-7**, and an enlarged view of the WWTP and downstream cross section is shown in **Figure 3-8**. Additionally, gage data at the time of the site visit was noted to correlate field observations with model outputs.

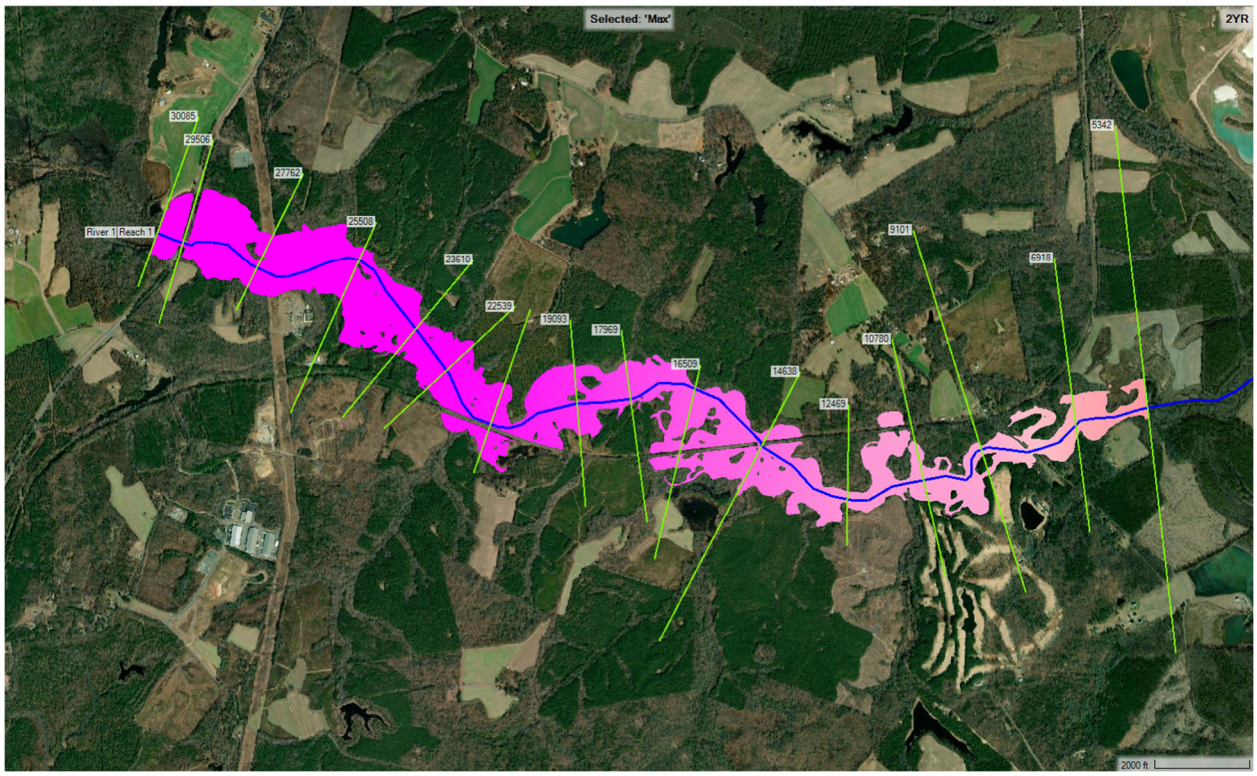


Figure 3-7: HEC-RAS 1D Study Reach of Polecat Creek with Base Flow Water Surface Elevation

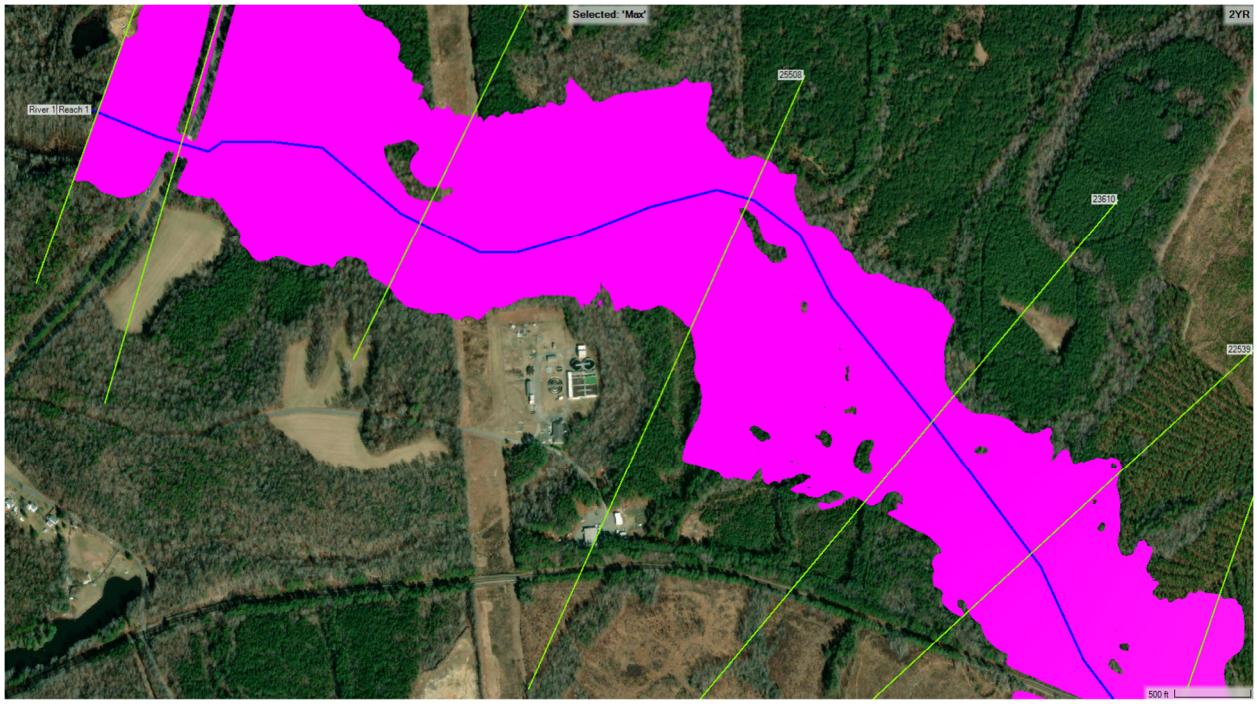


Figure 3-8: Enlarged View of WWTP and Cross Section along Polecat Creek Immediately Downstream of WWTP Return Channel

Flow data for Polecat Creek used in the model was gathered from the USGS's StreamStats web-based tool and validated against VDOT's Drainage Manual, Chapter 6 (Hydrology) Rural Regression Equations. The peak flowrates for each of the annual exceedance probabilities (AEP) analyzed in the model are listed in **Table 3-5**. The return flowrate for the treated effluent from the WWTP plant are also listed in the table. These flows were added at River Station (RS) 25508, the cross section along Polecat Creek immediately downstream of the WWTP return channel.

Table 3-5: Peak Flowrates at River Station 25508

Annual Exceedance Probability, AEP (%)	Equivalent Return Period (Years)	Existing Flowrate (cfs)	Return Effluent, Average Discharge (cfs)	Return Effluent, Maximum Discharge (cfs)	Total Peak Flowrate, Average Discharge (cfs)	Total Peak Flowrate, Max Discharge (cfs)
Base Flow[1]	-	77.7	5.74	10.08	83.4	87.8
50	2	750	5.74	10.08	756	760
20	5	1060	5.74	10.08	1066	1070
10	10	1510	5.74	10.08	1516	1520
4	25	2290	5.74	10.08	2296	2300
2	50	2990	5.74	10.08	2996	3000
1	100	3800	5.74	10.08	3806	3810
1. Base Flow represents the USGS gage data flow at 10:45 AM ET on April 8, 2025.						

Additional modeling input data is listed below:

- Manning's Roughness Coefficient, 'n' = 0.15
- Downstream Reach Boundary Condition, Normal Depth = 0.00131 ft/ft

3.2.2 Polecat Creek Model Results

The resulting water surface elevations (WSE) and average cross-sectional velocities are listed in **Table 3-6** and **Table 3-7** for RS 25508, which is located just downstream of the Caroline County WWTP outfall.

Table 3-6: Resulting WSE at RS 25508

Profile	Total Flow (cfs)			WSE (ft)		
	Existing	Existing plus Avg Discharge	Existing plus Max Discharge	Existing	Existing plus Avg Discharge	Existing plus Max Discharge
Base Flow	77.7	84.7	87.8	100.49	100.53	100.56
2YR	750	757	760	102.07	102.08	102.09
5YR	1060	1067	1070	102.47	102.48	102.48
10YR	1510	1517	1520	102.97	102.97	102.98
25YR	2290	2297	2300	103.68	103.69	103.69
50YR	2990	2997	3000	104.24	104.24	104.24
100YR	3800	3807	3810	104.81	104.82	104.82

Table 3-7: Resulting Average Cross Sectional Velocities at RS 25508

Profile	Total Flow (cfs)			Velocity (ft/s)		
	Existing	Existing plus Avg Discharge	Existing plus Max Discharge	Existing	Existing plus Avg Discharge	Existing plus Max Discharge
Base Flow	77.7	84.7	87.8	0.239	0.242	0.246
2YR	750	757	760	0.459	0.460	0.460
5YR	1060	1067	1070	0.504	0.505	0.505
10YR	1510	1517	1520	0.557	0.558	0.558
25YR	2290	2297	2300	0.636	0.636	0.637
50YR	2990	2997	3000	0.694	0.695	0.695
100YR	3800	3807	3810	0.754	0.754	0.755

As shown in **Table 3-6** and **Table 3-7**, the additional treated effluent results in no more than a 0.07 feet increase to the WSE, and no more than a 0.007 feet per second increase in average cross section velocity for both the average and maximum discharge flowrates. The channel-forming flow rate is typically associated with the flow arising from a 2-year recurrence interval storm event (Copeland et al, 2000; VDEQ, 2013). At the 2-year flow, the HEC-RAS model of Polecat Creek predicts a WSE increase of only 0.02 feet and a velocity increase of only 0.001 feet per second with the maximum discharge flow rate. The results indicate that the additional discharge from transferred flows would not alter the channel-forming flow, indicating no impacts to erosion.

Based on these results, there will be no erosive effects or change to the floodplain due to the additional treated effluent. As a result, beneficial uses of Polecat Creek, such as aesthetic value, will not be impacted by the transferred flow.

3.3 Effects of Water Transfer on Mattaponi River Flow Rates

The potential effects on river flow rates of receiving waters was evaluated by analyzing the USGS monitoring data at USGS Monitoring Gage 01674500 - Mattaponi near Beulahville (refer to **Figure 3-1** for gauge location). The estimated average flow rate discharged to the Mattaponi River via the Bowling Green WWTP is 0.4 mgd (average). Downstream of the confluence with Polecat Creek, the combined discharge flow to the Mattaponi Basin is 4.1 mgd (average).

The USGS Monitoring Gage at Mattaponi River near Beulahville is located several miles downstream of both WWTPs. **Figure 3-9** presents historical flow data at this location. Historical flow data over the past 10 years indicates the average flow rate of Mattaponi River is approximately 567 cfs. This includes flows from multiple wet weather events, with readings as high as 7,820 cfs; however, similar wet weather events appear to occur approximately every 2.5 years, according to the historical data.

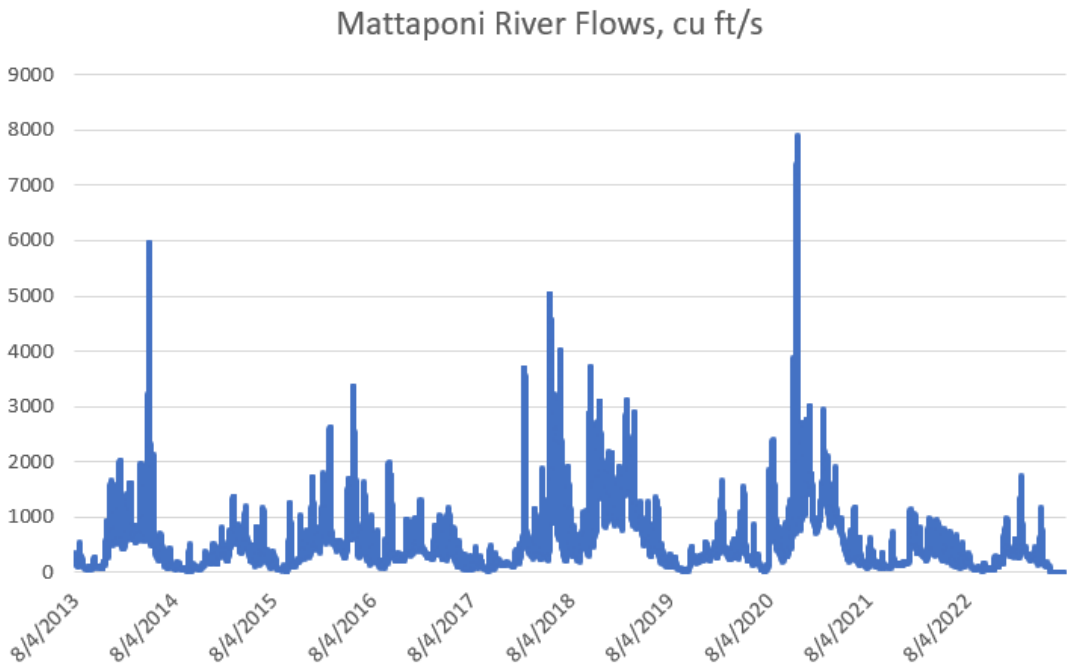


Figure 3-9: Mattaponi River USGS Stream Flow Data, 10 Years

A combined flow through the Caroline County Regional WWTP and Town of Bowling Green WWTP of 4.1 mgd (6.4 cfs) to the Mattaponi River would be an increase from 567 cfs to approximately 573 cfs, an average daily flow increase of approximately 1%. The 5th percentile low flow in the Mattaponi River at Beulahville is 57.1 cfs. The WWTP discharge would increase river flow by approximately 11%. During peak river flow events, WWTP discharges would increase river flows by about 0.1%. These transferred flows would not exacerbate natural high flow events in the river and would support river flows during periods of low streamflow.

At the closest USGS flow gage (#01674500) near Beulahville, VA, flood categories of action and minor flooding are defined at stage values of 16 ft and 20 ft, respectively. According to the current USGS stage-discharge rating for the gage, these stage values correspond to discharges of 4,088 cfs and 8,350 cfs, respectively. The proposed average discharge of transferred flows projected is 4.1 mgd (6.4 cfs) – equivalent to only 0.1% to 0.2% of the river flow at flood stage. Hence, the proposed additional flow will have no observable impact on flood conditions in times of high flow.

Overall, the effects of transferred flows from the Rappahannock River are not expected to significantly affect the Mattaponi River. Key findings of this analysis include the following:

- Flow changes are relatively small and are not expected to adversely affect instream and offstream beneficial uses of the Mattaponi River.

- During periods of lower river flow, transferred flows discharged from the WWTPs would help to maintain river flows to support beneficial uses.
- During naturally occurring high flow events, transferred flows discharged from the WWTPs would not significantly increase flow rates, indicating minimal flooding risk.

4. Beneficial Uses and Aquatic Life of the Mattaponi River

The Mattaponi River provides multiple instream and offstream beneficial uses. The river provides public water supply, irrigation water supply, serves as a cultural and aesthetic resource, and supports aquatic habitat and resources. This section describes these beneficial uses of the Mattaponi River.

4.1 Public Water Supply

The Mattaponi River is a freshwater resource that has the potential to provide offstream beneficial uses for public water supply. The Virginia State Water Resources Plan (DEQ, 2022) indicates that there are two existing surface water withdrawals within the Mattaponi River basin. Both withdrawals are located upstream of the location of return flows associated with this project. There are no existing permitted public water supply withdrawals on the Mattaponi River located downstream of proposed return flows. As a result, a transfer of water to the Mattaponi River basin would not affect existing public water supplies. Furthermore, transfer of water to the Mattaponi River would only increase the volume of water available for water supply purposes for any future downstream withdrawals.

4.2 Cultural Resources

The Mattaponi River in Caroline County has not been designated by DCR as a Scenic River, as depicted on the Virginia Outdoors Plan mapper. A downstream reach of the Mattaponi River has been determined to qualify for designation. The qualifying reach is situated more than ten river miles downstream of the mouth of Polecat Creek, where the river forms the boundary between King William County and King and Queen County, extending from Route 628 to Route 629. No impact to the aesthetic value of the qualifying reach of the Mattaponi River will occur as a result of the increased discharge.

The Virginia Cultural Resources Information System (V-CRIS) was consulted to ascertain the potentially significant historic resources in the vicinity of the discharge structure and at the mouth of Polecat Creek. Historic resources have not been recorded in V-CRIS in either of the reviewed locations. Any work to modify the existing discharge structure to accommodate the additional flow will be evaluated and permitted as a separate project.

4.3 Aquatic Habitat and Resources

Aquatic species of concern that are known or likely to be within a two-mile radius of the mouth of Polecat Creek at Mattaponi River are included in **Table 4-1**, as identified by the Virginia Department of Wildlife Resources (DWR) Fish and Wildlife Information Service (VaFWIS). The data provided is based on a review of the VaFWIS database on August 17, 2023.

Table 4-1: VaFWIS Aquatic Species Designated for Conservation Known or Likely to Occur within a 2-mile Radius of the Mouth of Polecat Creek into Mattaponi River

Common Name	Scientific Name	Conservation Status	VA Wildlife Action Plan Tier*
Atlantic sturgeon	*Acipenser oxyrinchus*	Federal Endangered; State Endangered	I
Dwarf wedgemussel	*Alasmidonta heterodon*	Federal Endangered; State Endangered	I
Spotted turtle	*Clemmys guttata*	Collection Concern	III
Yellow lance	*Elliptio lanceolata*	Federal Threatened; State Threatened	II
Yellow lampmussel	*Lampsilis cariosa*	-	II
Bridle shiner	*Notropis bifrenatus*	-	I

Descriptions of federally protected species identified in the project area, including the Atlantic sturgeon, dwarf wedgemussel, and yellow lance, are included in Attachment D of the Joint Permit Application. The analysis for these species concludes that no impacts are anticipated as a result of the increased discharge.

The National Ocean and Atmospheric Administration's (NOAA) EFH Tool was reviewed. The Tool was utilized to identify the species for which EFH has been designated in the Mattaponi River. The Tool depicts the upper limit of designated EFH as terminating to the east of the Richmond Tappahannock Highway (VA-360) crossing over the Mattaponi River. As such, no EFH has been designated in the vicinity of the confluence of Polecat Creek and the Mattaponi River. The increased discharge volume is not anticipated to adversely affect EFH.

4.4 Agricultural Uses

The Virginia State Water Resources Plan (DEQ, 2022) describes agricultural withdrawals in the Mattaponi River basin. Transfer of water from the Rappahannock River to the Mattaponi River basin is not expected to adversely affect agricultural uses on the Mattaponi River. Additional WWTP discharge flows transferred to the Mattaponi River may further support agricultural uses, especially during periods of low natural instream flow (i.e., drought), when the transfer could augment river flows for agricultural uses.

4.5 Recreation

The Mattaponi River is used for recreational paddling, boating, fishing, and wildlife viewing. The effluent discharge structure is clearly marked, as required by the U.S. Coast Guard for recreational safety. The slight increase in WWTP discharges would support recreation uses during periods of low natural streamflow. The transferred flows will not adversely affect the recreational use of the river.

4.6 Aesthetic Value

The aesthetic value of Polecat Creek and Mattaponi River derives from the forests and marshes that flank the waterways, providing natural scenery and wildlife viewing opportunities. The HECRAS model of Polecat Creek and flow rate analysis of the Mattaponi River indicate that the WWTP discharges

transferred to the river will not impact erosion, water surface elevations, and aesthetic value of the receiving basin. As the model shows that the change in flows will be within the normal range of natural fluctuations of the river flows, erosion rates and water surface elevations will remain within the river's normal range and will therefore not alter the natural beauty of the river through degradation of the channel.

4.7 Navigation

The Mattaponi River is used by recreational boaters. The impact to navigation will be negligible compared to the current conditions. The change in river flows will be within normal fluctuations in the river flow due to natural variance in hydrologic inputs to the watershed. During periods of low natural streamflow, transferred flows would support river flows for navigation and other purposes. The proposed project is not anticipated to adversely affect recreational navigation.

4.8 Waste Assimilation

The Mattaponi River provides beneficial dilution and waste assimilation and will continue to provide assimilation of the additional return flows from the Caroline County and Bowling Green WWTPs. These WWTPs have existing permits with pollutant load limits to protect instream water quality. The quality of the additional WWTP return flows will be subject to permitting through the Virginia Pollutant Discharge Elimination System (VPDES) to protect instream water quality. The level of treatment needed to meet future permit limits and protect water quality will be determined through the VPDES permitting process.

5. Conclusion

The proposed project would result in a net transfer of water from the Rappahannock River (withdrawal basin) to the Mattaponi River (receiving basin). These rivers are important water resources that provide a variety of instream and offstream beneficial uses. This memorandum presents a review of the beneficial uses associated with both river basins. The consumptive use and return flow rates were estimated based on historical consumption rates for Caroline County. A HECRAS model was performed to evaluate potential impacts to Polecat Creek and concluded that the WWTP discharges transferred to the creek will not alter water surface elevation or flow velocities, indicating that there will be no impacts on erosion or floodplain in the stream. Furthermore, modeling of the Rappahannock River concluded that the withdrawal would not adversely affect hydrodynamic or downstream salinity in the river. Overall, the withdrawal and transfer of water from the Rappahannock River basin to the Mattaponi River is not expected to adversely affect beneficial uses of these rivers.

Hazen

6. References

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APPENDIX C
SUMMARY OF WATER DEMAND PROJECTIONS MEMORANDUM

DEQ Response to Additional Information Request
Caroline County Rappahannock River Water Supply Project
JPA No. 20-0514
September 11, 2023

Summary of Water Demand Projections

Caroline County Rappahannock River Water Supply Project

September 2023

1. Introduction

The purpose of this memorandum is to summarize the water demand projections for Caroline County and its project partners to establish the basis of need for additional long-term water supply. Caroline County (along with all other cities, counties, and towns in Virginia) is required to conduct water supply planning over a planning horizon of at least 30 years. In 2016, Caroline County commissioned the development of a Water Master Plan that included projected water demands. The Water Master Plan documented the County's projected demands in phases from 2022 through 2047 and included a projection of an ultimate build-out flow. To assess water needs for the water supply project, the Water Master Plan projected water demands were reviewed and interpolated to the planning years for the Rappahannock River Water Supply Project. Additionally, this memorandum updates the 2016 Water Master Plan water demand projections with recent planning analyses in the County's service area and specific industrial development projects.

The Virginia State Water Resources Plan (DEQ, 2022) indicates that Caroline County is among the localities with the highest anticipated population increases between 2020 and 2040 due to its proximity to northern Virginia and Washington DC. As such, the Water Master Plan evaluation considered the impacts of Transit Oriented Development (TOD) because of an anticipated high-speed rail stop in Caroline County. Once completed, the Virginia Department of Rail and Public Transportation (DRPT) high-speed rail project will be routed between Richmond, VA and Washington, D.C. The high-speed rail project is expected to bring additional growth and development to the County, resulting in an increase in water demand. The Federal Railroad Administration released a Final Environment Impact Statement in May 2019 and a Record of Decision in September 2019.

The County is expecting significant industrial and commercial growth and anticipates the construction of multiple industrial facilities that will rapidly increase water demand in the County. To promote water conservation, the County plans to supply certain facilities with domestic reuse water from its wastewater treatment plant for non-potable purposes. Additional water withdrawals will be needed to support these anticipated industrial facilities. Water demands from the Master Plan were updated with specific water demand information for anticipated industrial facilities in the County.

Caroline County adopted a resolution to form a partnership with the Town of Bowling Green and the Town of Port Royal for this Rappahannock River Water Supply Project. Water demands for the Town of Port Royal were analyzed as part of the Caroline County Water Master Plan and are included in the Caroline County demand projections. This memorandum includes a summary of demand projections for the Town of Bowling Green from the 2011 Regional Water Supply Plan.

This memorandum presents the basis for the proposed river withdrawal rates and supports the statement of need for the Rappahannock River Water Supply Project. Total water demand projections for this water supply project are inclusive of anticipated needs to supply these municipalities. Due to the anticipated 15-year term of the Virginia Water Protection permit (e.g. 2023 through 2038) to authorize construction and operation of the proposed Rappahannock River raw water intake, planning year 2038 was used to determine the anticipated withdrawal rates for purposes of this memorandum.

2. Caroline County Water Needs

Caroline County currently supplies water to three existing public water systems by operating fourteen groundwater wells with a total capacity of 1.36 million gallons per day (mgd). The Town of Bowling Green has three groundwater wells with a combined capacity of approximately 0.217 mgd.

Caroline County and the Town of Bowling Green are located within the Eastern Virginia Groundwater Management Area (EVGMA), which has experienced a significant groundwater level decline in recent years. **Figure 2-1** provides an illustration of the decline in the groundwater table between 1998 and 2018.

The Virginia Department of Environmental Quality (DEQ) is committed to reducing groundwater withdrawals throughout the EVGMA (DEQ, 2018). Furthermore, the Virginia State Resources Plan (DEQ, 2022) indicates that "*new and existing groundwater users in Caroline County… could face challenges in meeting the regulatory criteria for issuance of a groundwater withdrawal permit*." These limitations preclude Caroline County's ability to tap additional groundwater sources to meet anticipated future water supply needs. The limited regional groundwater resources create a need for the County to reduce its reliance on groundwater. The County is committed to preserving groundwater resources by developing a surface water supply to meet future water supply needs.

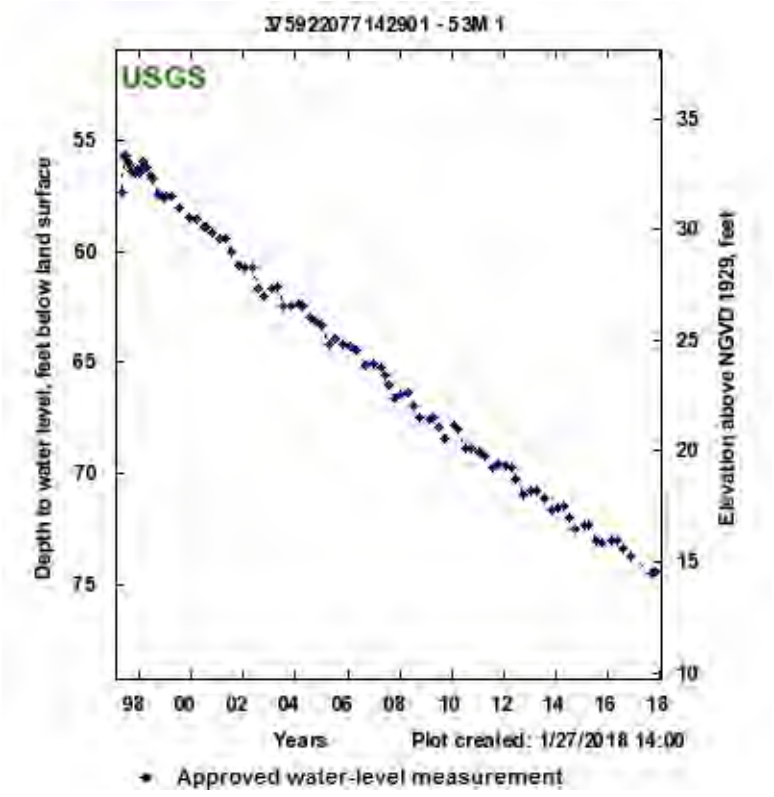


Figure 2-1: Observed Groundwater Levels at USGS Monitoring Well in Caroline County

The County's population is expected to grow significantly in the near- and long-term planning years, resulting in additional water demand beyond the County's current permitted groundwater withdrawal capacity. The County's Comprehensive Plan for planning year 2030 describes anticipated land use and population growth in the County. Additional industrial development projects are expected to further drive growth and water demands in the County.

An alternative water supply source is needed to meet the County's long-term water supply planning needs and to minimize groundwater withdrawals. The County conducted a water supply analysis that identified the Rappahannock River as a viable source of surface water to meet the growing needs of the County and its partners and reduce reliance on groundwater. The following sections present an analysis of projected water demands and water withdrawals for the Rappahannock River water supply project.

3. Caroline County Water Demand Projections

This section summarizes water demand projections from the County's Water Master Plan and presents additional anticipated water demands associated with proposed industrial facilities in the County.

3.1 Water Demand Projection Approach

The water demand projections in the County's Water Master Plan were developed by identifying areas of anticipated future development in lieu of a County-wide population increase. Each development area was assigned a development density based on future land use and the planning year in which the development is expected to occur.

It should be noted that the Water Master Plan made several assumptions in the development of the water demand projections. The Water Master Plan projections did not include demands for military use (i.e., Fort A.P. Hill). Caroline County does not anticipate needing to supply water to Fort A.P. Hill because the Fort receives water through an established long-term contract with a private water utility. Additionally, the Water Master Plan projections include water needs for the Town of Port Royal but do not reflect participation from the Town of Bowling Green. Water demand projections from the Town of Bowling Green were added to the County's water demand projections in this memorandum.

The assumptions for the development of Caroline County's residential water demands are as follows:

- The total residential water demand was calculated using the size of each growth area, a percentage of developable land within the area, a density of units based on anticipated zoning, a capita rate per unit, and a daily water demand per capita.
- A density between 1 to 2.5 units per acre based upon the residential classification found in the Caroline County zoning ordinance or the proposed number of units in subdivision plans.
- A rate of 2.61 people per unit from the 2010 Comprehensive Plan was used to estimate future population growth.
- A demand of 100 gallons per capita per day (gpcd) was used to estimate residential demand per the Virginia Department of Health (VDH) Waterworks Regulations.

The assumptions for the development of the commercial and light industrial water demands are as follows:

- The total commercial and industrial water demands were calculated based on the size of each parcel, a percentage of developable land within the area, and a unit demand per acre estimate.
- It was assumed that a percentage of area would be developable based on the 2010 Caroline County Comprehensive Plan.
- The County Comprehensive Plan was used to determine flow/acre for specific parcels.

Maximum day water demands were calculated by applying peaking factors to the average day water demand projections. The peaking factors used to evaluate withdrawal permit applications were provided by the DEQ Office of Water Supply and are as follows:

- Maximum day peaking factor of 1.6
- VDH certification factor of 1.1

The VDH certification factor accounts for the VDH public water supply requirement of the permitted capacity to be 10% greater than peak day. Both peaking factors are applied to the average day water demand to determine the maximum daily water demand, resulting in a total maximum day peaking factor of 1.76 (1.6 x 1.1 = 1.76).

The development of the water demand projections included an analysis of the County's potential to reduce demand by implementing additional water conservation measures. Caroline County currently has policies and measures in place to prevent water overuse and waste. The utility's billing rate structure is tiered based on monthly metered water usage, which provides customers with a financial incentive to minimize water use.

The County also has measures in place to prevent water loss due to leaks in the distribution system. Each of the County's groundwater wells are metered, and withdrawal data is compared to water sales data to identify water loss. In 2014, approximately 19% of water produced was unaccounted for in billing data, which is consistent with industry norms for water loss. If a significant increase in water loss is observed, County staff would begin surveying for undetected leaks in the distribution system.

The projected demands presented in this memorandum reflect the per-capita usage rate of 100 gpcd stipulated by VDH Waterworks Regulations (12 VAC 5-590-690). This rate is an industry standard that reflects recent trends towards water conservation and modern construction practices to reduce water consumption.

3.2 Existing Water Demands

Historical water production was reviewed to establish a baseline of existing demands. **Table 3-1** summarizes existing demands for Caroline County, Town of Port Royal, and the Town of Bowling Green for the year 2019. Water demands in 2022 remained consistent with these baseline values. An existing average demand of 0.58 MGD was incorporated into water demand projections.

Table 3-1: 2019 Historical Water Production

	Caroline County and the Town of Port Royal	Town of Bowling Green	Total
Annual Withdrawal (MG)	210.0	54.3	552.5
Average Day (MGD)	0.58	0.15	1.52
Peak Day Withdrawal (MGD)	0.74	0.27	2.03

3.3 Residential and Commercial Water Demand Projections from Water Master Plan

The water demand projections summarized in the Caroline County Water Master Plan were reviewed to determine the total water demand in each planning year for the water supply project. The Caroline County Water Master Plan included residential demand projections for scenarios with and without the Transit Oriented Development as summarized in **Table 3-2**. For purposes of assessing water supply project needs, residential water demands between these two scenarios were used in the analysis.

Table 3-2: Caroline County Water Master Plan Residential Demands

Demand Category	2028, mgd	2033, mgd	2038, mgd	2043, mgd	2048, mgd
Residential without TOD	0.46	0.78	1.12	1.49	1.87
Residential with TOD	1.30	2.41	3.38	3.75	4.13
Residential Demand – Selected for Water Supply Project	**0.96**	**1.76**	**2.47**	**2.85**	**3.23**

[1] Caroline County water demand projections include the Town of Port Royal
[2] Water demand projections linearly interpolated from the Water Master Plan (date).
[3] Transit Oriented Development

Commercial demands were adapted from the Caroline County Water Master Plan and linearly interpolated to planning years for the water supply project. **Table 3-3** summarizes the projected cumulative commercial demands based on the Water Master Plan.

Table 3-3: Caroline County Water Master Plan Commercial Demands

Demand Category	2028, mgd	2033, mgd	2038, mgd	2043, mgd	2048, mgd
Commercial	0.63	1.01	1.34	1.42	1.51

[1] Water demand projections linearly interpolated from the Water Master Plan and include TOD demands.

The water withdrawal projections were calculated assuming a 5 percent increase from maximum day demand to account for water treatment plant (WTP) process water. In addition to the projected demands for domestic water use, a portion of water withdrawn from the river will be used at the WTP for filter backwash, filter-to-waste, residuals processing, sample collection, continuous monitoring, facility cleaning, and other on-site non-potable uses.

3.4 Water Demands for Industrial Facilities

Industrial demands for Caroline County were updated based on specific water needs for anticipated industrial facilities in Caroline County. The County coordinated with planned industrial facility owners via the economic development process to obtain information on water needs. The water demands for anticipated industrial facilities in the County exceed the industrial demand projections from the Caroline County Water Master Plan. To update industrial water needs, the County obtained water demand information for these anticipated facilities.

Water demands for three primary industrial development projects are described in the following subsections. As part of the economic development process, these industrial development projects were named Project Tract, Project Clean Arc, and Project Tricycle.

3.4.1 Project Tract

Table 3-4 presents the details of project Tract. The project consists of an 855 acre development in a Planned Technology Zone in Caroline County. Water will be needed primarily for industrial cooling purposes. Between 2025 and 2027, the anticipated water demand is expected to increase incrementally each year by approximately 200,000 gallons per day. The annual increase results in a cumulative total demand of 600,000 gallons per day during Phase 1 of Project Tract.

Table 3-4: Project Tract Details

Item	Description
Project Name	Tract
Water Demand Class	Industrial Cooling
Location	Carmel Church-Jericho Road
Applicant	VALCO Caroline County, LLC
Census Tract	9905
Voting District	Carmel Church
Post Office-Zip Code	Ruther Glen, 22546
Maximum Day Water Demand	600,000 gallons per day

3.4.2 Project Clean Arc

Table 3-5 summarizes the details of the project Clean Arc. The project consists of a 1,502 acre development in a Planned Technology Zone in Caroline County. Water will be needed primarily for industrial cooling purposes. Phase 1 of Project Clean Arc will necessitate a total demand of 600,000 gallons per day between the years 2025 and 2027. Phase 2 of project Clean Arc includes an additional demand of approximately 800,000 gallons per day by 2034. The total anticipated maximum day water demand for Project Clean is 1,400,000 gallons per day.

Table 3-5: Project Clean Arc Details

Item	Description
Project	Clean Arc
Water Demand Class	Industrial Cooling
Location	Ladysmith
Census Tract	9905
Voting District	Mattaponi
Post Office-Zip Code	Ruther Glen, 22546
Maximum Day Water Demand	1,400,000 gallons per day

3.4.3 Project Tricycle

Table 3-6 presents the details of the project Tricycle. The project consists of a 994 acre development in a Planned Technology Zone in Caroline County. Water will be needed primarily for industrial cooling purposes. Project Tricycle will be developed in three phases with total water demands as follows:

- Phase 1 – maximum day demand of 600,000 gallons per day by year 2030
- Phase 2 – an additional 800,000 gallons per day by year 2033
- Phase 3 – an additional 1,000,000 gallons per day by year 2039

The cumulative total anticipated water demand for Project Tricycle is 2,400,000 gallons per day.

Table 3-6: Project Tricycle Details

Item	Description
Project Name	Tricycle
Water Demand Class	Industrial Cooling
Location	Ladysmith
Census Tract	9905
Voting District	Madison
Maximum Day Water Demand	2,400,000 gallons per day

3.4.4 Summary of Industrial Water Demands

The industrial water demand is expected to increase over time due to phased construction of these industrial projects (**Figure 2-2**). The total cumulative amount for these projects in the year 2040 is 4,600,000 gallons per day. As maximum day demands were provided by anticipated industrial users, average day demands for industrial facilities were estimated using the standard peaking factor.

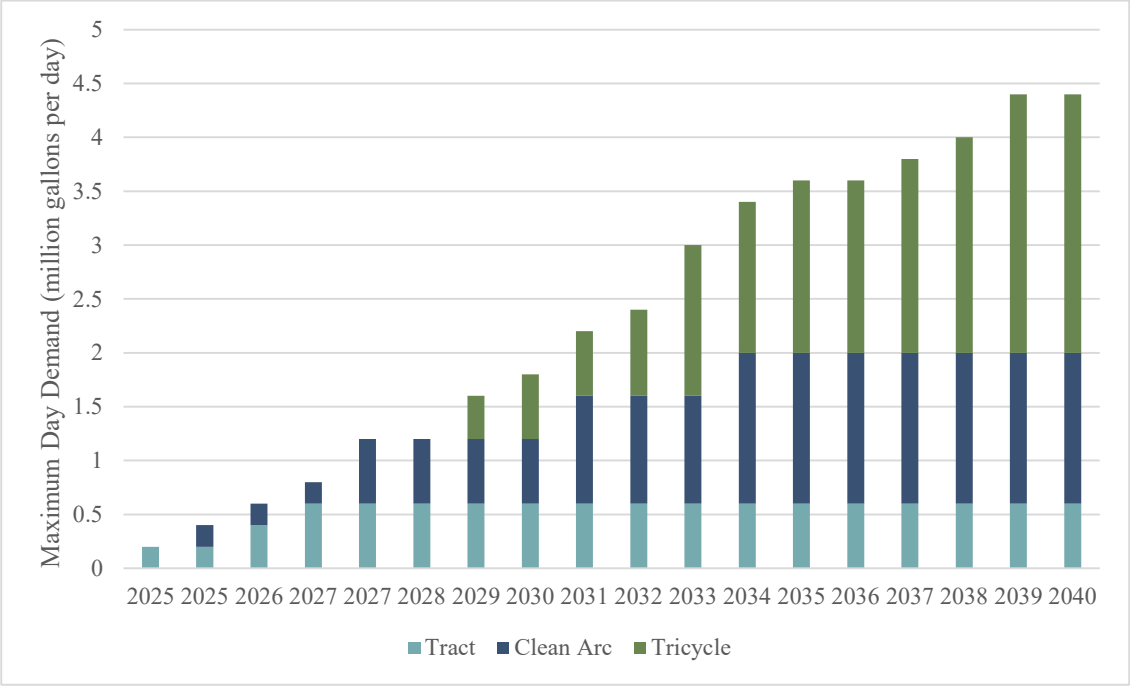


Figure 2-2: Maximum Day Demand for Anticipated Industrial Projects

3.5 Caroline County Average and Maximum Day Water Demand Projections

Table 3-7 summarizes the projected average day and maximum day demands for Caroline County and the Town of Port Royal, including residential, commercial, and industrial demands. The standard peaking factors provided by DEQ and VDH were used to estimate maximum day demands.

Table 3-7: Caroline County and Port Royal Projected Average and Maximum Day Demands

Demand Category	Source	2028, mgd	2033, mgd	2038, mgd	2043, mgd	2048, mgd
Current Demands (2022)	Historical Data	0.58	0.58	0.58	0.58	0.58
Residential [1]	Master Plan	0.96	1.76	2.47	2.85	3.23
Commercial	Master Plan	0.63	1.01	1.34	1.42	1.51
Industrial [2]	Anticipated Projects	0.75	1.88	2.63	2.88	2.88
Total average day demand	----	2.92	5.23	7.01	7.73	8.19
Total maximum day demand	-----	5.14	9.20	12.35	13.60	14.41

[1] Residential water demand adapted from the Water Master Plan based on a midpoint between TOD and non-TOD scenarios (refer to Table 2-2)
[2] Average day industrial demands estimated based on maximum day demands provided by anticipated industrial users.

4. Town of Bowling Green Water Demand Projections

The Town of Bowling Green is located within Caroline County and the Eastern Virginia Groundwater Management Area. Similar to Caroline County, the Town faces similar water supply issues associated with limited groundwater supply. In 2019, Caroline County adopted a resolution to include the Town of Bowling Green as a partner in the water supply project. The 2011 Regional Water Supply Plan includes water demand projections for the Town of Bowling Green. **Table 4-1** provides a summary of maximum day water demand projections for the Town of Bowling Green. The peaking factors provided by DEQ and VDH described in Section 2 were used to estimate maximum day demands.

Table 4-1: Town of Bowling Green Average and Maximum Day Water Demand Projections

	2028 (mgd)	2033 (mgd)	2038 (mgd)	2043 (mgd)	2048 (mgd)
Average day demand	0.40	0.44	0.50	0.61	0.71
Maximum day demand	0.70	0.78	0.88	1.07	1.25

[1] Water withdrawals include a 5% increase to account for water treatment plant process water.
[2] Water demand projections interpolated from the Regional Water Supply Plan (date).

4.1 Summary of Total Water Withdrawal Projections

Table 4-2 summarizes the combined demand projections for the Rappahannock River Water Supply Project for Caroline County (including the Town of Port Royal) and the Town of Bowling Green. The water withdrawal projections were calculated assuming a 5 percent increase from maximum day demand to account for water treatment plant (WTP) process water. In addition to the projected demands for domestic water use, a portion of water withdrawn from the river will be used at the WTP for filter backwash, filter-to-waste, residuals processing, sample collection, continuous monitoring, facility cleaning, and other on-site non-potable uses.

Table 4-2: Summary of Water Withdrawals for Caroline County and the Town of Bowling Green

Category	2028 (mgd)	2033 (mgd)	2038 (mgd)	2043 (mgd)	2048 (mgd)
Caroline County: [1]					
Caroline County total average day water demand	2.92	5.23	7.01	7.73	8.19
Caroline County total average day withdrawal	3.07	5.49	7.37	8.11	8.59
Caroline County total max day withdrawal	5.40	9.66	12.96	14.28	15.13
Town of Bowling Green: [2]					
Town of Bowling Green average day water demand	0.40	0.44	0.50	0.61	0.71
Town of Bowling Green average day withdrawal	0.42	0.47	0.53	0.64	0.75
Town of Bowling Green max day withdrawal	0.74	0.82	0.93	1.12	1.31
Total Withdrawals:					
Total average day withdrawal	3.49	5.96	7.90	8.75	9.34
Total maximum day withdrawal	6.14	10.48	13.89	15.40	16.44

[1] Caroline County water demand projections include the Town of Port Royal. Water demand projections include residential, commercial, and industrial use.
[2] Water withdrawals include a 5% increase to account for water treatment plant process water.

The combined demand projections for Caroline County and the Town of Bowling Green were used as the basis for the proposed average river withdrawal rates. It is anticipated that the withdrawal permit will apply through the year 2038; therefore, **Table 4-3** summarizes the proposed withdrawal rates for the 2038 planning year, which corresponds to the anticipated end of the 15-year permit term.

Table 4-3: Summary of Proposed Withdrawal Rates for Planning Year 2038

Permitted Withdrawal Condition	Withdrawal Rate
Average Daily	7.9 mgd
Maximum Monthly	337 mg
Maximum Daily	13.9 mgd
Maximum Instantaneous	13.9 mgd
Maximum Annual	2,884 mg

5. References

Caroline County. 2010. Caroline County Comprehensive Plan

Caroline County Department of Public Utilities. 2016. Caroline County Water Master Plan.

Caroline County and the Town of Bowling Green. 2011. Regional Water Supply Plan Water Demand Management Actions. DC to Richmond Southeast Highspeed Rail. http://dc2rvarail.com/ Accessed on December 5, 2019.

Department of Environmental Quality, 2022. Virginia State Water Resources Plan

APPENDIX A

PROJECT DRAWINGS

DEQ Response to Additional Information Request
Caroline County Rappahannock River Water Supply Project
JPA No. 20-0514
September 11, 2023

APPENDIX A.1
RIVER INTAKE DRAWINGS

DEQ Response to Additional Information Request
Caroline County Rappahannock River Water Supply Project
JPA No. 20-0514
September 11, 2023

LEGEND

RIVER DEPTH

- 0 – 2 FEET
- 2 – 4 FEET
- 4 – 6 FEET
- 6 – 8 FEET
- 8 – 10 FEET
- 10 – 12 FEET
- 12 – 14 FEET
- 14 – 16 FEET
- 16 – 18 FEET
- 18 – 20 FEET
- 20 – 22 FEET
- 22 – 24 FEET
- 24 – 26 FEET
- 26 – 28 FEET
- 28 – 30 FEET
- 30 – 32 FEET
- 32 – 34 FEET

INTAKE LOCATION
1"=500'

N

CHERYL G & DONALD K SEAY
19095 TIDEWATER TRL
FREDERICKSBURG, VA 22408

CARL S HEFLIN
19005 TIDEWATER TRL
FREDERICKSBURG, VA 22406

CHERYL G & DONALD K SEAY
19095 TIDEWATER TRL
FREDERICKSBURG, VA 22408

TIDEWATER TRAIL (ROUTE 17)

MARVIN THOMAS DUNCAN CROMER
19169 TIDEWATER TRL
FREDERICKSBURG, VA 22408

4–A–16

INTAKE LOCATION
1"=100'

N

TEMPORARY COFFERDAM

INTAKE LOCATION

(3) 42" WEDGE–WIRE TEE SCREENS

60" MICROTUNNEL AND 30" RAW WATER PIPELINE

TREELINE

100 YEAR FLOODPLAIN

RAW WATER PUMP STATION 80'x60'

PARKING LOT

FENCE 200'x250'

GATE

TEMPORARY CONSTRUCTION LAYDOWN AREA

30" RAW WATER PIPELINE

ACCESS ROAD

CHERYL G & DONALD K SEAY
19095 TIDEWATER TRL
FREDERICKSBURG, VA 22408

Draper Aden Associates
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1030 Wilmer Avenue, Suite 100
Richmond, VA 23227
804-264-2228 Fax: 804-264-8773
Blacksburg, VA
Charlottesville, VA
Hampton Roads, VA
Raleigh, NC
Fayetteville, NC
Northern Virginia
Virginia Beach, VA

DESIGNED: MSH
DRAWN: JYG
CHECKED: MSH

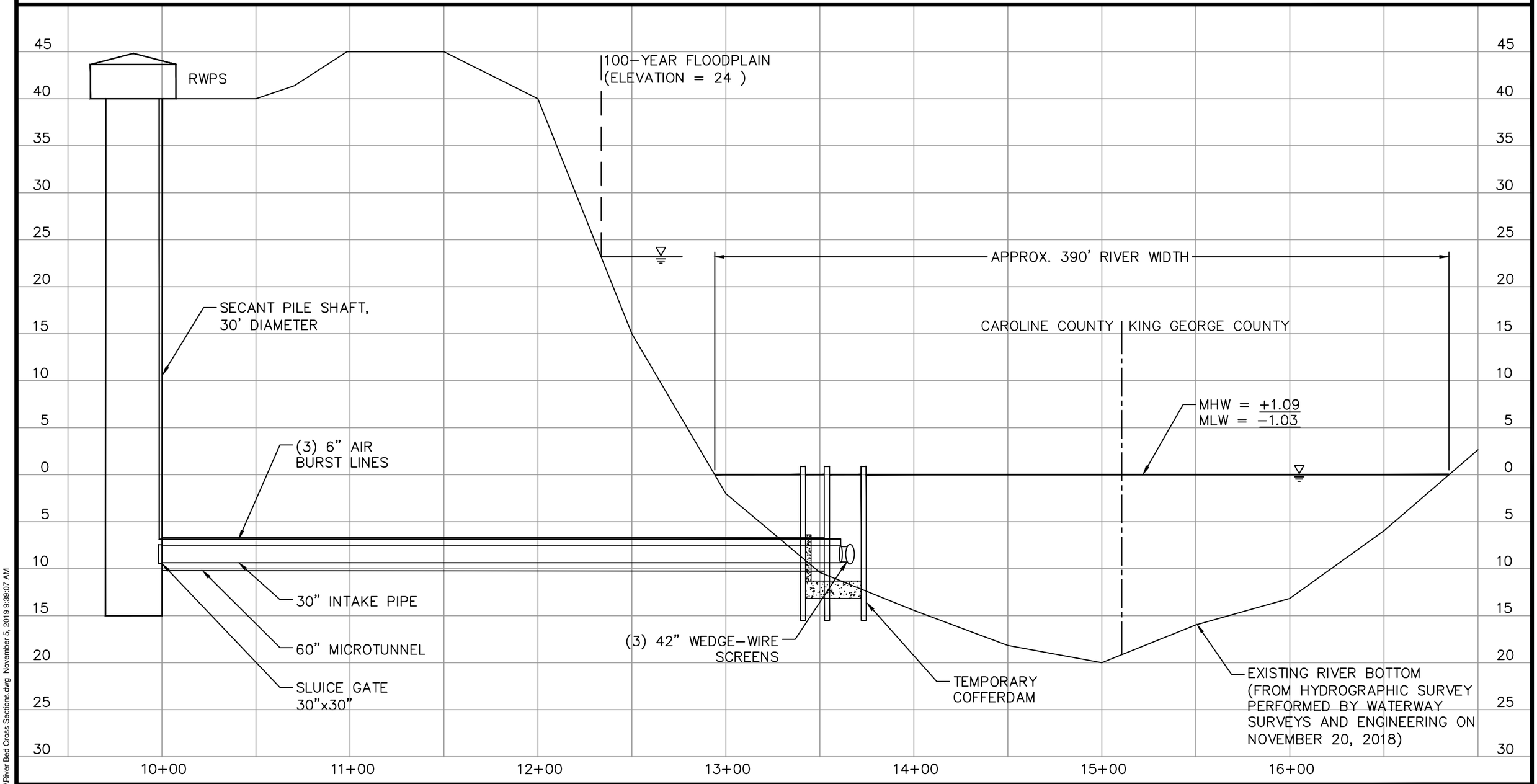
INTAKE LOCATION - PLAN
RAPPAHANNOCK RIVER WATER WITHDRAWAL
CAROLINE COUNTY, VIRGINIA

SCALE: AS SHOWN

PROJECT: R15287R-05

FIGURE 1

P:\R15\200\R15287R\R15287R-03\CAD\River Bed Cross Sections.dwg November 5, 2019 9:39:05 AM



NOTE: VERTICAL AXIS IS ELEVATION IN FEET

Draper Aden Associates
Engineering • Surveying • Environmental Services
1030 Wilmer Avenue, Suite 100
Richmond, VA 23227
804-264-2228 Fax: 804-264-8773
Blacksburg, VA
Charlottesville, VA
Hampton Roads, VA
Raleigh, NC
Fayetteville, NC
Northern Virginia
Virginia Beach, VA

DESIGNED: MSH
DRAWN: JYG
CHECKED: MSH

INTAKE LOCATION PROFILE
RAPPAHANNOCK RIVER WATER WITHDRAWAL
CAROLINE COUNTY, VIRGINIA

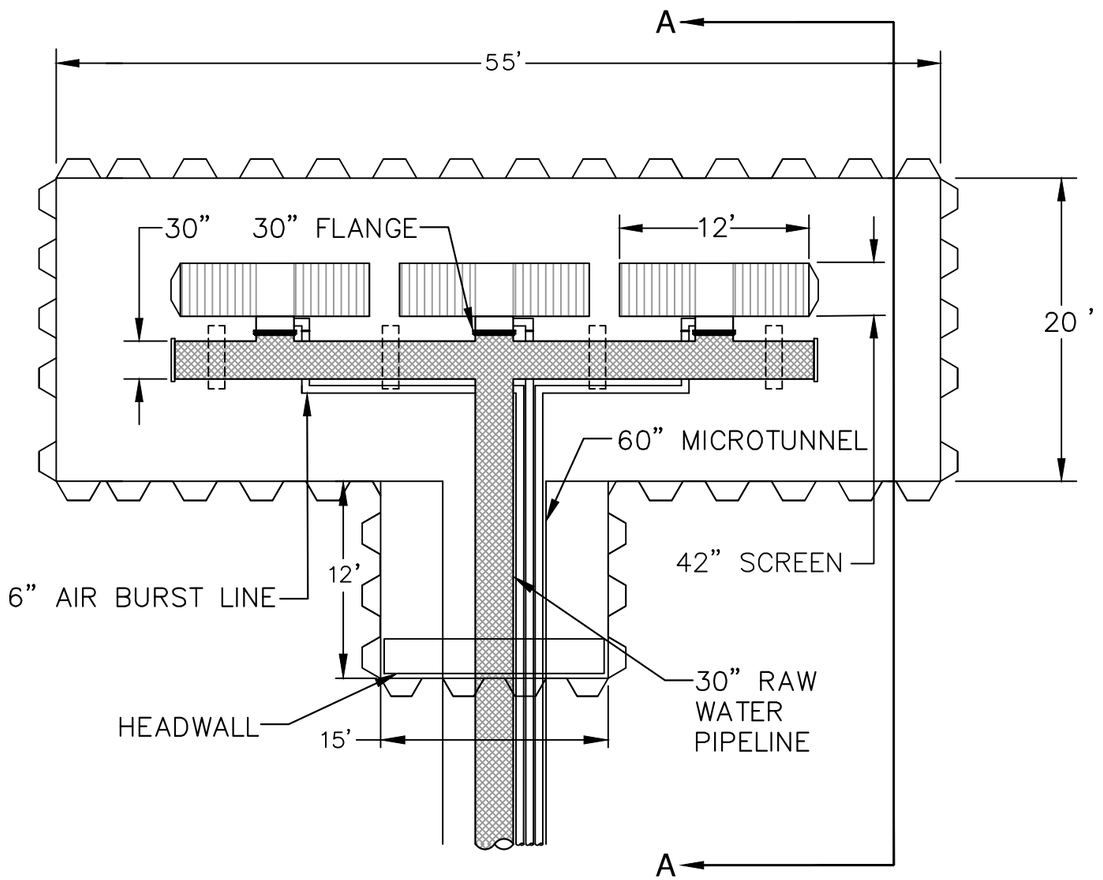
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VERTICAL: 1" = 20'

PROJECT: R15287R-05

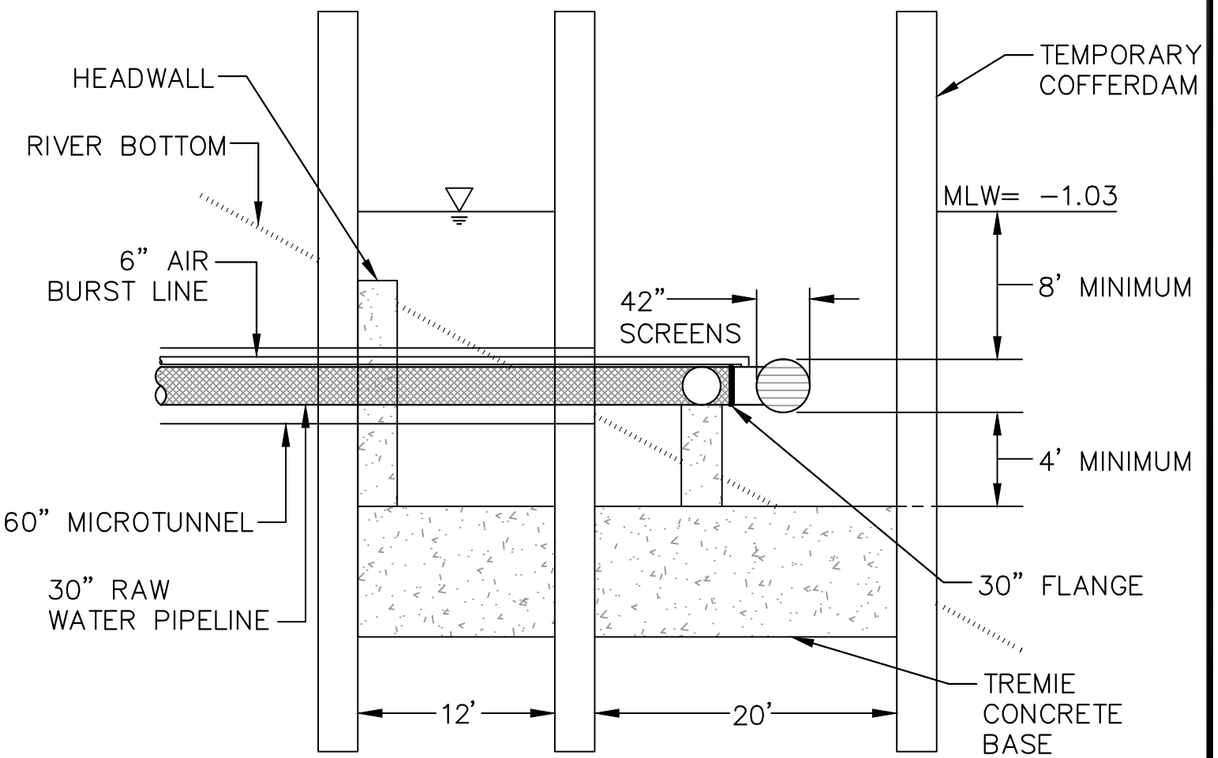
FIGURE 2

P:\R15\200\R15287R\R15287R-03\CAD\River Bed Cross Sections.dwg November 5, 2019 9:39:07 AM

INTAKE SCREENS - PLAN: 1"=10'



INTAKE SCREENS - SECTION A - A: 1"=10'



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Blacksburg, VA
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Hampton Roads, VA
Raleigh, NC
Fayetteville, NC
Northern Virginia
Virginia Beach, VA

DESIGNED: MSH
DRAWN: JYG
CHECKED: MSH

INTAKE LOCATION - PLAN
RAPPAHANNOCK RIVER WATER WITHDRAWAL
CAROLINE COUNTY, VIRGINIA

SCALE: AS SHOWN

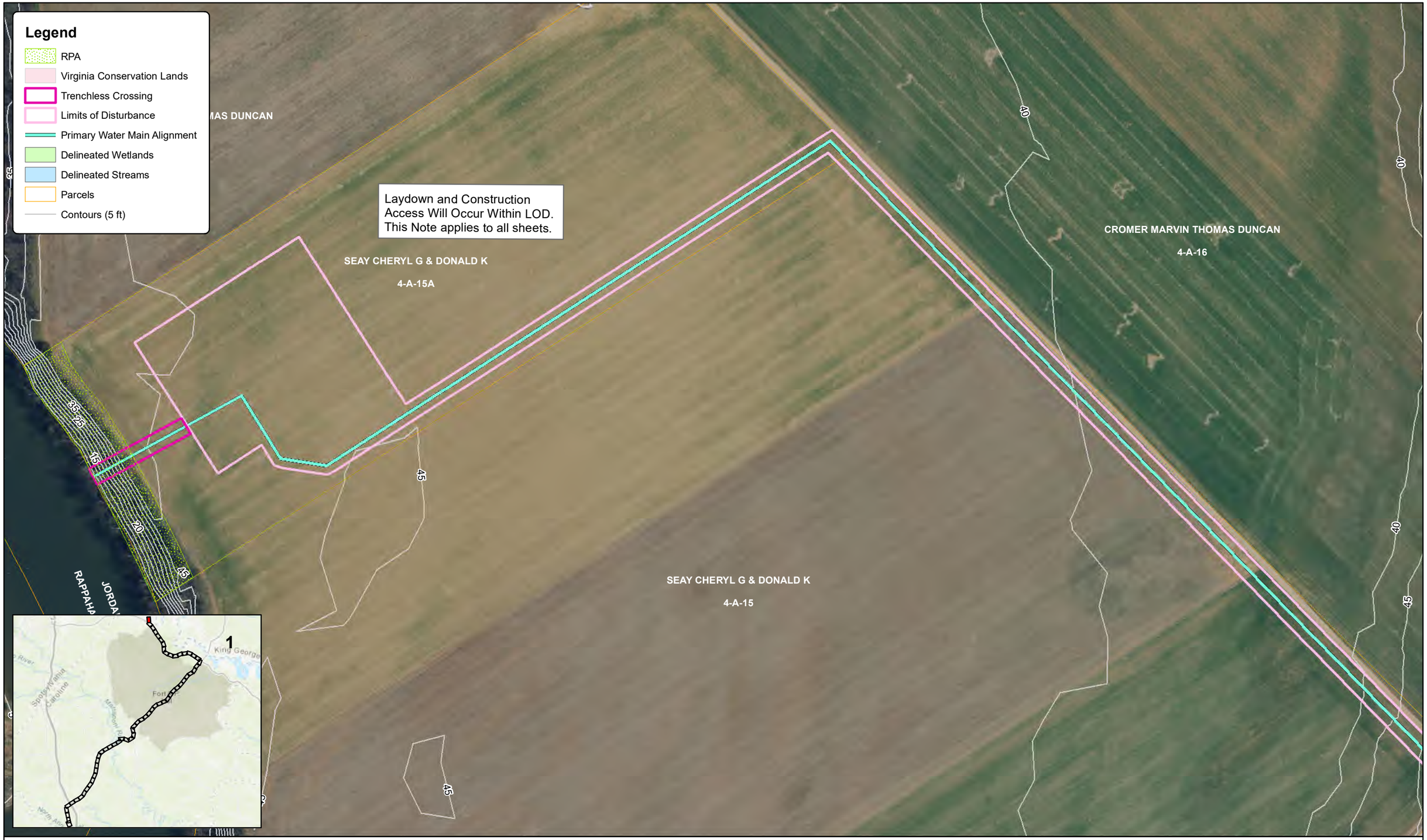
PROJECT: R15287R-05

FIGURE 3

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APPENDIX A.2
RAW WATER PIPELINE, FINISHED WATER PIPELINE, AND WTP SITE DRAWINGS

DEQ Response to Additional Information Request
Caroline County Rappahannock River Water Supply Project
JPA No. 20-0514
September 11, 2023



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DAA# R15287R-05

Potential Raw Water Main Index Maps
Caroline County, Virginia

0 100 200 400 Feet



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DAA# R15287R-05

Potential Raw Water Main Index Maps

Caroline County, Virginia

0 100 200 400 Feet


Legend
RPA
Virginia Conservation Lands
Trenchless Crossing
Limits of Disturbance
Primary Water Main Alignment
Delineated Wetlands
Delineated Streams
Parcels
Contours (5 ft)
PETTIGREW WILDLIFE MANAGEMENT AREA
COMMONWEALTH OF VA DEPT OF GAME & INLAND FISHERIES
11-A-44
PARKER JOSEPH W & PATRICIA LIFE ESTATE
4-A-18
17
FORT AP HILL CONSERVATION AREA
FORT A P HILL
44-A-1
3
King George
Spotsylvania
Caroline

Legend

- RPA
- Virginia Conservation Lands
- Trenchless Crossing
- Limits of Disturbance
- Primary Water Main Alignment
- Delineated Wetlands
- Delineated Streams
- Parcels
- Contours (5 ft)

PETTIGREW WILDLIFE MANAGEMENT AREA

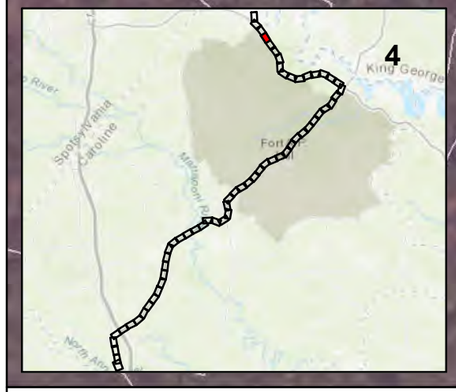
COMMONWEALTH OF VA DEPT OF GAME & INLAND FISHERIES
11-A-44

HAYMOUNT LIMITED PARTNERSHIP
C/O HAYMOUNT ASLI V LLLP
11-A-46

FORT AP HILL CONSERVATION AREA

FORT A P HILL
44-A-1

17



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Potential Raw Water Main Index Maps
Caroline County, Virginia

0 100 200 400 Feet



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Potential Raw Water Main Index Maps

Caroline County, Virginia

0 100 200 400 Feet



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Potential Raw Water Main Index Maps

Caroline County, Virginia

0 100 200 400 Feet

Legend

- RPA
- Virginia Conservation Lands
- Trenchless Crossing
- Limits of Disturbance
- Primary Water Main Alignment
- Delineated Wetlands
- Delineated Streams
- Parcels
- Contours (5 ft)

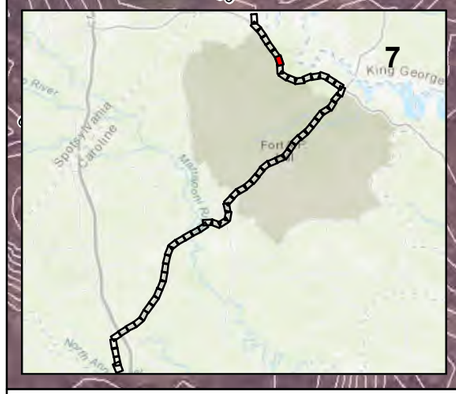
COMMONWEALTH OF VA DEPT OF GAME & INLAND FISHERIES
11-A-44

PETTIGREW WILDLIFE MANAGEMENT AREA

17

FORT AP HILL CONSERVATION AREA

FORT A P HILL
44-A-1



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Potential Raw Water Main Index Maps
Caroline County, Virginia

0 100 200 400 Feet


Legend
RPA
Virginia Conservation Lands
Trenchless Crossing
Limits of Disturbance
Primary Water Main Alignment
Delineated Wetlands
Delineated Streams
Parcels
Contours (5 ft)
COMMONWEALTH OF VA DEPT OF GAME & INLAND FISHERIES 11-A-44
PETTIGREW WILDLIFE MANAGEMENT AREA
FORT AP HILL CONSERVATION AREA
FORT A P HILL 44-A-1
CRAWFORD JAMES ALLEN & CATHERINE THERESA 11-A-10
HAYDEN GLENN E & HAYDEN KYLE W & HAYDEN MICHAEL W 11-A-11
DOWNING TIMOTHY & PORSCHE BRAD 11-A-12
CHILDERS KYLE ANTHONY & SHEARL 11-A-14A
POWELL SCOTT R & SHERRI A 11-A-14
HOWARD ANDREW J & JESSICA D 11-A-15E
PARKER WALTER WILLIAM SR & ERRERA-PARKER SUSAN M 11-A-16
HOWARD OTHA ALLEN & CATHERINE P 11-A-15
HOWARD OTHA RAY & BROOKS JENNIFER LEA 11-A-15B
STAPLES VIOLA P 11-A-15D
STAPLES VIOLA P 11-A-17
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King George
Spotsylvania
Caroline

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- Primary Water Main Alignment
- Delineated Wetlands
- Delineated Streams
- Parcels
- Contours (5 ft)

GARBER BONNIE ANN & THOMAS TEMPLEMAN
11-A-19A

SHIFLETT MATTIE E & GREEN DEBBIE R
11-A-19

STEVENS FAMILY CEMETERY
11-A-18

FORT AP HILL CONSERVATION AREA

FORT A P HILL
44-A-1

FOLEY MARY A
11-A-20A

LOGAN VICTOR R & WENDY R
11-A-20A1

MCMILLAN HUBERT O
11-A-20A2

YOUNG NANCY G
11-A-20

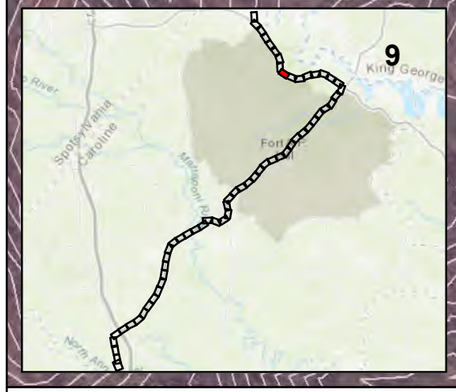
GREEN DAVID B & DEBBIE R
11-A-19B

STAPLES VIOLA P
11-A-17

STAPLES VIOLA P
11-A-15D

HOWARD C

17




Legend
RPA
Virginia Conservation Lands
Trenchless Crossing
Limits of Disturbance
Primary Water Main Alignment
Delineated Wetlands
Delineated Streams
Parcels
Contours (5 ft)
YOUNG NANCY G
11-A-20
COCKE JOHN RUFFIN
11-2-B
HICKS TAYLOR A
11-A-39
HICKS CHRISTOPHER P & RHONDA
11-A-40
HICKS CHRISTOPHER P & RHONDA
11-A-41
FOLEY MARY A
11-A-20A
HICKS CHRISTOPHER P
11-A-42
HICKS CHRISTOPHER P
11-A-42
HICKS CHRISTOPHER P
11-A-43
POWERS ELAINE R
11-3-11A
POWERS ELAINE R
11-3-10A
SALISBURY JAMES R
11-3-9A
SALISBURY JAMES R
11-3-8A
ROLLINS RICHARD LEWIS & JUNE W
11-3-7A
POWERS ELAINE R
11-3-6A
DIXON BURTON DANIEL JR
11-3-5A
DIXON BURTON DANIEL JR
11-3-4A
DAVIS TAMIAMMIE S
TAMIAMMIE S
11-3-3A
TAYLOR LOUISE SURLES
11-3-2A
JONES JACQUELINE JONES MORRIS JR
17
FORT AP HILL
CONSERVATION AREA
FORT A P HILL
44-A-1
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King George
Spotsylvania
Caroline


Legend
RPA
Virginia Conservation Lands
Trenchless Crossing
Limits of Disturbance
Primary Water Main Alignment
Delineated Wetlands
Delineated Streams
Parcels
Contours (5 ft)
JONES MORRIS LEWIS JR & ARNETTA
11-A-37
JONES MORRIS L JR & OTHERS
11-A-36
GARNETT BETTY & GARNETT CHARLES
11-A-35
CROWLEY DAISY I
11-A-34
MCKENNEY ADELINE E
11-A-33
TAYLOR PHILIP
11-A-32
JOHNSON WINFIELD SR ESTATE C/O JOHN JOHNSON EXEC
11-A-31
COTTRELL RICHARD
11-A-30
MYERS LISA & DRUMGOLE LISA VICTORIA
12-1-1
VIAR MICHAEL D & HART CARLENE
12-A-9
GROGG DANNY RAY
12-A-10
JONES JACQUELINE JONES MORRIS JR
11-3-1A
JONES JACQUELINE JONES MORRIS JR
11-3-4B
JONES MORRIS L JR & OTHERS
11-3-2B
JONES MORRIS L JR & OTHERS
11-3-3B
JONES MORRIS L JR & OTHERS
11-3-4B
17
FORT AP HILL CONSERVATION AREA
FORT A P HILL
44-A-1
11
King George
Spotsylvania
Caroline



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DAA# R15287R-05

Potential Raw Water Main Index Maps

Caroline County, Virginia

0 100 200 400 Feet


Legend
RPA
Virginia Conservation Lands
Trenchless Crossing
Limits of Disturbance
Primary Water Main Alignment
Delineated Wetlands
Delineated Streams
Parcels
Contours (5 ft)
GARRETT CORY D
12-A-37B
ABRAHAM JOHN J JR
12-A-38
PHILLIPS JR EST
LIAM E/ROLLINS
12-A-11
CAY JOHN E III TR
12-A-12
VA CONSERVATION LANDS
17
13
King George
Fort
Spotsylvania
Caroline
North Anna

Legend

- RPA
- Virginia Conservation Lands
- Trenchless Crossing
- Limits of Disturbance
- Primary Water Main Alignment
- Delineated Wetlands
- Delineated Streams
- Parcels
- Contours (5 ft)

GARRETT JAMES R & HELEN A
12-A-37A

GARRETT COURT D
12-A-37B

GAY MONT LLC
C/O JOHN CAY
12-A-20D

KETNER FLOURETT M & MARK L
12-A-21

RHOAD STEVEN R
12-A-20D2

GAY MONT LLC
C/O JOHN CAY
12-A-20D

STEINC CALEB & JULIE R
12-A-19

RHOAD STEVEN R
12-A-20D1

17

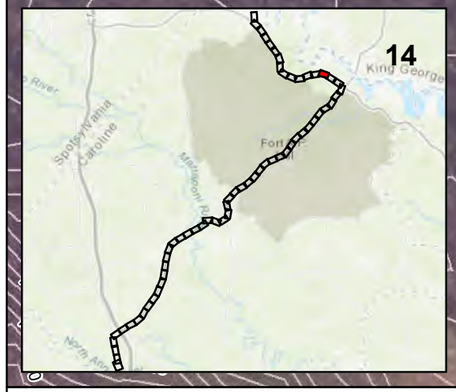
VA CONSERVATION LANDS

CAY JOHN E III TR
12-A-12

12-3-B

DOBSON ROBERT HUGH
12-3-A

DOBSON ROBERT HUGH
12-3-A



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Potential Raw Water Main Index Maps
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0 100 200 400 Feet


Legend
RPA
Virginia Conservation Lands
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Primary Water Main Alignment
Delineated Wetlands
Delineated Streams
Parcels
Contours (5 ft)
CCG POND INC
12-A-18
VA CONSERVATION LANDS
12-A-3
HOLLOWY C B JR
12-3-B
J T J GOULDMAN FARMS INC
12-A-17
GOULDMAN FARMS INC
12-A-14
DOBSON ROBERT HUGH
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DOBSON ROBERT HUGH
HOLLOWAY C B JR
12-A-13
WILKERSON VIRGINIA JOYCE
21-A-1
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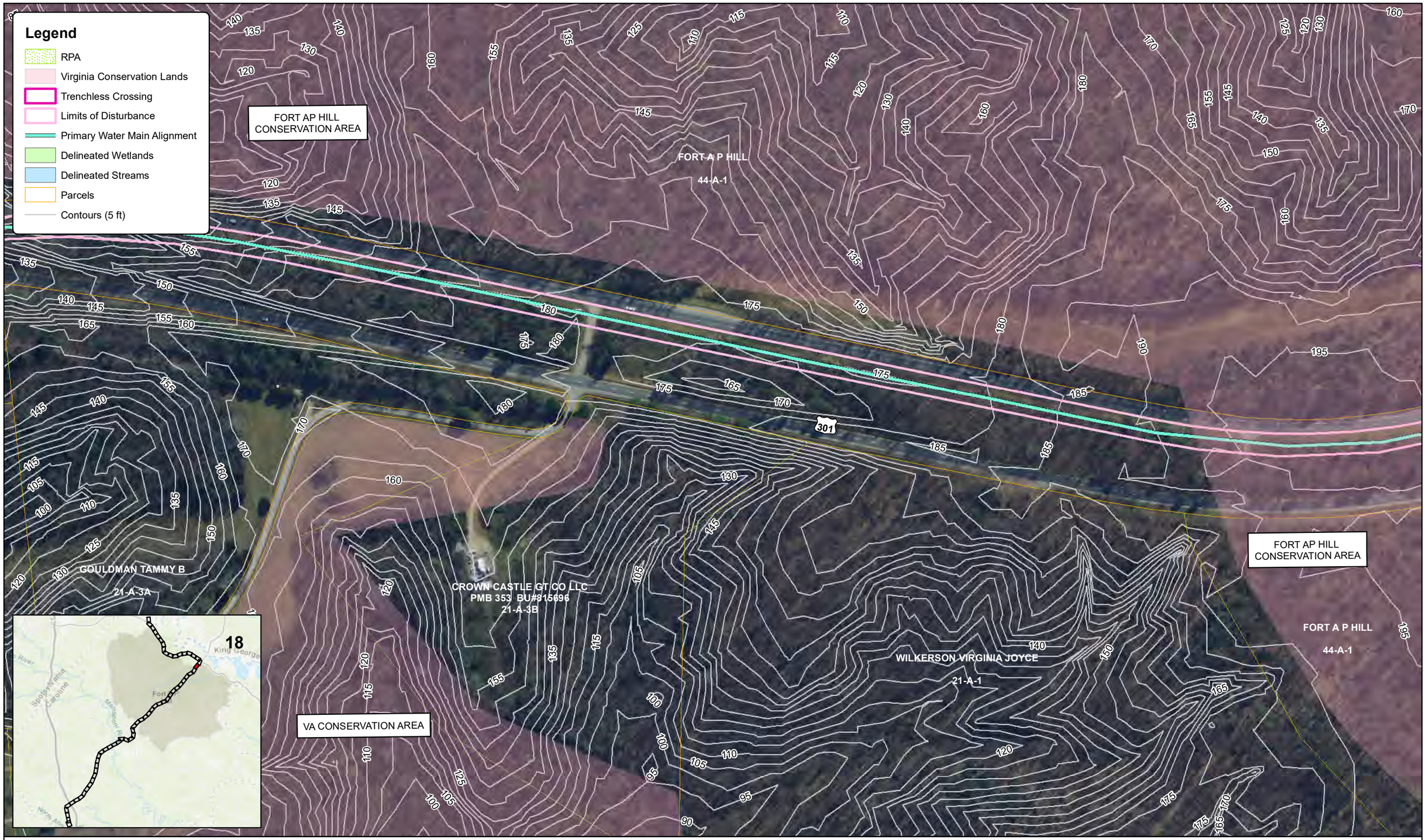
DAA# R15287R-05

Potential Raw Water Main Index Maps

Caroline County, Virginia

0 100 200 400 Feet


Legend
RPA
Virginia Conservation Lands
Trenchless Crossing
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Contours (5 ft)
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44-A-1
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BOOKER E DERWIN JR & BOOKER WILLIAM H & HOLLOWAY C B JR
22-A-4
GOULDMAN FARMS INC
22-A-13A
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AS KERMIT P JR & AUDREY C
22-A-3
CARPENTER WILLIAM D & PHYLLIS SUE
22-A-14
J T J GOULDMAN FARMS INC
22-A-13
GOULDMAN TAMMY B
21-A-3A
CARPENTER PHYLLIS G
21-A-3
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301
King George
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Caroline

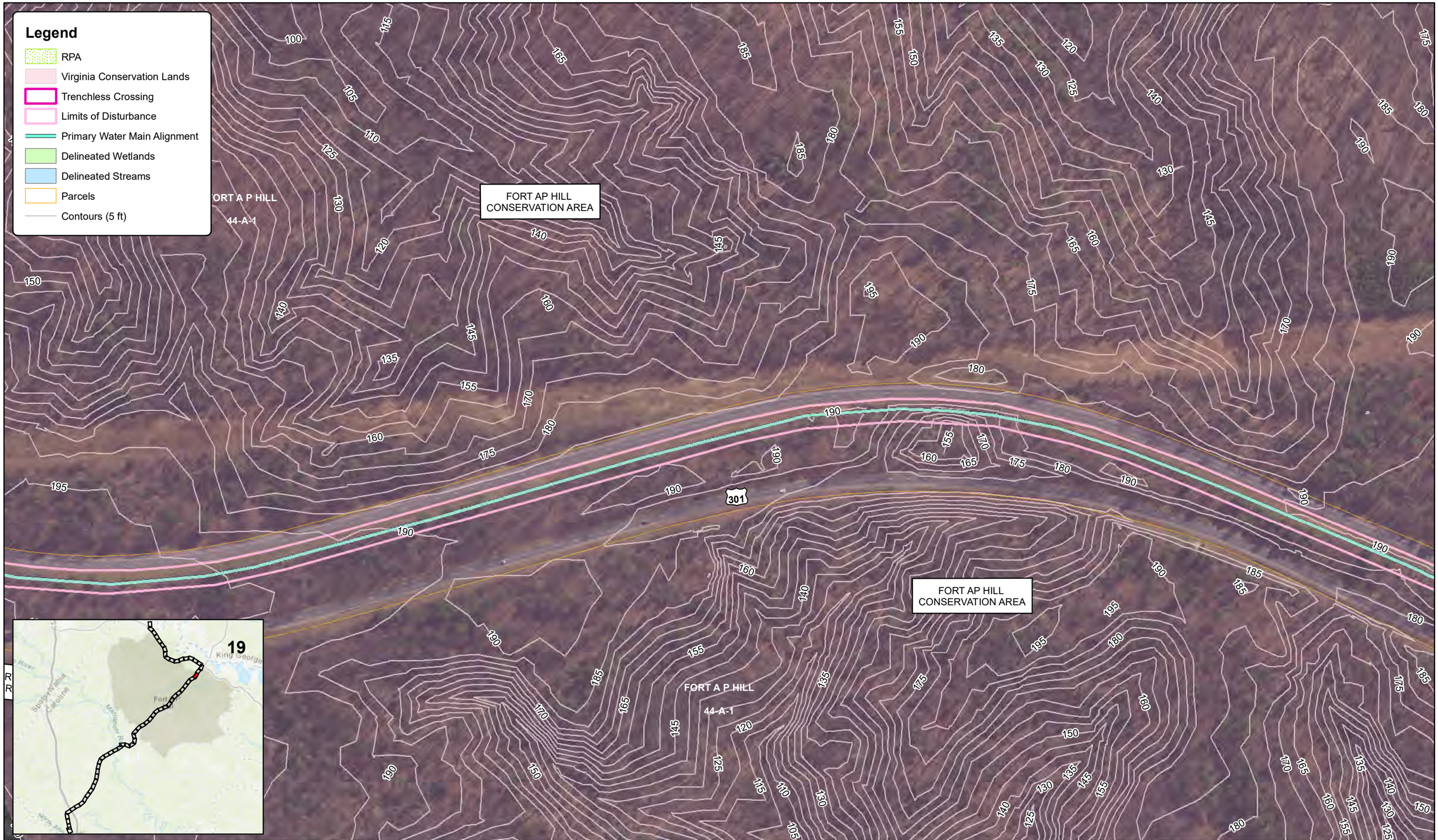


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Caroline County, Virginia

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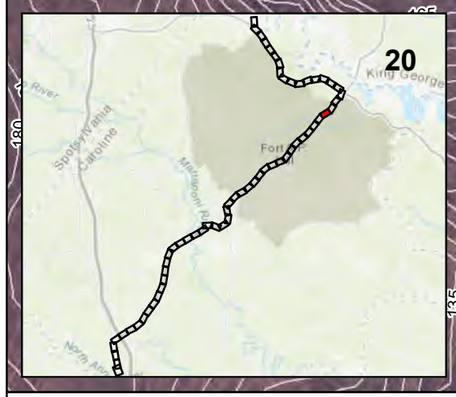
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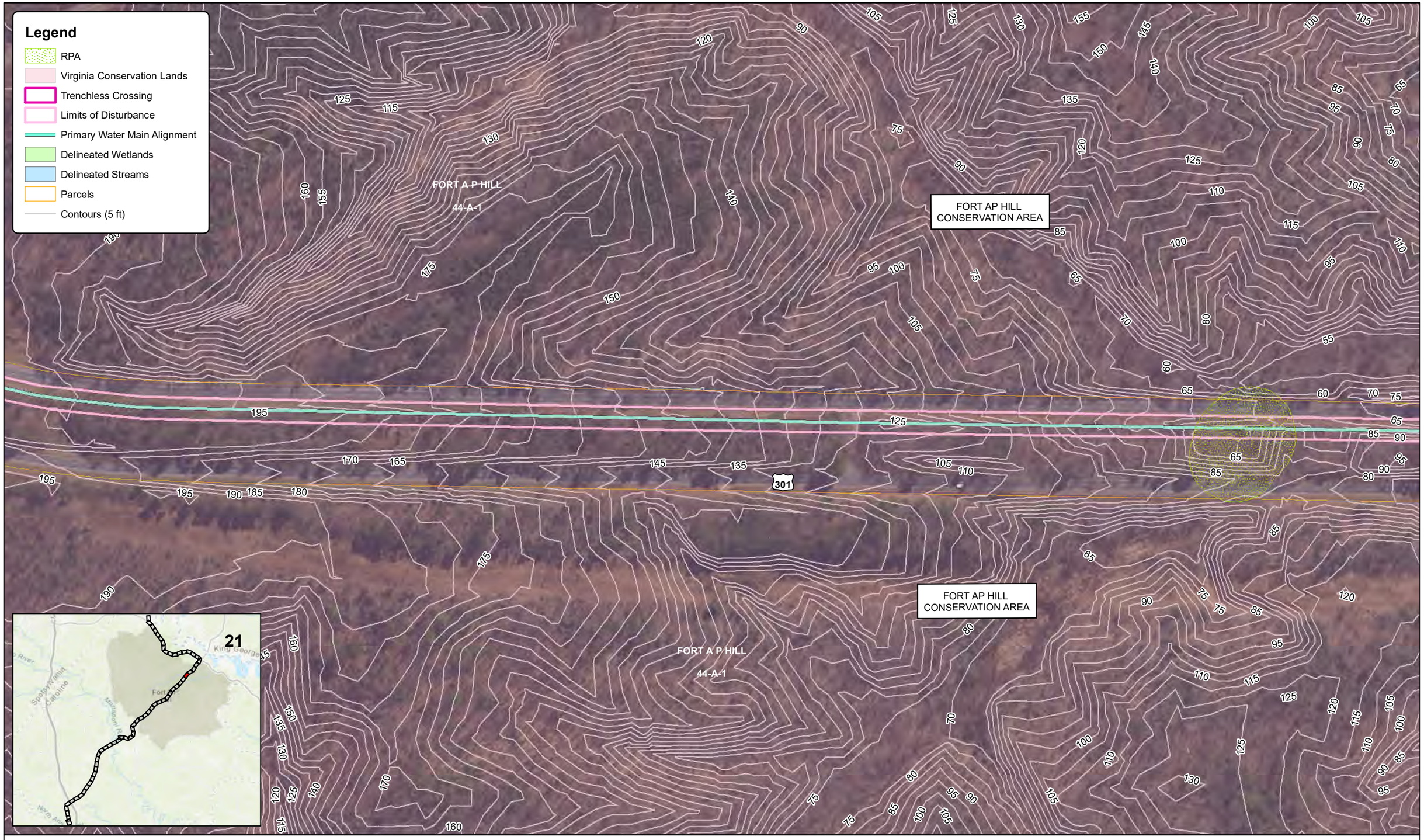
- RPA
- Virginia Conservation Lands
- Trenchless Crossing
- Limits of Disturbance
- Primary Water Main Alignment
- Delineated Wetlands
- Delineated Streams
- Parcels
- Contours (5 ft)

FORT A P HILL
44-A-1

FORT AP HILL
CONSERVATION AREA

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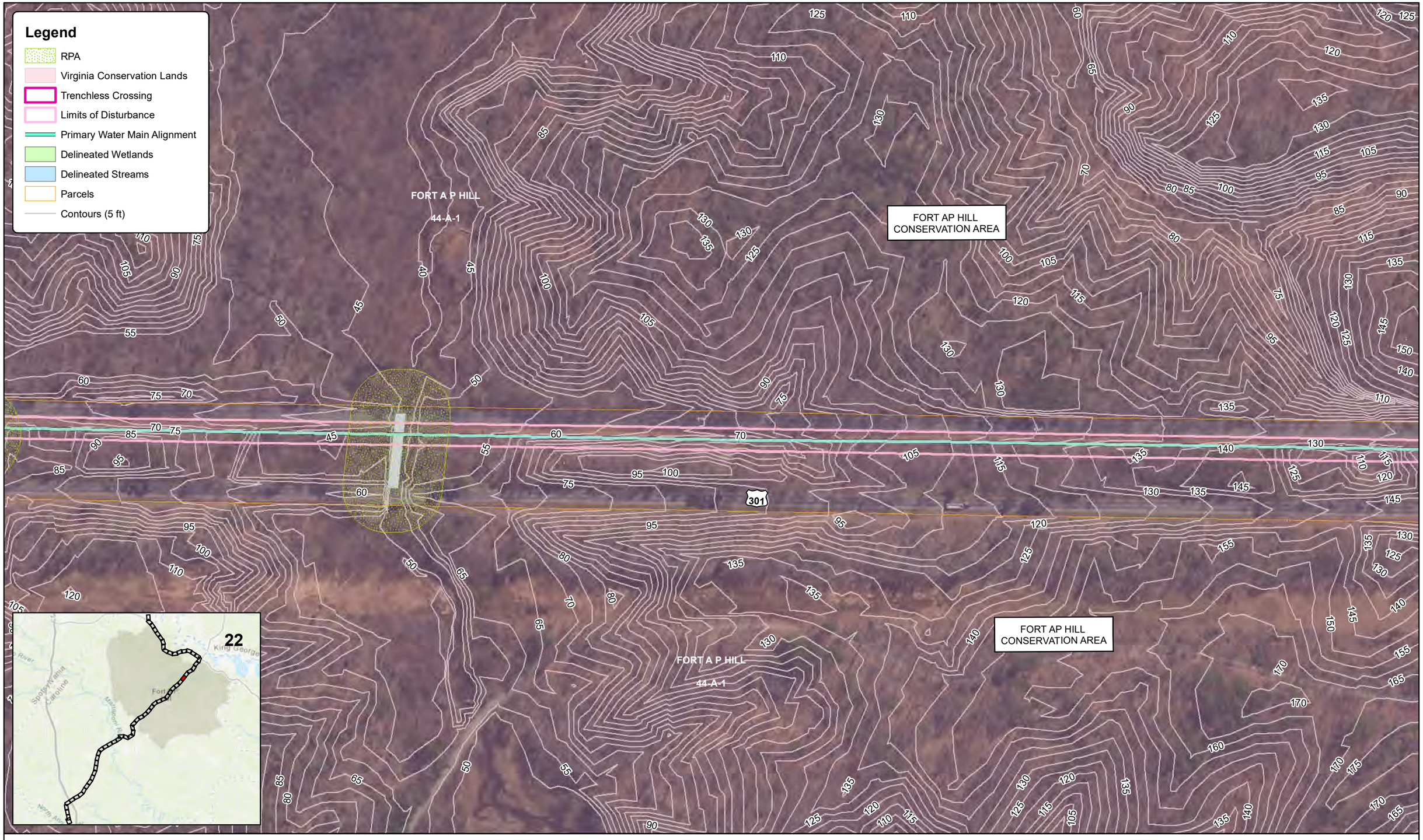
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Potential Raw Water Main Index Maps

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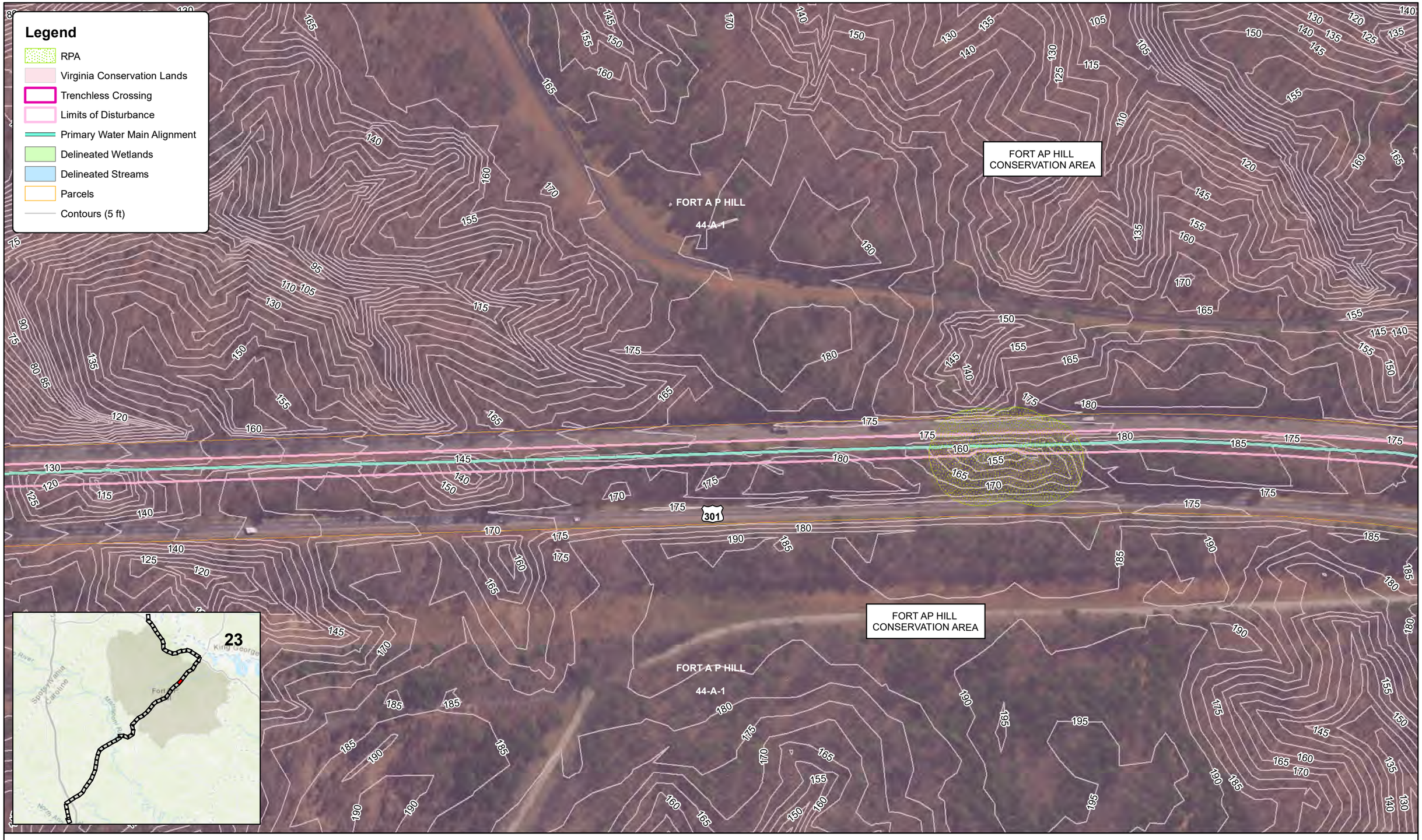
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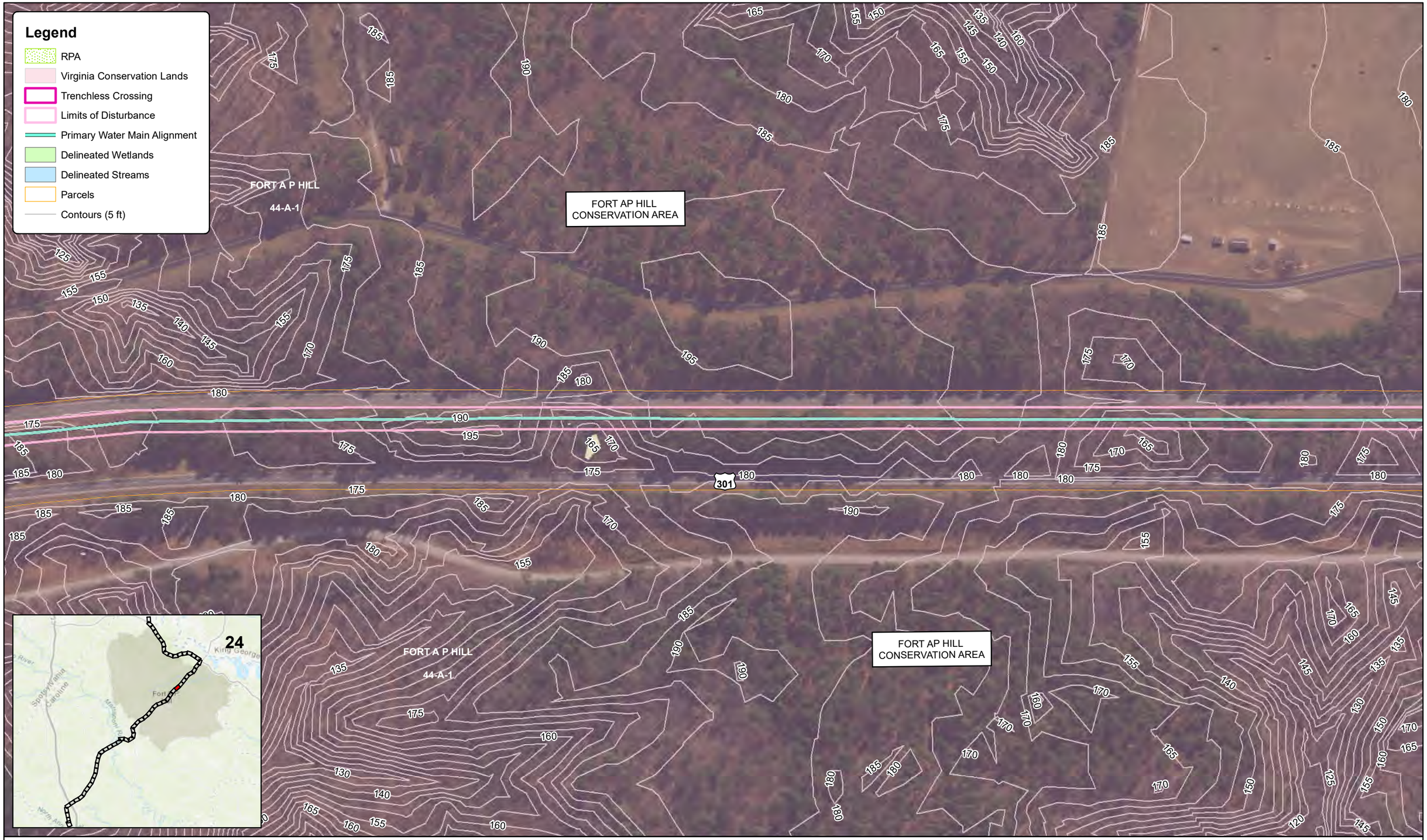


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CONSERVATION AREA
FORT AP HILL
CONSERVATION AREA
FORT A P HILL
44-A-1
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King George



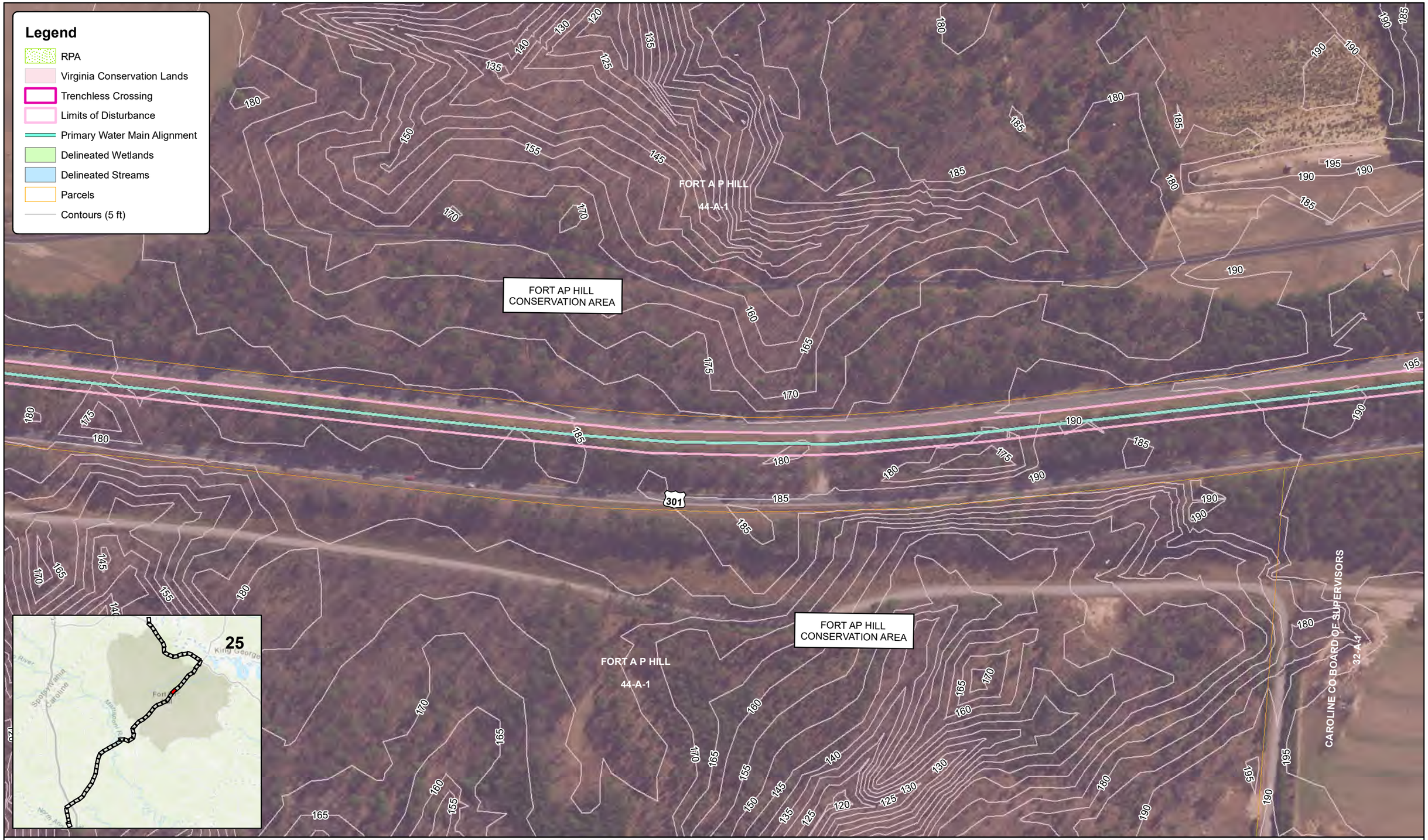
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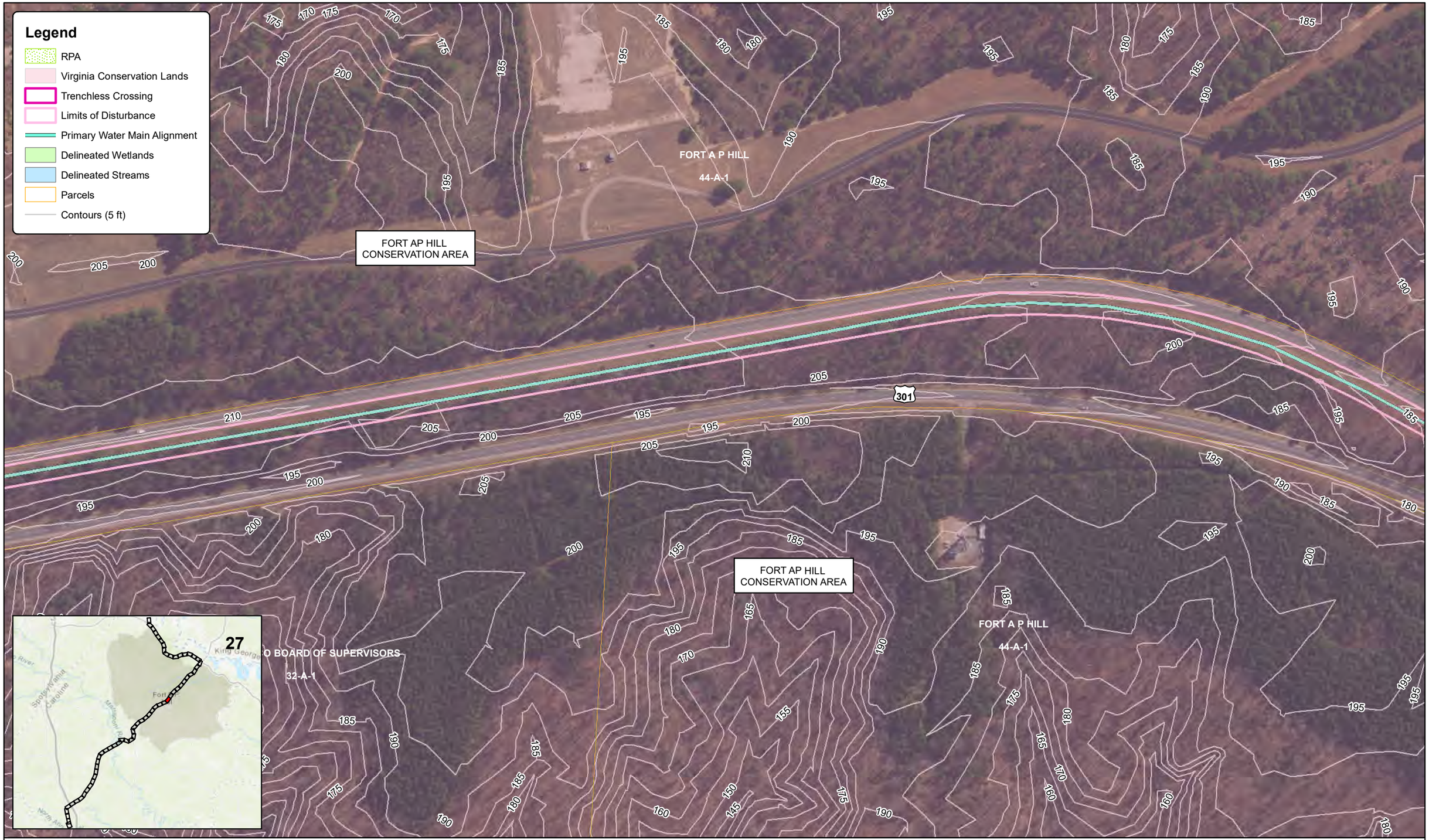
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FORT AP HILL
CONSERVATION AREA
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- Primary Water Main Alignment
- Delineated Wetlands
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- Contours (5 ft)

FORT AP HILL CONSERVATION AREA

FORT A P HILL

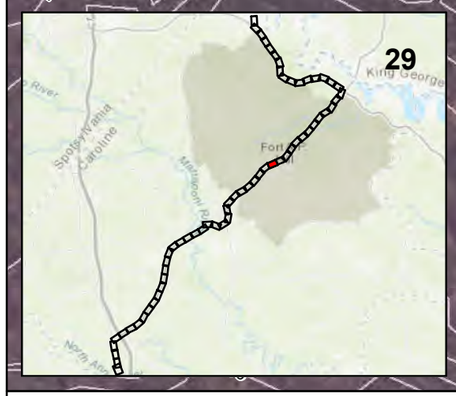
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FORT AP HILL CONSERVATION AREA

FORT A P HILL

44-A-1

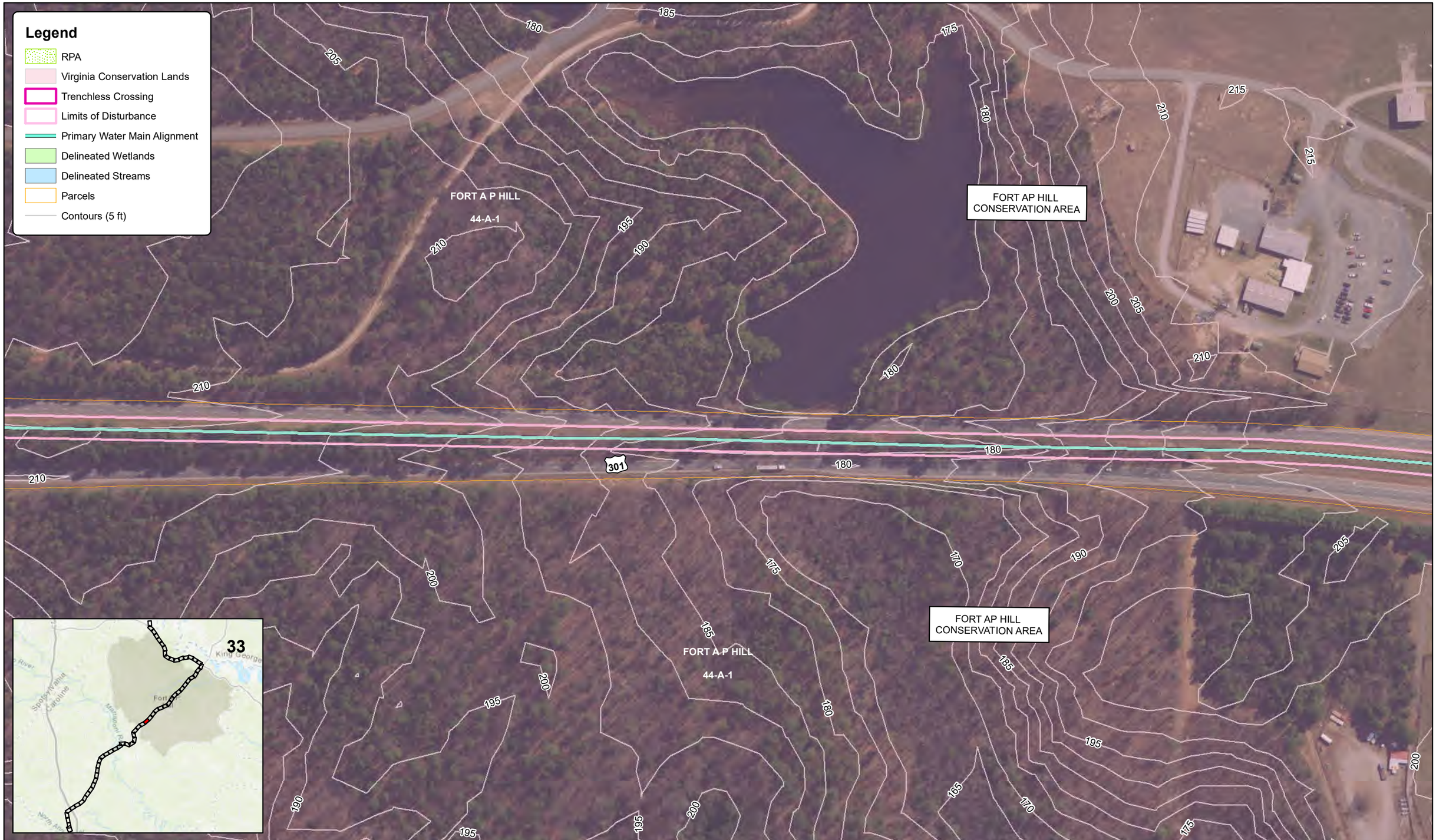
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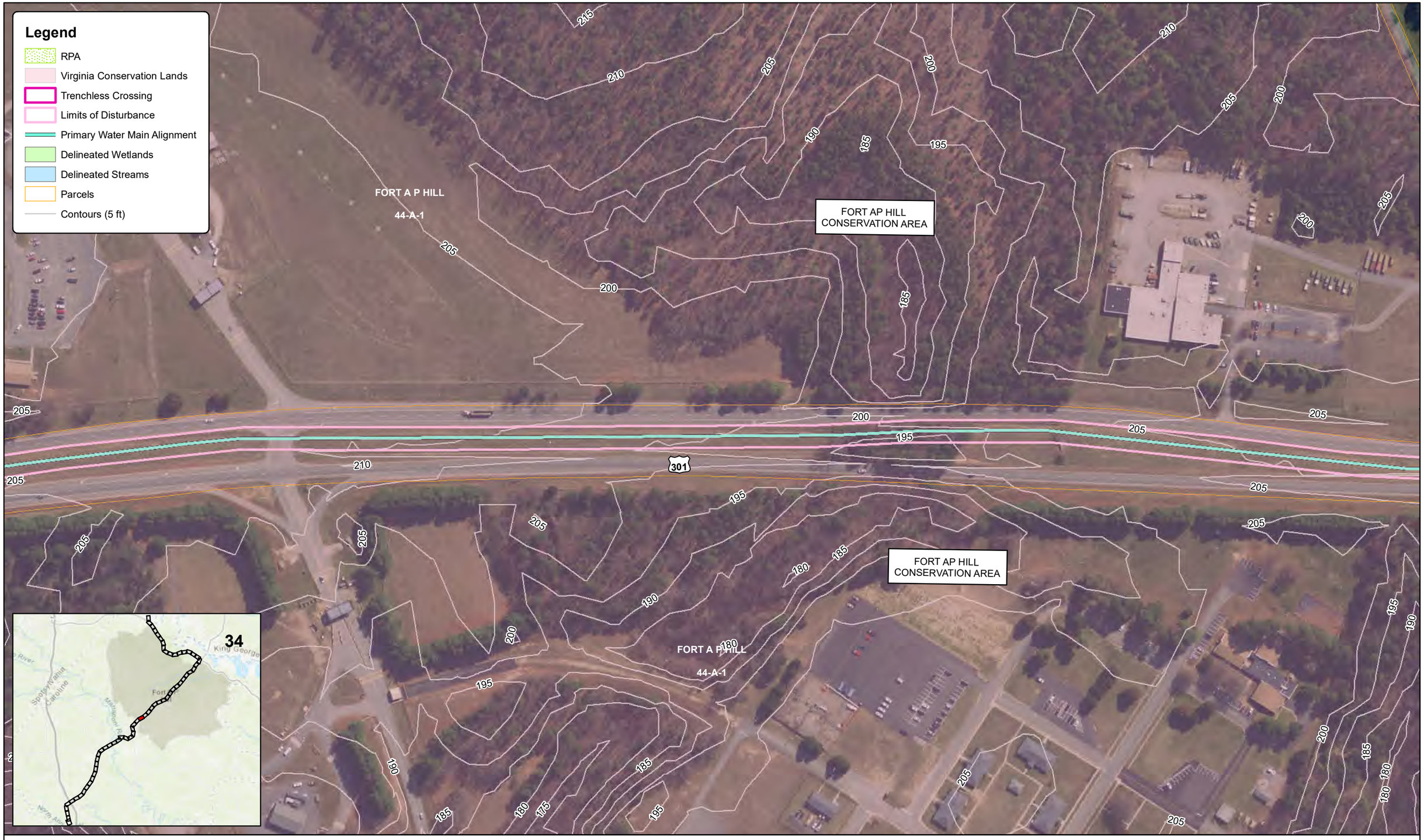



Legend
RPA
Virginia Conservation Lands
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Delineated Streams
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FORT AP HILL
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FORT AP HILL
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Caroline
FORT A P HILL
44-A-1
FORT AP HILL
CONSERVATION AREA


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Delineated Streams
Parcels
Contours (5 ft)
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44-A-1
FORT AP HILL
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King George
Caroline
FORT A P HILL
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FORT AP HILL
CONSERVATION AREA



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CAROLINE CO BOARD OF SUPERVISORS
44-A-21

MAHON FAMILY PARTNERSHIP LLP
43E-3-1

SMG LLC
44-A-6

SMG LLC
44-A-4

SMG LLC
44-A-5

VILLAGE SELF STORAGE II LLC
43-A-45

CRISMOND JAMES E
43E-2-2

ELLIOTT CARROLL F TR
43E-2-1

ELLIOTT CARROLL F TR
43-A-46

HARRIS DAWN M
43-A-48

FORT AP HILL
CONSERVATION AREA

BHAGAT MORESHWARKUMAR M & DIPTI M
44-A-3

BHAGAT MORESHWARKUMAR M & DIPTI M
44-A-7

CHASE STREET HOPS LLC
44-A-4A

CHASE STREET HOPS LLC
44-A-2

TOWN OF BOWLING GREEN
43-A-42C1

TRS OF BOWLING GREEN CHRISTIAN FELLOWSHIP
43-18-1-1

TRS OF BOWLING GREEN CHRISTIAN FELLOWSHIP
43-18-1-2

ANDERSON FAMILY LIMITED PARTNERSHIP
44-A-1B

NORTHVIEW PROPERTIES L C
43-A-42C

MAHON FAMILY PARTNERSHIP LLC
44-A-1A

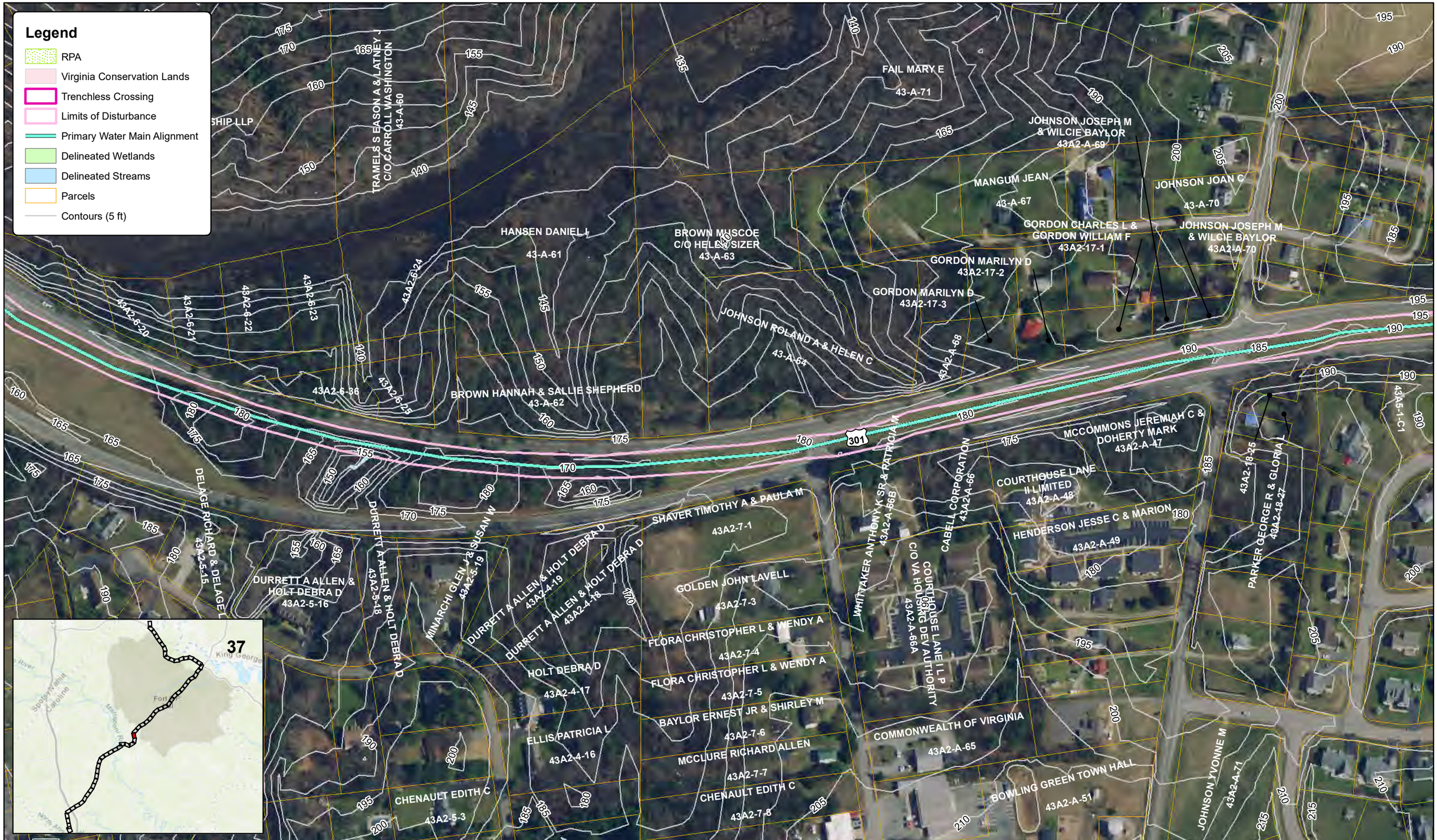
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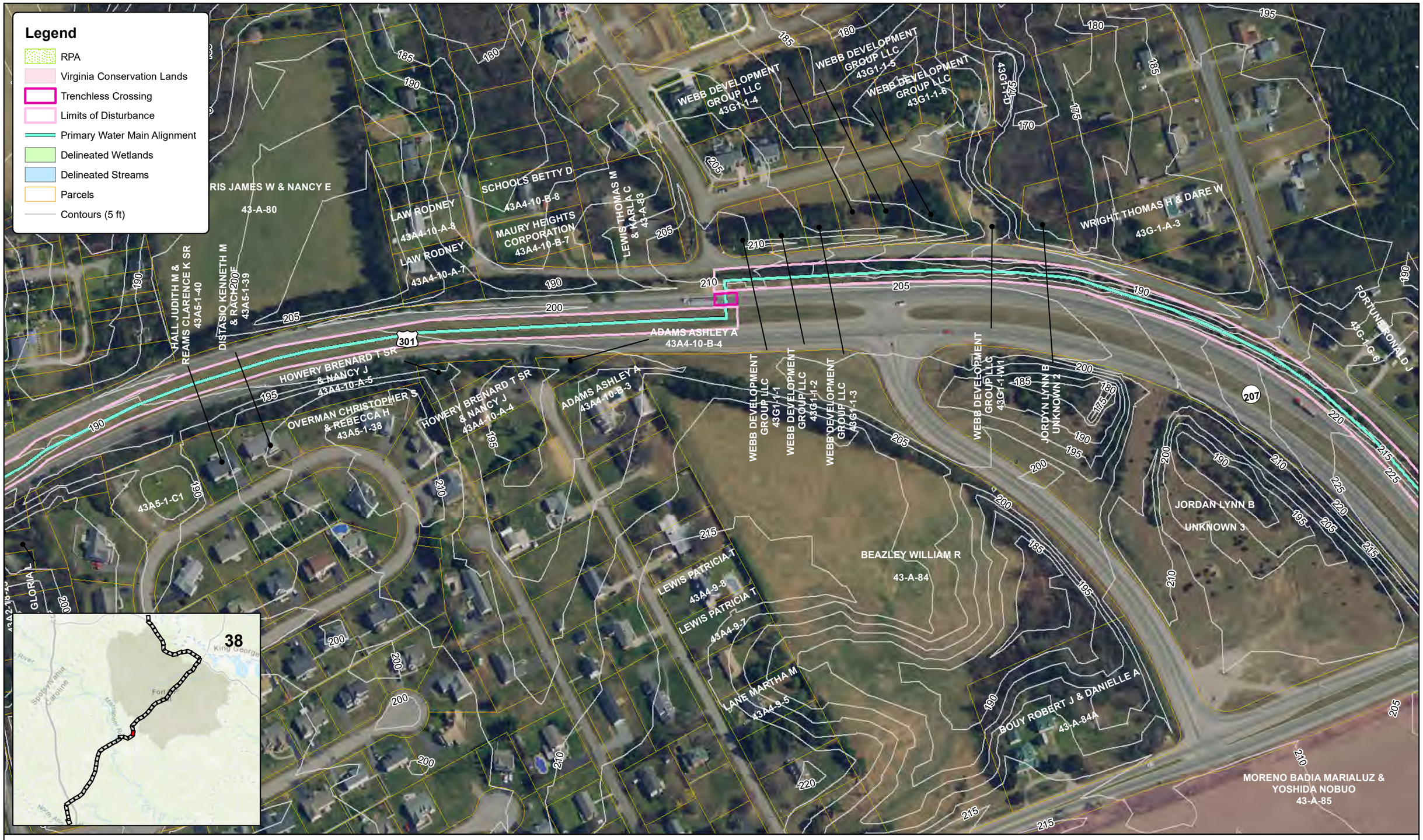
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Legend
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SWAIN PETER & NANCY
43E-4-17
TAYLOR SANDRA A
43E-4-1
HOLLYMONT TRUST
43E-4-3
CALLAHAN ROSIE
200 A-57
JOHNSON JOAN C
43-A-56
MAHON FAMILY PARTNERSHIP LLP
43E-4-5
MAHON FAMILY PARTNERSHIP LLP
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MAHON FAMILY PARTNERSHIP LLP
43E-4-6
BUSH MARSHA G
43E-3-21
FOWLER ANN
43E-3-22
AMATO VITO & JOSEPHINE
43-A-51
GILES MARK A
43-A-52
CUTLIP DONALD B
43-A-53
TRS OF VET OF FOREIGN WARS
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43-A-54
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43-A-48
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AMATO VITO & JOSEPHINE
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AMATO VITO & JOSEPHINE
43-A-50
MANNS MICHAEL N & CAROL H &
43E-1-1
HANSEN DANIEL I
43E-1-3
HANSEN DANIEL I
43E-1-4
HANSEN DANIEL I
43E-1-5
HANSEN DANIEL I
43E-1-6
MANNS MICHAEL N & CAROL H
43E-1-2
MANNS MICHAEL N & CAROL H
43-A-35
HANSEN DANIEL I
43E-1-8
HANSEN DANIEL I
43E-1-7
HANSEN DANIEL I
43-A-34
COMMONWEALTH OF VA VDOT
43E-A-1
SWAIN PETER B LIFE ESTATE
43-A-33
MAHON FAMILY PARTNERSHIP LLP
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43A2-6-21
43A2-6-20
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TRAMEL S EASON A & LATNEY J C/O CARROLL WASHINGTON
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FAIL MARY E
43-A-71
JOHNSON JOSEPH M & WILCIE BAYLOR
43A2-A-69
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JOHNSON JOAN C
43-A-70
GORDON CHARLES L & GORDON WILLIAM F
43A2-17-1
JOHNSON JOSEPH M & WILCIE BAYLOR
43A2-A-70
GORDON MARILYN D
43A2-17-2
GORDON MARILYN D
43A2-17-3
HANSEN DANIEL J
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JOHNSON ROLAND A & HELEN C
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BROWN HANNAH & SALLIE SHEPHERD
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43A2-6-22
43A2-6-23
43A2-6-24
43A2-6-25
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PARKER GEORGE R & GLORIA L
43A2-18-27
SHAVER TIMOTHY A & PAUL A M
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GOLDEN JOHN LAVELL
43A2-7-3
FLORA CHRISTOPHER L & WENDY A
43A2-7-4
FLORA CHRISTOPHER L & WENDY A
43A2-7-5
BAYLOR ERNEST JR & SHIRLEY M
43A2-7-6
MCCLURE RICHARD ALLEN
43A2-7-7
CHENAULT EDITH C
43A2-7-8
WHITTAKER ANTHONY K SR & PATRICIA M
43A2-A-66B
CABELL CORPORATION
43A2-A-66
COURTHOUSE LANE II L P C/O VA HOUSING DEV AUTHORITY
43A2-A-66A
COMMONWEALTH OF VIRGINIA
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43A2-A-51
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DURRETT A ALLEN & HOLT DEBRA D
43A2-5-16
43A2-5-18
43A2-5-19
43A2-4-19
43A2-4-18
HOLT DEBRA D
43A2-4-17
ELLIS PATRICIA L
43A2-4-16
CHENAULT EDITH C
43A2-5-3
DELAGE RICHARD & DELAGE
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MINARCHI GLEN J & SUSAN W
43A2-5-19
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Spotsylvania
Caroline
Fort
North Anna



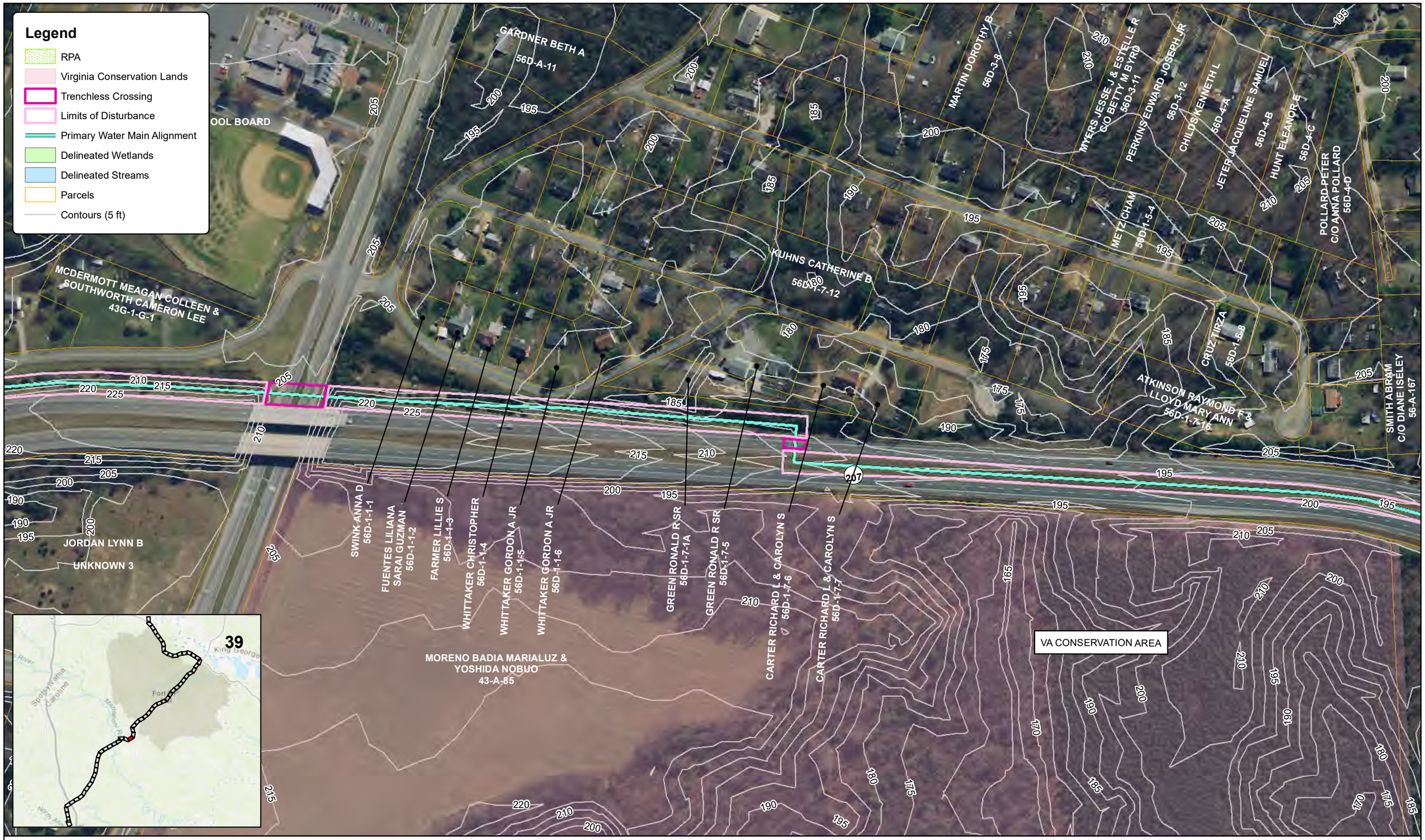
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GARDNER BETH A
56D-A-11
MARTIN DOROTHY B
56D-3-8
MYERS JESSE J & ESTELLE R C/O BETTY M BYRD
56D-3-11
PERKINS EDWARD JOSEPH JR
56D-3-12
CHILDS KENNETH L
56D-4-A
JETER JACQUELINE SAMUEL
56D-4-B
HUNT ELEANOR E
56D-4-C
POLLARD PETER C/O ANNA POLLARD
56D-4-D
METZ CHAM
56D-1-5-A
CRUZ TIRZA
56D-1-5-B
ATKINSON RAYMOND F & LLOYD MARY ANN
56D-1-7-16
SMITH ABRAM C/O DIANE ISELEY
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KUHNS CATHERINE B
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MCDERMOTT MEAGAN COLLEEN & SOUTHWORTH CAMERON LEE
43G-1-G-1
OOL BOARD
JORDAN LYNN B
UNKNOWN 3
SWINK ANNA D
56D-1-1-1
FUENTES LILIANA SARAI GUZMAN
56D-1-1-2
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56D-1-1-3
WHITTAKER CHRISTOPHER
56D-1-1-4
WHITTAKER GORDON A JR
56D-1-1-5
WHITTAKER GORDON A JR
56D-1-1-6
GREEN RONALD R SR
56D-1-7-1A
GREEN RONALD R SR
56D-1-7-5
CARTER RICHARD L & CAROLYN S
56D-1-7-6
CARTER RICHARD L & CAROLYN S
56D-1-7-7
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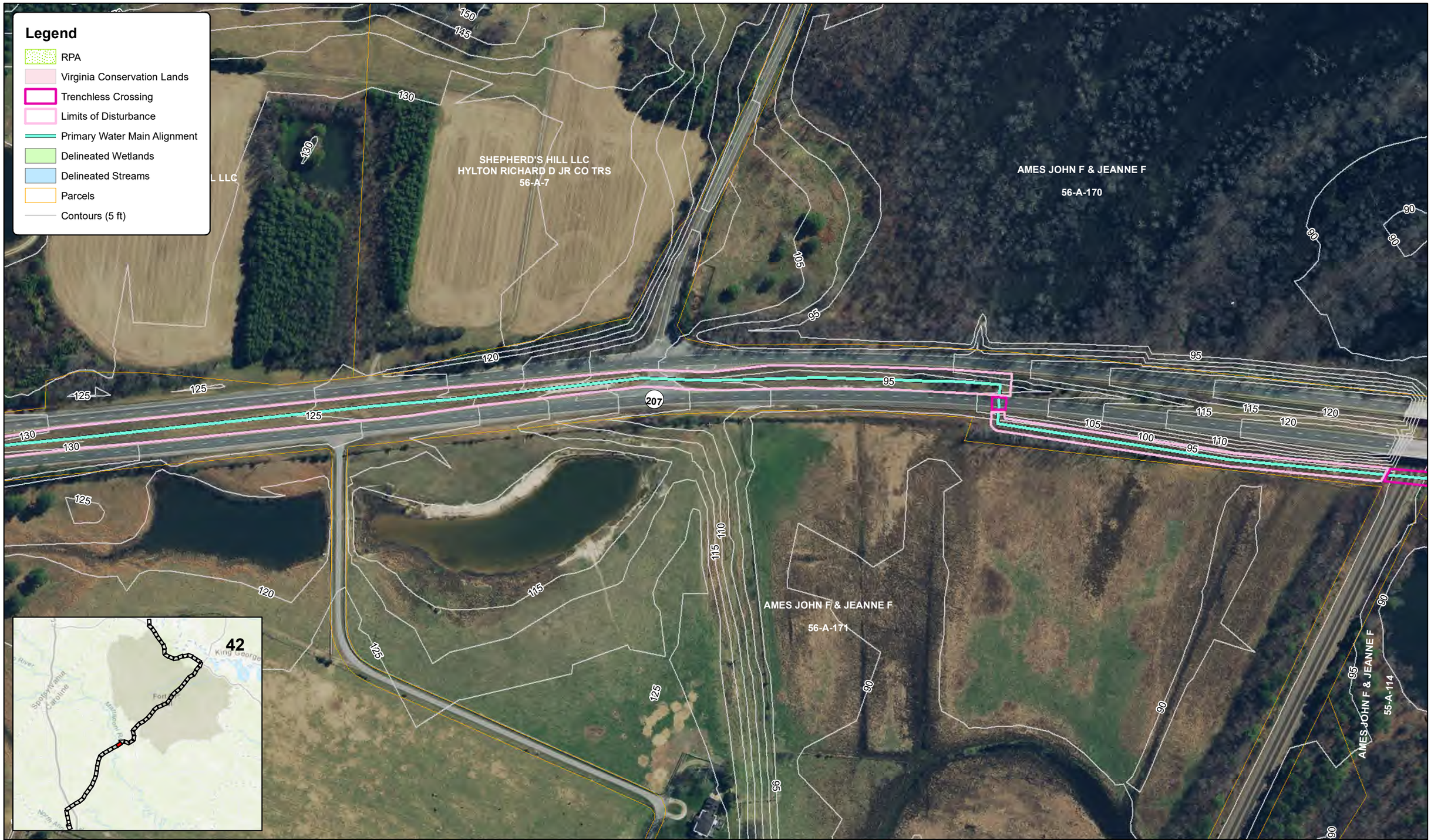
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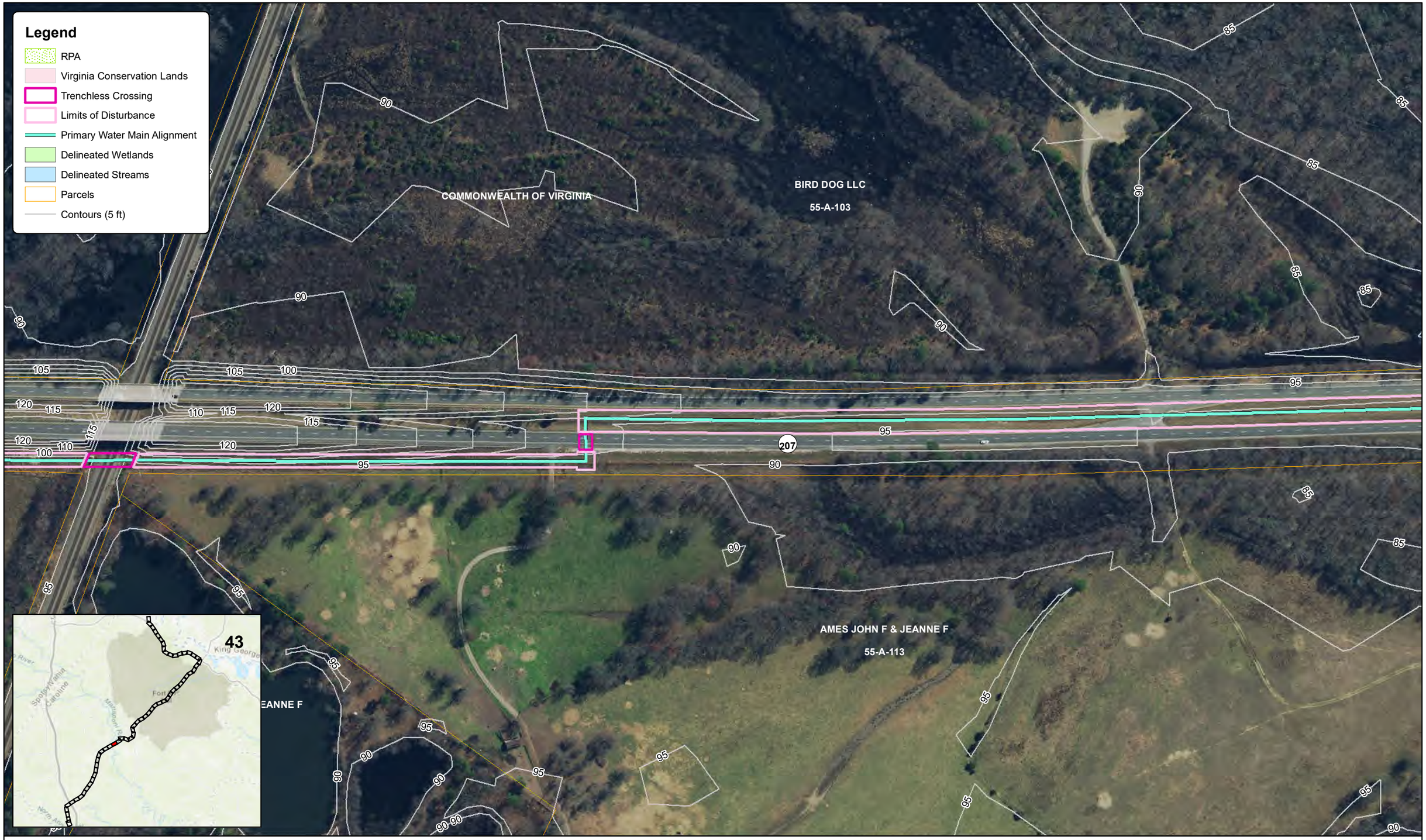


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SHEPHERD'S HILL LLC
HYLTON RICHARD D JR CO TRS
56-A-7
AMES JOHN F & JEANNE F
56-A-170
AMES JOHN F & JEANNE F
56-A-171
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MATTAPONI RIVER
BLANTON LEWIS P & MARY S
55-A-112
BLANTON LEWIS P & MARY S
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55C-1-5
OGNIBENE JAMES V & KATHLEEN M
55C-1-4
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55C-1-3
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55C-1-2
HOUSDEN VALERIE J
55-A-110
SCHON MARK A & WEINHOLD ROBIN K
C/O SUSAN SCHON
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Spotsylvania
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0 100 200 400 Feet



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DAA# R15287R-05

Potential Raw Water Main Index Maps
Caroline County, Virginia

0 100 200 400 Feet

Legend

- RPA
- Virginia Conservation Lands
- Trenchless Crossing
- Limits of Disturbance
- Primary Water Main Alignment
- Delineated Wetlands
- Delineated Streams
- Parcels
- Contours (5 ft)

RHODES TROY
69-7-1

NAPIER THOMAS N & DEBRA A
69-7-2

HAISLOP WILLIAM C JR & KIMBERLY S
69-7-3

MORROW ROGER DAVID JR & BROOKS VICKI MARLENE
69-7-4

GAUMER JOSEPH & SHIRLEY
69-7-5

POIRIER JOSEPH M & SUSAN C
69-7-6

CF LAND HOLDINGS LLC
69-7-7

NOEL TASHIA
69-7-8

SMITH CECIL E & BETTY F
69-7-9

CF LAND HOLDINGS LLC
69-A-46

COLLINS CHARLES B OR BETTY A TRS &
COLLINS DAVID ALLISON
69-A-46A

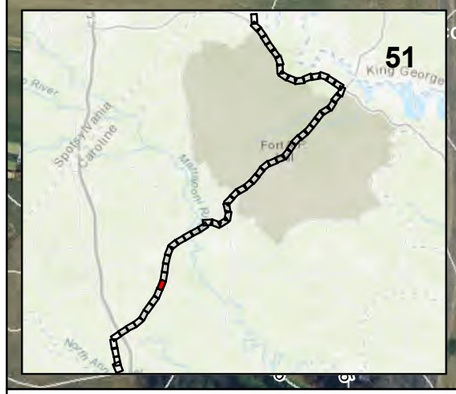
TRS OF RUTHER GLEN CONGREGATIO
69-A-45

BEACH PAUL J & BRENDA T
69-A-43D

BEACH PAUL J & BRENDA T
69-A-43B

TERRELL DONALD S
69-A-43

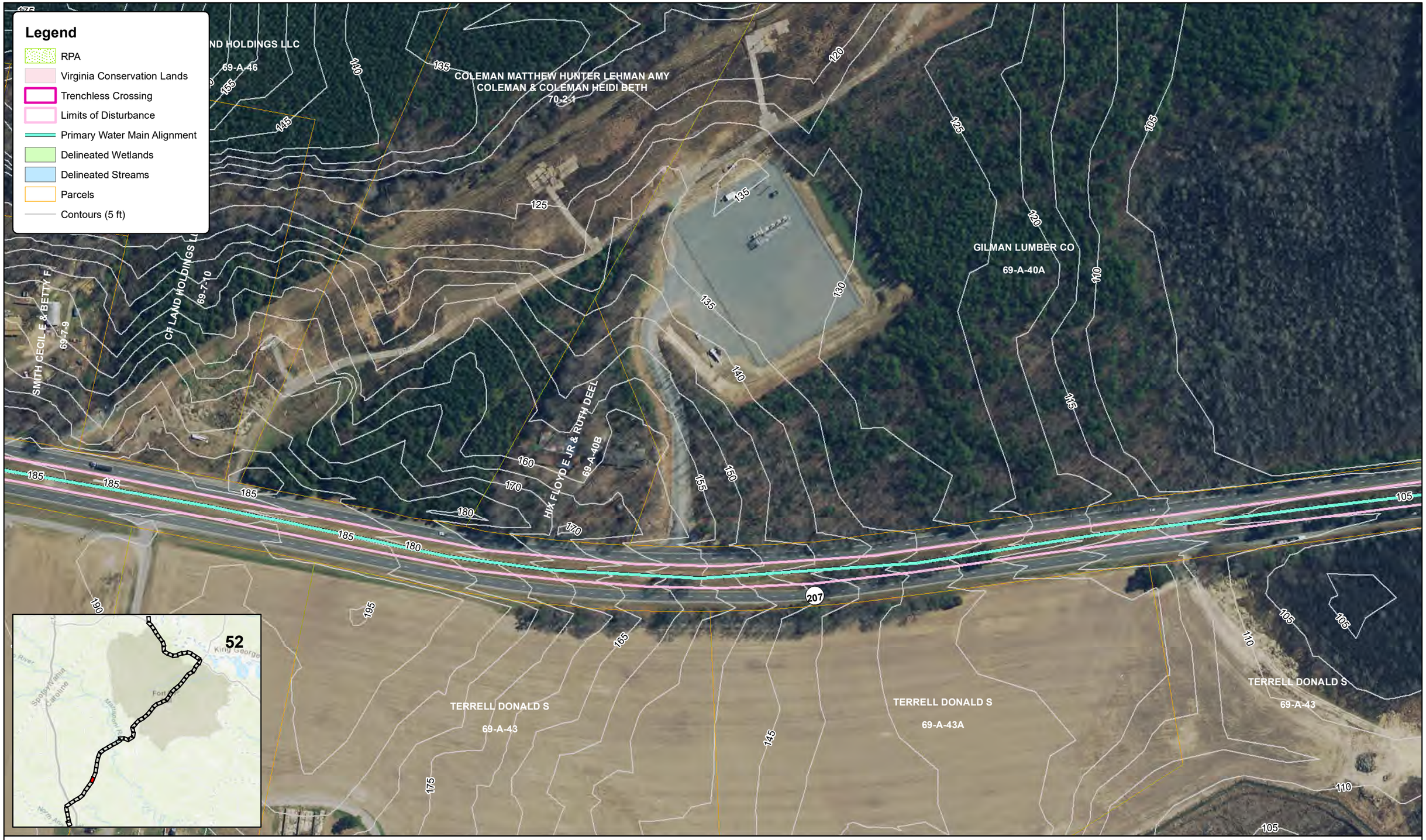
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Potential Raw Water Main Index Maps
Caroline County, Virginia

0 100 200 400 Feet


Legend
RPA
Virginia Conservation Lands
Trenchless Crossing
Limits of Disturbance
Primary Water Main Alignment
Delineated Wetlands
Delineated Streams
Parcels
Contours (5 ft)
ND HOLDINGS LLC
69-A-46
COLEMAN MATTHEW HUNTER LEHMAN AMY
COLEMAN & COLEMAN HEIDI BETH
70-2-1
GILMAN LUMBER CO
69-A-40A
SMITH CECIL E & BETTY F
69-7-9
C& LAND HOLDINGS L
69-7-10
HIX FLOYD E JR & RUTH DEEL
69-A-40B
TERRELL DONALD S
69-A-43
TERRELL DONALD S
69-A-43A
TERRELL DONALD S
69-A-43
207
52
King George
Fort
Spotsylvania
Caroline
Middlesex
North Anna


Legend
RPA
Virginia Conservation Lands
Trenchless Crossing
Limits of Disturbance
Primary Water Main Alignment
Delineated Wetlands
Delineated Streams
Parcels
Contours (5 ft)
69-A-40A
M C DEAN INC
69-A-40
WHITTAKER MICHAEL W & BARBARA C LIFE ESTATE
69-A-36
WOODLAWN FARM INC
69-A-42
STAPLES WENDY
69-A-41
207
53
110
115
120
105
145
140
130
150
155
160
165
170
175
180
185
190
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135



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Potential Raw Water Main Index Maps
Caroline County, Virginia

0 100 200 400 Feet



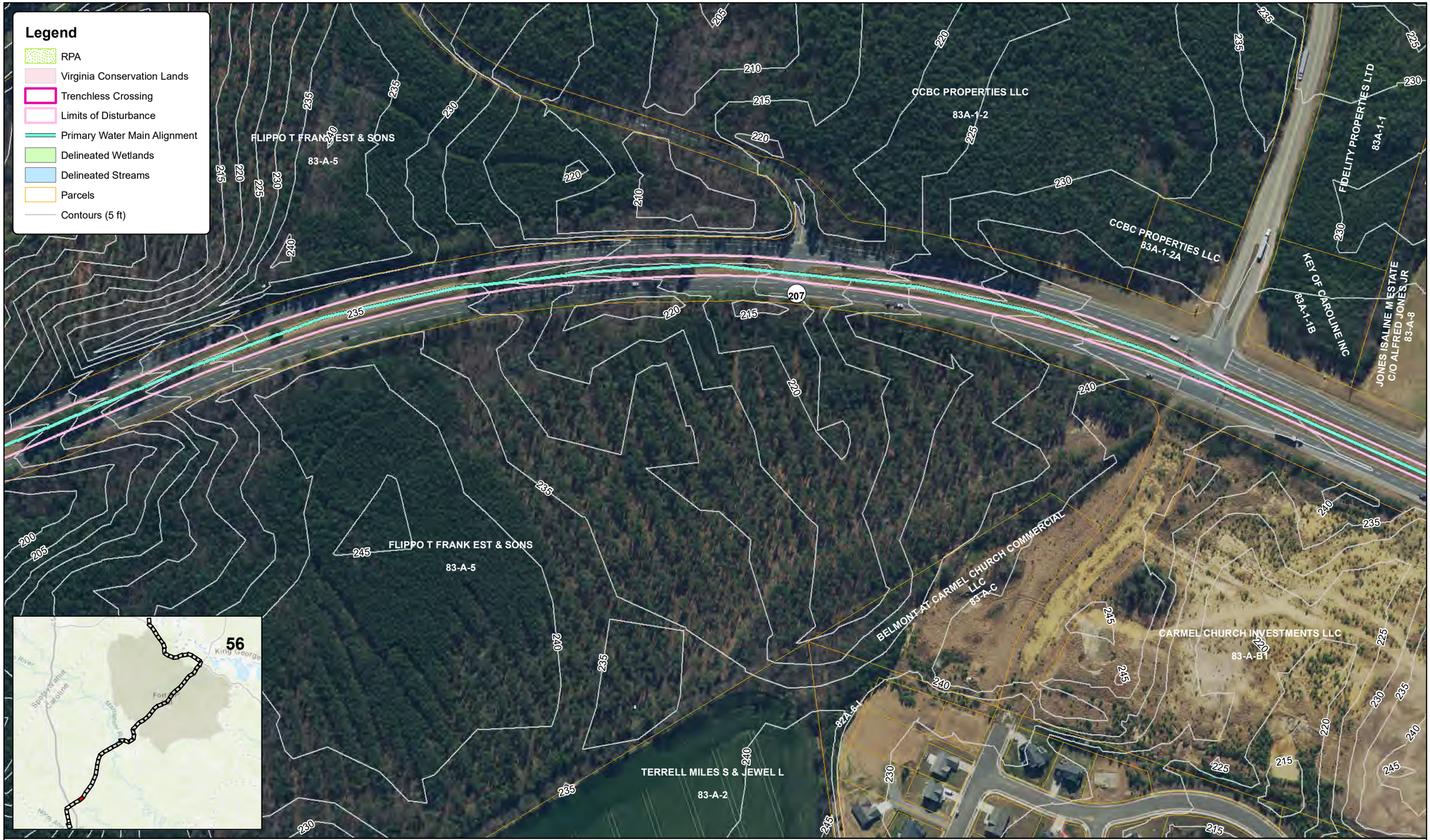
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Potential Raw Water Main Index Maps

Caroline County, Virginia

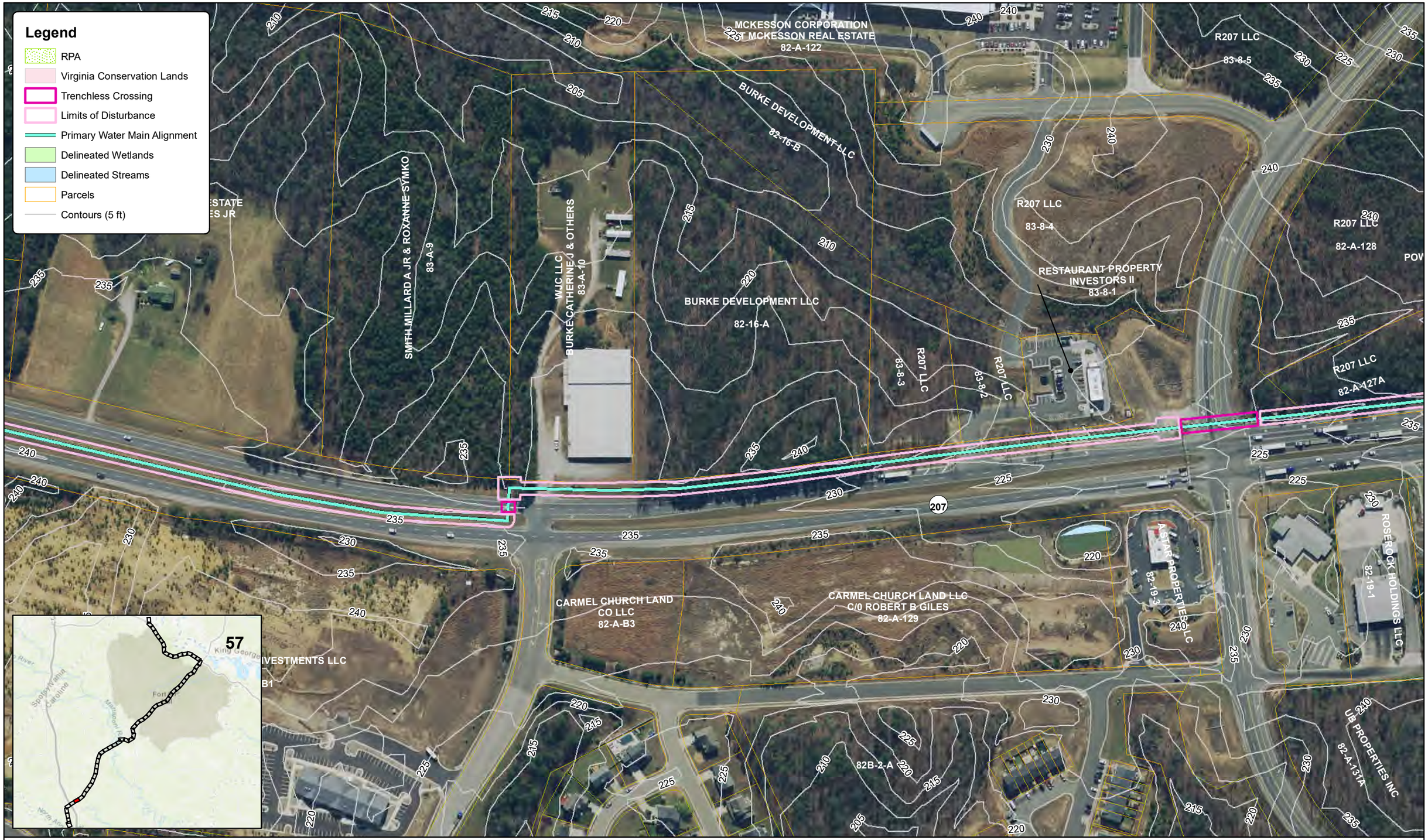
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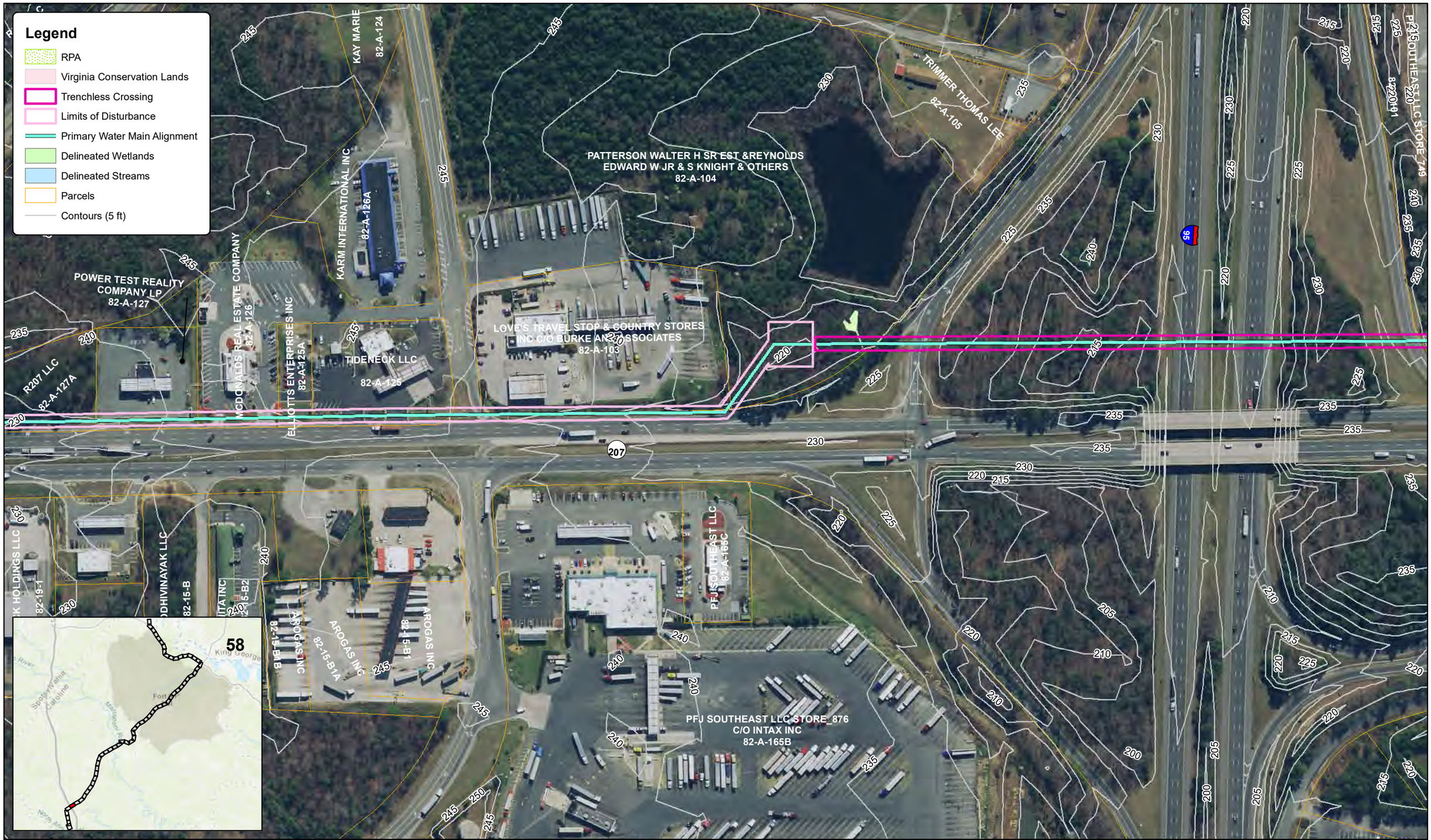


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Potential Raw Water Main Index Maps
Caroline County, Virginia

0 100 200 400 Feet


Legend
RPA
Virginia Conservation Lands
Trenchless Crossing
Limits of Disturbance
Primary Water Main Alignment
Delineated Wetlands
Delineated Streams
Parcels
Contours (5 ft)
MCKESSON CORPORATION
ST MCKESSON REAL ESTATE
82-A-122
BURKE DEVELOPMENT LLC
82-16-B
SMITH MILLARD A JR & ROXANNE SYMKO
83-A-9
WJC LLC
BURKE CATHERINE J & OTHERS
83-A-10
BURKE DEVELOPMENT LLC
82-16-A
R207 LLC
83-8-5
R207 LLC
83-8-4
RESTAURANT PROPERTY
INVESTORS II
83-8-1
R207 LLC
83-8-3
R207 LLC
83-8-2
R207 LLC
82-A-128
R207 LLC
82-A-127A
CARMEL CHURCH LAND
CO LLC
82-A-B3
CARMEL CHURCH LAND LLC
C/0 ROBERT B GILES
82-A-129
A STAR PROPERTIES LLC
82-19-3
ROSEROCK HOLDINGS LLC
82-19-1
UB PROPERTIES INC
82-A-131A
82B-2-A
207
57


Legend
RPA
Virginia Conservation Lands
Trenchless Crossing
Limits of Disturbance
Primary Water Main Alignment
Delineated Wetlands
Delineated Streams
Parcels
Contours (5 ft)
KAY MARIE
82-A-124
KARM INTERNATIONAL INC
82-A-126A
PATTERSON WALTER H SR EST &REYNOLDS EDWARD W JR & S KNIGHT & OTHERS
82-A-104
TRIMMER THOMAS LEE
82-A-105
POWER TEST REALITY COMPANY LP
82-A-127
MCDONALDS REAL ESTATE COMPANY
82-A-126
ELLIOTTS ENTERPRISES INC
82-A-125A
TIDENECK LLC
82-A-125
LOVE'S TRAVEL STOP & COUNTRY STORES INC C/O BURKE AND ASSOCIATES
82-A-103
R207 LLC
82-A-127A
PFJ SOUTHEAST LLC STORE_749
95
207
PFJ SOUTHEAST LLC
82-A-165C
PFJ SOUTHEAST LLC STORE_876
C/O INTAX INC
82-A-165B
AROGAS INC
82-15-B1A
AROGAS INC
82-15-B1
AROGAS INC
82-15-B1B
ODHIVINAYAK LLC
82-15-B
ITA INC
82-15-B2
K HOLDINGS LLC
82-19-1
58



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Potential Raw Water Main Index Maps

Caroline County, Virginia

0 100 200 400 Feet



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Potential Raw Water Main Index Maps

Caroline County, Virginia

0 100 200 400 Feet

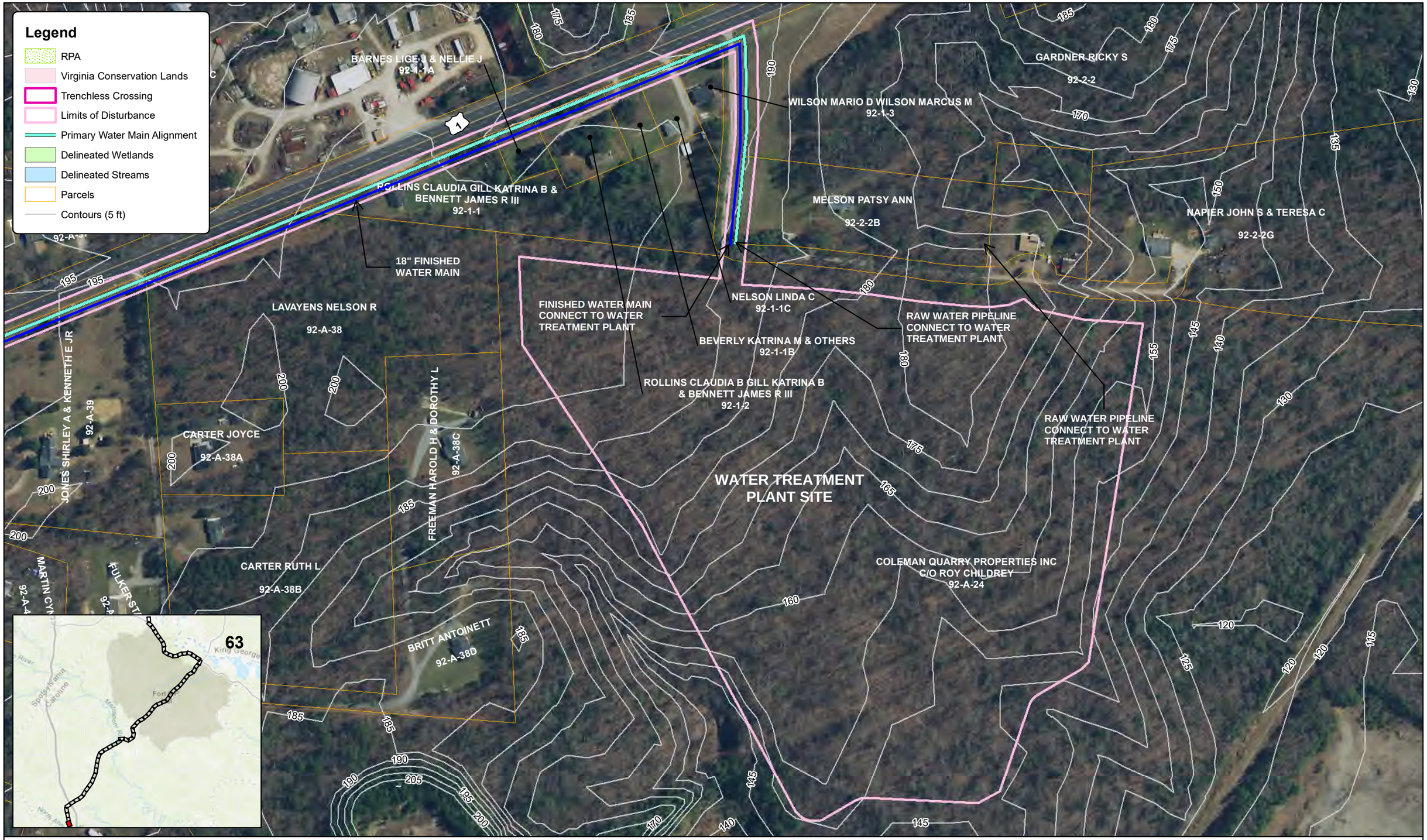


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DAA# R15287R-05

Potential Raw Water Main Index Maps
Caroline County, Virginia

0 100 200 400 Feet


Legend
RPA
Virginia Conservation Lands
Trenchless Crossing
Limits of Disturbance
Primary Water Main Alignment
Delineated Wetlands
Delineated Streams
Parcels
Contours (5 ft)
CAROLINE 40 LLC
92-A-48
BEVERLY RUTH O
92-A-46
YATES ROBIN
92-A-46C
ALLEN ELLIS W & KATHY O
92-A-37A
H & L PRICE INC
92-A-36
BARN
LAVAYENS NELSON R
92-A-38
THORNTON CHARLES W & LILLIAN C
92-A-37
NELSON LINDA C
92-A-46B
GREENE LESLIE A & WANDA N
92-A-46A
SMITH WAYNE WRIGHT JR
92A-A-8
18" FINISHED WATER MAIN
BOXLEY LORENZO W & THELMA H
92A-7-1
JONES SHIRLEY A & KENNETH E JR
92-A-39
CARTER JOYCE
92-A-38A
FREEMAN HAROLD H & DOROTHY L
92-A-38C
CARTER RUTH L
92-A-38B
BRITT ANTOINETT
92-A-38D
MARTIN CYNTHIA
92-A-45
FULKER STACEY M
92-A-39C
ESTES MICHAEL
92-A-44
FREEMAN LAURA H
92-A-39B
REEVES DAVID J & TARA L
92-A-39A1
COLEMAN QUARRY PROPERTIES INC C/O ROY CHILDREY
92-A-24
SMITH KELVIN SR & ARTREYCA
92A-7-1A
JOHNSON SHIRLEY
92A-7-1B
JUSTICE MIKE L & ANDREA H
92-A-56A
LEEPER RICHARD & DEBORA
92A-A-10
VAUGHAN GREGORY W & JUDSON T III
92A-A-11
GODLEY PATRICIA ANN & HOCKADAY MICHAEL WAYNE
92A-A-12
FORTUNE DWAYNE E & THERESA M
92A-7-2
NAPIER HORACE & BEATRICE
92A-A-13
62
King George
Fort
Spotsylvania
Caroline
North Anna



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Potential Raw Water Main Index Maps
Caroline County, Virginia

0 100 200 400 Feet

APPENDIX A.3
RAW WATER PIPELINE TRENCHLESS CROSSING PLANS AND PROFILES

DEQ Response to Additional Information Request
Caroline County Rappahannock River Water Supply Project
JPA No. 20-0514
September 11, 2023

PUMP AROUND NOTES

I. DESCRIPTION

1. THE WORK SHALL CONSIST OF INSTALLING A PUMP AROUND WHEN CONSTRUCTION ACTIVITIES TAKE PLACE WITHIN THE STREAM CHANNEL.

II. MATERIAL SPECIFICATIONS

1. SANDBAGS: SANDBAGS SHALL CONSIST OF MATERIALS WHICH ARE RESISTANT TO ULTRAVIOLET RADIATION, TEARING AND PUNCTURE, AND WOVEN TIGHTLY ENOUGH TO PREVENT LEAKAGE OF FILL MATERIAL (I.E., SAND, FINE GRAVEL, ETC.)

III. CONSTRUCTION REQUIREMENTS

1. ALL EROSION AND SEDIMENT CONTROL DEVICES SHALL BE INSTALLED AS THE FIRST ORDER OF WORK.
2. THE HEIGHT OF THE SANDBAGS SHALL BE INDICATED IN SECTION A–A. THE SANDBAGS SHALL BE PLACED ON A SMOOTH PREPARED SURFACE.
3. ALL EXCAVATED MATERIALS SHALL BE DISPOSED OF OUTSIDE THE 100–YEAR FLOODPLAIN UNLESS APPROVED ON THE PLANS.
4. ALL DEWATERING OF THE CONSTRUCTION AREA SHALL BE PUMPED TO A DEWATERING DEVICE (VA E&S STANDARD AND SPEC 3.26 OR DIRT/SEDIMENT BAG).
5. THE PUMP SHALL BE SUFFICIENT SIZE TO CONVEY NORMAL STREAM FLOW.
6. SEDIMENT CONTROL DEVICES ARE TO REMAIN IN PLACE UNTIL ALL DISTURBED AREAS ARE STABILIZED AND THE INSPECTING AUTHORITY APPROVES THEIR REMOVAL.

STREAM UTILITY CROSSING NOTES

1. CLEARING SHALL BE DONE BY CUTTING, NOT GRUBBING. THE ROOTS AND STUMPS SHALL BE LEFT IN PLACE TO HELP STABILIZE THE BANKS AND ACCELERATE REVEGETATION.
2. CROSSING WIDTH – THE WIDTH OF CLEARING SHALL BE MINIMIZED THROUGH THE RIPARIAN AREA. THE LIMITS OF DISTURBANCE SHALL BE AS NARROW AS POSSIBLE INCLUDING NOT ONLY CONSTRUCTION OPERATIONS WITHIN THE CHANNEL ITSELF BUT ALSO CLEARING DONE THROUGH THE VEGETATION GROWING ON THE STREAM BANKS AND APPROACHES TO THE STREAM.
3. NO CONSTRUCTION VEHICLE CROSSING IS PERMITTED IN THE CREEK.
4. CONTROL RUNOFF ALONG THE RIGHT OF WAY TO PREVENT SEDIMENT LADEN RUNOFF FROM FLOWING INTO THE STREAM. RUNOFF SHALL BE DIVERTED TO SEDIMENT FILTERING DEVICES AT A MINIMUM 50–FT FROM THE STREAM.
5. THE TIME BETWEEN INITIAL DISTURBANCE OF THE STREAM AND FINAL STABILIZATION SHALL BE KEPT TO A MINIMUM.
6. TO THE EXTENT OTHER CONSTRAINTS ALLOW, STREAMS SHALL BE CROSSED DURING PERIOD OF LOW FLOW.

STREAM UTILITY CROSSING NOTES (CONT.)

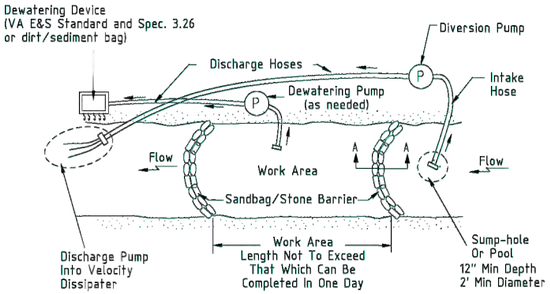
7. FILL PLACED WITHIN THE CHANNEL – THE ONLY FILL PERMITTED IN THE CHANNEL SHALL BE CLEAN AGGREGATE, STONE OR ROCK. NO SOIL OR OTHER FINE ERODIBLE MATERIAL SHALL BE PLACED IN THE CHANNEL. THIS RESTRICTION INCLUDES ALL FILL FOR TEMPORARY CROSSINGS, DIVERSIONS, AND TRENCH BACKFILL WHEN PLACED IN FLOWING WATER. IF THE STREAM FLOW IS DIVERTED AWAY FROM THE CONSTRUCTION ACTIVITY THE MATERIAL ORIGINALLY EXCAVATED FROM THE TRENCH MAY BE USED TO BACKFILL THE TRENCH.
8. INSTALL CREEK CROSSING BYPASS IN ACCORDANCE WITH DETAIL 5.1.
9. SEDIMENT –LADEN WATER FROM PUMPING OR DEWATERING SHALL NOT BE DISCHARGED DIRECTLY TO A STREAM, FLOW SHALL BE ROUTED THROUGH A SEDIMENT FILTERING DEVICE, DEWATERING SUMP, OR A FLAT, WELL VEGETATED AREA ADEQUATE FOR REMOVING SEDIMENT BEFORE THE PUMPED WATER REACHES THE STREAM.
10. MATERIAL EXCAVATED FROM THE TRENCH SHALL BE PLACED AT LEAST 20 FEET FROM THE STREAM BANK TOPS AND SURROUNDING SILT FENCE TO MINIMIZE SEDIMENT–LADEN RUNOFF.
11. STREAM BANK/CHANNEL RESTORATION – STREAM BANKS/CHANNELS SHALL BE RESTORED TO THEIR ORIGINAL LINE AND GRADE AND STABILIZED WITH RIP RAP OR VEGETATIVE BANK STABILIZATION.

OPEN CUT STREAM CROSSING NOTES

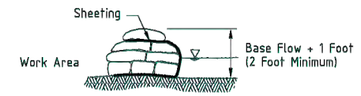
1. THE WATERLINE SHALL BE INSTALLED WITH A MINIMUM COVER OF 3.5 FEET AT ALL LOCATIONS.
2. INSTALL STREAM CROSSING RESTORATION WITH RIP RAP. RIP RAP SHALL NOT BE PLACED ABOVE THE EXISTING STREAM BED OR EXISTING BANK ELEVATION.
3. RIP RAP SHALL BE CLASS II, PLACED IN A DOUBLE THICK BLANKET, MINIMUM 18" THICK.
4. THE STREAM WILL BE PUMPED AROUND THE AREA OF CONSTRUCTION. SEE DETAIL 5.1.

The Virginia Stream Restoration & Stabilization Best Management Practices Guide

DETAIL 5.1: PUMP-AROUND PRACTICE



PLAN



Cross Section Of Sandbag/Stone Diversion

SECTION A-A

Adapted From
Maryland's Waterway
Construction Gudielines

TEMPORARY INSTREAM CONSTRUCTION MEASURES	DECEMBER 2003	VIRGINIA DEPARTMENT OF CONSERVATION RECREATION

Draper Aden Associates
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1030 Wilmer Avenue, Suite 100
Richmond, VA 23227
804-264-2228 Fax: 804-264-8773
Blacksburg, VA
Charlottesville, VA
Hampton Roads, VA
Raleigh, NC
Fayetteville, NC
Northern Virginia
Virginia Beach, VA

DESIGNED	MSH
DRAWN	SLH
CHECKED	MSH
DATE	7/1/20

STREAM CROSSING - NOTES AND DETAILS

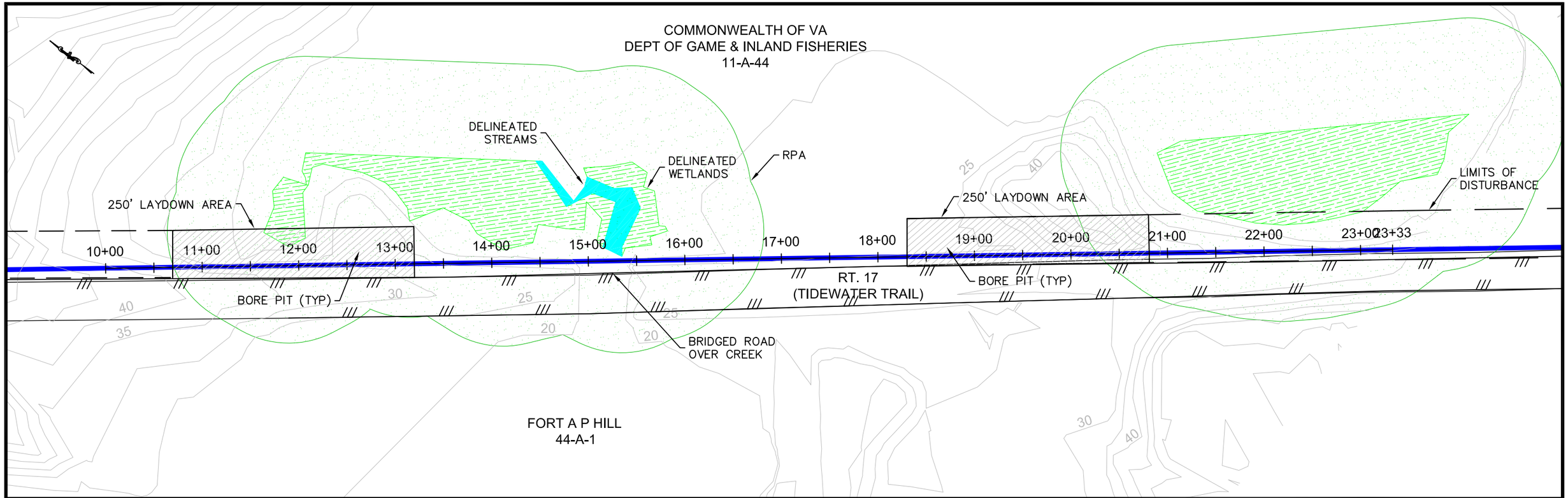
CAROLINE COUNTY, VIRGINIA

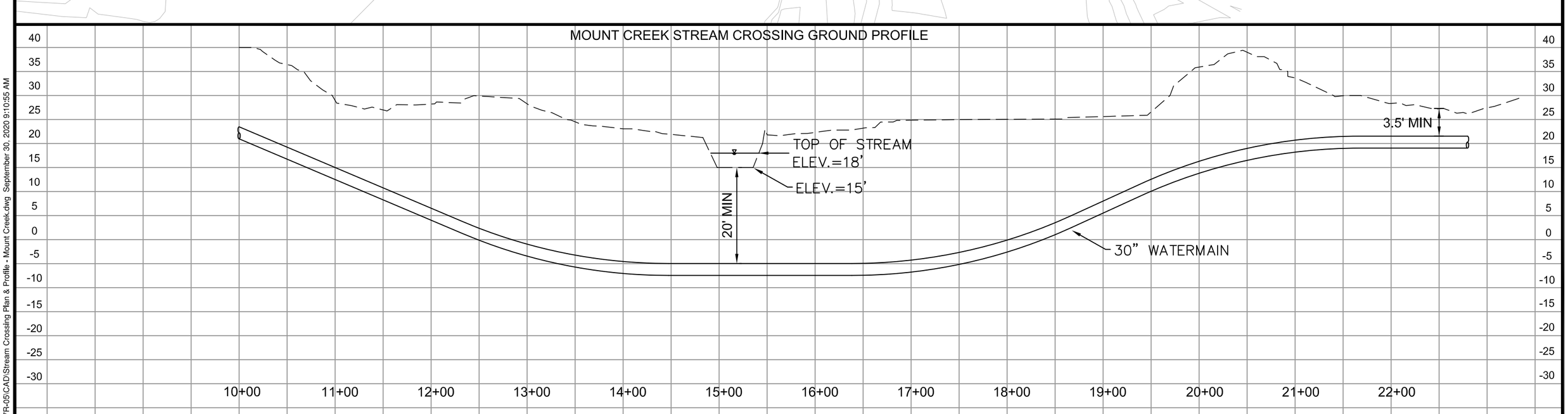
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PROJECT: R15287R-05

FIGURE 7

P:\R15200\R15287R\R15287R-05\CAD\Stream Crossing Plan & Profile.dwg October 5, 2020 8:00:07 AM





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Charlottesville, VA
Hampton Roads, VA
Raleigh, NC
Fayetteville, NC
Northern Virginia
Virginia Beach, VA

DESIGNED	MSH
DRAWN	SLH
CHECKED	MSH
DATE	7/1/20

STREAM CROSSING - PLAN & PROFILE

MOUNT CREEK TRENCHLESS STREAM CROSSING #4

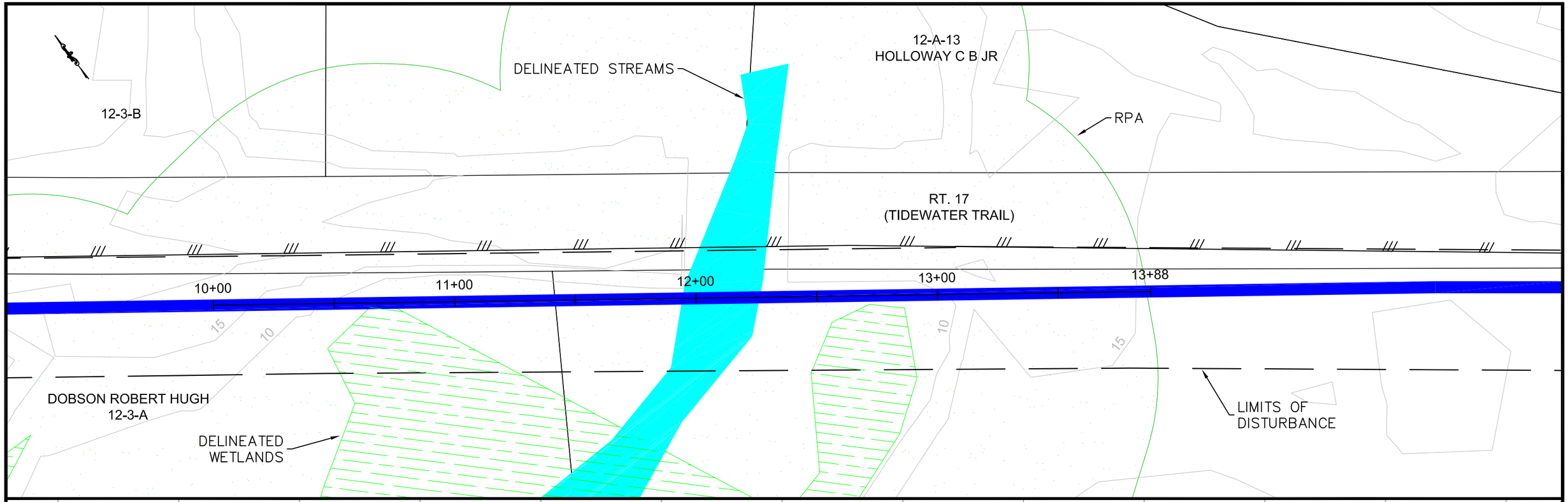
CAROLINE COUNTY, VIRGINIA

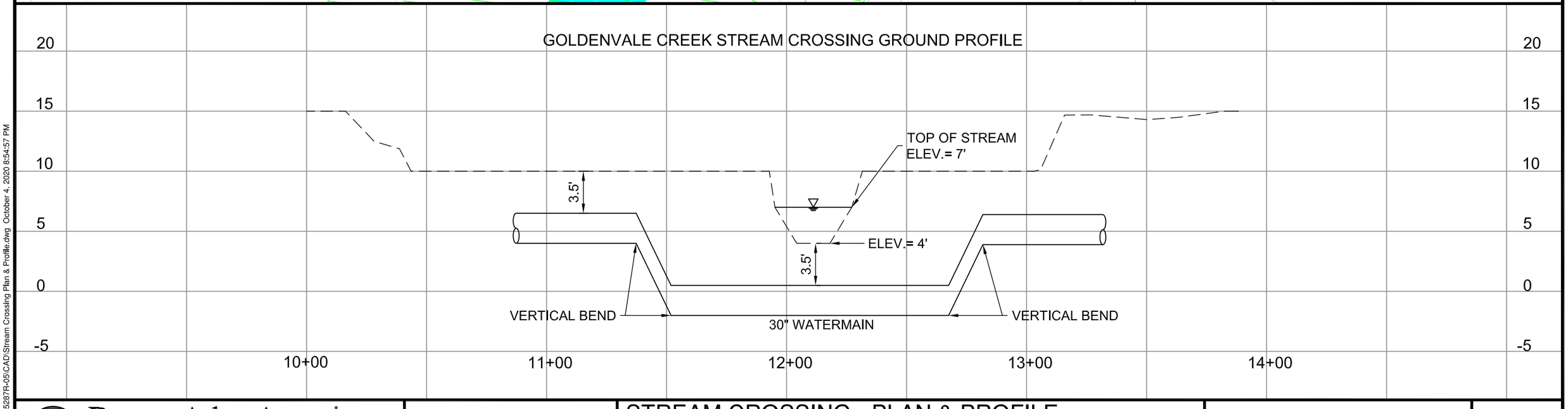
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PROJECT: R15287R-05

FIGURE 2

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Charlottesville, VA
Hampton Roads, VA
Raleigh, NC
Fayetteville, NC
Northern Virginia
Virginia Beach, VA

DESIGNED	MSH
DRAWN	SLH
CHECKED	MSH
DATE	7/1/20

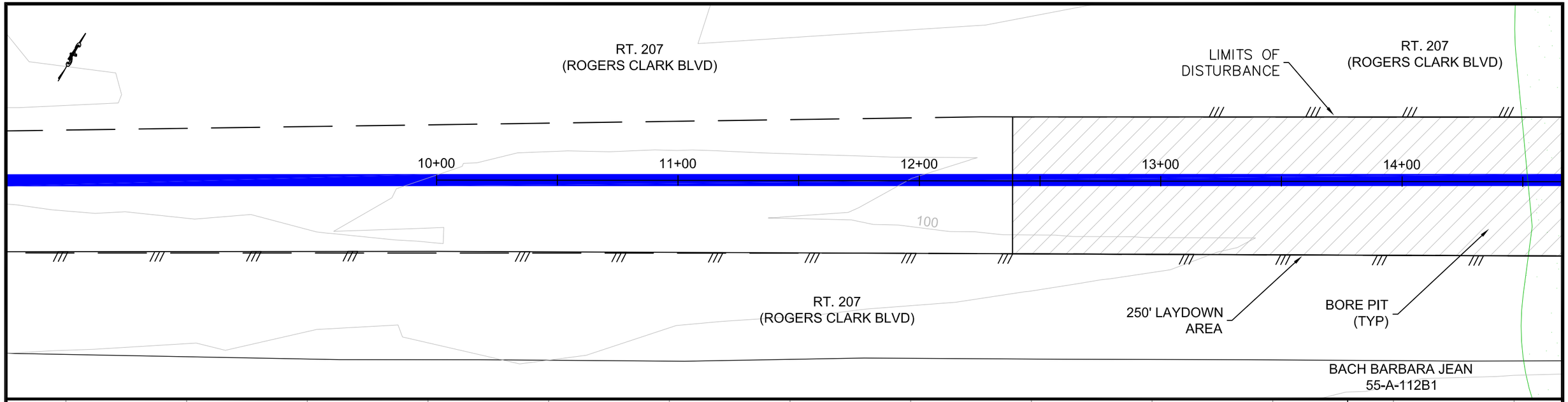
STREAM CROSSING - PLAN & PROFILE
GOLDENVALE CREEK STREAM CROSSING #29
CAROLINE COUNTY, VIRGINIA

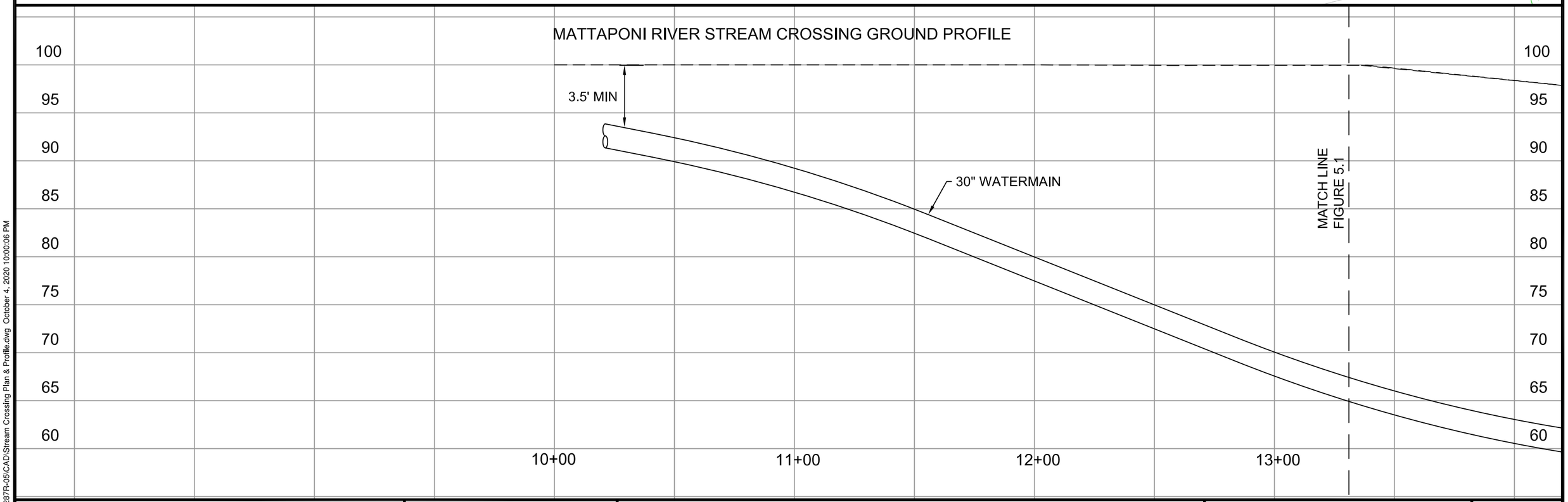
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PROJECT: R15287R-05

FIGURE
3

P:\R15\200\R15287R\R15287R-05\CAD\Stream Crossing Plan & Profile.dwg October 4, 2020 8:54:57 PM





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Hampton Roads, VA
Raleigh, NC
Fayetteville, NC
Northern Virginia
Virginia Beach, VA

DESIGNED	MSH
DRAWN	SLH
CHECKED	MSH
DATE	7/1/20

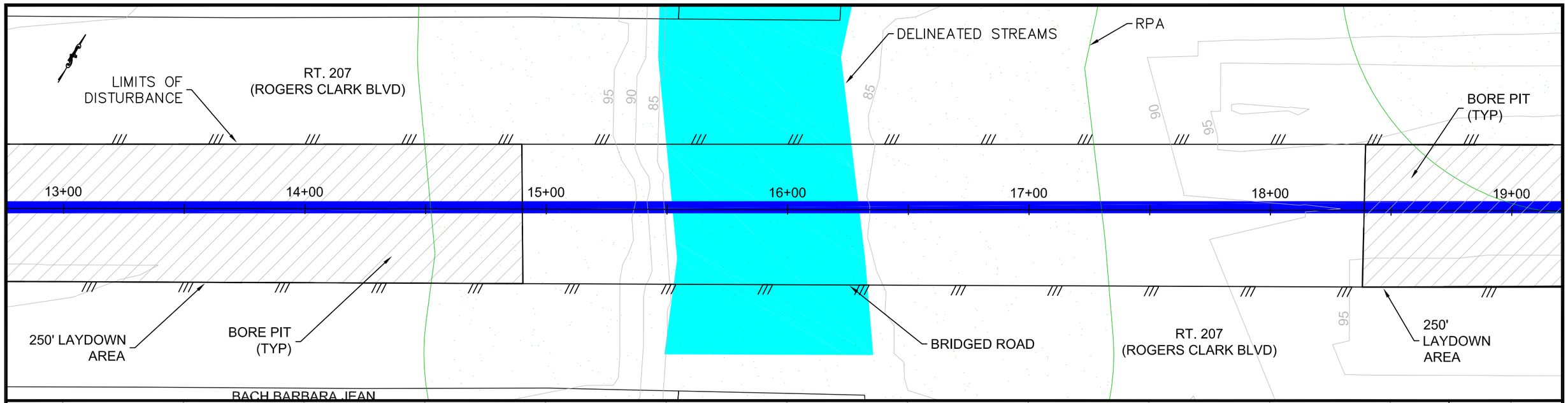
STREAM CROSSING - PLAN & PROFILE
MATTAPONI RIVER STREAM CROSSING #17
CAROLINE COUNTY, VIRGINIA

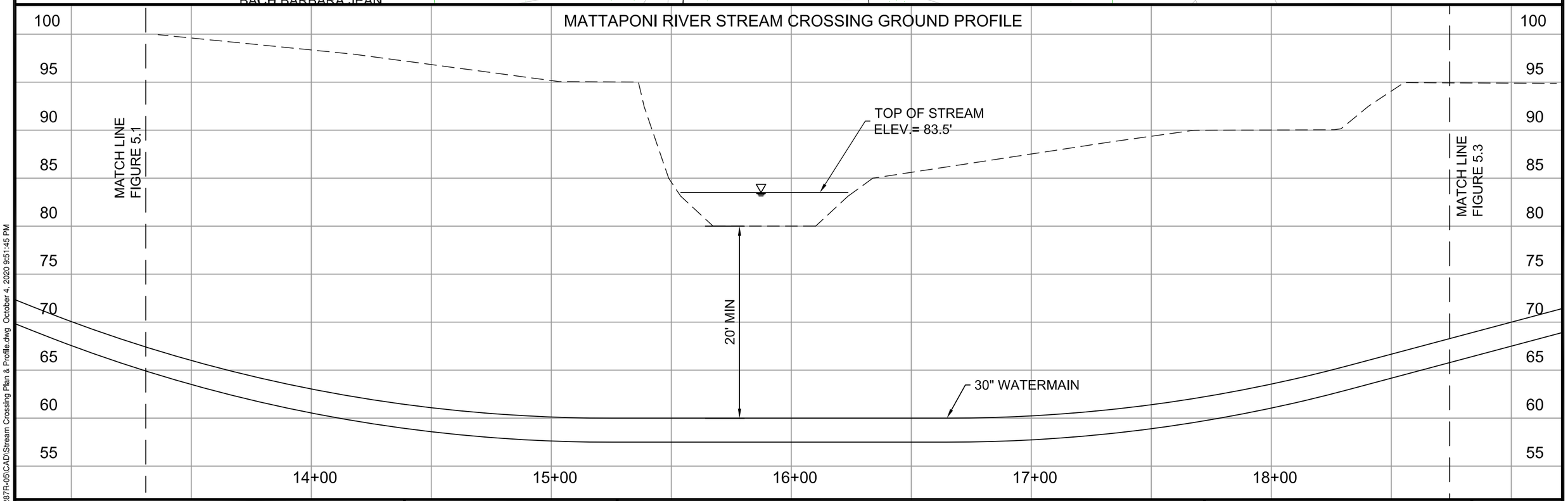
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PROJECT: R15287R-05

FIGURE 5.1

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Charlottesville, VA
Hampton Roads, VA
Raleigh, NC
Fayetteville, NC
Northern Virginia
Virginia Beach, VA

DESIGNED	MSH
DRAWN	SLH
CHECKED	MSH
DATE	7/1/20

STREAM CROSSING - PLAN & PROFILE

MATTAPONI RIVER STREAM CROSSING #17

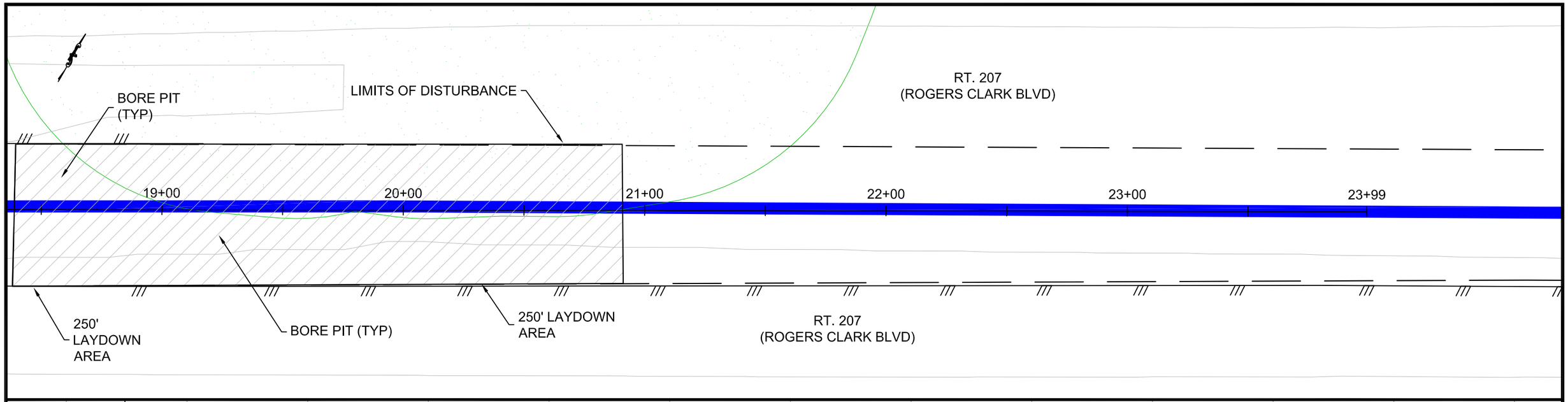
CAROLINE COUNTY, VIRGINIA

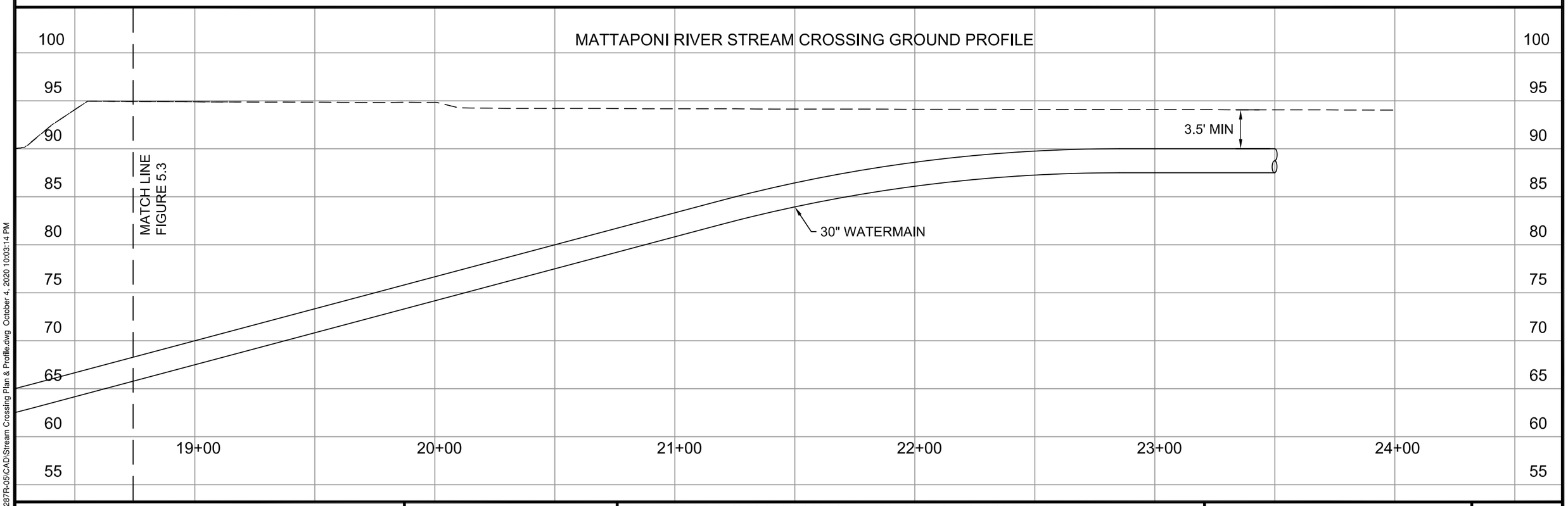
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PROJECT: R15287R-05

FIGURE 5.2

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Charlottesville, VA
Hampton Roads, VA
Raleigh, NC
Fayetteville, NC
Northern Virginia
Virginia Beach, VA

DESIGNED	MSH
DRAWN	SLH
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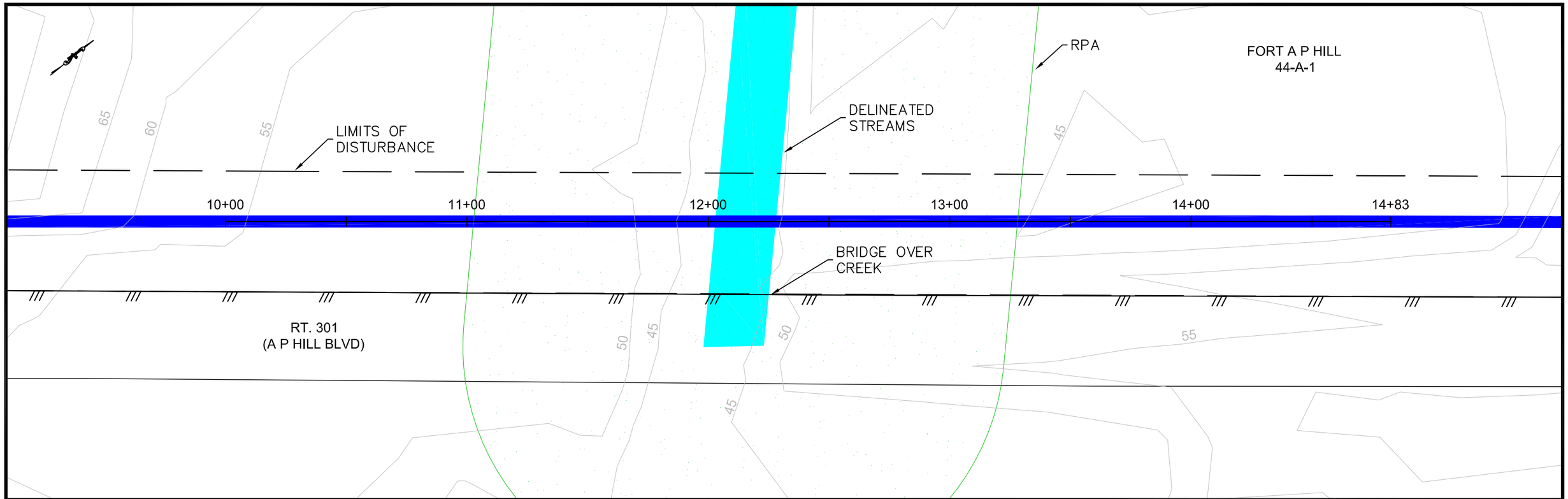
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CAROLINE COUNTY, VIRGINIA

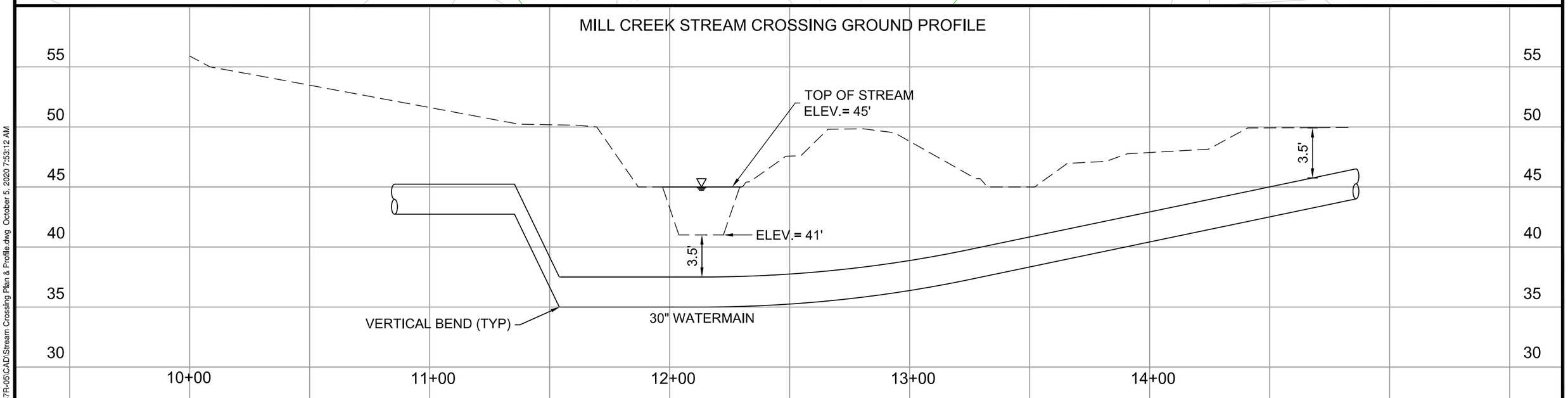
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PROJECT: R15287R-05

FIGURE 5.3

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STREAM CROSSING - PLAN & PROFILE
MILL CREEK STREAM CROSSING #7
CAROLINE COUNTY, VIRGINIA

SCALE: H: 1"=40' V: 1"=5'

PROJECT: R15287R-05

FIGURE
4

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69-A-40A

RT. 207
(ROGERS CLARK BLVD)

10+00
11+00
12+00
13+00
14+00

RT. 207
(ROGERS CLARK BLVD)

POLECAT CREEK STREAM CROSSING GROUND PROFILE

110
105
100
95
90
85
80
75
70

3.5' MIN

30" WATERMAIN

MATCH LINE
FIGURE 6.2

10+00
11+00
12+00
13+00
14+00

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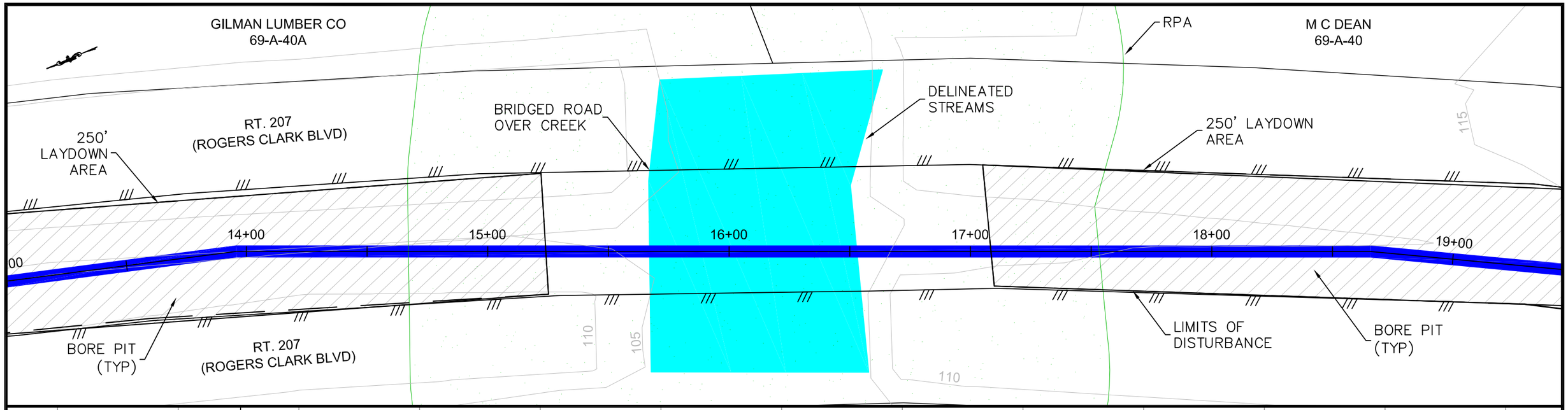
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POLECAT CREEK STREAM CROSSING #20
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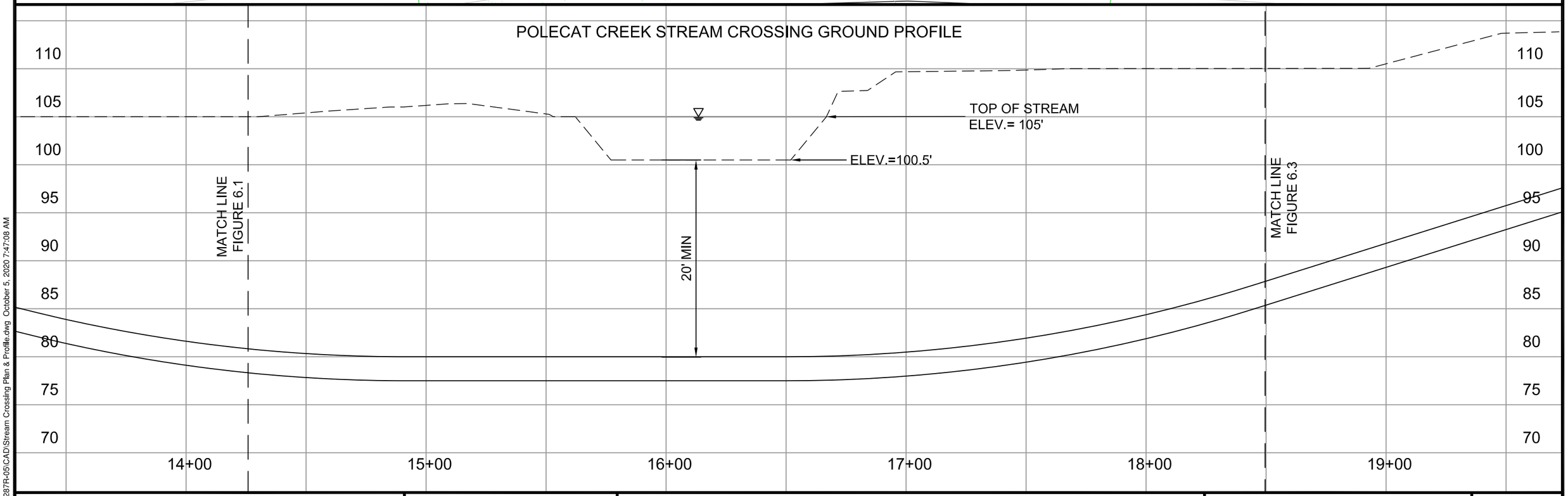
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FIGURE
6.1

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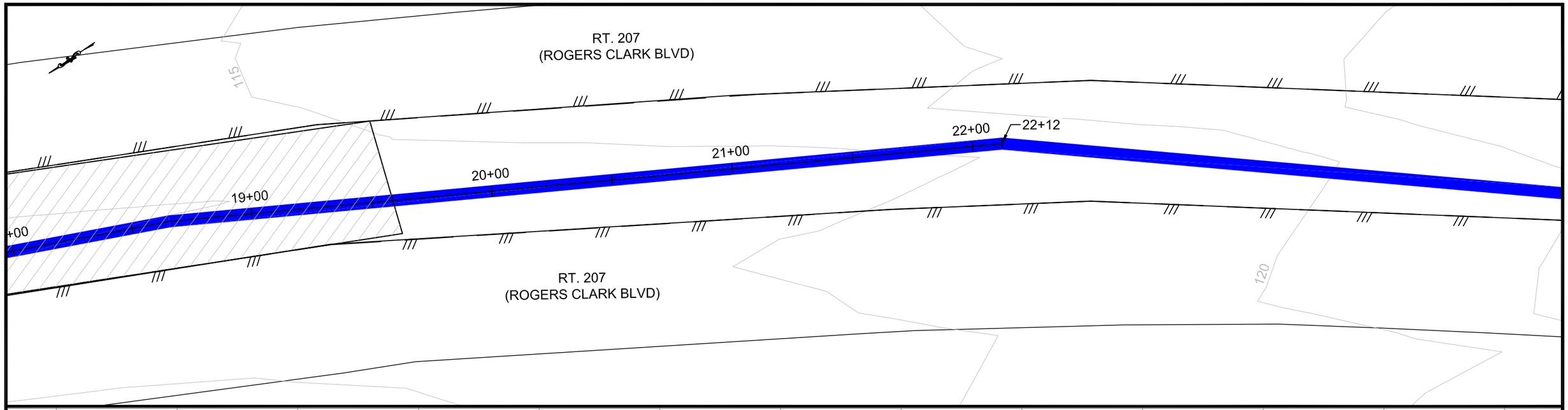
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CAROLINE COUNTY, VIRGINIA

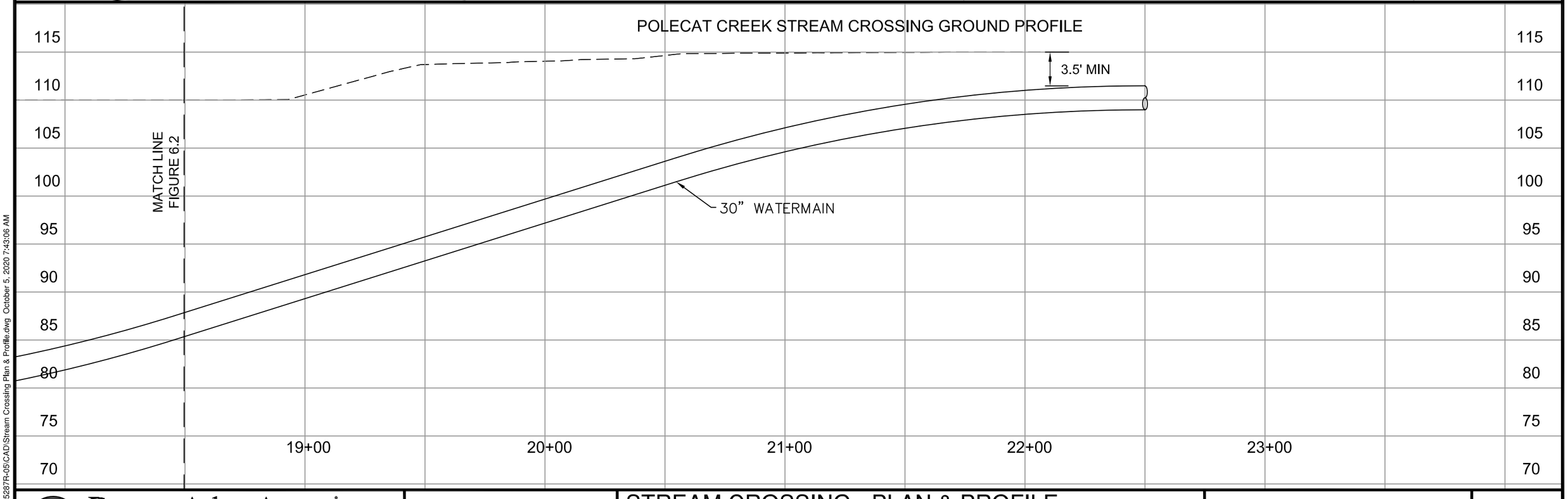
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FIGURE 6.2

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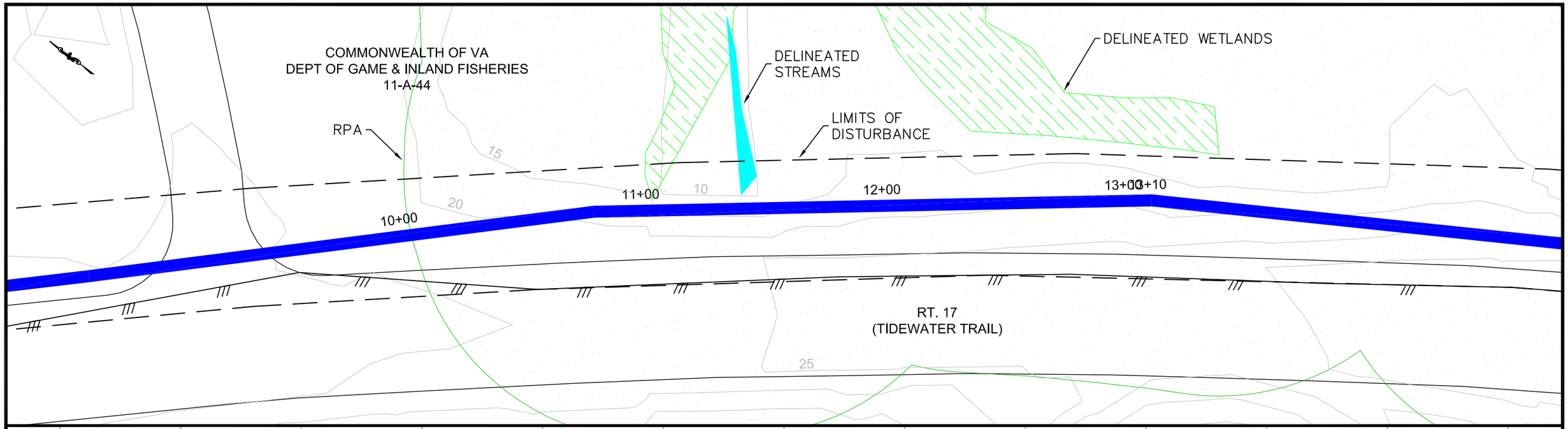
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POLECAT CREEK STREAM CROSSING #20
CAROLINE COUNTY, VIRGINIA

SCALE: H: 1"=40' V: 1"=10'

PROJECT: R15287R-05

FIGURE 6.3

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STREAM CROSSING - PLAN & PROFILE
WARE CREEK STREAM CROSSING #1
CAROLINE COUNTY, VIRGINIA

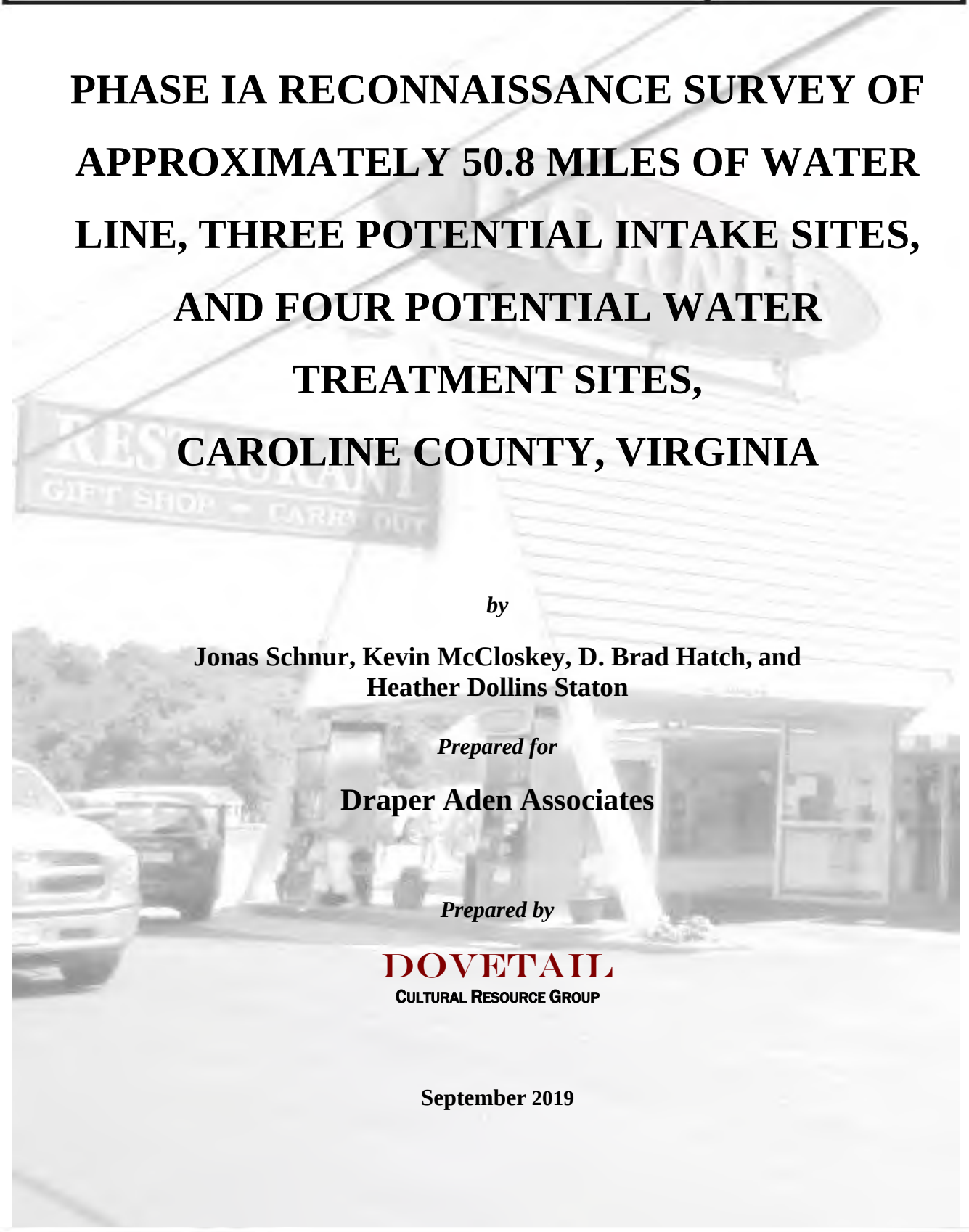
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PROJECT: R15287R-05

FIGURE 1

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PHASE IA RECONNAISSANCE SURVEY OF APPROXIMATELY 50.8 MILES OF WATER LINE, THREE POTENTIAL INTAKE SITES, AND FOUR POTENTIAL WATER TREATMENT SITES, CAROLINE COUNTY, VIRGINIA



by

Jonas Schnur, Kevin McCloskey, D. Brad Hatch, and Heather Dollins Staton

Prepared for

Draper Aden Associates

Prepared by

DOVETAIL
CULTURAL RESOURCE GROUP

September 2019

Received by VMRC on March 27, 2020 /lra

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Phase IA Reconnaissance Survey of Approximately 50.8 Miles of Water Line, Three Potential Intake Sites, and Four Potential Water Treatment Sites, Caroline County, Virginia

by

Jonas Schnur, Kevin McCloskey, D. Brad Hatch, and Heather Dollins Staton

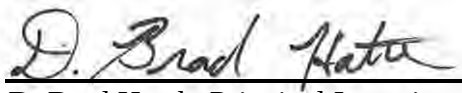
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September 2019



September 5, 2019

D. Brad Hatch, Principal Investigator — Date
Dovetail Cultural Resource Group

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ABSTRACT

On behalf of Draper Aden Associates (Draper Aden), Dovetail Cultural Resource Group (Dovetail) conducted a Phase IA cultural resource reconnaissance study of a series of locations for a potential water line and potential associated facilities, collectively known as the Caroline County Water Supply project. The project area for this study comprises: a potential raw water main route which extends 32.1 miles (51.7 km); an alternative raw water main route which overlaps extensively, but covers an additional 18.7 miles (30.1 km); three potential water intake areas covering 880 acres (356.1 ha); and four potential water treatment facility locations covering 1,172 acres (474.3 ha). The reconnaissance study comprised a visual inspection of the proposed project area and was completed on August 8, 2018, February 26, 2019, and May 30, 2019. The goals of the work were to identify locations within the project area with the potential to contain intact archaeological sites and architectural resources in the project vicinity and make recommendations for any additional investigations.

The Phase IA architectural study noted all above-ground resources 50 years of age or older within the project's architectural project area. For the two water main routes, the architectural project area is defined as the area adjacent to the potential water main. For the potential raw water intake sites and water treatment plants the architectural project area extends 500 feet (152.4 m) from the impact-area boundaries. Within the architectural project area, Dovetail identified 50 previously recorded resources, 10 of which have been previously listed in, or determined eligible or potentially eligible for listing in, the National Register of Historic Places (NRHP) and 216 above-ground, previously unrecorded resources. Nine of the previously recorded resources have received a formal eligibility evaluation and were last surveyed less than five years ago and as such Dovetail **recommends that they will not require a revisit during the Phase IB surve**y. Dovetail recommends **that the remaining 257 above-ground resources within the architectural project area may require a Phase IB-level survey.** The list of resources recommended for the Phase IB will likely reduced as the project's limits of disturbance are established.

The surveyed archaeological project area included two alternatives for a water main, three potential areas for water intake sites from the Rappahannock River, and four parcels containing potential water treatment plant sites. For the two water main routes, the archaeological project area is defined as the area within 25 feet (7.6 m) of the edge of pavement. For the potential raw water intake sites and water treatment plants the archaeological project area includes the entirety of the parcels. Eighteen previously recorded archaeological sites are located within the project area, none have been evaluated for listing in the NRHP by DHR staff. During the archaeological survey it was noted that large portions of the water main routes are disturbed and will not require further testing. Some areas in the potential locations for water treatment plants are also disturbed. Dovetail **recommends that all intact soils with less than 15 percent slope, as well as all sites that have been found eligible or not yet evaluated, be subjected to subsurface testing should ground disturbing activities be planned in those areas.** Within the intake and treatment areas currently under consideration approximately 350 acres (141.6 ha) are considered not suitable for Phase IB survey, leaving 1,350 acres (546.3 ha) or 79.4 percent of the area suitable for further study.

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INTRODUCTION

On behalf of Draper Aden Associates (Draper Aden), Dovetail Cultural Resource Group (Dovetail) conducted a Phase IA cultural resource reconnaissance study of a potential raw water main route, an alternative raw water main route, three potential water intake locations, and four potential water treatment plant locations in Caroline County, Virginia (Figure 1, p. 2). In association with Draper Aden, Caroline County is planning the installation of a water line and associated facilities, collectively known as the Caroline County Water Supply project. A cultural resource survey is required for this project due to the involvement of the United States Army Corps of Engineers and the application for a water withdrawal permit from the Virginia Department of Environmental Quality. The project area for this study comprises a potential raw water main route which extends approximately 32.1 miles (51.7 km); an alternative raw water main route which overlaps extensively, but covers an additional 18.7 miles (30.1 km); three potential water intake areas which cover approximately 880 acres (356.1 ha), the first of which had been provisionally eliminated from consideration due to the presence of multiple cultural resources; and four potential water treatment facility locations which cover approximately 1,172 acres (474.3 ha). The reconnaissance study comprised a visual inspection of the potential and alternative raw water main routes and a visit to the most likely locales for the water treatment facility within the parcels accompanied by representatives from Draper Aden and Hazen and Sawyer (Hazen) and was completed on August 8, 2018, February 26, 2019, and May 30, 2019. The goals of the work were to identify locations within the project area with the potential to contain intact archaeological sites, previously recorded architectural resources, and previously unrecorded architectural resources older than 50 years in the project vicinity and make recommendations for any additional investigations. No subsurface investigations or architectural documentation was completed during this phase of work.

The Phase IA archaeological survey was completed by D. Brad Hatch who meets or exceeds the standards established for Archaeologist and Historian by the Secretary of the Interior (SOI). The Phase IA architectural survey was completed by Heather Dollins Staton who meets or exceeds the standards established for Architectural Historian and Historian by the SOI.

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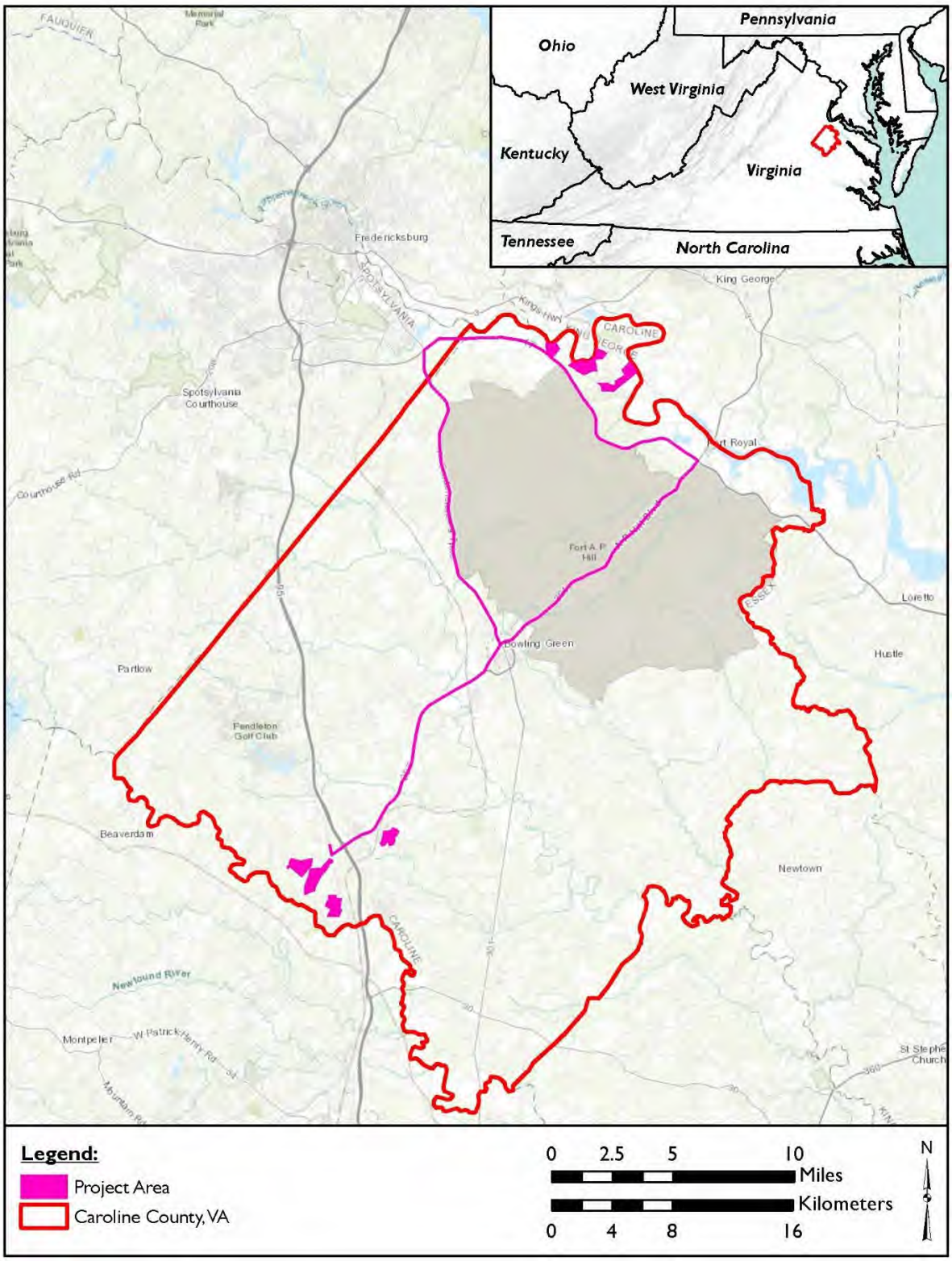


Figure 1: Location of the Project Area and Caroline County (Esri 2019a).

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PROJECT AREA DESCRIPTION

The Caroline County Water Supply project area is located in Caroline County, Virginia and comprises three potential water intake areas, four potential water treatment facility locations, a potential raw water main route, and an alternate raw water main route. The water intake areas are located in northern Caroline County along the Rappahannock River. The water treatment facility locations are located in southwestern Caroline County within 3 miles (4.8 km) of Ruther Glen. The potential raw water main route runs from near the intersection of U.S. Route 1 (Route 1) and State Route 207 (Route 207) east along Route 207 into Bowling Green where it continues straight onto U.S. Route 301 (Route 301). The potential alignment continues along Route 301 to its intersection with U.S. Route 17 (Route 17) where it turns north and follows Route 17 and terminates near Moss Neck Manor Lake. The alternate raw water main route splits from the potential raw water main route in Bowling Green where it turns north on Route 2. The alternate route continues along Route 2 until its intersection with Route 17 where it turns east and terminates near Moss Neck Manor Lake (Photo 1; Figure 2–Figure 5, pp. 4–7; Photo 2–Photo 5, pp. 8–9).



Photo 1: Typical Setting for Potential Water Main and Alternate Route for Water Main, View of A.P. Hill Boulevard (Route 301), Looking Southwest.

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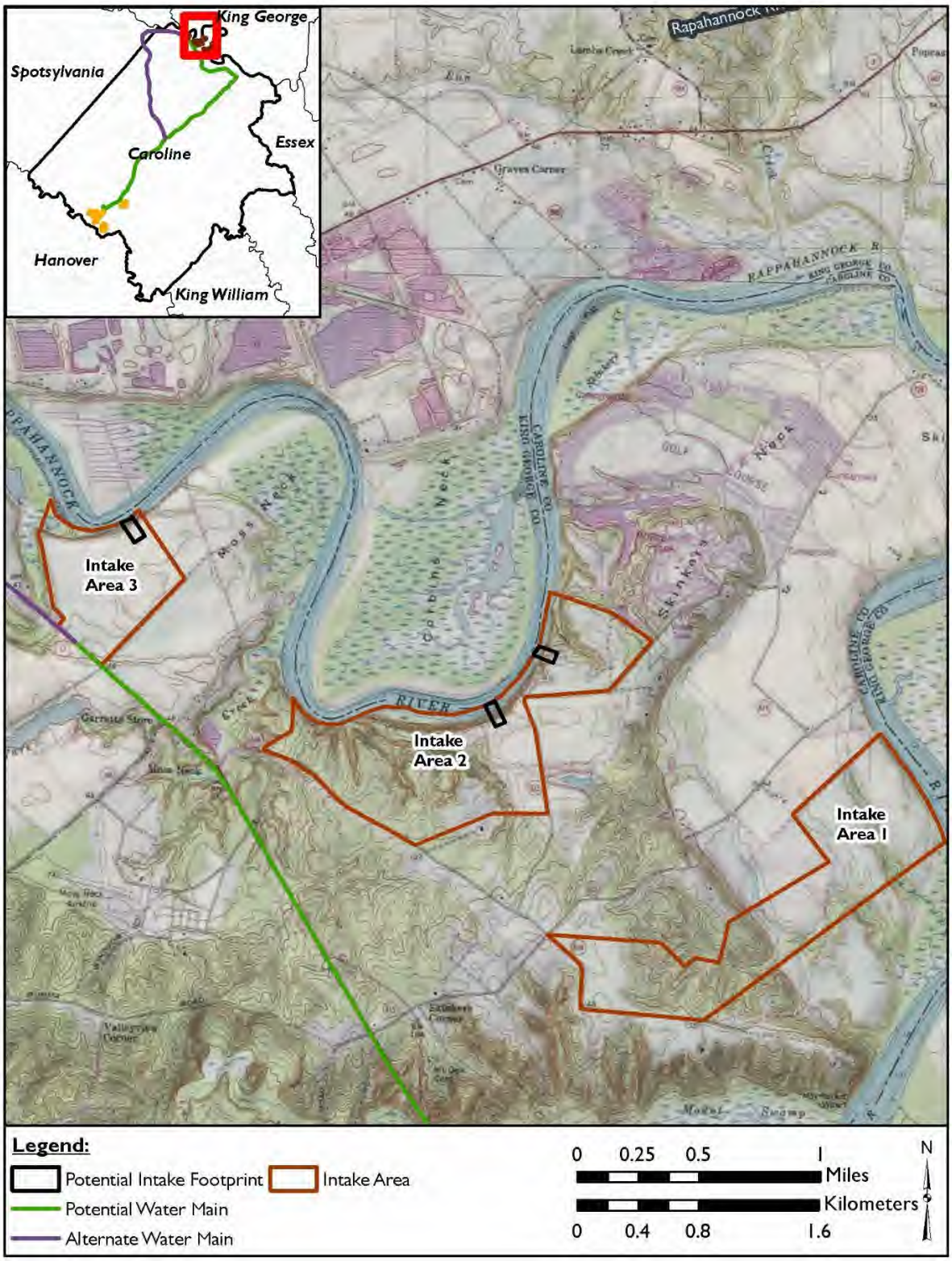


Figure 2: Location of the Intake Areas on the United States Geological Service (USGS) Topographic Map (Esri 2019b).

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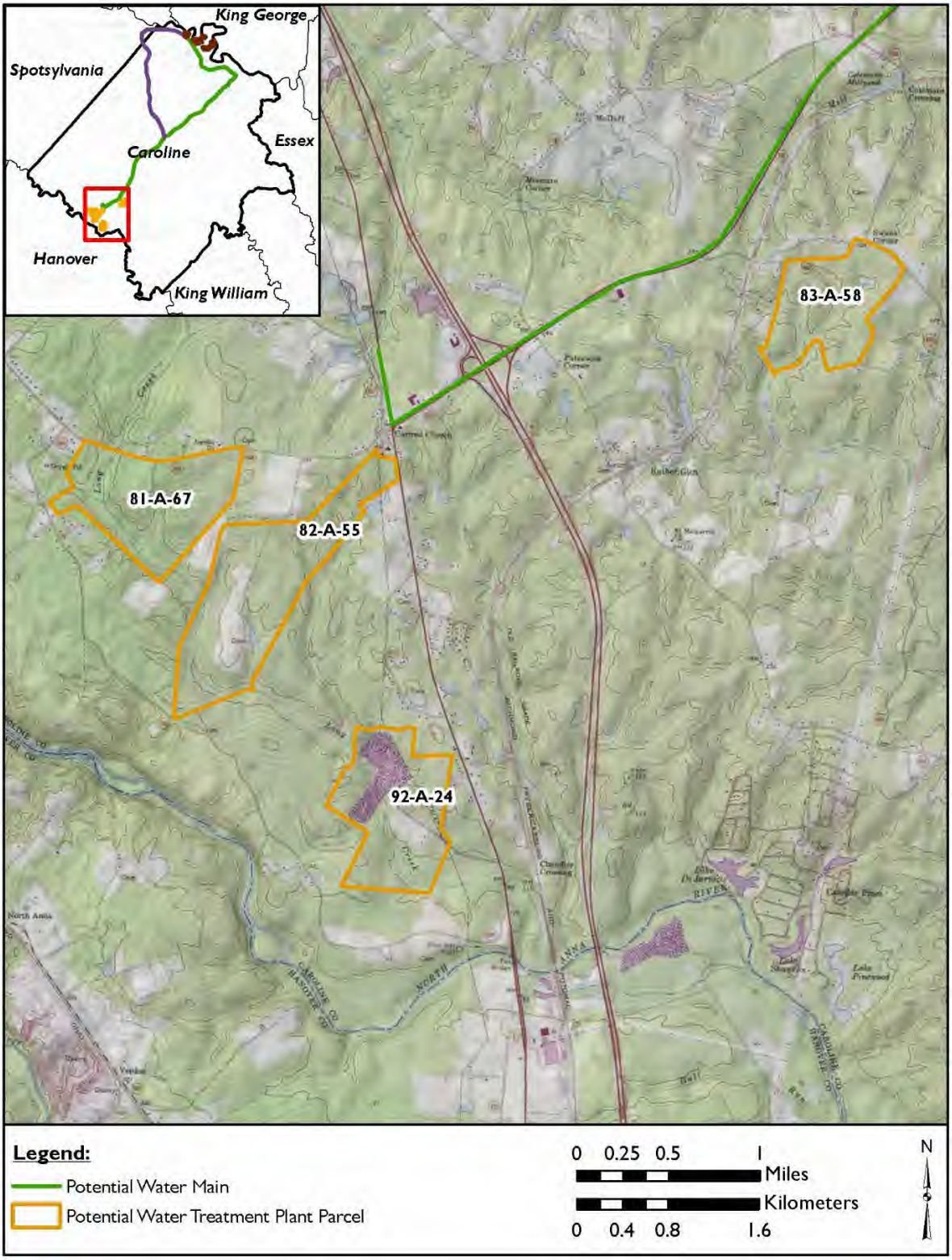


Figure 3: Location of the Water Treatment Parcels on the United States Geological Service (USGS) Topographic Map (Esri 2019b).

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Figure 4: Location of the Intake Areas on Aerial Imagery (VGIN 2017).

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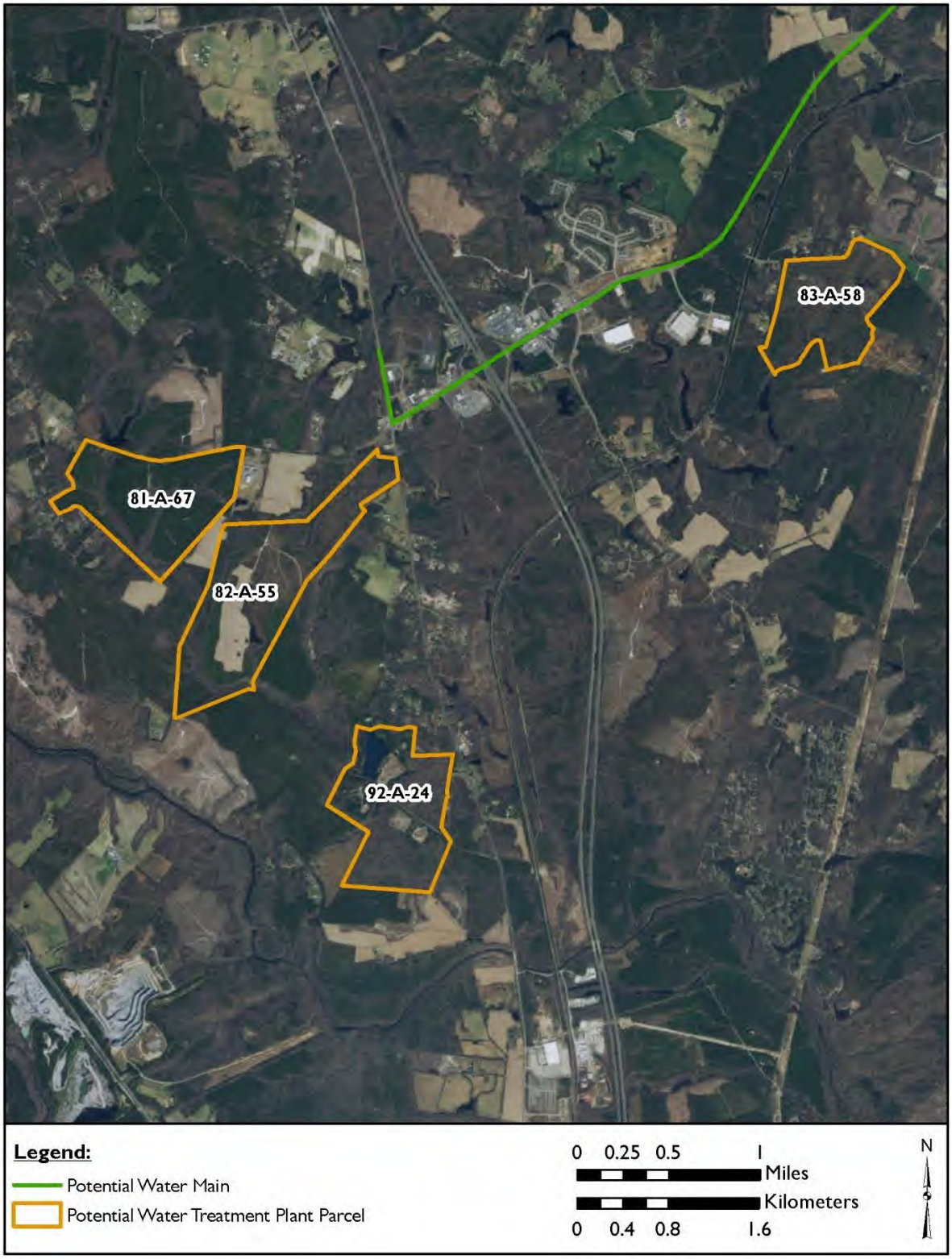


Figure 5: Location of Water Treatment Parcels on Aerial Imagery (VGIN 2017).

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Photo 2: Typical Setting of Water Intake Area, Potential Raw Water Intake Area 2, Skinkers Neck Road, Looking North.



Photo 3: Overview of Potential Water Treatment Plant Site, Parcel 82-A-55, Agricultural Fields, Looking East.

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Photo 4: Overview of Potential Water Treatment Plant Site, Parcel 83-A-58, Wooded Area, Looking Southeast.



Photo 5: Overview of Potential Water Treatment Plant Site, Parcel 92-A-24, Modern Quarry, Looking Northeast.

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ENVIRONMENTAL SETTING

The project area spans Caroline County, Virginia from Ruther Glen to Port Royal. Caroline County remains rural, although land use has shifted over time from farming to logging.

Geology and Topography

Caroline County is bordered by King George County to the north, Spotsylvania County to the northwest, Hanover County to the south, and King William, King and Queen, and Essex Counties to the east. Situated in east-central Virginia, the project area lies east of Lake Anna and entirely in the Coastal Plain region. The Coastal Plain in Virginia is divided into several sub-provinces which include the Lowlands located along the banks of the Chesapeake and major rivers that feed it and the Uplands comprising the rest of the Coastal Plains (Roberts and Bailey 2000). The project area is found in the western Coastal Plain near the convergence of the Piedmont and the Coastal Plain province. The Coastal Plain region can be characterized as broad and nearly level, with gently sloping ridges composed of sediments resting on the eroded surface of Precambrian to early Mesozoic rock.

Hydrology

The Caroline County intake areas are drained by the Rappahannock River, which empties into the Chesapeake Bay between Westland, Virginia and Deltaville, Virginia. The four potential water treatment facility areas drain south into the North Anna River that flows east into the Pamunkey River. The Pamunkey River continues east to its confluence with the York River which flows into the Chesapeake Bay between Gloucester Point and Yorktown, Virginia. The Chesapeake Bay continues to flow east into the Atlantic Ocean. The areas crossed by the potential raw and alternative water mains span almost the entirety of Caroline County, and are drained by various tributaries within the North Anna and Rappahannock watersheds.

Soils

Fertile, well-drained soils attracted both humans and game over millennia. Moreover, the wild grasses, fruits, and seeds consumed by people both before and after the adoption of agriculture flourished in such settings. As a consequence, numerous archaeologists have cited the correlation between the distribution of level to gently sloping, well-drained, fertile soils and archaeological sites (e.g., Lukezic 1990; Potter 1993; Turner 1976; Ward 1965). Soil scientists classify soils according to natural and artificial fertility and the threat posed by erosion and flooding, among other attributes. Soil Classes 1 and 2 represent the most fertile soils, those best suited for not only agriculture but for a wide range of uses. Of course, soil productivity must be considered in relation to the productivity of the surrounding soils as well. Class 1 soils occupy a very small portion of the overall project area, never more than 4 percent of any of the treatment or intake areas. However, a more substantial portion of the project area is occupied by Class 2 soils, at least 40 percent in every one of those areas (Table 1–Table 7, pp. 12–15). Because of the linear nature and substantial length versus narrow width of the water main

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corridors, soil survey data is of limited use, as it is often mapped in blocks larger than the width of the corridor, much of which is occupied by obvious road grading.

Table 1: Soils in Intake Area 1 Location (Soil Survey Staff 2017).

Soil Name	Class	Slope	Characteristics	Percentage of Project Area
Altavista fine sandy loam	2e	2 –6	Moderately Well Drained, Prone to Erosion	4.90%
Bojac sandy loam	2e	0–6	Well Drained, Prone to Erosion	7.40%
Chastain silt loam	6w	0–2	Poorly Drained	0.70%
Kempsville-Emporia complex	1	0–2	Well Drained	0.40%
Kempsville-Emporia complex	2e	2–6	Well Drained, Prone to Erosion	17.40%
Kempsville-Emporia complex	3e	6–10	Well Drained, Prone to Erosion	7.70%
Nevarc sandy loam	6e	15–50	Moderately Well Drained, Prone to Erosion	24.30%
State fine sandy loam	2e	2–6	Well Drained, Prone to Erosion	3.30%
Tomotley-Roanoke complex	4w	0–2	Poorly Drained	3.40%
Wickham fine sandy loam	2s	0–2	Well Drained, Shallow	10.80%
Wickham fine sandy loam	2e	2–6	Well Drained, Prone to Erosion	19.10%
Water	N/A	N/A	N/A	0.60%

Table 2: Soils in Intake Area 2 Location (Soil Survey Staff 2017).

Soil Name	Class	Slope	Characteristics	Percentage of Project Area
Bama sandy loam	2e	2–6	Well Drained, Prone to Erosion	14.10%
Kempsville-Emporia complex	1	0–2	Well Drained	0.90%
Kempsville-Emporia complex	2e	2–6	Well Drained, Prone to Erosion	29.40%
Kempsville-Emporia complex	3e	6–10	Well Drained, Prone to Erosion	12.30%
Nevarc sandy loam	6e	15–50	Moderately Well Drained, Prone to Erosion	29.30%
Slagle-Kempsville complex	3e	2–15	Moderately Well Drained, Prone to Erosion	0.20%

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Soil Name	Class	Slope	Characteristics	Percentage of Project Area
Slagle fine sandy loam	2e	2–6	Moderately Well Drained, Prone to Erosion	10.70%
State fine sandy loam, 6 to 10 percent slopes, very rarely flooded	3e	6–10	Well Drained, Prone to Erosion	2.80%
Water	N/A	N/A	N/A	0.20%

Table 3: Soils in Intake Area 3 Location (Soil Survey Staff 2017).

Soil Name	Class	Slope	Characteristics	Percentage of Project Area
Altavista fine sandy loam	2w	0–2	Moderately Well Drained	2.90%
Rappahannock muck	7w	0–1	Very Poorly Drained	3.30%
State fine sandy loam	3e	6–10	Well Drained	5.60%
Wickham fine sandy loam	2s	0–2	Well Drained, Shallow	70.80%
Wickham fine sandy loam,	2e	2–6	Well Drained, Prone to Erosion	15.80%
Water	N/A	N/A	N/A	1.60%

Table 4: Soils in Potential Water Treatment Plant Site, Parcel 81-A-67
(Soil Survey Staff 2017).

Soil Name	Class	Slope	Characteristics	Percentage of Project Area
Chewacla silt loam	4w	0–2	Very Poorly Drained	0.90%
Kempsville-Emporia complex	1	0–2	Well Drained	3.70%
Kempsville-Emporia complex	2e	2–6	Well Drained, Prone to Erosion	37.60%
Kempsville-Emporia complex	3e	6–10	Well Drained, Prone to Erosion	28.10%
Roanoke loam	6w	0–2	Very Poorly Drained	0.20%
Slagle fine sandy loam	2e	2–6	Well Drained, Prone to Erosion	10.40%
Wehadkee silt loam	6w	0–2	Very Poorly Drained	19.10%

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Table 5: Soils in Potential Water Treatment Plant Site, Parcel 82-A-55
(Soil Survey Staff 2017).

Soil Name	Class	Slope	Characteristics	Percentage of Project Area
Chewacla silt loam	4w	0–2	Poorly Drained	8.80%
Kempsville-Emporia-Remlik complex	6e	15–50	Very Poorly Drained, Prone to Erosion	4.00%
Kempsville-Emporia complex	2e	2–6	Well Drained, Prone to Erosion	31.90%
Kempsville-Emporia complex	3e	6–10	Well Drained, Prone to Erosion	22.60%
Nevarc sandy loam	6e	15–50	Very Poorly Drained, Prone to Erosion	7.60%
Slagle-Kempsville complex	3e	2–15	Well Drained, Prone to Erosion	9.70%
Slagle fine sandy loam	2e	2–6	Well Drained, Prone to Erosion	14.80%
Water	N/A	N/A	N/A	0.50%

Table 6: Soils in Potential Water Treatment Plant Site, Parcel 83-A-58
(Soil Survey Staff 2017).

Soil Name	Class	Slope	Characteristics	Percentage of Project Area
Bibb-Chastain complex, 0 to 2 percent slopes, frequently flooded	6w	0–2	Very Poorly Drained, Prone to Erosion	9.30%
Kempsville-Emporia complex	2e	2–6	Well Drained, Prone to Erosion	19.30%
Kempsville-Emporia complex	3e	6–10	Well Drained, Prone to Erosion	4.90%
Slagle-Kempsville complex	3e	2–15	Well Drained, Prone to Erosion	28.20%
Slagle fine sandy loam	2e	2–6	Well Drained, Prone to Erosion	32.80%
Suffolk fine sandy loam	2e	2–6	Well Drained, Prone to Erosion	4.50%
Water	N/A	N/A	N/A	0.90%

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Table 7: Soils in Potential Water Treatment Plant Site, Parcel 92-A-24
(Soil Survey Staff 2017).

Soil Name	Class	Slope	Characteristics	Percentage of Project Area
Altavista fine sandy loam, 2 to 6 percent slopes, very rarely flooded	2e	2–6	Well Drained, Prone to Erosion	2.40%
Bama sandy loam, 2 to 6 percent slopes	2e	2–6	Well Drained, Prone to Erosion	0.10%
Chewacla silt loam, 0 to 2 percent slopes, occasionally flooded	4w	0–2	Poorly Drained	6.20%
Kempsville-Emporia-Remlik complex, 15 to 50 percent slopes	6e	15–50	Very Poorly Drained, Prone to Erosion	1.80%
Kempsville-Emporia complex, 2 to 6 percent slopes	2e	2–6	Well Drained, Prone to Erosion	23.90%
Kempsville-Emporia complex, 6 to 10 percent slopes	3e	6–10	Well Drained, Prone to Erosion	15.80%
Nevarc sandy loam, 15 to 50 percent slopes	6e	15–50	Very Poorly Drained, Prone to Erosion	0.10%
Pits, gravel, 0 to 3 percent slopes	8s	0–3	Very Poorly Drained, Shallow	26.50%
Slagle fine sandy loam, 2 to 6 percent slopes	2e	2–6	Well Drained, Prone to Erosion	18.20%
Wehadkee silt loam, 0 to 2 percent slopes, frequently flooded	6w	0–2	Very Poorly Drained	5.10%

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HISTORIC CONTEXT

Prehistoric Periods

The prehistoric cultural sequence of Virginia's Coastal Plain parallels that of the other areas of Virginia and the Middle Atlantic Region. It is generally broken into three periods: Paleoindian (13,000–10,000 B.P.), Archaic (10,000–3,200 B.P.) and Woodland (3,200–400 B.P.). Which are often further divided into Early, Middle and Late periods. While this sequence represents a cultural continuum, archaeologists have noted that periods of adaptational stability are punctuated by periods of rapid change that do not necessarily correlate with the traditional cultural periods (Custer 1984; Smith 1986).

Pre-Clovis (Pre-13,000 B.P.)

The 1927 discovery, at Folsom, New Mexico of a fluted point in the ribs of an extinct species of bison proved that ancient North Americans had immigrated during the Pleistocene. It did not, however, establish the precise timing of the arrival of humans in the Americas, nor did it adequately resolve questions about the lifestyle of those societies (Meltzer 1988:2–3). Recent discoveries suggest humans possibly occupied the Americas, including Virginia, prior to the appearance of Clovis fluted points in the archaeological record (Boyd 2003; Carr 2018; Goodyear 2005). Both the stratigraphic record and the radiocarbon assays from the recently excavated Cactus Hill site in Sussex County suggest the possibility of human occupation of Virginia well before the fluted point makers appeared on the scene (McAvoy and McAvoy 1997). Buried strata at the Cactus Hill Site, in Sussex County, Virginia have returned radiocarbon dates of 15,000 years ago from sandy strata situated below levels containing fluted points (McAvoy and McAvoy 1997:165). The Cactus Hill data suggest pre-Clovis peoples relied on unfluted knives, prismatic blade-like flakes chipped from prepared cobbles and sandstone grinding and abrading tools, possibly indicating production of wood and bone tools. Because these tools do not possess unique characteristics which immediately identify them as dating to the Pleistocene, archaeologists must recognize the possibility that 15,000-year old sites have been overlooked for years (Boyd 2003; Carr 2018; Goodyear 2005).

Paleoindian Period (13,000–10,000 B.P.)

The Native American occupation of the eastern portion of North America dates to approximately 13,000 to 10,000 B.P. The Paleoindian settlement-subsistence pattern revolved around hunting and foraging in small nomadic bands. These bands focused on hunting caribou, elk, deer, and now extinct mega-fauna (Goodyear et al. 1979; Meltzer 1988; Smith 1986). Evidence for this occupation is manifest in fluted projectile points used for hunting. Fluted points are rare and often identified as isolated occurrences. While these discoveries are infrequent, the eastern half of the United States has some of the highest concentrations of these finds. Almost 1,000 known fluted projectile points have been discovered in Virginia (Anderson and Faught 1998). While the fluted Clovis and Folsom projectile points are the best known of the Paleoindian point types, others include Hardaway-Dalton and Hardaway Side-Notched (Barber and Barfield 1989). Paleoindian stone tools are usually made from high quality

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cryptocrystalline lithic material. The Paleo tool kit included scrapers, gravers, unifacial tools, wedges, hammerstones, abraders, and other tools used for chopping and smashing (Gardner 1989).

Archaic Period (10,000–3200 B.P.)

The Archaic period is generally divided into three phases, Early (10,000–8800 B.P.), Middle (8800–5500 B.P.), and Late (5500–3200 B.P.). There does not appear to be a dramatic change in the tool kits of the Early Archaic and their Paleoindian predecessors. Their settlement and subsistence patterns appear to be very similar (Anderson et al. 1996; Cable 1996). The transition into the Archaic period is marked by an increase in site size and artifact quantity, as well as an increase in the number of sites (Egloff and McAvoy 1990). Diagnostic artifacts of the Early Archaic period include the Kirk Corner-Notched and Palmer Corner-Notched projectile points (Coe 1964; Custer 1990). In addition, some bifurcated stem points such as St. Albans and LeCroy appear to be associated with the increased use of hafted endscapers (Coe 1964). The Early Archaic also marks the first appearance of ground stone tools such as axes, celts, adzes and grinding stones. At the close of this period, we see a shift to an increased reliance on a wider range of lithic resources.

While there appears to be a relatively high degree of cultural continuity between the Early and Middle Archaic periods, sites dating to the Middle Archaic period are more numerous suggesting an increase in population, and sites appear to be occupied for longer periods of time. The Middle Archaic period coincides with a relatively warm and dry period that may have resulted in widespread population movements (Delcourt and Delcourt 1987; Stoltman and Baerreis 1983). Mouer (1991:10) sees the primary cultural attributes of the Middle Archaic as "small-group band organization, impermanent settlement systems, infrequent aggregation phases, and low levels of regional or areal integration and interaction". Projectile points diagnostic of the Middle Archaic period include Stanley Stemmed, Morrow Mountain Stemmed, Guilford Lanceolate, and Halifax Side-Notched.

The Late Archaic period is often seen as the culmination of trends that began during the Early and Middle Archaic (Dent 1995:178). Dent (1995:178) suggests that the Late Archaic is "a time that contains both the ends of one way of life and the beginnings of a significant redirection". The artifact assemblage is dominated by bifacial tools; however, expedient flake scrapers, drills, perforators and utilized flakes are characteristic of these assemblages. Ground stone tools, including adzes, celts, and axes are seen during this period, with the grooved axe making its first appearance during the Late Archaic (Dent 1995:181–182). Diagnostic projectile points of the narrow blade tradition, often viewed as the early portion of the Late Archaic period, include the Vernon, Bare Island/Lackawaxen, Clagett, and Holmes (Dent 1995; Mouer 1991).

The period of time from approximately 4500 B.P. to 3200 B.P. is referred to as the Transitional period by some (Mouer 1991), while others argue that due to the lack of pottery it is more accurately classified as an extension of the Late Archaic (Dent 1995:180). By the early portion of this time period, glacial retreat had led to higher sea levels on the Atlantic seaboard. This allowed for the development of large estuaries and tidal wetlands that were conducive to the development of coastal resources such as fish and shellfish. Sites dating to this time period are

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often located in areas where populations can exploit these types of resources, such as river valleys, the lower portion of the coastal plain tributaries of major rivers, and near swamps. This led archaeologists to postulate that fish began to play a larger role in the subsistence system. Platform hearths seen during this period are interpreted as being associated with fish processing (Dent 1985:185). The first definitive evidence of shellfish exploitation is seen during this period on the lower reaches of the Potomac River (Potter 1982).

Transitional period sites tend to be larger than those of the Archaic periods, likely reflecting an increase in population, however, there is still no evidence for year-round occupation. Dent (1995) argues that the larger sites may be misinterpreted as reflecting longer term occupation and may simply be sites that were revisited for short periods on many occasions. Material culture associated with the Transitional period includes steatite or soapstone vessels as well as the ground stone tools discussed above. Broad-blade points associated with the later portion of the Late Archaic or Transitional period include the Savannah River, Susquehanna, Perkiomen, Dry Brook, and Orient Fishtail projectile points (Dent 1995; Mouer 1991).

Woodland Period (3200–400 B.P.)

The Woodland period is divided into three phases, Early (3200 B.P.–2300 B.P.), Middle Woodland (2300–1100 B.P.), and Late (1100–400 B.P.). The introduction of pottery, agriculture, and a more sedentary lifestyle mark the emergence of the Woodland period. The population surge that began in the Archaic continues in this period. The concurrent development of agriculture and pottery led early theorists to posit that they were linked; however, few still support this position. Alternatively, the evolution of technological and subsistence systems, as well as various aspects of pan–Eastern interaction, are currently believed to underlie the evolution of ceramic vessels (Egloff 1991).

Steatite tempered Marcey Creek pottery, dating to the Early Woodland period, are thought to be the earliest ceramic wares in Virginia's Piedmont. Marcey Creek wares, considered experimental, are typically shallow, slab-built forms (Dent 1995; McLearen 1991). Another steatite-tempered ware, Selden Island, followed Marcey Creek and soon other temper types appear in the archaeological record (McLearen 1991). Approximately 1100 B.P. there is a shift from the earlier slab construction techniques to coil and conoidal or globular vessels. This shift is accompanied by the introduction of surface treatments such as cord marking and net impression (Dent 1995; McLearen 1991). Projectile points associated with the Early Woodland period include Rossville Stemmed and possibly Piscataway Stemmed (Dent 1995).

The Middle Woodland is marked by the rise of certain sociocultural characteristics that include "interregional interaction spheres, including the spread of religious and ritual behaviors which appear in locally transformed ways; localized stylistic developments that sprung up independently alongside interregional styles increased sedentism and evidence of ranked societies or incipient ranked societies" (McLearen 1992:55). While there is a degree of commonality among Middle Woodland peoples, one of the striking characteristics of this period is the rise of regional trends, particularly in pottery. Coastal Plain and Piedmont ceramic styles can be distinguished, as well as north-south differences that correspond to river drainages that drain into the Chesapeake Bay or Albemarle Sound. The diversity of surface treatments increase after 1500 B.P. and analysis of the regional pottery indicates that the

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Potomac, the Rappahannock, and Upper Dan were slightly different cultural subareas in the physiographic province of the Piedmont (Hantman and Klein 1992). The Middle Woodland period also sees the introduction of the triangular or Levanna projectile point.

The Late Woodland period is marked by an increased reliance on agriculture, attendant population growth, larger villages and increased sociocultural complexity (Turner 1992). Ceramic types of the Late Woodland period in the Coastal Plain include the quartz-tempered Gaston Simple Stamped and sand/crushed rock-tempered Dan River pottery (Hantman and Klein 1992). The trend towards sedentary settlements continues throughout the Late Woodland period. In the early portion of this period, settlements consist of small clusters of houses with little to no internal organization. However, by 300 B.P., larger villages are observed. Features associated with these villages include palisades, houses, hearths, storage pits, and burials (Hantman and Klein 1992). The smaller Madison triangular projectile point is generally associated with the Late Woodland period.

Historic Period

Contact Period (1607–1630)

The area that is now Caroline County was inhabited by Native Americans long before its establishment as the 29th county of the Commonwealth of Virginia in 1727 (Wingfield 1924:1). The Pamunkey Indians, the most powerful Indian tribe under Chief Powhatan's rule, inhabited the area around Caroline County for many generations prior to European contact (Barbour 1969:5). Initial contact with Europeans occurred around 1570 and contact persisted from then on and included contact with the French, Spanish, and the English explorers and colonists (Barbour 1969:5).

The founding of Jamestown in 1607 prompted immediate exploration of the surrounding area. Captain John Smith explored what is now Caroline County at least three times between 1607 and 1609. He visited the area on one occasion as a captive of the Youngtamund tribe of the present-day Hanover County region. The Youngtamund tribe felt that Smith was too great of a responsibility for a local chief, so they sent him to Powhatan's brother, Opechancanough. It was during this trip to Opechancanough that Smith passed through Caroline County. According to legend, Opechancanough placed Smith on display to show that the white man was neither a god nor a supernatural being and that Indians should not fear the Europeans (Campbell 1954:6).

The Pamunkey tribe played a vital role in preventing the settlement of this area. On March 22, 1622, as the English continued to expand west, Opechancanough led an attack on Jamestown where over 300 settlers were killed. As a result, the House of Burgesses enacted a law that forbade settlement of the area occupied by the Pamunkey, punishable by death. This remained law until 1646 (Campbell 1954:8).

Settlement to Society Period (1630–1750)

In 1634 the House of Burgesses divided the colony into eight political subdivisions. Consequently, Caroline County became part of York and would remain in York County until

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1645 when the House of Burgesses removed the Potomac and Rappahannock valleys from the county and formed Chicacoan, which later became Northumberland County. Land along the Pamunkey and Mattaponi rivers remained in York and land along the Rappahannock went to Northumberland. These two sections of the region would not be reunited until the colony established Caroline as an official county in 1727, named after Queen Caroline of Ansbach, the wife of King George II (Campbell 1954:11; Wingfield 1924:1).

The Pamunkey were successful at stopping the English expansion until the 1650s when the Senenca and Tuscarora tribes of the Iroquois Nation began an attack on the Pamunkey. As a result of the attacks, the Pamunkey began to migrate east (Campbell 1954:10). Governor William Berkeley approved of this migration, much to the disdain of the colonists, because he profited immensely from trade with various Native American tribes. Nathaniel Bacon, Jr. took the case of the colonists to the House of Burgess to defend against the migration. When William Berkley refused to stop the movement of the Pamunkey, Bacon defended the colonists himself. T.E. Campbell (1954:18) states in his book *Colonial Caroline*: *A History of Caroline County, Virginia* that "the deeds of Nathaniel Bacon, Jr. influenced the development of Caroline County's history more than any other man in the seventeenth century." The frontier was opened to settlement with Bacon's defeat of the Pamunkey. In 1679, the colonial council built Fort Mattapony to control and encourage settlement of Caroline County (Campbell 1954:10). The area continued to grow due to the success of tobacco, the cash crop of the colony.

In 1706, Anne, queen of the Pamunkeys, went before the royal government asking them to patent tracts of land to Native Americans of her tribe in the same manner they patented lands to the whites, but to issue the lands to the tribe as a whole rather than individually. The royal government agreed to her request, and the agreement stands to this day. The Pamunkey and two sub-tribes, the Mattaponi and the Chickahominy, still hold portions of the original land that was patented in 1706 (Campbell 1954:40–41).

By the early-eighteenth century, the Rappahannock river became a well-traveled shipping route and several towns began to establish themselves along the river including Port Royal in 1744 (Caroline County 2010:5-3).

Colony to Nation Period (1750–1789)

Throughout the eighteenth century, as the importance of the Rappahannock River as a shipping route continued to grow, plantations began to line the banks of the river in Caroline County. Along with farming, grist-milling was a significant industry in the county and at least six mills were situated on the Peumansend (Mill) Creek. On May 27, 1771 the Rappahannock, James, and Roanoke rivers swelled from almost two weeks of rain that had fallen in the mountains of western Virginia. This flood is considered eighteenth century Virginia's greatest natural disaster and Ryland Randolph of Henrico wrote at the time "all the great rivers of this county were swept by inundations never before experienced, which changed the face of nature and left traces of violence that will remain for ages" (Moody Jr. 1970). This flood resulted in great loss of life and farm lands.

Caroline County was the first Virginia county to officially separate from the royal government after the Declaration of Independence was affirmed by the Continental Congress in 1776.

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Although no military action took place in Caroline County, the county produced many ardent supporters of the Revolution, such as Edmund Pendleton and John Penn who was a signer the Declaration of Independence (Independence Hall Association 1999).

Early National Period (1789–1830)

After the Revolution, the newly-formed nation went through a period of renewal. Many improvements were needed including updated infrastructure. In the early-nineteenth century, many major public roads went through Caroline County. The precursors of Routes 17 and 301 were two of Caroline County's vital highways (Fall 1989:129,349). According to 1820 census records, the population of Caroline County stood at 18,008 people with 11,470 being enslaved Africans (United Sates Federal Population Census [U.S. Census] 1820). The majority of the population was involved in agriculture.

Antebellum Period (1830–1860)

Transportation projects continued to expand during the Antebellum period as more roads, railroads, and canals were being built. By 1848, the Richmond, Fredericksburg, and Potomac (RF&P) Railroad passed through Caroline County's Bowling Green and linked the town to Richmond and points north. More than half of Caroline County's land was used for farming by 1860 and by this time, Caroline County was a large producer of tobacco (Caroline County 1850).

Civil War (1861–1865)

Due to Caroline County's location and proximity to Richmond, the Confederate Capital, it was widely traversed by both Union and Confederate forces throughout the Civil War. Large portions of the County were greatly impacted from battles, skirmishes, and large armies camping and traversing across the land (Caroline County 2010:5-4).

After General Thomas Jonathon "Stonewall" Jackson was shot by friendly fire at the Battle of Chancellorsville in 1863, Lee recommended that he recuperate somewhere safe and well behind enemy lines. Jackson selected Thomas C. Chandler's 740-acre plantation named "Fairfield" in Guinea Station (Stuart 2019). Although they were offered the house, Jackson and his doctors designated a nearby outbuilding as a make-shift hospital. On May 10, 1863 Jackson died of pneumonia brought on by his wounds. The building stands today and acts as a commemoration to General Jackson (Stuart 2019).

In 1864, the Battle of the North Anna River (composed of a series of smaller actions) was principally fought in Caroline County as part of Grant's Overland Campaign. The Overland Campaign was a coordinated offensive strategy meant to decimate Confederate troops as the Union Army made their way to Richmond (American Battlefield Trust n.d.). On May 23rd and 24th, the Union Army met Lee's entrenched Army of Northern Virginia on the south side of the North Anna River. Due to the "inverted V" defenses set up by Lee, Grant was forced to divide his army into three parts to attack. After somewhat of a stalemate, Grant withdrew his army back across the river and was able to outflank the Army of Northern Virginia and

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continue his advance on Richmond. Although the outcome of this battle was indeterminate, Grant continued his Overland Campaign on through to the Siege of Petersburg which would eventually lead to Lee's surrender (American Battlefield Trust n.d.).

Another notable event to take place in Caroline County was the death of President Abraham Lincoln's assassin, John Wilkes Booth. Booth had fled Washington, D.C., after shooting Lincoln and was pursued south by Federal troops. On April 26, 1865, Wilkes was shot in the neck on Richard Henry Garrett's porch in Port Royal and died shortly after (Gray 1985:26).

Reconstruction and Growth (1865–1917)

Because of the immense impact of the Civil War, Caroline County, like the rest of Virginia, had a prolonged and difficult Reconstruction period. Homes, land, and livestock were decimated during the war. Land values plummeted, and parcels were selling at a fraction of their pre-war price. The white residents as well as the newly freed African Americans endeavored to start their new lives after the war.

In an attempt to lessen the burden, new industries were introduced. New businesses and mills began to spring up, partially due to new depots being built along the RF&P Railroad (Caroline County 2010: 5-4). Around 1896, Caroline County's first excelsior mill was established in the small village of Woodford along the RF&P (Fisher and Sparenborg 2011:198; Wingfield 1924:26). Excelsior, sometimes called wood fiber or wood wool, consists of thin, fine strands of wood used for packing material and inexpensive filling for mattresses and upholstered furniture (Graves 1913:2). The excelsior plant at Woodford created jobs for residents and stimulated the local economy so that by the end of the first quarter of the twentieth century, Woodford's population had increased more than threefold. The success of this first mill encouraged competitors to establish their own excelsior mills in small communities all along the RF&P, sometimes in conjunction with lumber mills, in order to take advantage of the cheap and readily available pine forests of the county. Mills were established at Guinea, Milford, Penola, and Ruther Glen; as a result, excelsior soon became Caroline County's largest industry (Fisher and Sparenborg 2011:198; Wingfield 1924:26).

World War I to World War II (1911–1945)

The early-twentieth century brought many changes to Caroline County. The arrival of gasoline-powered machinery transformed Caroline County as it did the rest of rural Virginia. Faster and more powerful farming equipment was used over slower steam and horse-powered equipment, which led to higher productivity from farmers. Gasoline-powered automobiles were also being used over horse-drawn vehicles, which led to necessary road improvements for the operation of these new vehicles. Electrification was brought to the rural areas of the county by the Rural Electrification Administration. New business enterprises started to develop as well such as the Caroline County Bank (now Union Bank & Trust), a telephone company, and Bowling Green Power & Light Company (Caroline County 2010: 5-4).

Although Caroline County was also hit by the Great Depression, an Emergency Relief Committee was established in 1932 to respond to the crisis. One of the largest developments as part of this was a $20,000 road project on Route 38 which provided jobs for about 40 men.

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As part of this project, work was also done on "public school buildings, the firehouse, sidewalks in Bowling Green and Milford, water works and sidewalks in Port Royal and work on courthouse lots" (Caroline county 2010: 5-5). During this time, many had to rely on home food production as well, and cash crops such as tobacco, lumber, cucumbers, and sweet potatoes were added to the range of products grown in Caroline County (Caroline County 2010: 5-5).

Schooling changed during this time as well. Prior, students rode the train to Ashland or Richmond. Around 1910 one of the first school groups in the county started to develop in Sparta with plans for a community high school. Following this meeting, the first high school in Caroline County was established with 68 students (Caroline County 2010:5-4). African American children were not permitted to attend this school, and they had to set up segregated schooling elsewhere, such as at the rural Jericho School, in Ruther Glen (Neville and Clarke 2003). In 1941, 77,000 acres (31.16 ha) east of Bowling Green was acquired by the United States Military to be used as a training area for the U.S. 1st Army. The military reservation was named Fort A.P. Hill in honor of Confederate Lieutenant General Ambrose Powell Hill. During the building of this complex, many "farms, schools, churches, cemeteries, gristmills, storage houses, and stores" were demolished and many families were forced from their homes and displaced elsewhere (Caroline County 2010: 5-5). This massive training complex is still used by all branches of the military and many other governmental agencies (Gray 1985:25).

The New Dominion (1945–Present)

Caroline County has experienced many changes throughout the last half of the twentieth century: "new interstate highways were constructed to connect Caroline with urban areas to the north and south, schools were consolidated and integrated, a water system was constructed in Milford, a community center was constructed in Dawn and the Courthouse was renovated" (Caroline County 2010:5-6). Throughout all of this, Caroline County still remains primarily rural and agricultural, and with easy access to Interstate 95 (I-95), Caroline County is able to quickly transport their agricultural products to markets all along the eastern seaboard (Caroline County 2010:5-6). Caroline County has a total area of 539 square miles (1,396 sq km), 533 square miles (1,380 sq km) are land and six square miles (15.54 sq km) are water. The county is located in the Rappahannock Area Development Commission (RADCO) region, which is the fastest growing region in the Commonwealth. Caroline experienced a large increase in population from 1960 to 1990. The population grew from 12,725 in 1960 to 19,217 in 1990 with the largest increase occurring in the 1970s (Caroline County 2010). In spite of this population boom, the population increase leveled in the 1980s and has not kept up with the rest of the region and it is the most rural county in the RADCO region (Caroline County 2010).

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SURVEY METHODOLOGY

The goals of the survey were to identify locations within the project area with the potential to contain intact archaeological sites and architectural resources older than 50 years in the project vicinity and make recommendations for any additional investigations. The survey methodology employed to meet these goals was chosen with regard to the project's scope (i.e., provide important data on the integrity of surface and subsurface deposits and identify potential archaeological sites and architectural resources) and local field conditions. Based on the topographic and environmental setting and the background review, the project area was judged to have high potential to contain prehistoric and historic archaeological sites that meet the National Register of Historic Places (NRHP) age criteria. For the two water main routes, the archaeological project area is defined as the area within 25 feet (7.6 m) of the edge of pavement. For the potential raw water intake sites and water treatment plants the archaeological project area includes the entirety of the parcels.

The Phase IA architectural study included identifying all above-ground resources over 50 years in age (1969) within the project's architectural project area. For the potential raw water main and the alternative raw water main route, the architectural project area is defined as the area within and adjacent to the water main and is inclusive of any resource 50 years of age or older whose feeling or setting may be impacted by the project. For the potential raw water intake sites and potential water treatment plants the architectural project area is defined as extending 500 feet (152.4 m) from the parcel boundaries. This project area was determined based on preliminary layouts provided to Dovetail in August 2018. If the plans for this project are further refined before the Phase IB, the project area for the Phase IB may be reduced or expanded, depending on footprint size, building/structure height, location selection, etc.

Dovetail conducted a background literature and records review of the project area at the Virginia Department of Historic Resources (DHR). The Civil War Sites Advisory Commission (CWSAC) maps for the area, historic topographic maps, and the historic map collection at the Library of Congress were also examined. This research included examining the records of previous cultural resource investigations and previously recorded archaeological sites and architectural properties within a 0.5-mile (0.8-km) radius of the project area. The purpose of this work was to obtain information to complete a context of the property and surrounding area.

The field survey consisted of a visual inspection of the 32.1-mile (51.7-km) potential raw water main route and the 18.7-mile (30.1-km) alternative raw water main route, as well as a visit to the most likely locations of the three potential raw water intake areas and four potential water treatment plant sites in consultation with representatives from Draper Aden and Hazen. No subsurface investigations or architectural documentation was completed during this work.

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BACKGROUND RESEARCH

Prior to conducting fieldwork, the potential of the project area to contain cultural resources eligible for listing in the NRHP was assessed by searching the DHR files, maps, and reports, and American Battlefield Protection Program Maps (ABPP) to obtain required information (ABPP 2017). Work included a review of previous cultural resource surveys, and examination of archaeological and architectural resources within 0.5-mile (0.8-km) of the potential intake areas and potential water treatment plant areas. Because the potential raw water main and alternative raw water main are extremely long and cover most of the county and their potential impact is so minor, a reduced background review radius of 150 feet (45.72 m) was used for the water main and alternative water main portions of the project area. Limited research was also conducted to note the historic use of the project area, as depicted on mapping and in historic aerial photographs.

American Battlefield Protection Program Maps

The 2002 Civil War Battlefield Preservation Act directed the Secretary of the Interior, through the American Battlefield Protection Program (ABPP), to update the 1992 Civil War Sites Advisory Commission (CWSAC) Report on the Nation's Civil War Battlefields. The update was required to address preservation activities at each battlefield since 1993 as well as changes in environmental conditions of the battlefields and other relevant developments. As part of the update, the ABPP created a four-tiered system that included such factors as historic significance, current condition, and level of threat to determine preservation priorities among the battlefields. The reports defined portions of battlefields in terms of Study Area, Core Area, and those portions potentially eligible for the National Register (PotNR). Reports, some still drafts, were released between 2008 and 2011. The report for Virginia's 122 battlefields was released in July 2009 (ABPP 2009).

Using the ABPP website and the ABPP layer on VCRIS, it appears that three of the four potential sites for the water treatment plant fall within the North Anna Battlefield (042-0123) PotNR boundaries and those defined by DHR (ABPP 2017; VCRIS 2017).

Historic Map Review

Research was conducted to note the historic use of this area, as depicted on mapping and in historic aerial photographs. Historic topographic maps from the United States Geological Survey (USGS), and the Library of Congress' historic map collection were examined during this investigation. Information gathered from this research provided preliminary data on the potential for archaeological sites and architectural resources within the parcel. The purpose of this work was to obtain information to complete a context of the property and surrounding area.

While aerial photography exists for the project area, it only extends back to the late 1960s and historic topographic maps did not provide much information beyond Civil War period historic mapping. Indeed, some of the most detailed maps of the project area that show historic

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the three potential raw water intake areas and four potential water treatment plants (parcels 81-A-67, 82-A-55, 83-A-58, and 92-A-24) (Table 8, p. 34). Of those 53, four are listed in the NRHP and Virginia Landmarks Register (VLR). Situated on 318.5 acres (128.9 ha) of land, Gay Mont (016-0032) is a two-story, frame dwelling constructed around 1790 in the Colonial style. It has several associated secondary resources, including a tennis court, croquet field, kitchen, garden, and cemetery. It was listed in the NRHP in 1972. The Jericho School (016-5014) is a one-story, frame, early-twentieth-century school and was listed in the NRHP in 2014. Saint Julien (088-0061) is a two-story, brick dwelling built in 1804 in the Federal style. The house and approximately 12 secondary resources stand on over 300 acres (121.4 ha) of land and was listed in the NRHP and VLR in 1975. The Bowling Green Historic District (171-5001) is a 279-acre (112.9-ha) district composed of 374 resources, including single-family dwellings and associated outbuildings, commercial buildings, and civic facilities. It was listed in the NRHP and VLR in 2003.

Five of the 53 resources have been determined eligible for listing in the NRHP. Grace Episcopal Church (016-0011) is a one-and-a-half-story, brick church dating to around 1833 and is reflective of the Classical Revival style. Associated with this resource are a cemetery and a privy. In addition to being eligible for the NRHP, it was listed in the VLR in 2018. Hayfield (016-0014) is a mid-eighteenth-century, single-family dwelling that was expanded and remodeled in the mid-nineteenth century. This brick building was determined eligible in 2009. In 2019, DHR staff determined that the house and school at 17335 and 17341 Washington Highway (042-0400), also known as Ellington, is eligible for the NRHP. The property contains a two-story, brick house that was constructed around 1839 in the Federal style, an 1840, Federal-style school for boys, and four twentieth-century outbuildings. The Greater Port Royal Historic District (284-0044) comprises approximately 14,000 acres (5665.6 ha) and is made up of a wide variety of resource types, such as large mansions, small, single-family dwellings, commercial buildings, wharfs, and agricultural landscapes ranging from the seventeenth century to present day. In 2009, DHR staff determined that the Greater Port Royal Historic District is eligible for the NRHP. The remaining eligible resource, the Richmond, Fredericksburg and Potomac Railroad Historic District (500-0001) is a railroad line started around 1837 that spanned from the Potomac River to Richmond. It is currently owned and operated by CSX and was determined eligible in 2018. Of these five, four (016-0011, 016-0014, 284-0044, 500-0001) are located within the architectural project area. See the subsequent Results of the Phase IA Study chapter (p. 43) for more details.

DHR staff determined that three of the 53 resources are potentially eligible for the NRHP. The Esso Gas Station on Route 1 (016-0257) is a one-story pump station constructed in 1941. The North Anna Battlefield (043-0123) is a large resource that is related to the 1864 Civil War battle of the same name. The Richmond, Fredericksburg, and Potomac Railroad (088-5413) is a small segment of the larger railroad corridor. DHR determined these resources potentially eligible for the NRHP in 1996, 2007, and 2012, respectively.

Thirteen of the resources were determined not eligible for individual listing in the NRHP by DHR. This number includes Fort A.P. Hill Historic District (016-0349) and the armory within the district at 18272 A.P. Hill Boulevard (016-5091), six bridges (016-0007, 016-0344, 016-0347, 016-5027, 016-5087, and 016-5176), a church (016-0187), a religious monument (016-

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occupations consist of the military maps from the 1860s, such as a map of Caroline County from 1860 showing multiple historic occupations within the project area (Confederate States of America [CSA] 1860). Within intake Area 1, there are Civil War period Confederate fortifications; the intake area is also very near a historic house belonging to the Golden Family. Intake Area 2 also contains fortifications as well as a house belonging to Hare. Intake Area 3 does not contain any historic resources according to the 1860 map (Figure 6, p. 29).

The four water treatment facility locations also contain some historic occupations according to the 1860 CSA map. Parcels 92-A-24 and 82-A-55 both contain houses associated with the Madison family. Parcel 82-A-55 also contains a house owned by the Wortham family and potentially the Mount Carmel Church. Parcel 81-A-67 contains a house owned by J. Quarles and the northern boundary is very near a house owned by Tate. The 1860 map does not show any potential resources within 83-A-58 (Figure 7, p. 30).

The potential water line route and alternative route pass by a large number of historic houses and locations, including the historic town of Bowling Green. All of the roads that the pipeline routes run along are historic and given historic settlement patterns it is unsurprising that there are so many potential resources along the route (Figure 8, p. 31).

Previous Cultural Resource Surveys

A number of the previous cultural resource surveys within 0.5 mile (0.8 km) of the three potential intake areas, four potential water treatment plant areas, and within 150 feet (45.7 m) of the two potential raw water main routes in the DHR's archives include:

In 1979, Southside Historic Sites, Inc. (SHS) conducted a cultural resources survey of selected areas within the United States Army Post Fort A.P. Hill (Ayres and Beaudry 1979). During the archaeological survey, they identified a total of 51 resources ranging from early archaic through twentieth century. Only one of the sites, site 44CE0072, was recommended by SHS for further work. The rest were determined to be too heavily disturbed to warrant further investigation.

James Madison University (JMU) conducted a cultural resource survey in 1986 along five proposed lines for the planned construction of the Route 207 bypass in Caroline County and Bowling Green, Virginia. They identified 18 archaeological sites, 14 historic and four prehistoric/historic, within the project area. JMU did not recommend further work at any sites (Andrews 1986).

In January of 2008, Fort A.P. Hill conducted a Phase I archaeological survey on 27 forestry blocks which were comprised of a total of 658.2 acres (266.4 ha) throughout Fort A.P. Hill. Seven archaeological sites and two isolated finds were located. Five of the seven sites (44CE0294, 44CE0525, 44CE0526, 44CE0527, and 44CE0528) were recommended potentially eligible by the NRHP (Mullin 2008).

Between 1999 and 2001, Cultural Resources Inc. (CRI) conducted an archival assessment and Phase IA pedestrian reconnaissance to identify potential Civil War archaeological sites within Fort A.P. Hill. Throughout the 650 acres (263 ha) that were surveyed there were 77

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archaeological sites and seven "locations" (isolated finds) identified. Of these, 55 were recommended for Phase I subsurface testing should ground disturbing work occur in the future (CRI 2001).

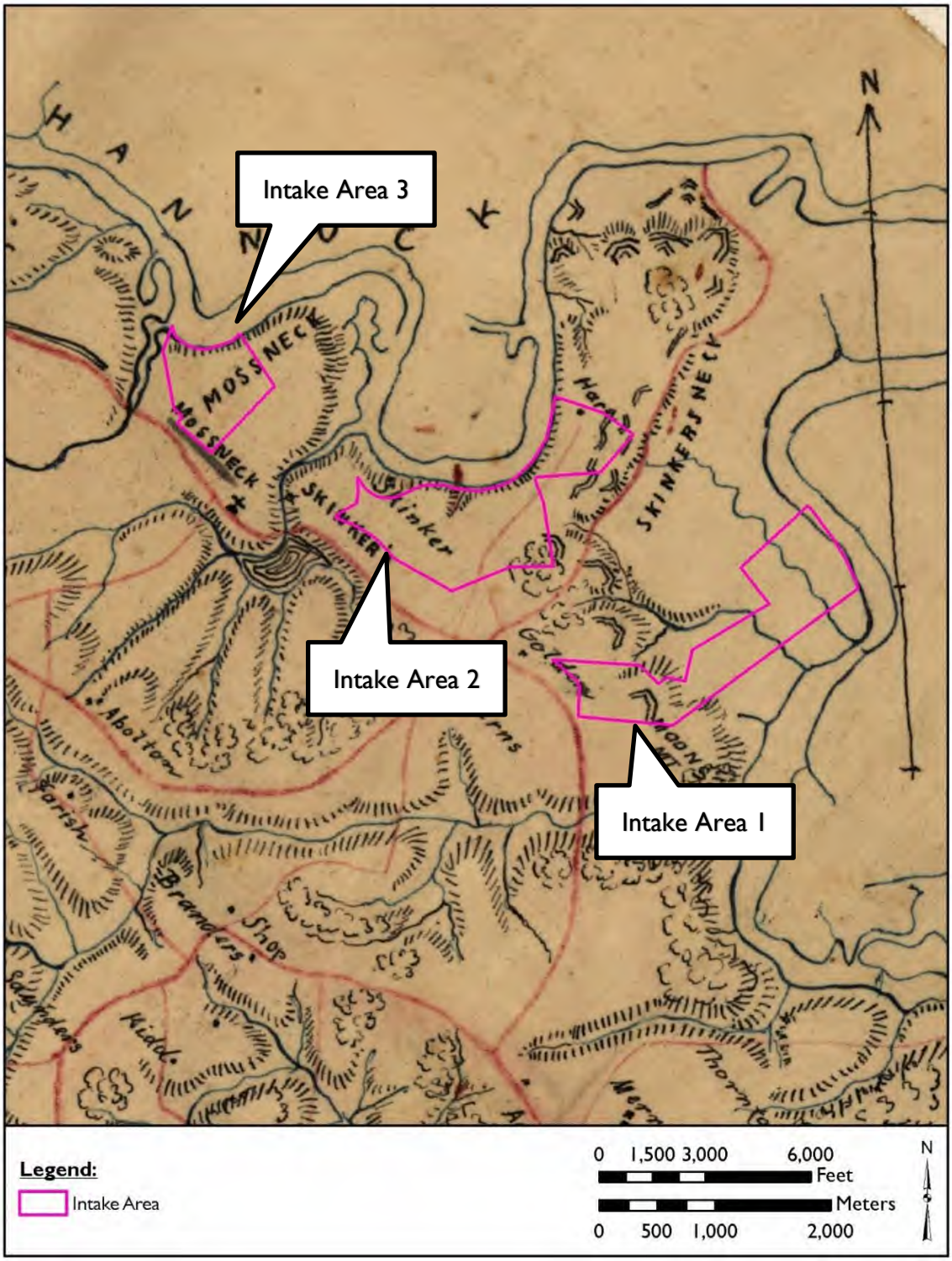


Figure 6: 1860 CSA Map Showing the Three Intake Areas (CSA 1860).

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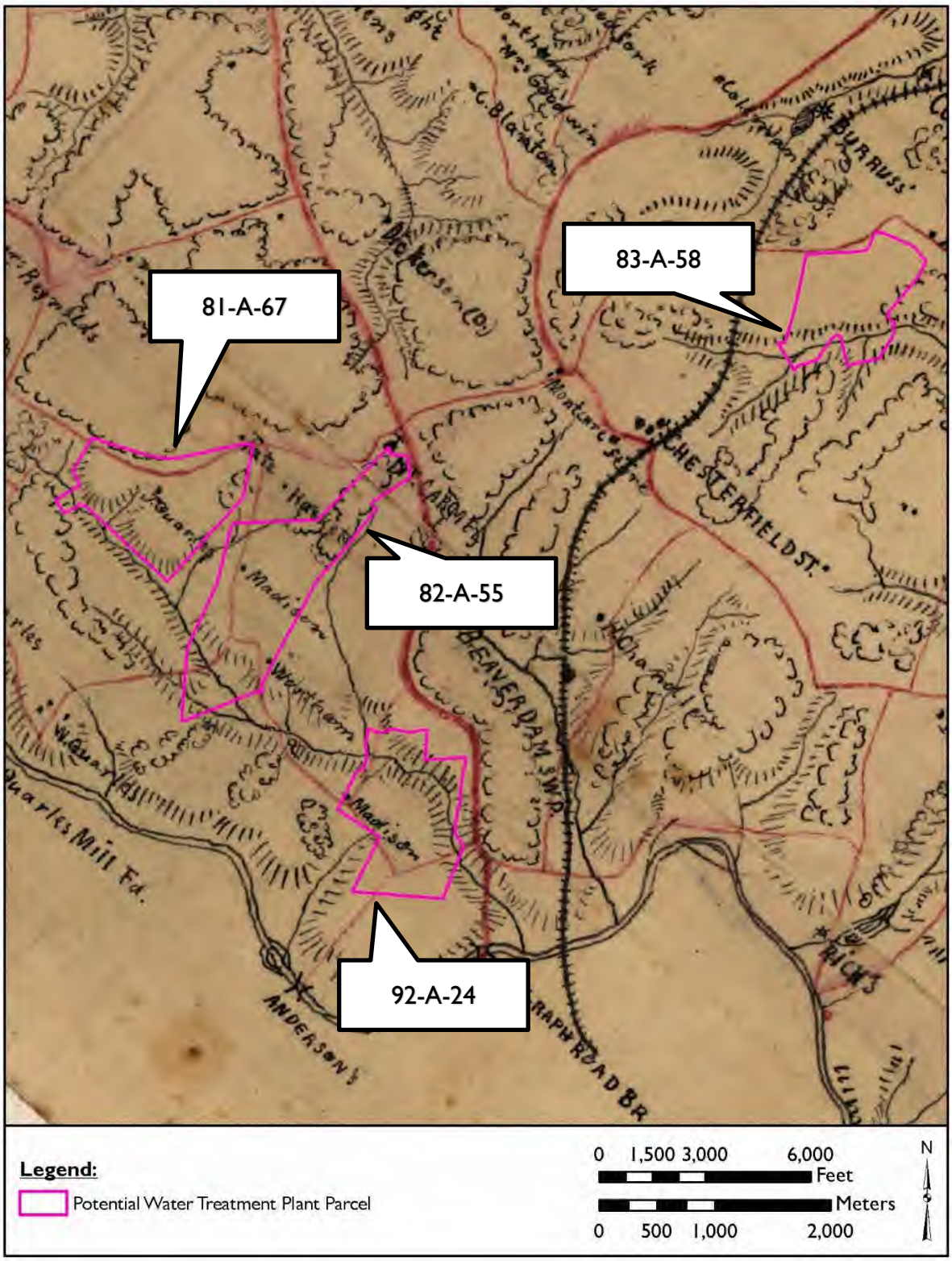


Figure 7: 1860 Map Showing Potential Water Treatment Facility Areas (CSA 1860).

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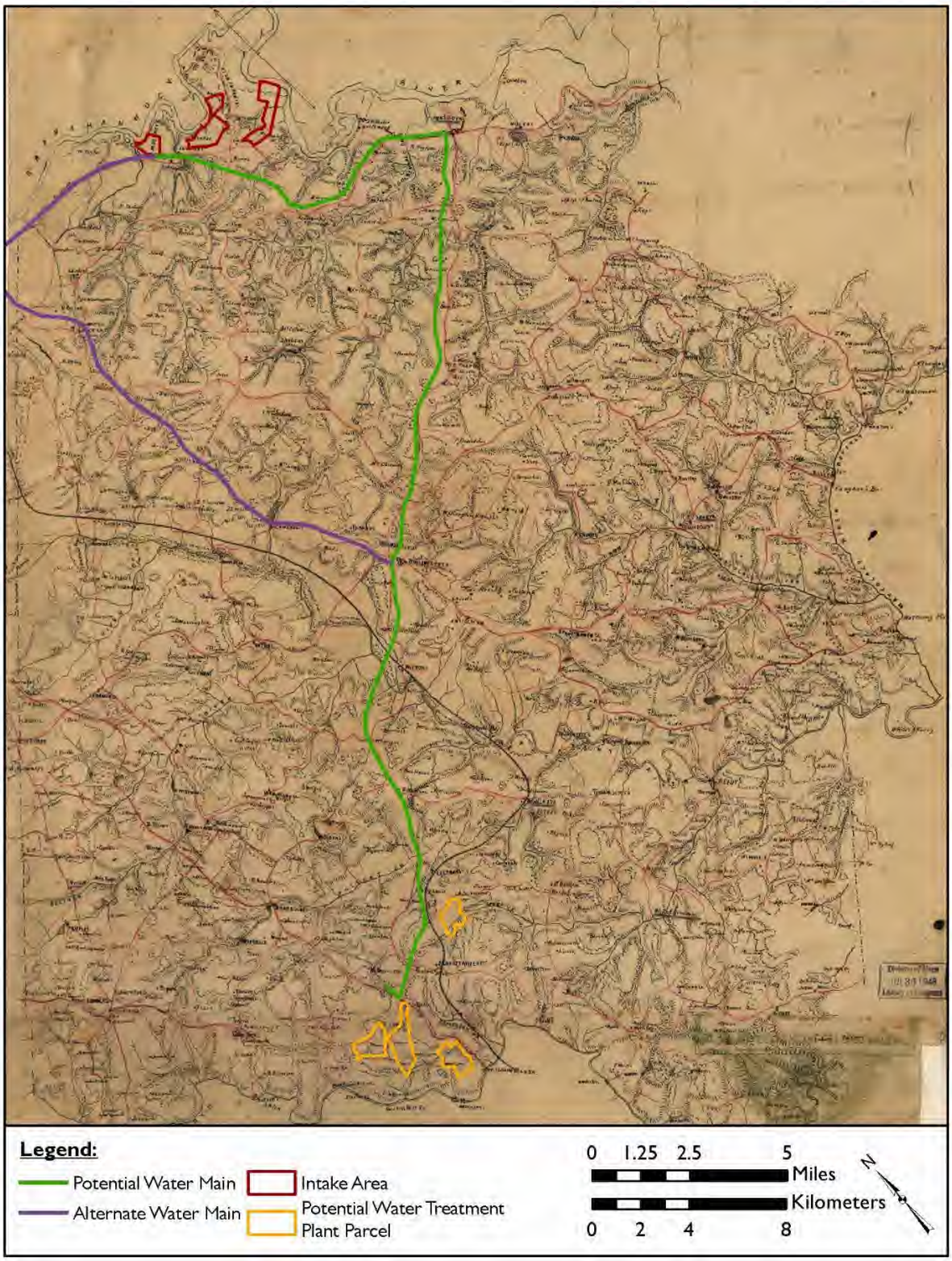


Figure 8: 1860 Map Showing the Entire Study Area (CSA 1860).

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In 1993, Gray & Pape, Inc. completed a Phase I cultural resources inventory of Fort A.P. Hill. During the architectural survey, they recorded 50 buildings and structures and recommended four for listing in the NRHP (Winter and Pezzoni 1993:i). The archaeological survey, comprising a systematic field survey and a predictive model, yielded 19 archaeological sites and 21 archaeological isolated finds. As a result, Gray & Pape recommended Phase II testing on eight sites, two of which were recommended eligible for the NRHP (Winter and Pezzoni 1993:i).

In 2010 the Virginia Department of Transportation (VDOT) conducted a Phase I archaeological survey associated with the proposed bridge replacement over the CSX Railroad on Rogers Clark Boulevard (Route 207) in Caroline County. Only one site was recorded during the survey (44CE0675) and it was recommended not eligible by VDOT (Cooke 2010).

The William and Mary Center for Archaeological Research completed an archaeological assessment of the Echo Dell Site (44KG0009) in 2007. The assessment included the excavation of 109 shovel tests and four test units. The testing showed that the site is still intact and that further testing was recommended (W. Moore et al. 2007).

Between 1993 and 2011 Louis Berger & Associates, Inc. (Berger) conducted four surveys in the vicinity of the project area. The first, *Phase I Cultural Resources Survey, Caroline County Regional Jail Site, Fort A.P. Hill, Caroline County, Virginia*, was a Phase I survey that consisted of a pedestrian survey and then subsurface testing of potential areas. Eight sites were located, none of the sites were recommended for further testing (Busby 1993). In 2005, Berger conducted an archaeological survey in association with improvements to the interchange between I-95 and Route 207. Two archaeological sites were discovered, neither of which were recommended eligible for NRHP listing (Tippett and Rupnik 2005).

Berger conducted a Phase I archaeological survey in 2007 at Fort A.P. Hill. Twenty-five sites were located by the survey, 15 of which were recommended by Berger for inclusion on the National Register (E. Moore et al. 2007). In 2011 Berger conducted a Phase I survey along the proposed route of the Pender Camp Wastewater Force Main at Fort A.P. Hill. Only one site was found during the survey and it was not recommended to be eligible for NRHP listing (Fiedel 2011).

On behalf of Dominion Power, Dutton + Associates, LLC conducted a Phase I cultural resources survey for the Dominion Virginia Power Line 47 Rebuild Project. As part of this survey, which spanned Hanover, Caroline, and Spotsylvania counties, they identified 91 architectural resources, 10 of which, including five Caroline County resources, were either already in, or were recommended eligible for, the NRHP. As part of the archaeological survey, Dutton + Associates identified one newly recorded archaeological site (44CE0829) and seven previously recorded sites, none of which were recommended eligible for the NRHP (Dutton and Striker 2016:i).

Previously Identified Architectural Resources

There is a total of 53 resources within a 150-foot (45.7 m) radius of the potential raw water main and the alternative route for the raw water main and within a 0.5-mile (0.8-km) radius of

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0130), and three individual houses (Poplar Grove [016-0153], Holly Hill [016-0144], and Willie Brad Smith House [016-0345]) ranging in construction date from circa 1727 to 1922.

Of the 53 resources, 28 have not yet been evaluated for NRHP eligibility by DHR. A majority (n=20) are single-family dwellings. They represent a wide range of architectural styles and forms from the nearly 300-year period from 1670 to circa 1970, including Classical Revival, Queen Anne, and Colonial Revival. It is not uncommon for these one-, one-and-a-half, and two-story dwellings to have one or more outbuildings, including garages, sheds, or, in some circumstances, associated agricultural buildings. While they have not been evaluated for NRHP potential as individual resources, 10 are associated with the NRHP-listed Bowling Green Historic District. The remaining eight include a circa-1749, two-and-a-half-story tavern (016-0215), three churches ranging in date from circa 1870 to 1922 (016-0169, 016-0216, 016-0255), a cemetery, one-story headquarter building and a camp at A.P. Hill constructed in 1995 (016-0349-0022, 016-0349, 0035), and a circa-1948 restaurant and store (284-5014).

Table 8: Previously Recorded Architectural Resources Within 150 Feet (45.7 M) of the Potential Raw Water Main and the Alternative Route for the Raw Water Main and Within 0.5 Mile (0.8 Km) of the Potential Raw Water Intake Sites 1, 2, and 3 and Four Potential Water Treatment Plants.

DHR ID	Name and Address	Date of Construction	Previous Eligibility Determination	Project Segment
016-0007	Bridge, Route 684	post 1900	DHR Staff: Not Eligible, 2007	Potential Water Treatment Plant 83-A-58
016-0011	Destiny Ministries, Grace Episcopal Church, Grace Episcopal Church & Cemetery	ca. 1833	DHR Staff: Eligible, 2017; VLR Listing 2018	Alternative Route for Raw Water Main
016-0014	Hayfield, 18173 Tidewater Trail	ca. 1760	DHR Staff: Eligible, 2009	Potential Raw Water Intake Site, Area 3
016-0032	Gay Mont, 23348 Tidewater Trail	ca. 1790	NRHP Listing, 1972; VLR Listing, 1972	Potential Raw Water Main
016-0065	Haymount/ Lederer Expedition/ Skinker's Neck/Taliaferro Mount	1670	Not Evaluated	Potential Raw Water Intake Site, Area 1
016-0072	Yew Spring Farm	ca. 1846	Not Evaluated	Potential Raw Water Intake Site, Area 2
016-0097	Athens	ca. 1800	Not Evaluated	Potential Raw Water Main
016-0130	Baptist Monument, Jefferson Davis Highway	1922	DHR Staff: Not Eligible, 1996	Potential Water Treatment Plant 82-A-55
016-0144	Holly Hill, 15542 Holly Hill Drive	ca. 1727	DHR Staff: Not Eligible, 2010	Potential Raw Water Main
016-0153	Poplar Grove, 20194 Rogers Clark Highway	ca. 1830	DHR Board Det. Not Eligible, 1991	Potential Raw Water Main

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DHR ID	Name and Address	Date of Construction	Previous Eligibility Determination	Project Segment
016-0169	Jericho Baptist Church	ca. 1870	Not Evaluated	Potential Water Treatment Plant 81-A-67; Potential Water Treatment Plant 82-A-55; Potential Water Treatment Plant 92-A-24
016-0187	Carmel Baptist Church and Cemetery, Route 1	ca. 1830	DHR Staff: Not Eligible, 1981	Potential Water Treatment Plant 82-A-55
016-0215	Todd's Tavern	ca. 1749	Not Evaluated	Alternative Route for Raw Water Main
016-0216	Zion Grove Church and Cemetery	ca. 1910	Not Evaluated	Alternative Route for Raw Water Main
016-0254	House, Route 689	ca. 1870	Not Evaluated	Potential Water Treatment Plant 81-A-67
016-0255	Oxford Mt Zion Baptist Church, Route 613	1922	Not Evaluated	Potential Water Treatment Plant 82-A-55
016-0257	Elsie's This or That/Esso Gas Station, Route 1	1941	DHR Staff: Potentially Eligible, 1996	Potential Water Treatment Plant 82-A-55
016-0344	Bridge #1013, Campbell Creek	1932	DHR Staff: Not Eligible, 1995	Alternative Route for Raw Water Main
016-0345	Caroline Country Crafts/Wille Brad Smith House, Jefferson Davis Highway	1922	DHR Staff: Not Eligible, 1996	Potential Raw Water Main; Potential Water Treatment Plant 82-A-55
016-0347	Bridge #6017	1914	DHR Staff: Not Eligible, 1995	Potential Raw Water Intake Site, Area 2
016-0349	Fort A.P. Hill Historic District	ca. 1941	DHR Staff: Not Eligible, 1994	Potential Raw Water Main; Alternative Route for Raw Water Main; Potential Raw Water Intake Site, Area 2; Potential Raw Water Intake Site, Area 3
016-0349-0022	Headquarters, Fort A.P. Hill	1995	Not Evaluated	Potential Raw Water Main
016-0349-0035	Pender Camp, U.S. 17	Post 1970	Not Evaluated	Potential Raw Water Intake Site, Area 2
016-5014	Jericho School, Jericho Road	post 1917	NRHP and VLR Listed, 2014 (Criteria Not Listed)	Potential Water Treatment Plant 81-A-67
016-5026	George Anderson House-, 4390 Buckner Road	ca. 1930	Not Evaluated	Potential Raw Water Main
016-5027	Bridge # 1024, Bridge, spans Polecat Creek	ca. 1951	DHR Staff: Not Eligible, 2006	Potential Raw Water Main

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DHR ID	Name and Address	Date of Construction	Previous Eligibility Determination	Project Segment
016-5040	Terrell Cemetery, Jericho Road, Jericho Road	post 1830	Not Evaluated	Potential Water Treatment Plant 82-A-55
016-5087	Bridge #1026, Route 207 (west-bound), spanning CSX Railroad	ca. 1953	DHR Staff: Not Eligible, 2017	Potential Raw Water Main
016-5091	Fort A.P. Hill Armory	1986	DHR Staff: Not Eligible, 2017	Potential Raw Water Main
016-5101	House, 21028 Rogers Clark Boulevard	1949	Not Evaluated	Potential Raw Water Main
016-5163	House, 11435 Railroad Lane	ca. 1920	Not Evaluated	Potential Water Treatment Plant 83-A-58
016-5164	Little Rock Farm, 26389 Jefferson Davis Highway	ca. 1900	Not Evaluated	Potential Water Treatment Plant 92-A-24
016-5176	Bridge #1025	1953	DHR Staff: Not Eligible	Potential Raw Water Main
042-0123	North Anna Battlefield	1864	DHR Staff: Potentially Eligible, 2007	Potential Raw Water Main; Potential Water Treatment Plant 82-A-55
042-0400	House, 17341 Washington Highway/School, 17335 Washington Highway	ca. 1839	DHR Staff: Eligible, 2019	Potential Water Treatment Plant 92-A-24
048-5035	Echo Dell	Not Listed	Not Evaluated	Potential Raw Water Intake Site, Area 1
088-0050	Nottingham, 1801 Mills Drive	ca. 1774	Not Evaluated	Alternative Route for Raw Water Main
088-0061	Saint Julien, 9630 Sandy Lane, Route 2	1804	NRHP Listing, 1975; VLR Listing, 1975	Alternative Route for Raw Water Main
088-5413	CSX Railroad Corridor, Richmond, Fredericksburg & Potomac Railroad	ca. 1837	DHR Staff: Potentially Eligible, 2012	Potential Raw Water Main; Potential Water Treatment Plant 83-A-58; Potential Water Treatment Plant 92-A-24
171-0015	House, 103 E. Broaddus Ave	1902	Not Evaluated	Alternative Route for Raw Water Main
171-5001	Bowling Green Historic District	post 1750	NRHP Listing, 2003; VLR Listing, 2003	Potential Raw Water Main; Alternative Route for Raw Water Main
171-5001-0127	265 North Main Street	ca. 1970	Not Evaluated	Alternative Route for Raw Water Main
171-5001-0128	319 North Main Street	ca. 1970	Not Evaluated	Alternative Route for Raw Water Main
171-5001-0129	329 North Main Street	1875	Not Evaluated	Alternative Route for Raw Water Main
171-5001-0130	333 North Main Street	1875	Not Evaluated	Alternative Route for Raw Water Main

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DHR ID	Name and Address	Date of Construction	Previous Eligibility Determination	Project Segment
171-5001-0131	103 East Broddus Avenue	1902	Not Evaluated	Potential Raw Water Main
171-5001-0134	115 East Broddue Avenue	1908	Not Evaluated	Potential Raw Water Main
171-5001-0137	125 East Broddus Avenue	ca. 1920	Not Evaluated	Potential Raw Water Main
171-5001-0138	108 East Broddus Avenue	ca. 1930	Not Evaluated	Potential Raw Water Main
171-5001-0140	120 East Broddus Avenue	ca. 1960	Not Evaluated	Potential Raw Water Main
284-0044	Greater Port Royal Historic District	ca. 1790	DHR Board Det. Eligible, 2009	Potential Raw Water Main; Potential Raw Water Intake Site, Area 1
284-5014	Horne's Store & Restaurant, Restaurant, 25532 A.P. Hill Boulevard	ca. 1948	Not Evaluated	Potential Raw Water Main
500-0001	Richmond, Fredericksburg and Potomac Railroad Historic District	ca. 1837	DHR Staff: Eligible, 2018	Potential Raw Water Main; Potential Water Treatment Plant 83-A-58; Potential Water Treatment Plant 92-A-24

Previously Identified Archaeological Resources

Seventy-eight previously recorded archaeological sites are located within a 0.5-mile (0.8-km) radius of the three water intake areas, potential water treatment plant areas, and within 150 feet (45.7m) of the potential raw water main routes (Table 9). Fifty-two of these sites are historic, 17 are prehistoric, seven are multicomponent, and two did not have recorded temporal associations. The temporal distribution of previously recorded sites provides information on the expected attributes of potential archaeological sites within the project area.

The seventeen prehistoric sites range from the Archaic to Woodland periods. Five are listed as camps, eight as lithic scatters, one as a village site, and three have undetermined functions. Ten of the prehistoric sites (44CE0005, 44CE0006, 44SP0027, 44CE0608, 44CE0609, 44CE0610, 44CE0611, 44CE0612, 44CE0613, and 44CE0614) are completely or partially located within the project area.

The fifty-two historic sites include sites dating from the eighteenth through the twentieth centuries, though nineteenth- and twentieth-century components predominate. The DHR files identify twelve as residential, while the remainder reflect the varying historic uses of the area. Listed site functions include farmsteads, forts, mills, roads, earthworks, military camps, churches, cemeteries, ice houses, kilns, refuse pits, and scatters. Fifteen sites, 44CE0241, 44CE0436, 44CE0580, 44CE0391, 44CE0393, 44SP0627-0002, 44CE0599-001, 44CE0599-002, 44CE0599-003, 44CE0600, 44CE0601, 44CE0602, 44CE0603, 44CE0605 and 44CE0629-0001 are located partially in the project area.

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Table 9: Previously Recorded Archaeological Sites Within 0.5 mile (0.8 km) of Potential Intake Areas, Potential Water Treatment Plant Locations, and 150 feet (45.7m) of the Potential Raw Water Main Routes.

DHR ID	Site Types	Time Periods	Evaluation Status	Project Segment
44CE0005	null	Prehistoric/Unknown, 18th Century: 1st quarter	Not Evaluated	Potential Raw Water Main
44CE0006	null	Woodland	Not Evaluated	Potential Raw Water Main
44CE0022	null	Historic/Unknown, Early Archaic, Middle Archaic, Woodland	Not Evaluated	Potential Raw Water Main
44CE0032	Camp	Prehistoric/Unknown	Not Evaluated	Potential Raw Water Main
44CE0041	Trash scatter	20th Century	Not Evaluated	Potential Raw Water Main
44CE0085	Farmstead	Early Archaic Period, Middle Archaic Period, Antebellum Period, Civil War, Reconstruction and Growth	Not Evaluated	Potential Raw Water Main
44CE0087	Farmstead	19th Century, 20th Century	Not Evaluated	Potential Raw Water Main
44CE0088	null	Null	Not Evaluated	Potential Raw Water Intake Site 3
44CE0224	Dwelling, single	Historic/Unknown	Not Evaluated	Potential Raw Water Intake Site 1
44CE0235	Camp, Temporary	Middle Archaic	Not Evaluated	Potential Water Treatment Plant 82-A-55; Potential Water Treatment Plant Site 83-A-58
44CE0236	Kiln, Brick	19th Century	Not Evaluated	Potential Water Treatment Plant 82-A-55; Potential Water Treatment Plant Site 83-A-58
44CE0237	Camp, Temporary	Prehistoric/Unknown, 18th Century, 19th Century	Not Evaluated	Potential Water Treatment Plant 82-A-55; Potential Water Treatment Plant Site 83-A-58
44CE0238	Dwelling, Single	18th Century, 19th Century	Not Evaluated	Potential Water Treatment Plant 82-A-55; Potential Water Treatment Plant Site 83-A-58
44CE0239	Cemetery	19th Century	Not Evaluated	Potential Water Treatment Plant 82-A-55; Potential Water Treatment Plant Site 83-A-58
44CE0241	Farmstead	19th Century	Not Evaluated	Potential Raw Water Main

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DHR ID	Site Types	Time Periods	Evaluation Status	Project Segment
44CE0251	Fort	19th Century: 3rd quarter	Not Evaluated	Potential Water Treatment Plant 82-A-55; Potential Water Treatment Plant 92-A-24
44CE0253	Mill	Historic/Unknown	Not Evaluated	Potential Water Treatment Plant 82-A-55; Potential Water Treatment Plant 92-A-24
44CE0262	Camp, temporary	Woodland, 19th Century: 2nd/3rd quarter	Not Evaluated	Potential Raw Water Intake Site 1
44CE0263	null	Prehistoric/Unknown, 18th Century: 2nd half	Not Evaluated	Potential Raw Water Intake Site 1
44CE0264	Dwelling, single	19th Century	Not Evaluated	Potential Raw Water Intake Site 1
44CE0266	Village/Town	Woodland	Not Evaluated	Potential Raw Water Intake Site 1
44CE0277	Other	Historic/Unknown	DHR Staff: Not Eligible	Potential Raw Water Main
44CE0280	Lithic workshop	Prehistoric/Unknown, 20th Century	DHR Staff: Not Eligible	Potential Raw Water Main
44CE0282	Trash pit	20th Century	DHR Staff: Not Eligible	Potential Raw Water Main
44CE0310	Fort	19th Century: 3rd quarter	Not Evaluated	Potential Raw Water Intake Site 1
44CE0311	Fort	19th Century: 3rd quarter	Not Evaluated	Potential Raw Water Intake Site 1
44CE0312	Mill	19th Century	Not Evaluated	Potential Raw Water Intake Site 2
44CE0313	Earthworks	19th Century: 2nd half	Not Evaluated	Potential Raw Water Intake Site 2
44CE0320	Other	Null	Not Evaluated	Potential Water Treatment Plant 82-A-55
44CE0321	Dwelling, Single	19th Century: 2nd half	Not Evaluated	Potential Water Treatment Plant 82-A-55
44CE0391	Road	Indeterminate, 18th Century, 19th Century, 20th Century	DHR Staff: Not Eligible	Potential Raw Water Main
44CE0393	Road, Well	18th Century, 19th Century	DHR Staff: Not Eligible	Potential Raw Water Main
44CE0417	Military camp	20th Century	Not Evaluated	Potential Raw Water Main
44CE0433	Camp	Middle Woodland, Late Woodland	Not Evaluated	Potential Raw Water Intake Site 1
44CE0434	Dwelling, single	20th Century: 1st half	Not Evaluated	Potential Raw Water Intake Site 1
44CE0436	Road	19th Century: 1st half	DHR Staff: Not Eligible	Potential Raw Water Main
44CE0437	Camp, Dwelling, single	Archaic, Woodland, 18th Century	Not Evaluated	Potential Raw Water Intake Site 1

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DHR ID	Site Types	Time Periods	Evaluation Status	Project Segment
44CE0438	Camp, temporary, Other	Prehistoric/Unknown, 19th Century, 20th Century	Not Evaluated	Potential Raw Water Intake Site 1; Potential Raw Water Intake Site 2
44CE0439	Camp, Other	Late Archaic, 19th Century	Not Evaluated	Potential Raw Water Intake Site 1
44CE0440	Church	19th Century	Not Evaluated	Potential Raw Water Intake Site 1
44CE0443	Other	18th Century, 19th Century, 20th Century	Not Evaluated	Potential Raw Water Intake Site 1
44CE0444	Earthworks	19th Century: 3rd quarter	Not Evaluated	Potential Raw Water Intake Site 1
44CE0490	Camp, Dwelling, single	19th Century: 2nd half, 20th Century	DHR Staff: Eligible	Potential Raw Water Intake Site 2
44CE0580	Cemetery, Dependency, Dwelling, single, Garden	18th Century: 4th quarter, 19th Century	Not Evaluated	Potential Raw Water Main
44CE0599-001	Dam	19th Century	Not Evaluated	Potential Water Treatment Plant 82-A-55
44CE0599-002	Earthworks	19th Century	Not Evaluated	Potential Water Treatment Plant 82-A-55
44CE0599-003	Ice House	19th Century	Not Evaluated	Potential Water Treatment Plant 82-A-55
44CE0600	Dwelling, Single	18th Century, 19th Century, 20th Century	Not Evaluated	Potential Water Treatment Plant 82-A-55
44CE0601	Dwelling, Multiple	19th Century	Not Evaluated	Potential Water Treatment Plant 82-A-55
44CE0602	Dwelling, Multiple	19th Century	Not Evaluated	Potential Water Treatment Plant 82-A-55
44CE0603	Dwelling, Multiple	19th Century	Not Evaluated	Potential Water Treatment Plant 82-A-55
44CE0604	Dwelling, Single	18th Century, 19th Century	Not Evaluated	Potential Water Treatment Plant 82-A-55
44CE0605	Ice House	19th Century	Not Evaluated	Potential Water Treatment Plant 82-A-55
44CE0606	Dwelling, Single, School	19th Century, 20th Century	Not Evaluated	Potential Water Treatment Plant 82-A-55
44CE0607	Cemetery	19th Century	Not Evaluated	Potential Water Treatment Plant 82-A-55; Potential Water Treatment Plant 92-A-24

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DHR ID	Site Types	Time Periods	Evaluation Status	Project Segment
44CE0608	Lithic Scatter	Archaic	Not Evaluated	Potential Water Treatment Plant 82-A-55
44CE0609	Lithic Scatter	Prehistoric/Unknown	Not Evaluated	Potential Water Treatment Plant 82-A-55
44CE0610	Lithic Scatter	Prehistoric/Unknown	Not Evaluated	Potential Water Treatment Plant 82-A-55
44CE0611	Lithic Scatter	Archaic	Not Evaluated	Potential Water Treatment Plant 82-A-55
44CE0612	Lithic Scatter	Archaic	Not Evaluated	Potential Water Treatment Plant 82-A-55
44CE0613	Lithic Scatter	Prehistoric/Unknown	Not Evaluated	Potential Water Treatment Plant 82-A-55
44CE0614	Lithic Scatter	Prehistoric/Unknown	Not Evaluated	Potential Water Treatment Plant 82-A-55
44CE0629-0001	Camp, temporary	18th Century: 4th quarter	Not Evaluated	Alternative Route for Raw Water Main
44CE0629-0002	Camp, temporary	18th Century: 4th quarter	Not Evaluated	Alternative Route for Raw Water Main
44CE0675	Lithic scatter	Prehistoric/Unknown	DHR Staff: Not Eligible	Potential Raw Water Main
44CE0728	Farmstead, Military base/facility	20th Century: 1st half	DHR Staff: Not Eligible	Potential Raw Water Main
44CE0821	County courthouse, Store, Tavern/Inn	Colony to Nation, Early National Period, Reconstruction and Growth, World War I to World War II	DHR Staff: Potentially Eligible	Potential Raw Water Main
44CE0822	Farmstead	Reconstruction and Growth, World War I to World War II	DHR Staff: Potentially Eligible	Potential Raw Water Main
44CE897	Artifact Scatter	Early National Period, Antebellum Period, Civil War, Reconstruction and Growth, World War I to World War II	Not Evaluated	Potential Water Treatment Plant 82-A-55; Potential Water Treatment Plant Site 83-A-58
44CE898	Farmstead	Colony to Nation, Early National Period, Antebellum Period, Civil War, Reconstruction and Growth, World War I to World War II, The New Dominion	DHR Staff: Eligible	Potential Water Treatment Plant 82-A-55; Potential Water Treatment Plant Site 83-A-58

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DHR ID	Site Types	Time Periods	Evaluation Status	Project Segment
44CE899	Artifact Scatter	Colony to Nation	Not Evaluated	Potential Water Treatment Plant 82-A-55; Potential Water Treatment Plant Site 83-A-58
44CE900	Artifact Scatter	Colony to Nation, Early National Period, Antebellum Period, Civil War, Reconstruction and Growth, World War I to World War II	DHR Staff: Not Eligible	Potential Water Treatment Plant 82-A-55; Potential Water Treatment Plant Site 83-A-58
44CE901	Dwelling, Single	Colony to Nation, Early National Period, Antebellum Period	Not Evaluated	Potential Water Treatment Plant 82-A-55; Potential Water Treatment Plant Site 83-A-58
44KG0215	Trash scatter	20th Century: 1st half	Not Evaluated	Potential Raw Water Intake Site 3
44SP0027	Other	Middle Archaic	Not Evaluated	Alternative Route for Raw Water Main
44SP0040	Post office	null	Not Evaluated	Alternative Route for Raw Water Main
44SP0627-0001	Camp, temporary	18th Century: 4th quarter	Not Evaluated	Alternative Route for Raw Water Main
44SP0627-0002	Camp, temporary	18th Century: 4th quarter	Not Evaluated	Alternative Route for Raw Water Main

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RESULTS OF THE PHASE IA STUDY

The Phase IA fieldwork consisted of a visual inspection of the approximately 50.8 miles (65.7 km) of potential raw water main route and alternate raw water main route, approximately 1,900 acres (768.9 ha) of project area spread across three alternate water intake areas, and four parcels containing possible water treatment facility locations with representatives from both Draper Aden and Hazen (Figure 9–Figure 16, pp. 44–51). In some instances, the representatives pointed out the most likely locations for the water treatment facilities within the larger parcels and those areas were more closely examined for archaeological purposes.

Potential Raw Water Main

Architectural Phase IA Survey Results

There are 123 resources within the architectural project area of the potential raw water main, including 29 previously recorded resources and 94 previously unrecorded resources that are over 50 years in age (Table 10, p. 52; Photo 6, p. 55). Of those 123 resources, two are listed in the NRHP and VLR: Rose Hill at 2334 Tidewater Trail (016-0032) and the Bowling Green Historic District (171-5001). Constructed around 1790, Rose Hill is a two-story, frame dwelling that was once the centerpiece of a large plantation. It was listed in the NRHP and VLR in 1972. The Bowling Green Historic District surrounds the historic crossroads intersection of U.S. 301 and SR 207 and comprises nearly 300 acres (121.4 ha). This resource includes residential, commercial, governmental, religious, and educational buildings that range in construction date from the eighteenth to twentieth centuries. It was listed in the NRHP and VLR in 2003. Three resources have been determined eligible or potentially eligible for the NRHP by DHR staff. Two of these are historic districts (the Greater Port Royal Historic District [284-0044] and the Richmond, Fredericksburg and Potomac Railroad Historic District [500-0001]) and one is the location of a Civil War battle (North Anna Battlefield [042-0123]) (Figure 17–Figure 21, pp. 56–60).

DHR has determined that 10 resources are not eligible for listing in the NRHP, five of which are associated with Fort A.P. Hill, including the larger Fort A.P. Hill Historic District (016-0349). Of the remaining five not eligible resources, three are mid-twentieth century bridges and two are dwellings dating to the eighteenth and nineteenth centuries.

The remaining 108 resources include 17 previously recorded resources that have not received a formal determination of eligibility from DHR staff and 91 previously unrecorded resources that are 50 years of age or more. Although a majority of these resources are single-family dwellings that date to the early- to mid-twentieth century, there are some outliers constructed as early as circa 1800 (Athens [016-0097]). Approximately 19 are commercial in nature and include stores, service stations, motels, and restaurants predominately constructed during the twentieth century.

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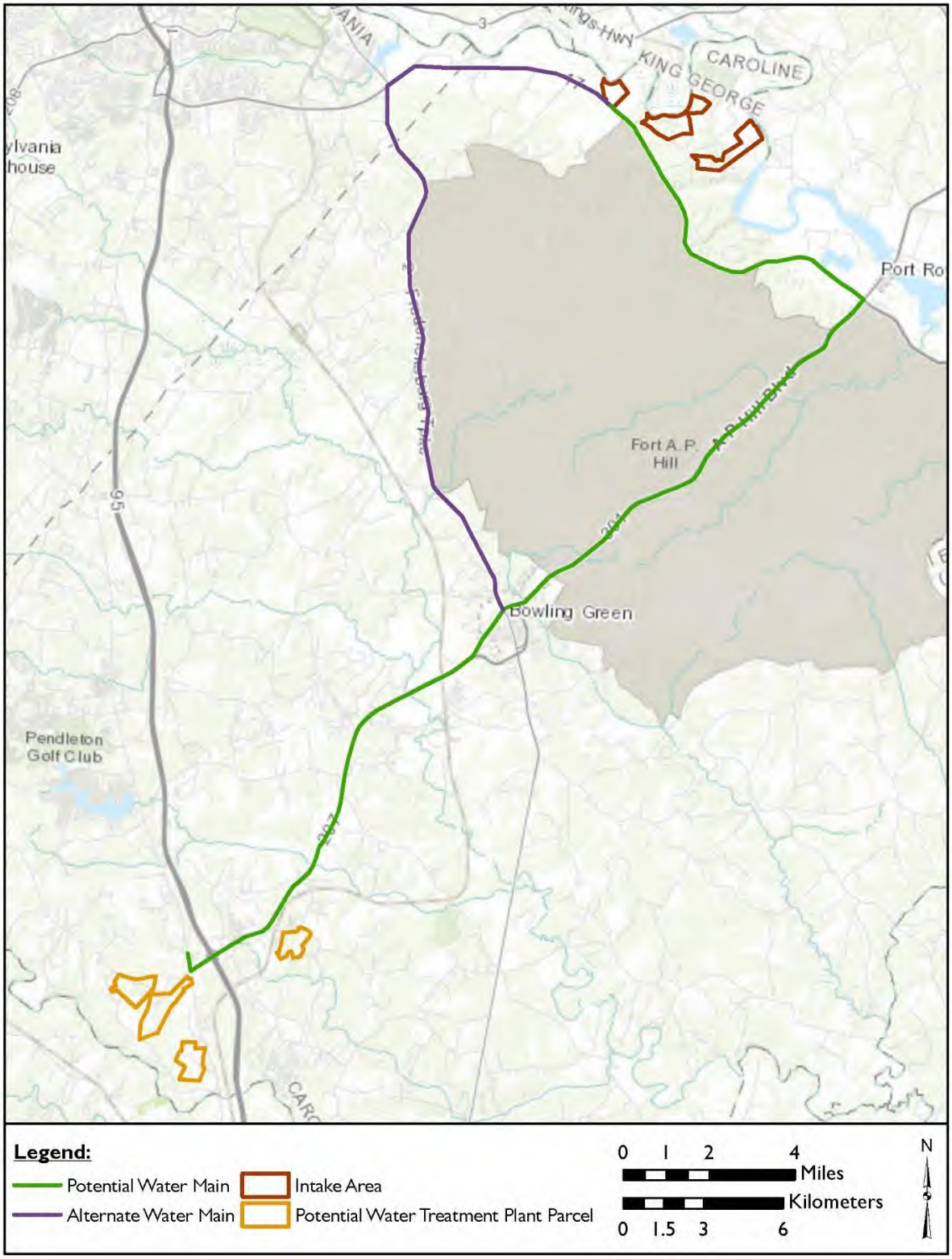


Figure 9: Overview of Project Area, Showing Treatment Areas, Intake Areas, and Water Main Routes (ESRI 2019a).

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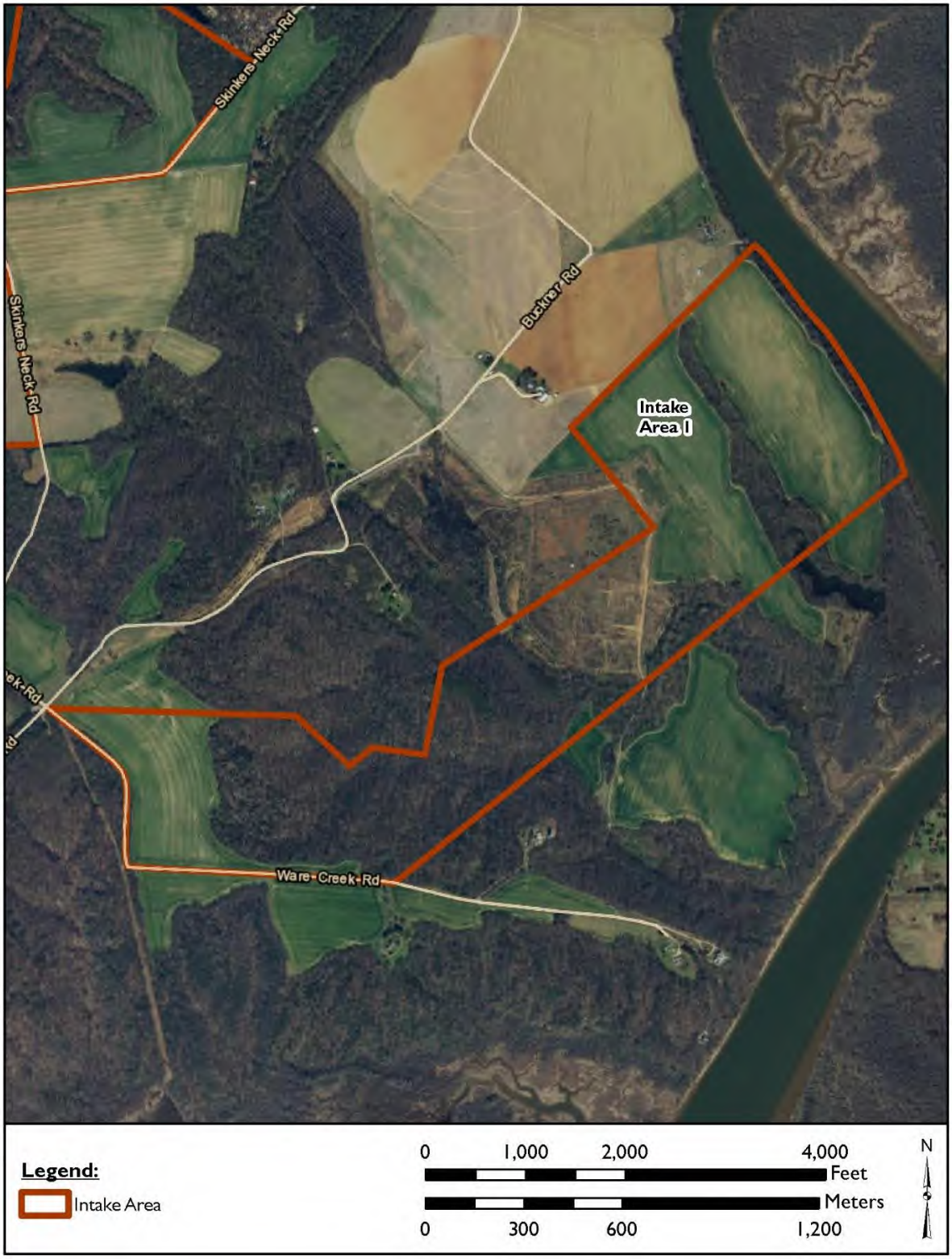


Figure 10: Potential Raw Water Intake Site, Area 1 (VGIN 2017).

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Figure 11: Potential Raw Water Intake Site, Area 2 (VGIN 2017).

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Figure 12: Potential Raw Water Intake Site, Area 3 (VGIN 2017).

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Figure 13: Potential Water Treatment Plant, Parcel 81-A-67 (VGIN 2017).

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Figure 14: Potential Water Treatment Plant, Parcel 82-A-55 (VGIN 2017).

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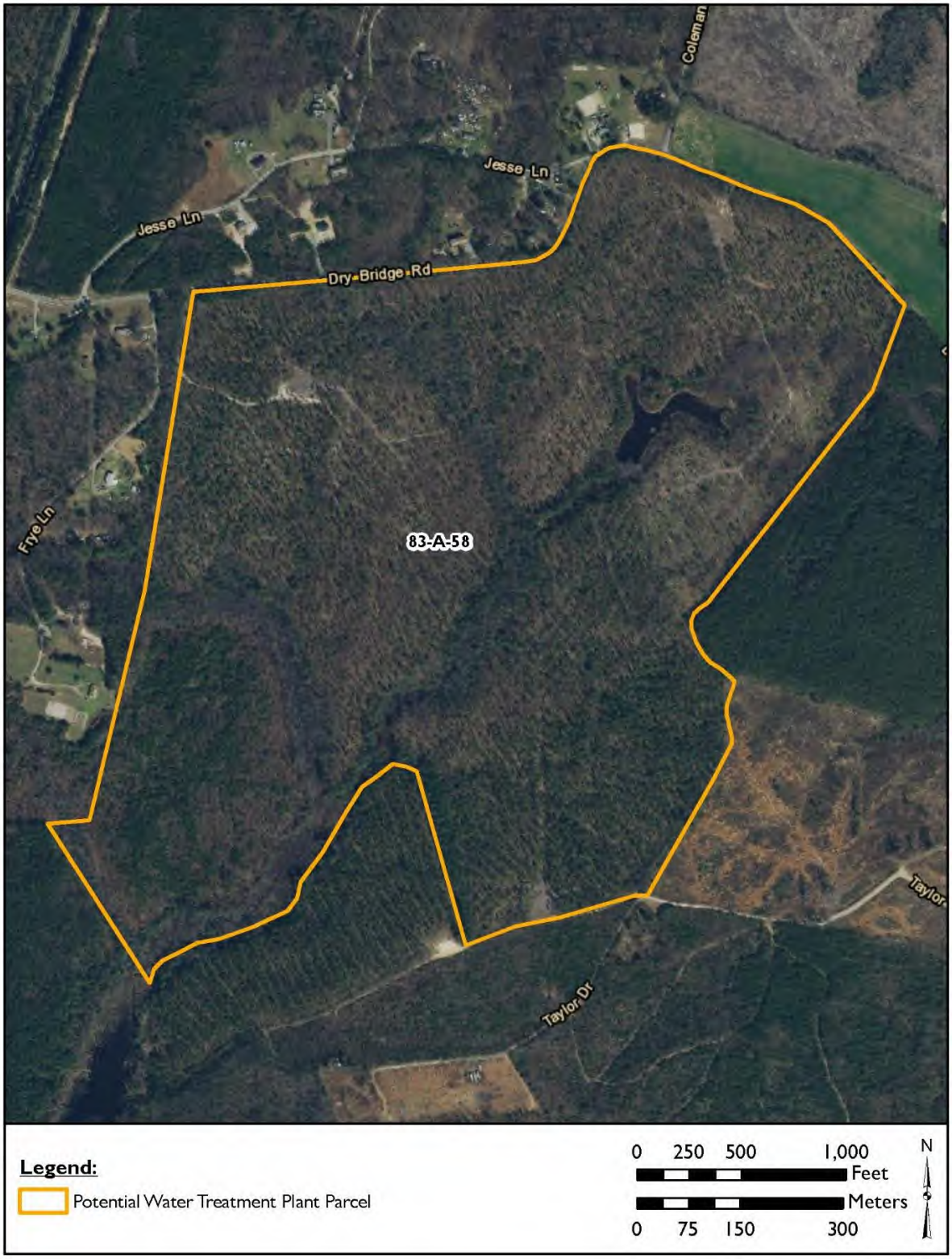


Figure 15: Potential Water Treatment Plant, Parcel 83-A-58 (VGIN 2017).

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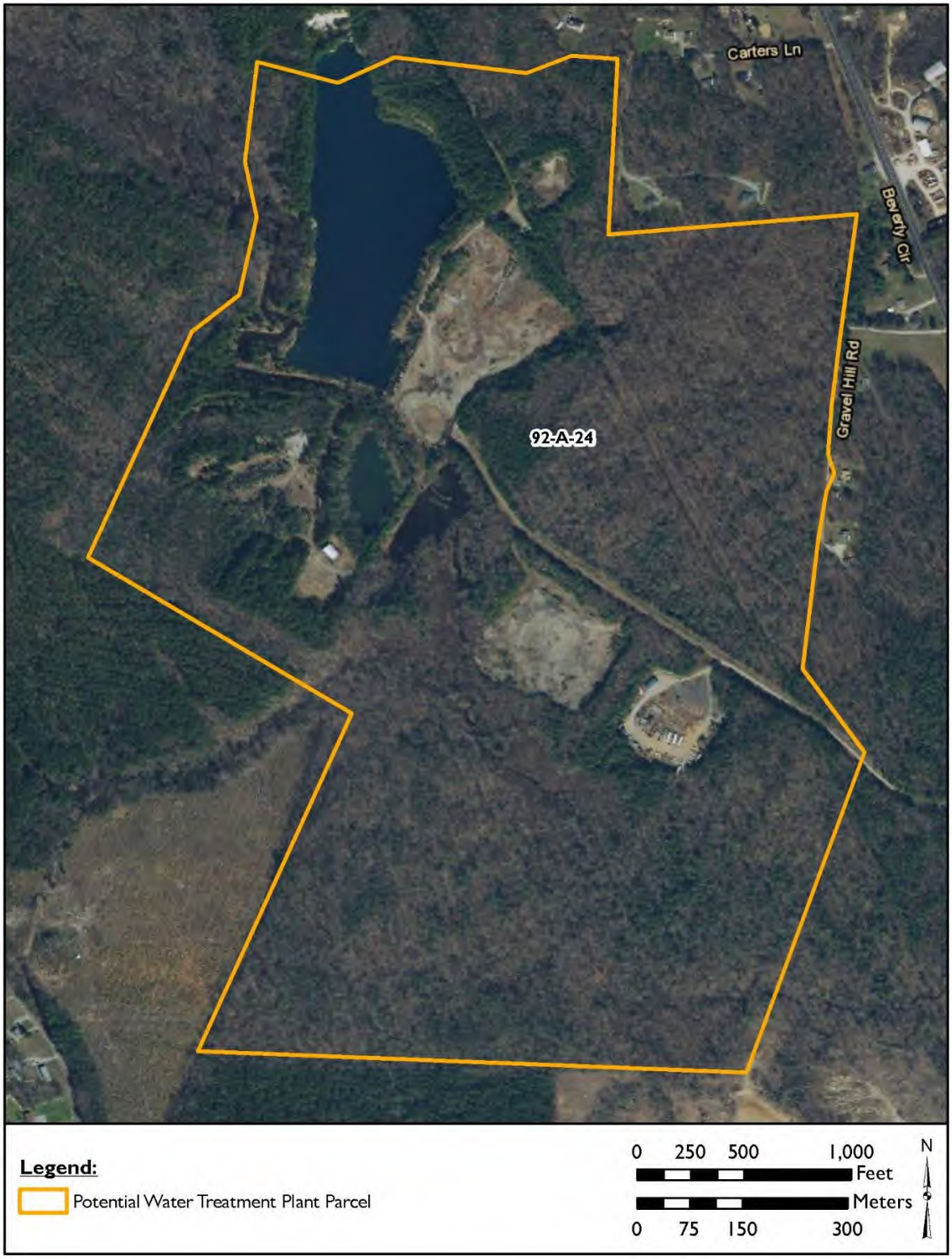


Figure 16: Potential Water Treatment Plant, Parcel 92-A-24 (VGIN 2017).

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Table 10: Architectural Resources within the Architectural Project Area of the Potential Raw Water Main. Potentially eligible, eligible, or NRHP-listed resources are noted in blue.

DHR ID	Name and Address	Date of Construction	Previous Eligibility Determination
016-0032	Rose Hill/Gay Mont, 23348 Tidewater Trail	ca. 1790	VLR Listing, 1972; NRHP Listing, 1972
016-0097	Athens, Route 207	ca. 1800	Not Evaluated
016-0104	Campbell's Country Club/Hopewell's Disciples Church, Route 207	1876	Not Evaluated
016-0144	Holly Hill, 15542 Holly Hill Drive	ca. 1727	DHR Staff: Not Eligible, 2010
016-0150	Magnolia Inn/Mount Olympus, Route 1	ca. 1850	Not Evaluated
016-0153	Poplar Grove, 20194 Rogers Clark Highway	ca. 1830	DHR Board Determined Not Eligible, 1991
016-0349	Fort A.P. Hill Historic District	ca. 1941	DHR Staff: Not Eligible, 1994
016-0349-0047	General Purpose Warehouse/TT1207, off North Range Road	1955	DHR Staff: Not Eligible, 2005
016-0349-0048	Airfield Operations Building/P01201, off North Range Road	1958	DHR Staff: Not Eligible, 2005
016-0349-0049	Theater Headquarters Area/SS0137, Killian Road	1959	DHR Staff: Not Eligible, 2005
016-5026	George Anderson House, 4390 Buckner Road	1986	Not Evaluated
016-5027	Bridge #1024, Route 207	1949	DHR Staff: Not Eligible, 2006
016-5087	Bridge #1026, Route 207 (westbound), spanning CSX Railroad, Rogers Clark Boulevard	1953	DHR Staff: Not Eligible, 2017
016-5091	Fort A.P. Hill Armory, 18272 A.P. Hill Boulevard	1986	DHR Staff: Not Eligible, 2011
016-5101	House, 21028 Rogers Clark Boulevard	1949	Not Evaluated
016-5176	Bridge #1025, Rogers Clark Boulevard	1953	DHR Staff: Not Eligible, 2017
042-0123	North Anna Battlefield	1864	DHR Staff: Potentially Eligible, 2007 Criterion A
171-0002	Glassellton, 302 Main Street	ca. 1846	Not Evaluated
171-5001	Bowling Green Historic District	post 1750	VLR Listing, 2003; NRHP Listing, 2003
171-5001-0131	House, 103 East Broddus Avenue	1902	Not Evaluated
171-5001-0132	House, 109 East Broddus Avenue	ca. 1970	Not Evaluated
171-5001-0133	House, 111 Broaddus Avenue	ca. 1910	Not Evaluated
171-5001-0134	House, 115 East Broddus Avenue	1908	Not Evaluated
171-5001-0135	House, 121 Broaddus Avenue	ca. 1910	Not Evaluated
171-5001-0137	House, 125 East Broddus Avenue	ca. 1920	Not Evaluated
171-5001-0140	House, 120 East Broddus Avenue	ca. 1960	Not Evaluated
171-5001-0141	House, 132 Broaddus Avenue	ca. 1970	Not Evaluated
284-0044	Greater Port Royal Historic District	1608-1958	DHR Board: Eligible, 2009, Criteria A and C
284-5012	House, 25592 A.P. Hill Boulevard	ca. 1960	Not Evaluated
284-5013	Port Royal Farm Stand/Commercial Building, 25550 A.P. Hill Boulevard	ca. 1990	Not Evaluated

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DHR ID	Name and Address	Date of Construction	Previous Eligibility Determination
284-5014	Horne's Store & Restaurant, 25532 A.P. Hill Boulevard	ca. 1948	Not Evaluated
500-0001	Richmond, Fredericksburg and Potomac Railroad Historic District	ca. 1837	DHR Staff: Eligible, 2018, Criteria A
N/A	Service Station, 25577 A.P. Hill Boulevard	ca. 1951	N/A
N/A	Port Royal Convenience Store, 25523 A.P. Hill Boulevard	ca. 1922	N/A
N/A	J.T.J. Gouldman Farms, 25513 Tidewater Trail	ca. 1935	N/A
N/A	House, 25432 Tidewater Trail	ca. 1945	N/A
N/A	House, 25404 Tidewater Trail	ca. 1965	N/A
N/A	House, 25433 Tidewater Trail	ca. 1930	N/A
N/A	Outbuilding, 7306 Edmont Road	ca. 1950	N/A
N/A	Restaurant, 18164 A.P. Hill Boulevard	ca. 1943	N/A
N/A	Motel, 18138 A.P. Hill Boulevard	ca. 1952	N/A
N/A	Motel, 18080 A. P. Hill Boulevard	ca. 1945	N/A
N/A	Store, 17518 A. P. Hill Boulevard	ca. 1930	N/A
N/A	Restaurant, 17468 A. P. Hill Boulevard	ca. 1932	N/A
N/A	Auto Dealership, 17398 A. P. Hill Boulevard	ca. 1956	N/A
N/A	VFW Bowling Green, 17532 A. P. Hill Boulevard	ca. 1963	N/A
N/A	House, 163 Broaddus Avenue	ca. 1962	N/A
N/A	House, 163 Broaddus Avenue	ca. 1962	N/A
N/A	House, 150 Broaddus Avenue	ca. 1950	N/A
N/A	House, 144 Broaddus Avenue	ca. 1960	N/A
N/A	Auto, 133 Broaddus Avenue	ca. 1960	N/A
N/A	House, 145 Martin Street	ca. 1955	N/A
N/A	House, 15478 Rogers Clark Boulevard	ca. 1955	N/A
N/A	House, 15490 Rogers Clark Boulevard	ca. 1965	N/A
N/A	House, 15489 Rogers Clark Boulevard	ca. 1968	N/A
N/A	House, 16044 Chester Lane	ca. 1945	N/A
N/A	House, W. Broaddus Avenue	pre 1960	N/A
N/A	House, 16036 Chester Lane	ca. 1968	N/A
N/A	House, 16174 Melville Lane	ca. 1950	N/A
N/A	House, 16184 Melville Lane	ca. 1964	N/A
N/A	House, 16197 Melville Lane	ca. 1945	N/A
N/A	House, 16223 Melville Lane	ca. 1941	N/A
N/A	House, 16246 Rogers Clark Boulevard	ca. 1953	N/A
N/A	House, 16206 Melville Lane	ca. 1967	N/A
N/A	Sycamore Hill Farm, 17611 Rogers Clark Boulevard	ca. 1939	N/A
N/A	Commercial, 17651 Rogers Clark Boulevard	ca. 1952	N/A
N/A	House, 17701 Rogers Clark Boulevard	ca. 1960	N/A
N/A	Service Station, 18068 Rogers Clark Boulevard	ca. 1960	N/A
N/A	House, 18099 Rogers Clark Boulevard	ca. 1948	N/A
N/A	Commercial Building, 18126 Rogers Clark Boulevard	ca. 1966	N/A
N/A	House, Minor Lane	pre 1966	N/A

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DHR ID	Name and Address	Date of Construction	Previous Eligibility Determination
N/A	House, 18173 Minor Lane	ca. 1922	N/A
N/A	House, 18331 Rogers Clark Boulevard	ca. 1958	N/A
N/A	House, 18362 Rogers Clark Boulevard	ca. 1962	N/A
N/A	House, 18412 Rogers Clark Boulevard	ca. 1963	N/A
N/A	House, 18440 Rogers Clark Boulevard	ca. 1960	N/A
N/A	House, 18470 Rogers Clark Boulevard	ca. 1959	N/A
N/A	House, 19072 Rogers Clark Boulevard	ca. 1949	N/A
N/A	House, 19472 Rogers Clark Boulevard	ca. 1955	N/A
N/A	House, Rogers Clark Boulevard	pre 1966	N/A
N/A	House, 20106 Rogers Clark Boulevard	ca. 1958	N/A
N/A	House, 22172 Colemans Mill Road	pre 1966	N/A
N/A	House, 23435 Rogers Clark Boulevard	ca. 1953	N/A
N/A	Commercial Building, 23804 Rogers Clark Boulevard	ca. 1962	N/A
N/A	House, Jefferson Davis Highway	ca. 1963	N/A
N/A	House, 22239 Telegraph Road	ca. 1961	N/A
N/A	House, 21376 Jefferson Davis Highway	ca. 1966	N/A
N/A	House, 21337 Jefferson Davis Highway	ca. 1962	N/A
N/A	Service Station and Garage, 21291-21303 Jefferson Davis Highway	ca. 1935 (garage ca. 1966)	N/A
N/A	House, 21308 Jefferson Davis Highway	ca. 1950	N/A
N/A	House, 21292 Jefferson Davis Highway	ca. 1950	N/A
N/A	House, 21274 Jefferson Davis Highway	ca. 1955	N/A
N/A	House, 21264 Jefferson Davis Highway	ca. 1912	N/A
N/A	House, 22213 Jefferson Davis Highway	ca. 1959	N/A
N/A	House, 22002 Jefferson Davis Highway	ca. 1948	N/A
N/A	House, 21358 Jefferson Davis Highway	ca. 1949	N/A
N/A	House, 25250 Tidewater Trail	ca. 1936	N/A
N/A	House, 25226 Tidewater Trail	ca. 1930	N/A
N/A	Historic Bridge, North of Tidewater Trail	pre 1954	N/A
N/A	House, 24255 Tidewater Trail	ca. 1963	N/A
N/A	House, 24164 Hazelwood Lane	ca. 1953	N/A
N/A	Commercial Building, 23315 Tidewater Trail	ca. 1952	N/A
N/A	House, 23219 Tidewater Trail	ca. 1957	N/A
N/A	House, Tidewater Trail	ca. 1950	N/A
N/A	House, 23199 Tidewater Trail	ca. 1959	N/A
N/A	House, 23192 Tidewater Trail	ca. 1947	N/A
N/A	House, 23059 Tidewater Trail	ca. 1963	N/A
N/A	House, 23021 Tidewater Trail	ca. 1959	N/A
N/A	House, 23003 Tidewater Trail	ca. 1963	N/A
N/A	House, 22559 Tidewater Trail	ca. 1964	N/A
N/A	House, 22531 Tidewater Trail	pre 1964	N/A
N/A	House, 22399 Tidewater Trail	ca. 1949	N/A
N/A	House, 22303 Tidewater Trail	ca. 1882	N/A
N/A	House, 22155 Tidewater Trail	ca. 1963	N/A
N/A	House, 22169 Tidewater Trail	ca. 1934	N/A
N/A	House, 22153 Tidewater Trail	ca. 1945	N/A
N/A	House, 21751 Tidewater Trail	ca. 1953	N/A
N/A	House, 21627 Tidewater Trail	ca. 1947	N/A
N/A	House, 24251 Tidewater Trail	ca. 1923	N/A

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DHR ID	Name and Address	Date of Construction	Previous Eligibility Determination
N/A	House, 23153 Tidewater Trail	ca. 1967	N/A
N/A	House, 22435 Tidewater Trail	ca. 1927	N/A
N/A	Dwellings, Southfield Drive	pre 1963	N/A
N/A	Commercial Building, 25445 Tidewater Trail	pre 1967	N/A



Photo 6: Examples of Resources Within the Architectural Project Area for the Potential Raw Water Main: Houses at 121 and 125 East Broaddus Avenue (171-5001-0135 and 171-5001-0137) (Left) and Horne's Store and Restaurant, 25532 A.P. Hill Boulevard (284-5014) (Right).

Archaeological Phase IA Survey Results

The potential route for the raw water main runs primarily along Routes 301, 17, and 207 beginning in northeastern Caroline County, near the three potential water intake locations along the Rappahannock River, and including short extensions along other roads to reach the specific location of each of the water intake areas. The path begins running southeast along Route 17 before turning to the southwest along Routes 301 and 207 (Photo 7, p. 61). Both the potential raw water main route and the alternate raw water main route were examined under the assumption that the water line would be placed within 25 feet (7.6 m) of the existing road. A single previously identified archaeological site, 44CE0391, crosses that 25-foot (7.6-m) corridor (Photo 8, p. 61; Figure 22, p. 62). Much of the area within 25 feet (7.6 m) of the edge of the pavement has been disturbed from road cuts, grading, and utility installation and therefore does not possess high potential for the presence of intact archaeological sites. Nevertheless, sections along the route that do not show evidence of obvious disturbance would need to be subjected to Phase IB archaeological survey. Extending the route of the water main beyond 25 feet (7.6 m) from the edge of pavement would increase the area with the potential for archaeological sites and potentially bring a number of nearby archaeological sites into play. Determining an exact percentage of disturbed or undisturbed area of the nearly 70 total miles covered by the two routes was not practicable within the framework of Phase IA survey, but a substantial amount of the corridor is unsuitable for testing. The remainder would require, at

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the current width, a single transect of shovel test pits (STPs) placed at 50-foot (15.2-m) intervals.



Figure 17: NRHP-Listed, Eligible, and Potentially Eligible Architectural Resources within the Potential Raw Water Main Architectural Project Area, Rose Hill (016-0032), Map 1 of 5 (VGIN 2017).

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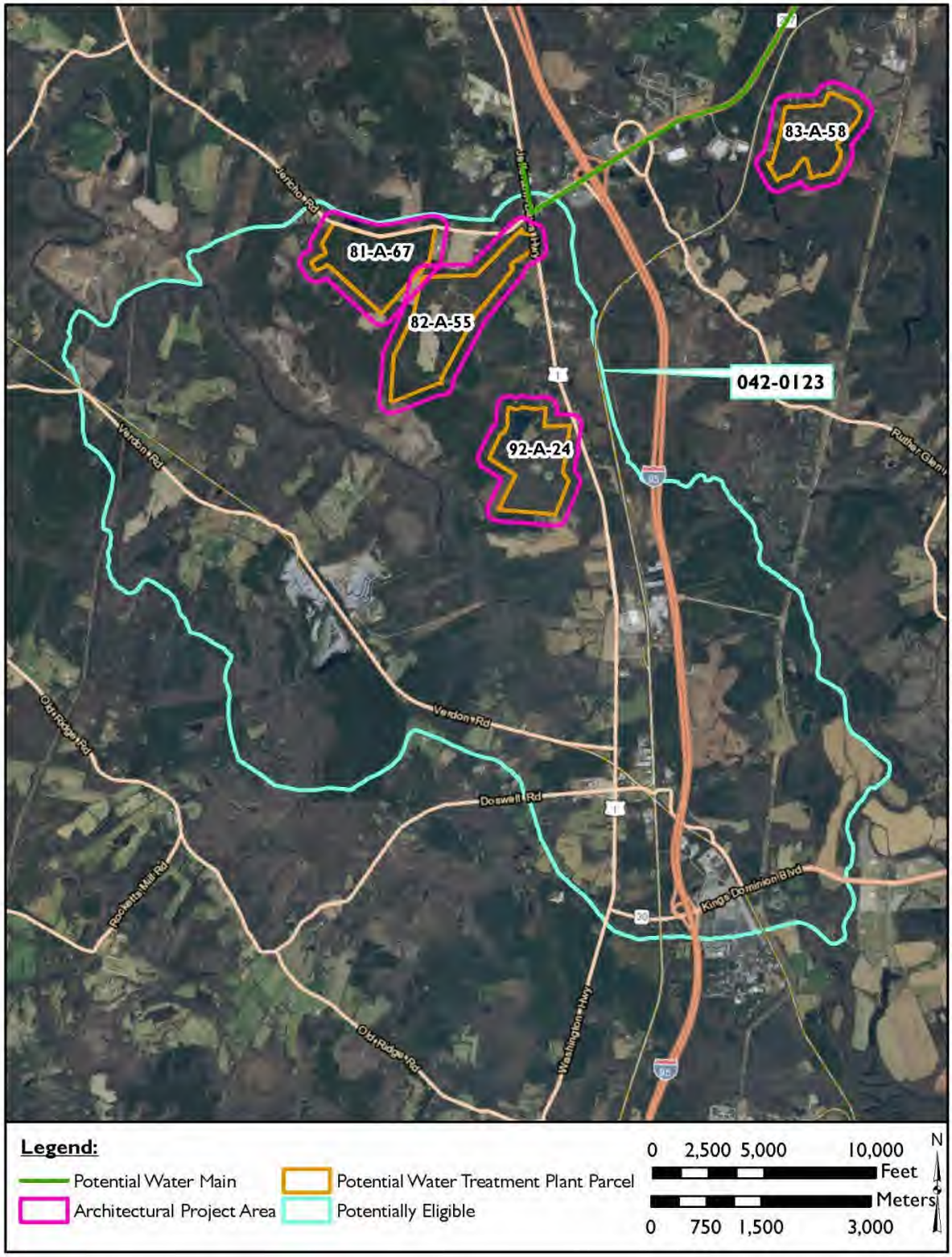


Figure 18: NRHP-Listed, Eligible, and Potentially Eligible Architectural Resources within the Potential Raw Water Main Architectural Project Area, North Anna Battlefield (042-0123), Map 2 of 5 (VGIN 2017).

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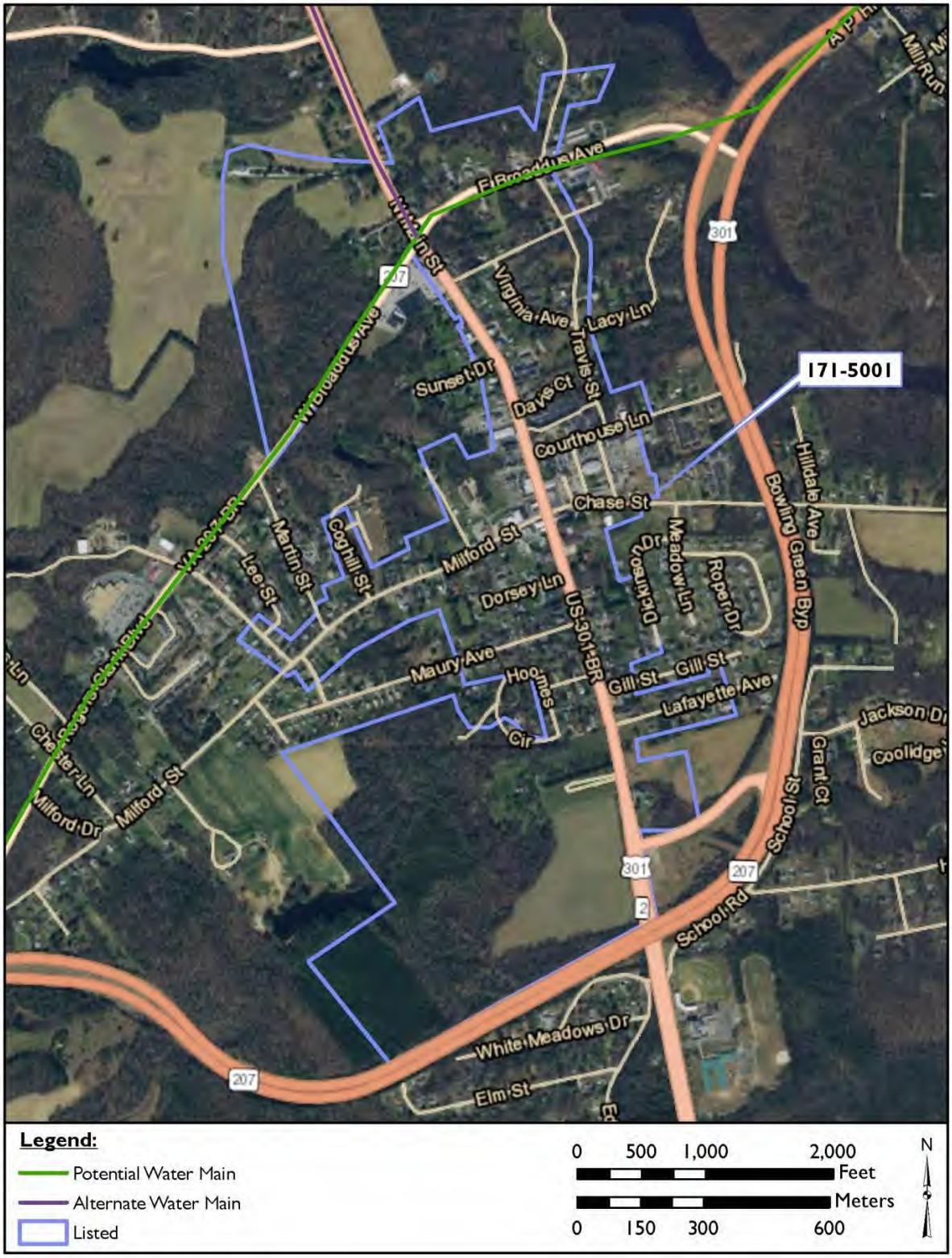


Figure 19: NRHP-Listed, Eligible, and Potentially Eligible Architectural Resources within the Potential Raw Water Main Architectural Project Area, Bowling Green Historic District (171-5001), Map 3 of 5 (VGIN 2017).

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Figure 20: NRHP-Listed, Eligible, and Potentially Eligible Architectural Resources within the Potential Raw Water Main Architectural Project Area, Greater Port Royal Historic District, Map 4 of 5 (VGIN 2017).

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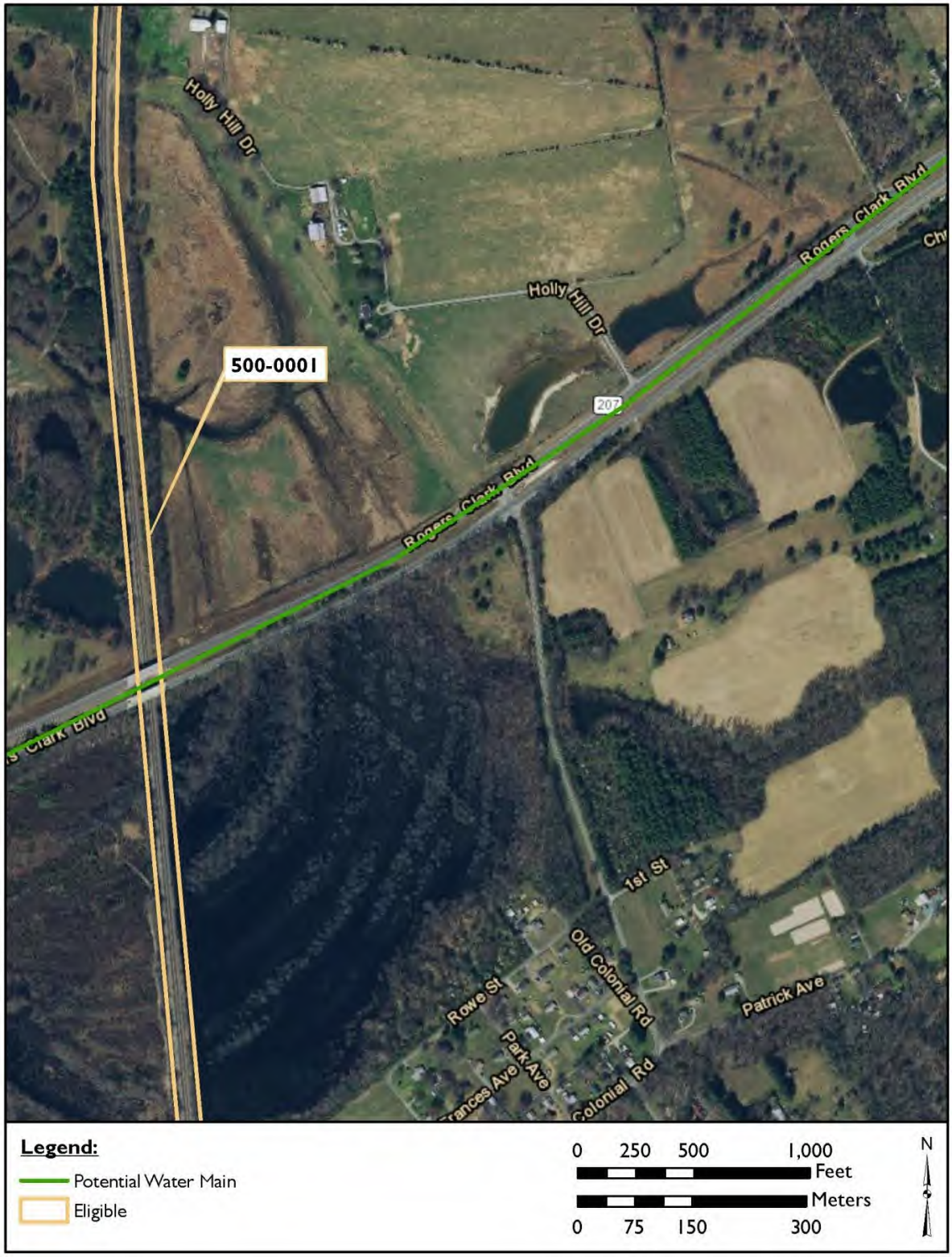


Figure 21: NRHP-Listed, Eligible, and Potentially Eligible Architectural Resources within the Potential Raw Water Main Architectural Project Area, Richmond, Fredericksburg and Potomac Historic District (500-0001), Map 5 of 5 (VGIN 2017).

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Photo 7: View Along Potential Raw Water Main Route, Looking Northwest.



Photo 8: Archaeological Site 44CE0391 in Project Area, Looking Northwest.

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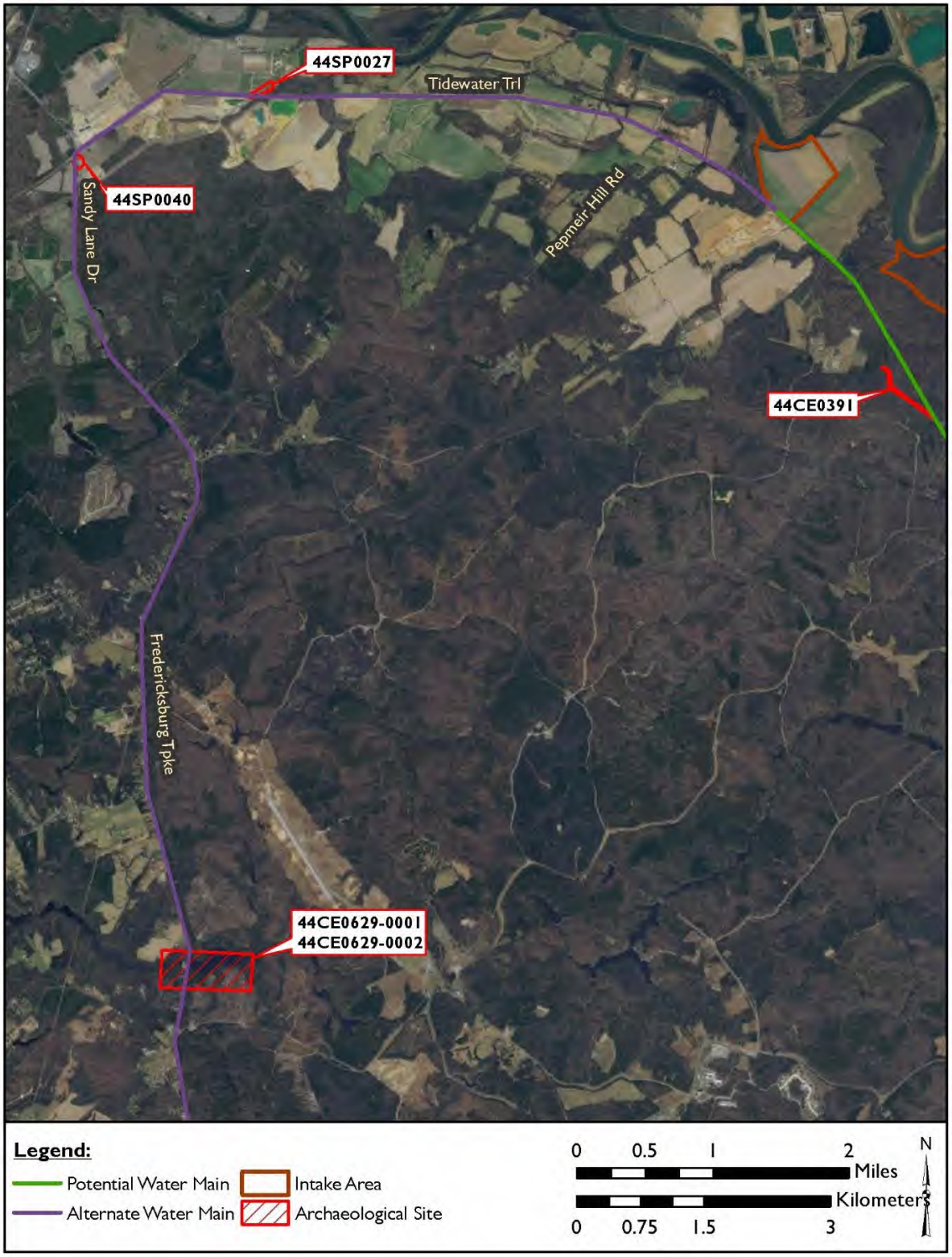


Figure 22: Previously Identified Archaeological Sites Overlapping Potential and Alternate Raw Water Mains (VGIN 2017).

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Alternative Route for Raw Water Main

Architectural Phase IA Survey Results

Within the architectural project area of the alternative route for raw water main there are 115 architectural resources, of which 13 are previously recorded and 102 are previously unrecorded properties that are over 50 years in age (Table 11, p. 64; Photo 9, p. 66). Of those 115 resources, four, Grace Episcopal Church at 4565 Fredericksburg Turnpike (016-0011), Saint Julien at 9630 Sandy Lane (088-0061), the Bowling Green Historic District (171-5001), and Hayfield (016-0014) are listed in, or determined eligible for listing in, the NRHP and VLR. Grace Episcopal was constructed around 1833 as a brick building in the Classical Revival style and was used a hospital for the Confederate Army during the Civil War. It was listed in the NRHP in 2019 under Criteria A and C. Saint Julien, a 1804, two-story single-family dwelling, reflects the Federal style and has several associated outbuildings dating to the nineteenth and twentieth centuries, including a dairy, slave quarter, and smoke/meat house. It was listed in 1975 under Criteria A and C. The Bowling Green Historic District is a district within the town of the same name. Located at a crossroads, it comprises a wide variety of building types, including residential, commercial, governmental, religious, and educational resources that range in construction date from the eighteenth to twentieth centuries. It was listed in the NRHP and VLR in 2003. Hayfield at 18173 Tidewater Trail (016-0014) is a circa-1760, Georgian-style dwelling that was modified in the mid-nineteenth century to reflect the Classical Revival style. In 2009, DHR staff determined this resource eligible for listing in the NRHP under Criterion C for architecture and noted that it had the potential to be eligible under Criterion A for its association with the Civil War (Figure 23–Figure 26, pp. 67–70). Only one resource has been formally determined not eligible for the NRHP by DHR staff: the 1932 Bridge #1013 that spans Route 2 across Campbell Creek (016-0344).

The remaining 110 resources includes eight previously recorded resources that have not received a formal determination of eligibility from DHR staff and 102 previously unrecorded resources that are 50 years of age or more. Although a majority of the 110 resources are single-family dwellings that date to the early- to mid-twentieth century, at least nine resources were constructed in the eighteenth century (e.g., Todd's Tavern [106-0215]) or nineteenth century (e.g., Captain Brook Farm [016-0050] and House, 329 North Main Street [016-5001-0129]). Approximately eight of the remaining 110 resources that have not received a formal eligibility evaluation or are previously unrecorded are non-residential in nature and include electric stations, stores, offices, and churches constructed between circa 1910 and circa 1968.

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Table 11: Architectural Resources within the Architectural Project Area of the Alternative Route for Raw Water Main. Potentially eligible, eligible, or NRHP-listed resources are noted in blue.

DHR ID	Name and Address	Date of Construction	Previous Eligibility Determination
016-0011	Destiny Ministries/Grace Episcopal Church, 4565 Fredericksburg Turnpike	ca. 1833	VLR Listing 2018; NRHP Listing 2019
016-0014	Hayfield, 18173 Tidewater Trail	ca. 1760	DHR Staff: Eligible, 2009 Criterion C, Potentially Eligible Criterion A
016-0049	Mount Pleasant No. 3, Nick Minarchi House	post 1800	Not Evaluated
016-0050	Captain Brook Farm, Route 2	ca. 1820	Not Evaluated
016-0157	Farish House/Hill View, Route 2	ca. 1830	Not Evaluated
016-0215	Todd's Tavern, Route 2	ca. 1749	Not Evaluated
016-0216	Zion Grove Church and Cemetery, Route 2	ca. 1910	Not Evaluated
016-0344	Bridge #1013, Campbell Creek, Route 2	1932	DHR Staff: Not Eligible, 1995
088-0061	Saint Julien, 9630 Sandy Lane	1804	VLR Listing, 1975; NRHP Listing, 1975
171-5001	Bowling Green Historic District	post 1750	VLR Listing, 2003; NRHP Listing, 2003
171-5001-0128	House, 319 North Main Street	ca. 1970	Not Evaluated
171-5001-0129	House, 329 North Main Street	1875	Not Evaluated
171-5001-0130	House, 333 North Main Street	1875	Not Evaluated
N/A	House and Corncrib, 19095 Tidewater Trail	pre 1966	N/A
N/A	House, 19005 Tidewater Trail	ca. 1912	N/A
N/A	Farm, 18294 Tidewater Trail	ca. 1910	N/A
N/A	House, 17437 Tidewater Trail	ca. 1932	N/A
N/A	House, 17347 Tidewater Trail	ca. 1925	N/A
N/A	House, 16245 Tidewater Trail	ca. 1953	N/A
N/A	Farm, 16132 Tidewater Trail	ca. 1911	N/A
N/A	House, 16071 Tidewater Trail	ca. 1953	N/A
N/A	House, 15427 Tidewater Trail	ca. 1956	N/A
N/A	House, 3460 Fredericksburg Turnpike	ca. 1968	N/A
N/A	House, 4004 Fredericksburg Turnpike	ca. 1970	N/A
N/A	House, 4024 Fredericksburg Turnpike	ca. 1966	N/A
N/A	House, 4217 Fredericksburg Turnpike	ca. 1949	N/A
N/A	House, 4363 Fredericksburg Turnpike	ca. 1929	N/A
N/A	House, 4409 Fredericksburg Turnpike	ca. 1932	N/A
N/A	House, Fredericksburg Turnpike	ca. 1965	N/A
N/A	House, 4402 Fredericksburg Turnpike	ca. 1930	N/A
N/A	House, 4414 Fredericksburg Turnpike	ca. 1952	N/A
N/A	House, 4473 Fredericksburg Turnpike	ca. 1956	N/A
N/A	Commercial Building and Dwelling, 4539 Fredericksburg Turnpike	ca. 1955	N/A
N/A	House, 4484 Fredericksburg Turnpike	ca. 1962	N/A
N/A	House, 4528 Fredericksburg Turnpike	ca. 1946	N/A
N/A	House, 4606 Fredericksburg Turnpike	ca. 1942	N/A
N/A	House, 4626 Fredericksburg Turnpike	ca. 1940	N/A

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DHR ID	Name and Address	Date of Construction	Previous Eligibility Determination
N/A	House, 5010 Fredericksburg Turnpike	ca. 1949	N/A
N/A	House, 5056 Fredericksburg Turnpike	ca. 1947	N/A
N/A	House, 5082 Fredericksburg Turnpike	ca. 1953	N/A
N/A	House, Fredericksburg Turnpike	ca. 1947	N/A
N/A	House, 5148 Fredericksburg Turnpike	ca. 1948	N/A
N/A	House, 5174 Fredericksburg Turnpike	ca. 1900	N/A
N/A	House, 14599 Long Branch Road	ca. 1965	N/A
N/A	Church, 14464 Long Branch Road	Unknown	N/A
N/A	House, 6088 Fredericksburg Turnpike	ca. 1957	N/A
N/A	House, 6160 Fredericksburg Turnpike	ca. 1962	N/A
N/A	Electric Station, Fredericksburg Turnpike	pre 1963	N/A
N/A	House, 6476 Fredericksburg Turnpike	ca. 1962	N/A
N/A	House, 6488 Fredericksburg Turnpike	ca. 1962	N/A
N/A	House, 7008 Fredericksburg Turnpike	ca. 1945	N/A
N/A	House, 7022 Fredericksburg Turnpike	ca. 1957	N/A
N/A	House, 7094 Fredericksburg Turnpike	ca. 1964	N/A
N/A	House, 7116 Fredericksburg Turnpike	ca. 1967	N/A
N/A	House, 7146 Fredericksburg Turnpike	ca. 1960	N/A
N/A	House, 7166 Fredericksburg Turnpike	ca. 1959	N/A
N/A	Commercial Building, 7218 Fredericksburg Turnpike	pre 1963	N/A
N/A	Auto Service, 7244 Fredericksburg Turnpike	ca. 1950	N/A
N/A	House, 7370 Fredericksburg Turnpike	ca. 1961	N/A
N/A	House, 7376 Fredericksburg Turnpike	ca. 1930	N/A
N/A	House, 7382 Fredericksburg Turnpike	ca. 1932	N/A
N/A	House, 7440 Fredericksburg Turnpike	ca. 1908	N/A
N/A	House, 8198 Fredericksburg Turnpike	ca. 1950	N/A
N/A	House, 8390 Fredericksburg Turnpike	ca. 1900	N/A
N/A	House, 8418 Fredericksburg Turnpike	ca. 1867	N/A
N/A	House, 9199 Fredericksburg Turnpike	ca. 1942	N/A
N/A	House, 10046 Fredericksburg Turnpike	ca. 1965	N/A
N/A	House, 11056 Fredericksburg Turnpike	ca. 1946	N/A
N/A	House, 10332 Fredericksburg Turnpike	ca. 1961	N/A
N/A	House, 10396 Fredericksburg Turnpike	ca. 1970	N/A
N/A	House, 11376 Fredericksburg Turnpike	ca. 1952	N/A
N/A	House, 12020 Fredericksburg Turnpike	ca. 1806	N/A
N/A	House, 15317 Woodslane Road	ca. 1958	N/A
N/A	House, 12571 Fredericksburg Turnpike	ca. 1950	N/A
N/A	House, 13113 Fredericksburg Turnpike	ca. 1962	N/A
N/A	House, 13141 Fredericksburg Turnpike	ca. 1960	N/A
N/A	House, 13922 Farmer Drive	ca. 1942	N/A
N/A	VDOT, 13257 Fredericksburg Turnpike	ca. 1966	N/A
N/A	VDOT, 13257 Fredericksburg Turnpike	pre 1966	N/A
N/A	House, 13956 Farmer Drive	ca. 1940	N/A
N/A	House, Fredericksburg Turnpike	pre 1966	N/A
N/A	House, Fredericksburg Turnpike	pre 1966	N/A
N/A	House, 13296 Fredericksburg Turnpike	ca. 1959	N/A
N/A	House, 13328 Fredericksburg Turnpike	ca. 1939	N/A
N/A	House, 13353 Fredericksburg Turnpike	ca. 1958	N/A
N/A	House, 13363 Fredericksburg Turnpike	ca. 1949	N/A

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DHR ID	Name and Address	Date of Construction	Previous Eligibility Determination
N/A	House, 13389 Fredericksburg Turnpike	ca. 1963	N/A
N/A	House, 13415 Fredericksburg Turnpike	ca. 1961	N/A
N/A	House, 14074 Fredericksburg Turnpike	ca. 1953	N/A
N/A	House, 14095 Fredericksburg Turnpike	ca. 1955	N/A
N/A	House, 14110 Fredericksburg Turnpike	ca. 1965	N/A
N/A	House, 14142 Fredericksburg Turnpike	ca. 1940	N/A
N/A	House, 14232 Fredericksburg Turnpike	ca. 1952	N/A
N/A	House, 14256 Fredericksburg Turnpike	ca. 1952	N/A
N/A	House, 14337 Fredericksburg Turnpike	ca. 1966	N/A
N/A	House, 14321 Fredericksburg Turnpike	ca. 1956	N/A
N/A	House, 14330 Fredericksburg Turnpike	ca. 1962	N/A
N/A	House, 14353 Fredericksburg Turnpike	ca. 1965	N/A
N/A	House, 14373 Fredericksburg Turnpike	ca. 1963	N/A
N/A	REC Electric, 14374-14408 Fredericksburg Turnpike	pre 1968	N/A
N/A	House, 14408 Fredericksburg Turnpike	ca. 1951	N/A
N/A	House, 14423 Fredericksburg Turnpike	ca. 1965	N/A
N/A	House, 14424 Fredericksburg Turnpike	ca. 1955	N/A
N/A	House, 356 Main Street	ca. 1950	N/A
N/A	House, 318 Main Street	ca. 1959	N/A
N/A	House, 302 Main Street	ca. 1850	N/A
N/A	House, 14577 Long Branch Road	ca. 1949	N/A
N/A	House, 7244 Fredericksburg Turnpike	ca. 1932	N/A
N/A	House, 7458 Fredericksburg Turnpike	ca. 1948	N/A
N/A	House, 7472 Fredericksburg Turnpike	ca. 1962	N/A
N/A	House, 8432 Fredericksburg Turnpike	ca. 1936	N/A
N/A	House, 9204 Woodford Road	ca. 1932	N/A
N/A	House, 13360 Fredericksburg Turnpike	ca. 1968	N/A
N/A	House, 14213 Fredericksburg Turnpike	ca. 1952	N/A
N/A	House, 16435 Paige Road	ca. 1947	N/A



Photo 9: Examples of Resources Within the Architectural Project Area for the Alternate Route for Raw Water Main: House, 4528 Fredericksburg Turnpike (Left) and Grace Episcopal Church (016-0011) (Right).

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Figure 23: NRHP-Listed, Eligible, and Potentially Eligible Architectural Resources within the Alternative Route for Raw Water Main Architectural Project Area, Destiny Ministry/Grace Episcopal Church (016-0011), Map 1 of 4 (VGIN 2017).

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Figure 24: NRHP-Listed, Eligible, and Potentially Eligible Architectural Resources within the Alternative Route for Raw Water Main Architectural Project Area, Saint Julien (088-0061), Map 2 of 4 (VGIN 2017).

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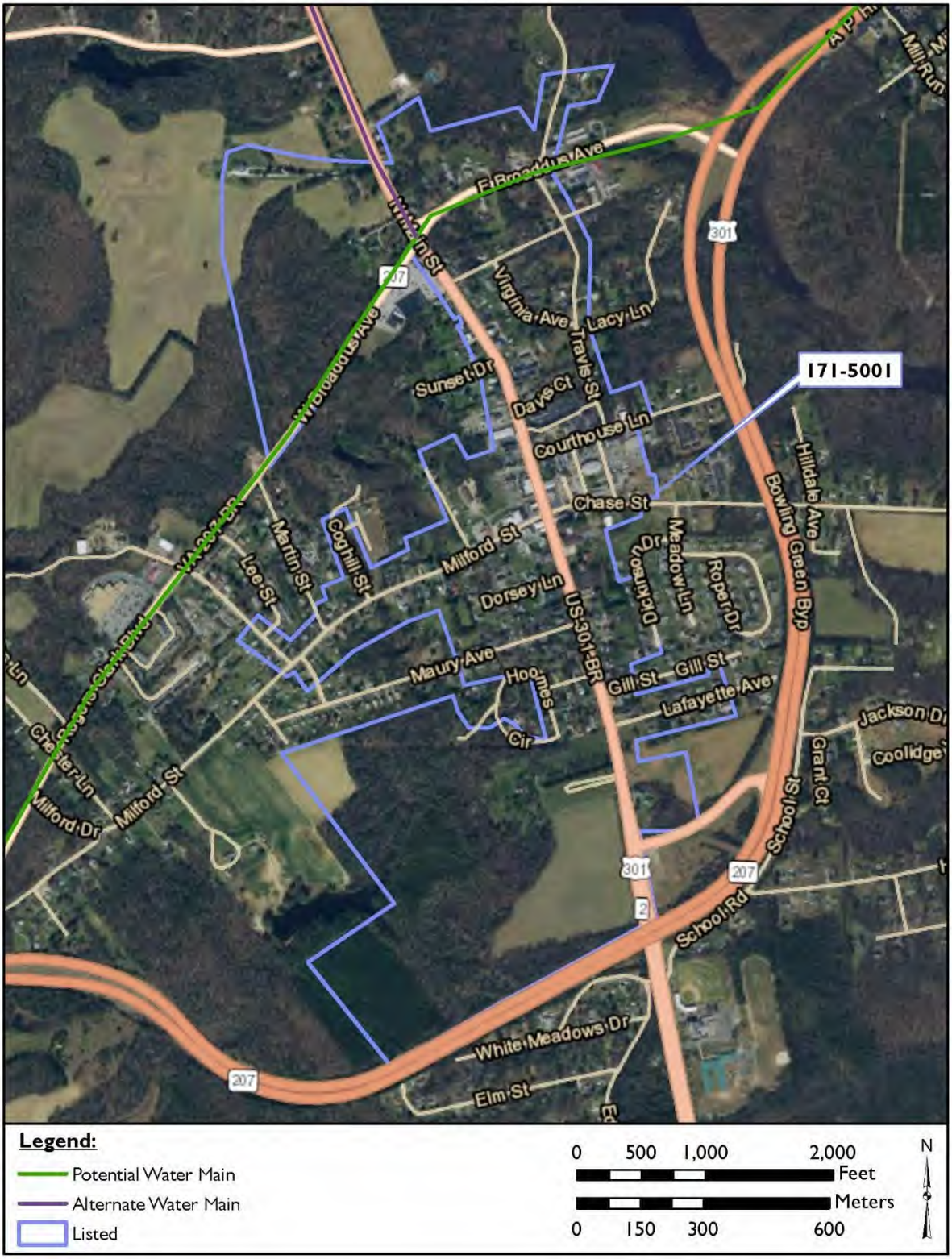


Figure 25: NRHP-Listed, Eligible, and Potentially Eligible Architectural Resources within the Alternative Route for Raw Water Main Architectural Project Area, Bowling Green Historic District (171-5001), Map 3 of 4 (VGIN 2017).

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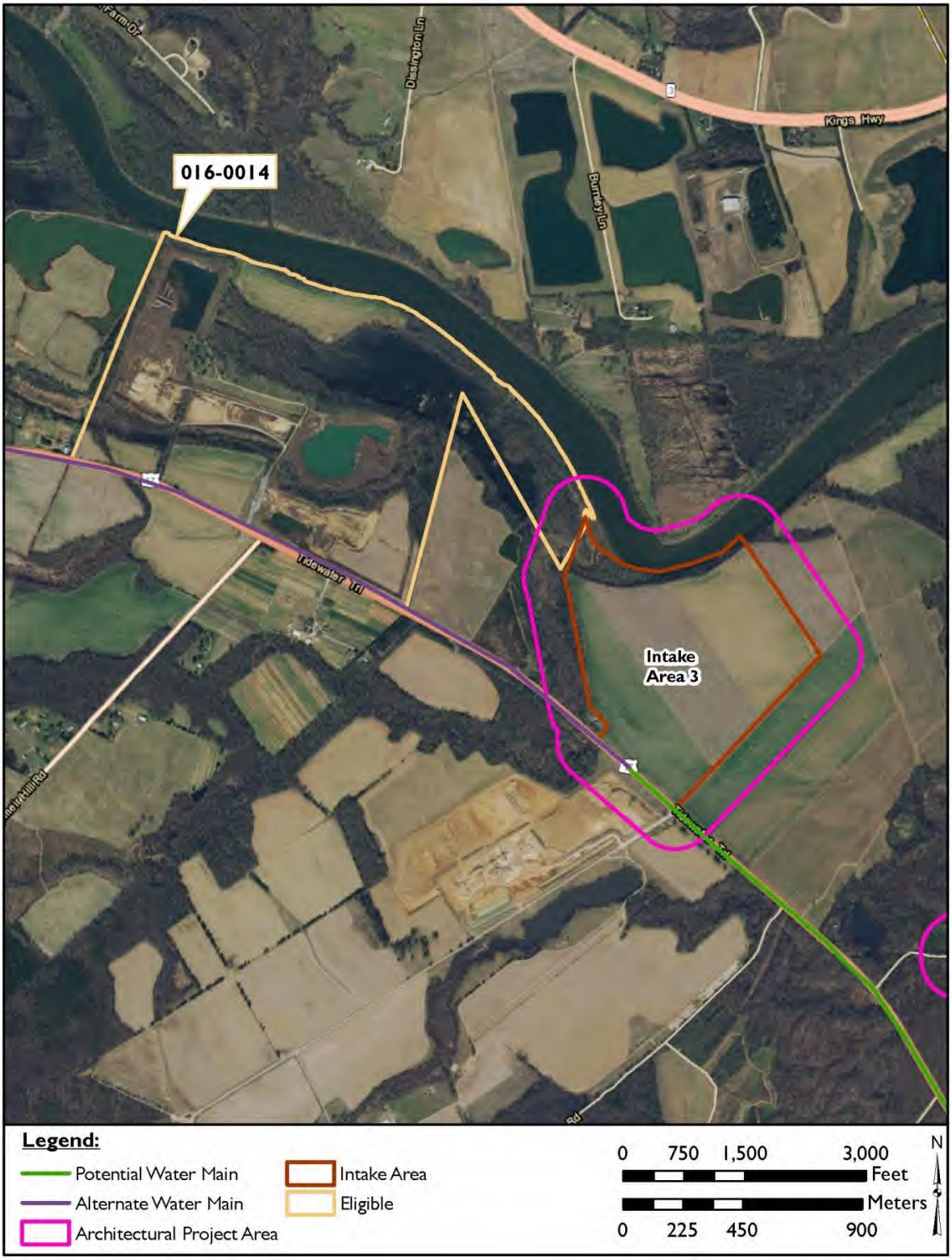


Figure 26: NRHP-Listed, Eligible, and Potentially Eligible Architectural Resources within the Alternative Route for Raw Water Main Architectural Project Area, Hayfield (016-0014), Map 4 of 4 (VGIN 2017).

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Archaeological Phase IA Survey Results

The alternate route for the raw water main runs along U.S. Highways 17 and 2 beginning in northeastern Caroline County, in the same area as the potential water main route. However, the alternate route travels to the northwest along Route 17 before turning to the southwest along Route 2, crossing into Spotsylvania County for a short distance. As was the case with the potential route for the water main, the alternative route was examined under the assumption that the water line would be placed within 25 feet (7.6 m) of the existing road. Four previously recorded archaeological sites, 44SP0027, 44SP0040, 44CE0629-0001, and 44CE0629-0002, cross over the route of the raw water main (Photo 10; Figure 22, p. 62). Much of the area within 25 feet (7.6 m) of the edge of the pavement has been disturbed from road cuts, grading, and utility installation and therefore does not possess high potential for the presence of intact archaeological sites. However, as discussed above with regards to the primary route, sections along the route that do not show evidence of obvious disturbance would need to be subjected to Phase IB archaeological survey, and any expansion of the route of the water main beyond 25 feet (7.6 m) from the edge of pavement would increase the area with the potential for archaeological sites. As was the case with the potential raw water main an exact percentage of disturbed area was not practicable within the framework of Phase IA survey, but a substantial amount of the corridor is unsuitable for testing. The remainder would require, at the current width a single transect of Shovel Test Pits (STPs) placed at 50-foot (15.2-m) intervals.



Photo 10: Typical Setting along Alternate Water Main Route, Looking Northeast.

Potential Raw Water Intake Site, Area 1

Architectural Phase IA Survey Results

There are three resources within the architectural project area of Potential Raw Water Intake Site, Area 1 (Table 12, p. 72; Photo 11, p. 72). Two of those are previously recorded with DHR: Haymount. Route 17 (016-0065) and the Greater Port Royal Historic District (284-0044). Haymount dates to the late-seventeenth-century. Although it was recorded as being

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demolished in 1975, this resource has never received a formal NRHP evaluation by DHR staff. The Greater Port Royal Historic District (284-0044) is a large rural historic district that includes area in three counties. In 2009, DHR staff determined this historic district eligible for listing in the NRHP under Criteria A and C with a period of significance of 1608 to 1958, with the potential for eligibility under Criterion D (Figure 27, p. 73). In addition, there is one previously unrecorded resource within a 500-foot (152.4-m) radius that is 50 years of age or more. Located at 3141 Buckner Road, the resource is agricultural in nature, with a circa-1932 dwelling and surrounding outbuildings.

Table 12: Architectural Resources within the Architectural Project Area of the Potential Raw Water Intake Site, Area 1. Potentially eligible, eligible, or NRHP-listed resources are noted in blue.

DHR ID	Name and Address	Date of Construction	Previous Eligibility Determination
016-0065	Haymount, Route 17	1670	Not Evaluated
284-0044	Greater Port Royal Historic District	1608–1958	DHR Board: Eligible, 2009, Criteria A and C
N/A	Racefield Farm, 3141 Buckner Road	ca. 1932	N/A



Photo 11: Example of a Resource Within the Architectural Project Area for the P Potential Raw Water Intake Site, Area 1; House, Northwest Elevation (Left), and Outbuilding, Southwest Elevation of Racefield Farm at 3141 Buckner Road.

Archaeological Phase IA Survey Results

Raw Water Intake Location Site, Area 1 was the easternmost of the three potential raw water intake locations surveyed, all of which are located along the southern bank of the Rappahannock River, in the northern corner of Caroline County (Figure 28, p. 74). Area 1 is characterized by a mixture of active agricultural fields and wooded areas, with the wooded areas generally occupying drainages unsuited for growing crops. Four previously identified archaeological sites, 44CE0262, 44CE0263, 44CE0264, and 44CE0437, occupy this area, and as such it has been preliminarily determined unsuitable for further consideration for use in this

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project and was not surveyed during the Phase IA studies. Should it for some reason be reconsidered for use, Phase IB subsurface testing would be required throughout the area.

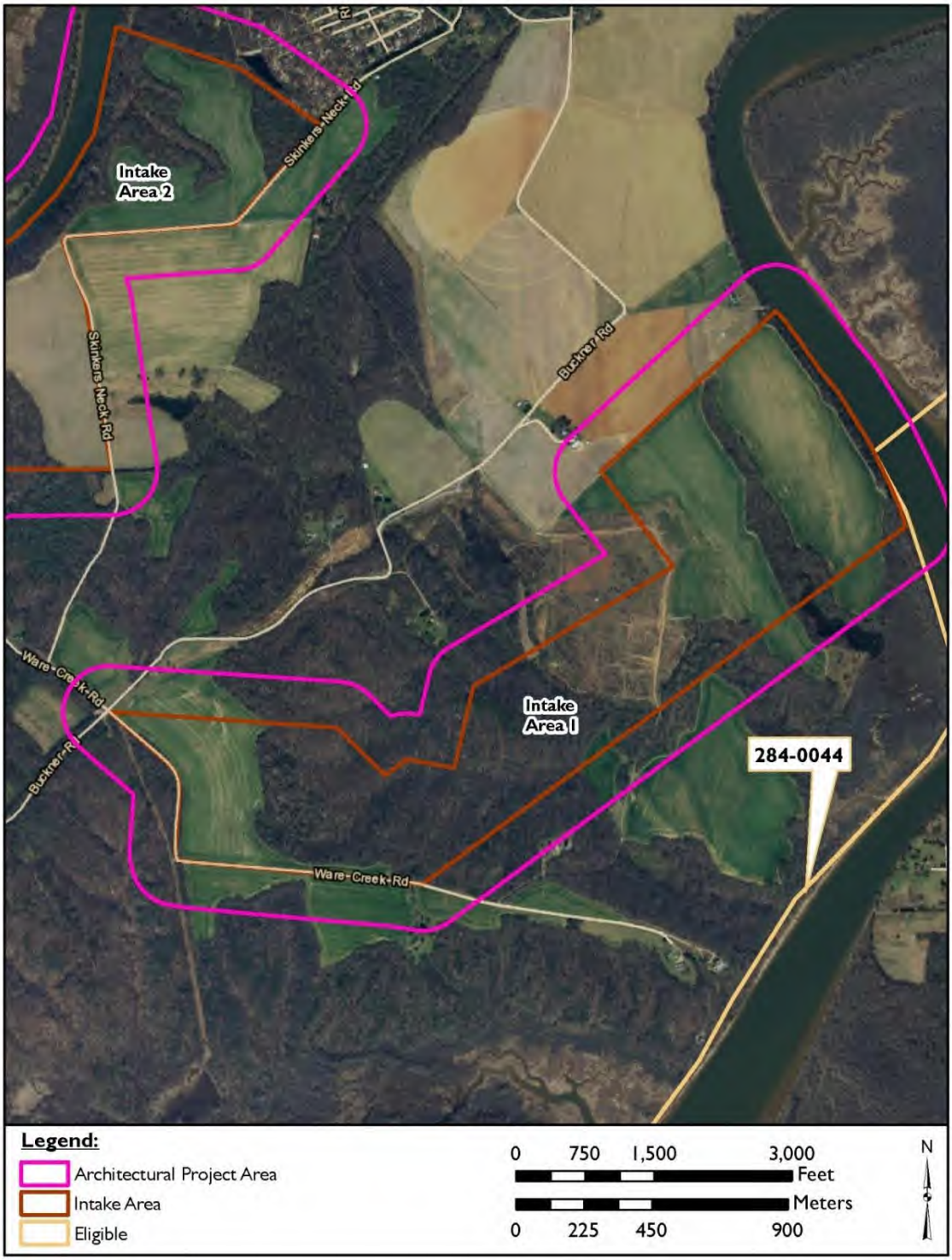


Figure 27: NRHP-Listed, Eligible, and Potentially Eligible Architectural Resources within the Potential Raw Water Intake Site, Area 1 Architectural Project Area, Greater Port Royal Historic District (284-0044) (VGIN 2017).

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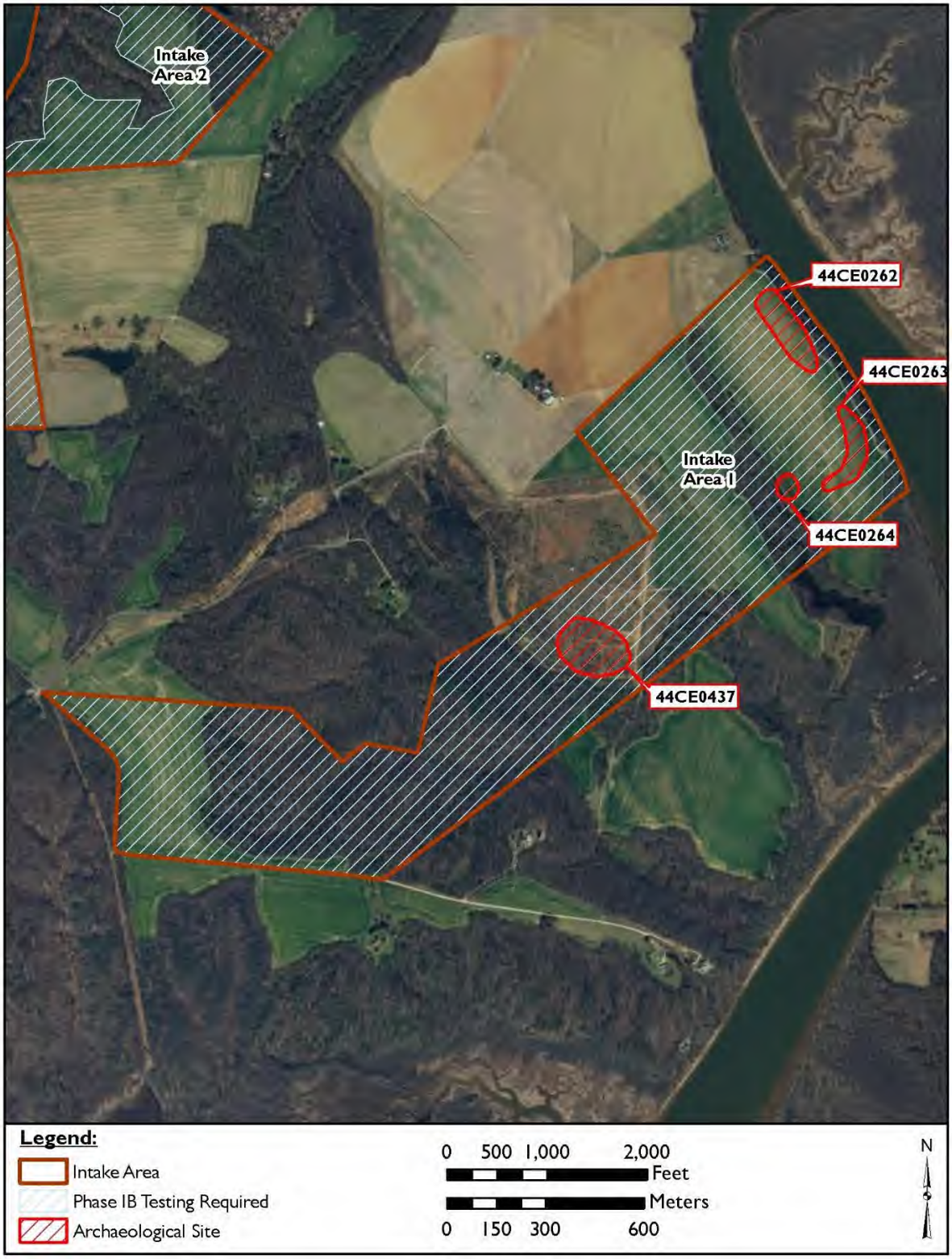


Figure 28: Potential Raw Water Intake Site, Area 1 (VGIN 2017).

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Potential Raw Water Intake Site, Area 2

Architectural Phase IA Survey Results

There are three resources within the architectural project area of Potential Raw Water Intake Site, Area 2 (Table 13; Photo 14; Figure 29, p. 76). One of those is previously recorded with DHR: Yew Spring Farm on Ware Creek Road (016-0072). This resource comprises a two-story, frame dwelling constructed around 1846 in the Federal style and a smoke/meat house. Yew Spring Farm has not been formally evaluated for the NRHP. There are two previously unrecorded resources within a 500-foot (152.4-m) radius that are 50 years of age or more, one of which is an early-twentieth century house and associated outbuildings, some of which are likely agricultural in nature, and the second is a one-story, frame, mid-twentieth-century corncrib on the west side of Skinkers Neck Road.

Table 13: Architectural Resources within the Architectural Project Area of the Potential Raw Water Intake Site, Area 2.

DHR ID	Name and Address	Date of Construction	Previous Eligibility Determination
016-0072	Yew Spring Farm	ca. 1846	Not Evaluated
N/A	Corncrib, Skinkers Neck Road	ca. 1950	N/A
N/A	House, 2673 Skinkers Neck Road	ca. 1915	N/A



Photo 12: Example of a Corncrib within Potential Raw Water Intake Site, Area 2 Architectural Project Area, Looking Northeast Corncrib, Skinkers Neck Road

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Figure 29: Potential Raw Water Intake Site, Area 2 Architectural Project Area (VGIN 2017). Note: There are no NRHP-listed, eligible, or potentially eligible resources within the architectural project area.

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Archaeological Phase IA Survey Results

Potential Raw Water Intake Location Site, Area 2, is located along the southern side of a sharp southward bend in the Rappahannock River. Two locations within Area 2 are currently under consideration for water intake facilities that will require ground disturbing activity (Photo 13; Figure 30, p. 78). Both of these locations cross from woods along the riverbank in the eastern portion of the river bend into the open agricultural fields to the east. No previously identified archaeological resources are located within this area, though site 44CE0313 is located approximately 1,400 feet (426.7 m) to the north. This area is occupied largely by gently rolling farm fields or woods lying adjacent to the Rappahannock River. This location, combined with the soils in the area, largely mapped as Class 1 or as type Class 2e, indicate a moderate to high probability for intact archaeological deposits, though the subtype "e" soils do have some tendency to erode, potentially impacting the preservation of any resources that may be present. Given these conditions and location, and the lack of any obvious disturbance, most parts of Area 2 will require Phase IB archaeological survey in locations where ground disturbing activities are proposed. However, small portions of Area 2, notably the wooded areas along the river, are rendered untestable by slope or drainages. Of the 380 acres (153.8 ha) in intake Area 2, approximately 138 acres (55.9 ha) are disturbed, leaving 242 acres (97.9 ha) suitable for Phase IB testing.



Photo 13: Overview of Intake Site, Area 2, Looking North.

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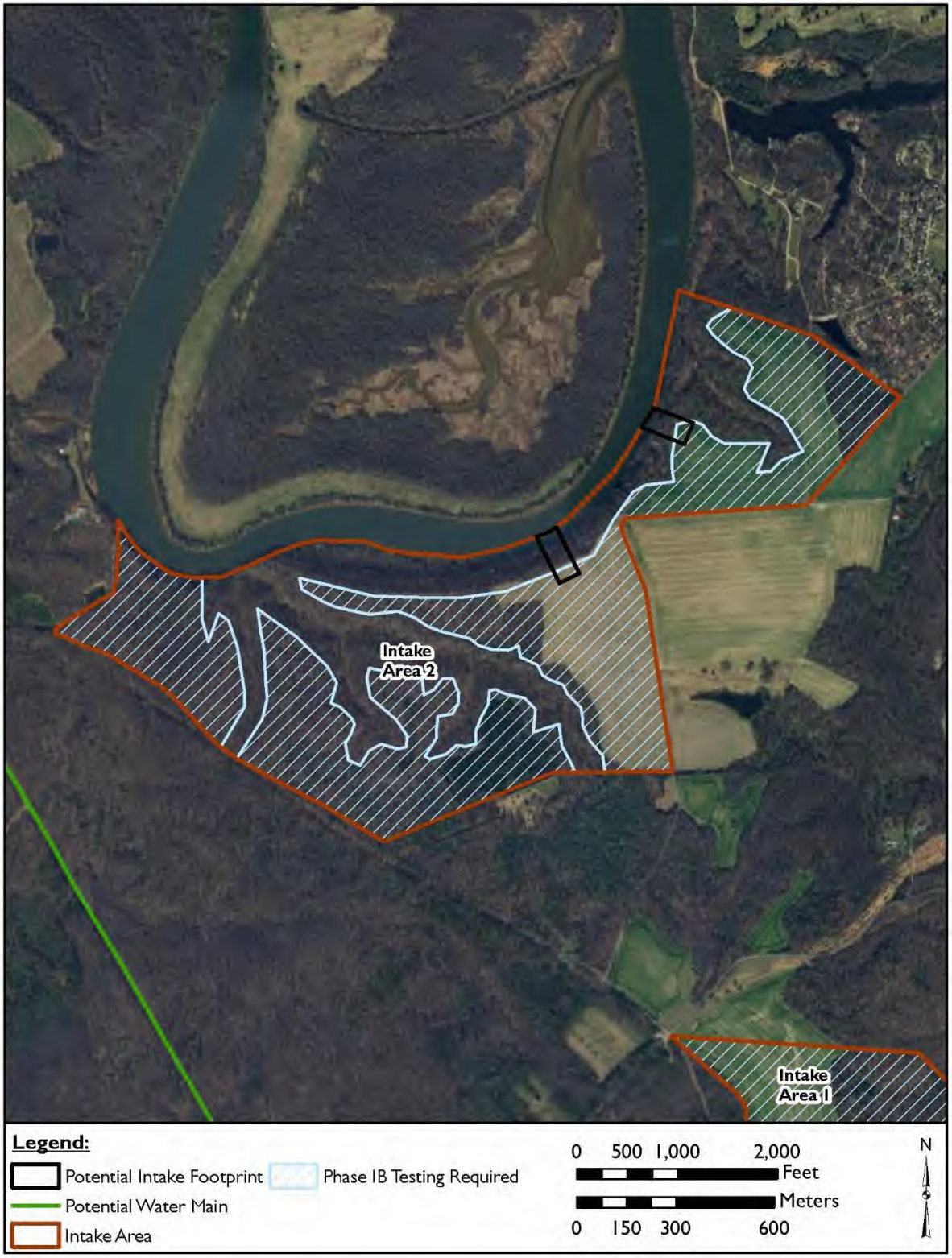


Figure 30: Potential Raw Water Intake Site, Area 2 (VGIN 2017).

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Potential Raw Water Intake Site, Area 3

Architectural Phase IA Survey Results

There are three resources within the architectural project area of Potential Raw Water Intake Site, Area 3 (Table 14). One of those is previously recorded with DHR: Hayfield, 18173 Tidewater Trail (016-0014). This property contains a circa-1760, Georgian-style dwelling later altered with Classical Revival detailing. In 2009, DHR staff determined this resource eligible for listing in the NRHP under Criterion C for architecture; they also noted that it had the potential to be eligible under Criterion A for its association with the Civil War (Figure 31, p. 80). There are two previously unrecorded resources within a 500-foot (152.4-m) radius of the parcel that are 50 years of age or more, both of which are twentieth-century, single-family dwellings with associated outbuildings, such as garages and a corncrib (Photo 14).

Table 14: Architectural Resources within the Architectural Project Area of the Potential Raw Water Intake Site, Area 3. Potentially eligible, eligible, or NRHP-listed resources are noted in blue.

DHR ID	Name and Address	Date of Construction	Previous Eligibility Determination
016-0014	Hayfield, 18173 Tidewater Trail	ca. 1760	DHR Staff: Eligible, 2009 Criterion C, Potentially Eligible Criterion A
N/A	House, 19005 Tidewater Trail	ca. 1912	N/A
N/A	House and Corncrib, 19095 Tidewater Trail	pre 1966	N/A



Photo 14: Example of a Corncrib within the Architectural Project Area for the Potential Raw Water Intake Site, Area 3, Located at 19095 Tidewater Trail, Looking Northeast.

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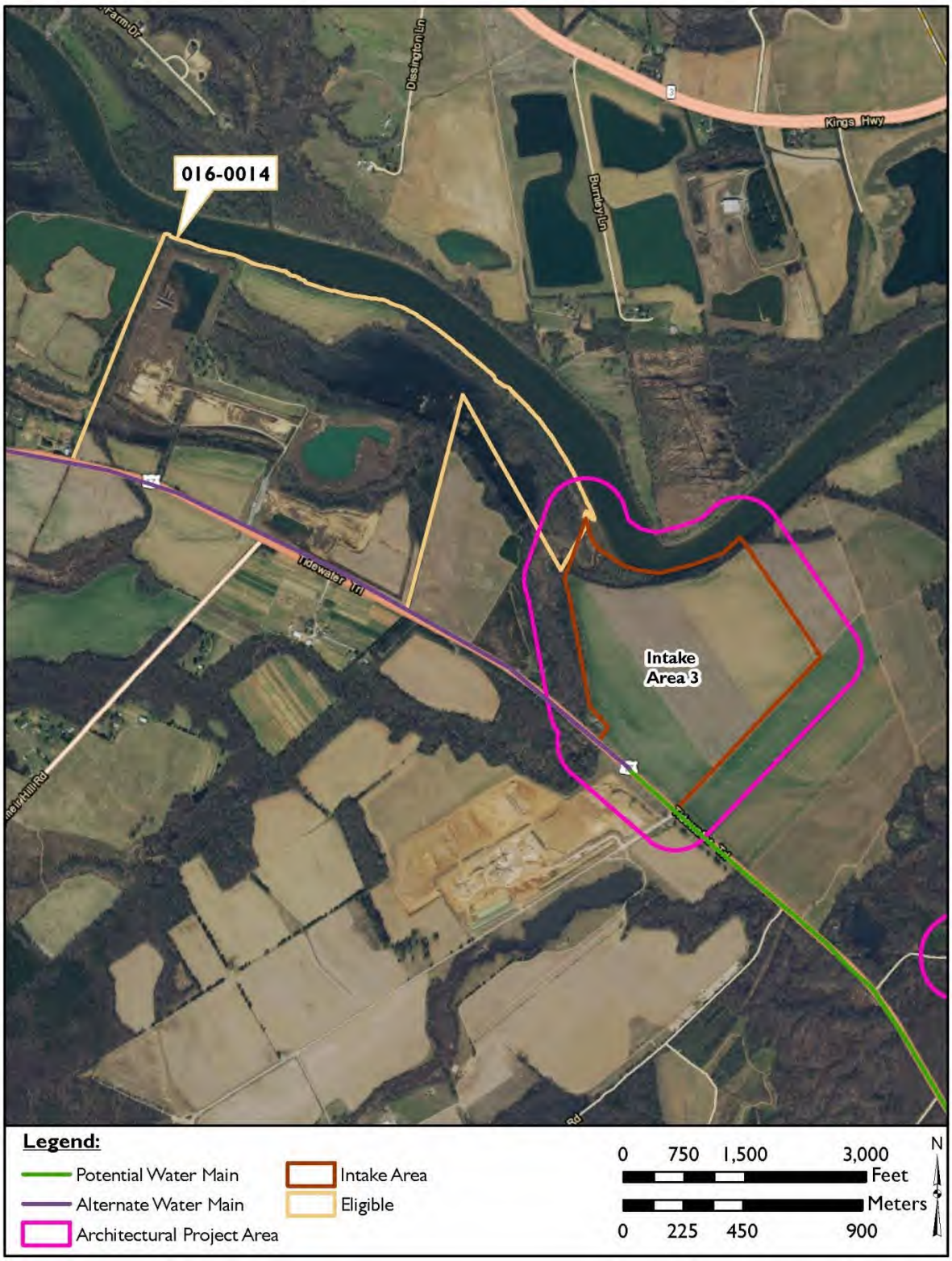


Figure 31: NRHP-Listed, Eligible, and Potentially Eligible Architectural Resources within the Potential Raw Water Intake Site, Area 3 Architectural Project Area, Hayfield (016-0014) (VGIN 2017).

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Archaeological Phase IA Survey Results

Potential Raw Water Intake Location Site, Area 3, is located in a plowed field lying between the northern side of Route 17 and south side of the Rappahannock River in a smaller bend of the river, to the east of Area 2 (Photo 15; Figure 32, p. 82). The proposed site within Area 3 for intake facilities is located on the eastern side of the bend, near the northern end of Area 3. No previously identified archaeological resources are located within this area, but it is immediately adjacent to a NRHP eligible architectural resource, the eighteenth-century house Hayfield (016-0014). Like Area 2, the location of Area 3 is well situated for both historic and prehistoric occupation, lying as it does in level ground adjacent to the Rappahannock River. This area is also mapped as having soils suitable for occupation, primarily Class 2s and 2e. Both of these subclass designations can somewhat limit the preservation of archaeological deposits, and the shallowness of the Class 2s soils is borne out by the visual reconnaissance, but the area does not seem so disturbed as to preclude Phase IB survey and associated subsurface testing, and the location and general suitability for occupation still give the area potential for archaeological resources. As such, any portion of this area impacted by the construction of water intake facilities would require Phase IB subsurface testing, with the exception of those wooded areas lying immediately along the river bank and associated drainages, which tend to be steeply sloped toward the water. Of the 148 acres (59.9 ha) in intake Area 2, approximately 13.5 acres (5.5 ha) are disturbed, leaving 134.5 acres (54.4 ha) suitable for Phase IB testing.



Photo 15: Overview of Potential Intake Area Location, Area 3, Looking West.

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Figure 32: Potential Raw Water Intake Site, Area 3 (VGIN 2017).

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Potential Water Treatment Plant, Parcel 81-A-67

Architectural Phase IA Survey Results

There are seven resources within the architectural project area of Potential Water Treatment Plant at Parcel 81-A-87, including three previously recorded resources and four previously unrecorded resources over 50 years of age (Table 16). One of the three previously recorded resources, the Jericho School (016-5014), is listed in the NRHP and VLR. It is a one-story, one-room, frame building that functioned as a school for the region's African American children during the early-twentieth century (Photo 16). The North Anna Battlefield (042-0123) is the location of an 1864 Civil War battle. Although there are portions of this resource that are heavily developed, especially around the I-95 corridor, large undeveloped areas remain. It was determined potentially eligible for the NRHP under Criterion A in 2007 (Figure 33–Figure 34, pp. 84–85). The remaining previously recorded resource, Jericho Baptist Church (016-0169), is noted as being demolished and has not received a formal NRHP eligibility evaluation. The four previously unrecorded resources over 50 years in age within a 500-foot (154.2-m) radius of the parcel are all residential in nature and date to the twentieth century.

Table 15: Architectural Resources within the Architectural Project Area of the Potential Water Treatment Plant, Parcel 81-A-67. Potentially eligible, eligible, or NRHP-listed resources are noted in blue.

DHR ID	Name and Address	Date of Construction	Previous Eligibility Determination
016-0169	Jericho Baptist Church, Jericho Road	ca. 1870	Not Evaluated
016-5014	Jericho School, Jericho Road	post 1917	NRHP and VLR Listed, 2014, Criteria Not Listed
042-0123	North Anna Battlefield	1864	DHR Staff: Potentially Eligible, 2007 Criterion A
N/A	House, 9000 Block of Jericho Road	pre 1963	N/A
N/A	House, 8207 Jericho Road	ca. 1956	N/A
N/A	House, 7656 Jericho Road	Unknown	N/A
N/A	House, 8018 Jericho Road	ca. 1960	N/A



Photo 16: Examples of a Resources within the Architectural Project Area for the Potential Water Treatment Plant, Parcel 81-A-67: Jericho School (016-5014), North Elevation (Left) and House, 9000 Block of Jericho Road, North Elevation (Right).

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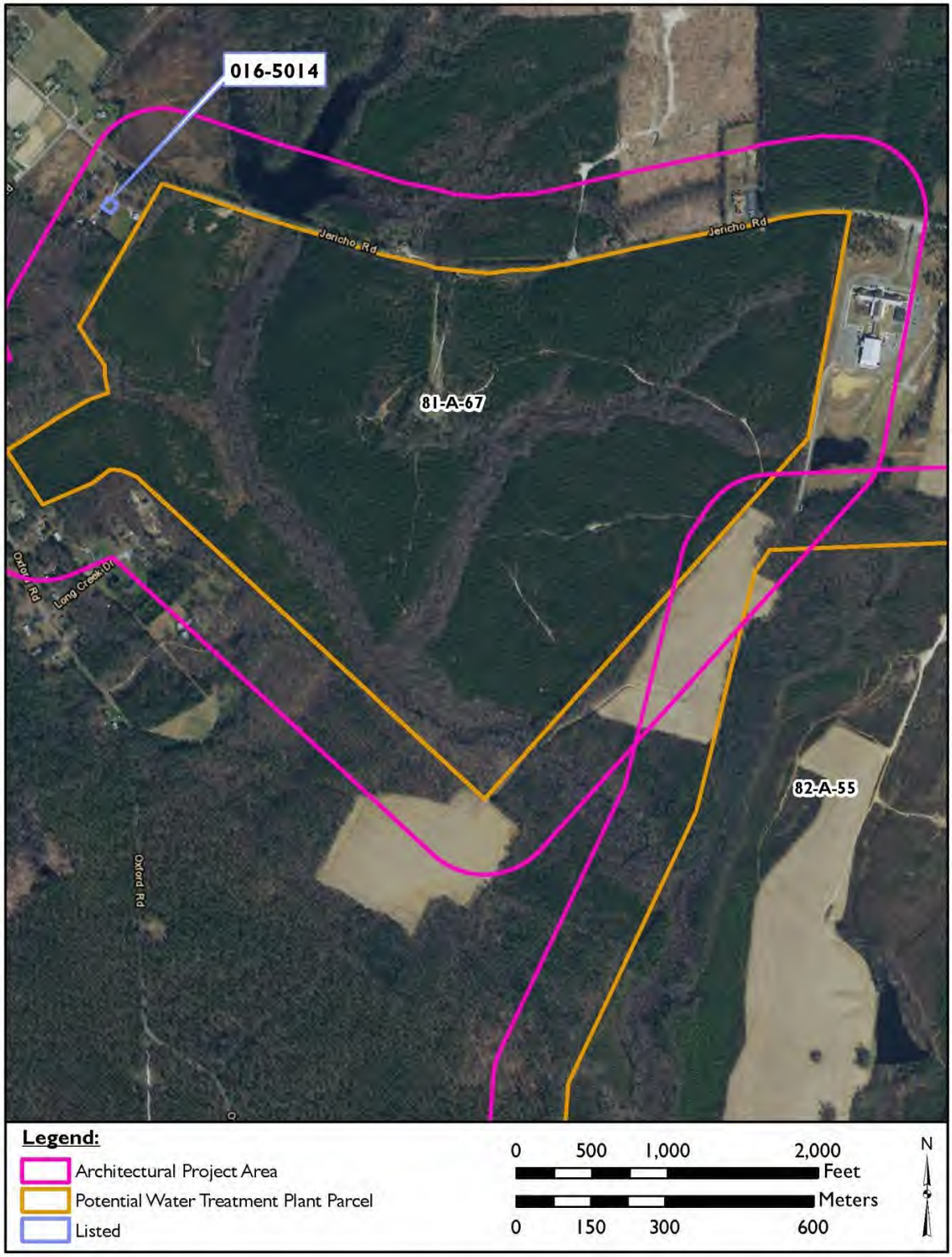


Figure 33: NRHP-Listed, Eligible, and Potentially Eligible Architectural Resources within the Potential Water Treatment Plant, Parcel 81-A-67 Architectural Project Area, Jericho School (016-5014), Map 1 of 2 (VGIN 2017).

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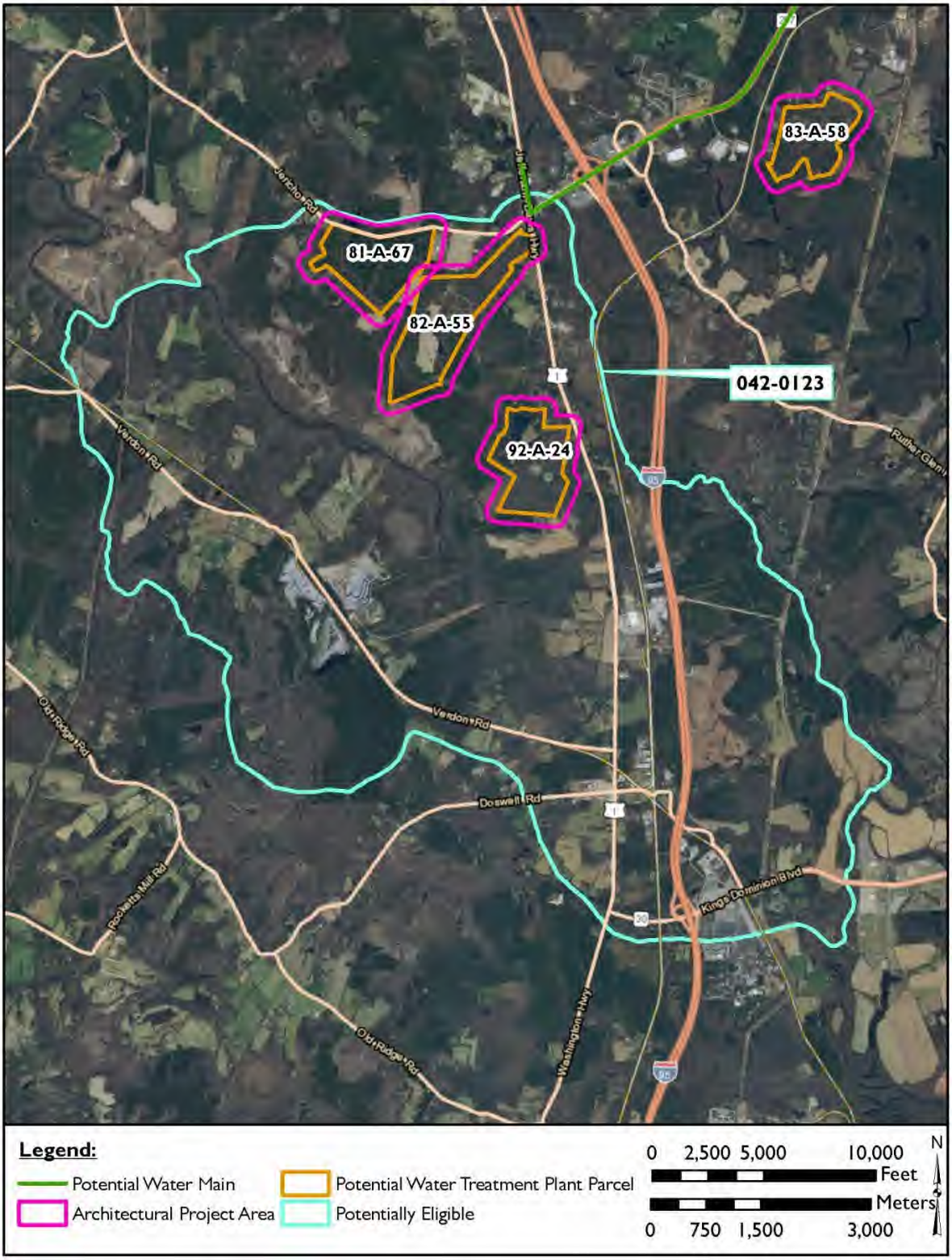


Figure 34: NRHP-Listed, Eligible, and Potentially Eligible Architectural Resources within the Potential Water Treatment Plant, Parcel 81-A-67 Architectural Project Area, North Anna Battlefield (042-0123), Map 2 of 2 (VGIN 2017).

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Archaeological Phase IA Survey Results

Parcel 81-A-67, located on the south side of Jericho Road (Virginia State Road 658) approximately 2 miles (3.2 km) west of I-95 in Ruther Glen, included a single potential Water Treatment Plant Location (Figure 35, p. 87). As is the case with all of the water treatment parcels, the plant location is preliminary and as such, though survey focused on that location, the entire parcel was considered. The proposed location is in the center of the parcel, approximately 700 feet (213.4 m) south of Jericho Road. The entirety of this relatively level wooded area is mapped as containing Kemspville-Emporia complex soils, which depending on slope are either Class 1, 2e, or 3e. All of these are well suited for occupation, and have a relatively high probability for containing archaeological deposits, though the sub-class "e" soils do have some tendency to erode, potentially limiting the preservation of cultural remains should they be present. It should also be noted that two of the archaeological sites discussed above, 44CE0602 and 44CE0608, are located just to the southeast of this parcel. The potential location includes some disturbance, notably a nineteenth-century home site, occupied until recently, and roads. The remainder of the parcel is, in general, similarly well suited for occupation, though survey would be precluded in the steep drainages located within the parcel. With the exception of the parts of these areas directly impacted by these disturbances, the potential water treatment plant site within parcel 81-A-67, is likely to require Phase IB subsurface archaeological testing, including metal detection as the treatment plant site lies within the North Anna Battlefield (042-0123). Parcel 81-A-67 has a total area of 284 acres (113.3 ha), approximately 254 acres (102.8 ha) are suitable for Phase IB testing. However, as discussed, the finalized water treatment plant footprint would occupy only a small portion of this total area.

Potential Water Treatment Plant, Parcel 82-A-55

Architectural Phase IA Survey Results

There are 12 resources within the architectural project area of Potential Water Treatment Plant at Parcel 82-A-55, including four previously recorded resources and eight previously unrecorded resources over 50 years of age (Table 16, p. 88). Two of those, Esso Gas Station (016-0257) and the North Anna Battlefield (042-0123), have been determined potentially eligible for listing in the NRHP by DHR staff. The Esso Gas Station is a one-story, brick building that once served the automobile traffic on Route 1 (Photo 17, p. 88). The North Anna Battlefield is a large resource that spans several counties and is the location of an 1864 Civil War battle (Figure 36–Figure 37, pp. 89–90).

One resource was determined not eligible for individual listing in the NRHP: Carmel Baptist Church (016-0187). This circa-1830, Greek Revival-style religious building suffered severe loss of integrity when a late-nineteenth-century fire destroyed most of the church's original elements. The remaining previously recorded resource, the post-1830 Terrell Cemetery on Jericho Road (016-5040), has not been evaluated for its NRHP potential.

The eight previously unrecorded resources over 50 years in age within a 500-foot (154.2-m) radius of the parcel are all residential in nature. Most range in construction date from around

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1920 to 1960; however, there is one turn-of-the-twentieth-century resource that consists of house ruins and foundation (Photo 18, p. 91).



Figure 35: Potential Water Treatment Plant, Parcel 81-A-67 (VGIN 2017).

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Table 16: Architectural Resources within the Architectural Project Area of the Potential Water Treatment Plant, Parcel 82-A-55. Potentially eligible, eligible, or NRHP-listed resources are noted in blue.

DHR ID	Name and Address	Date of Construction	Previous Eligibility Determination
016-0187	Carmel Baptist Church, Route 1	ca. 1830	DHR Staff: Not Eligible, 1986
016-0257	Esso Gas Station/Elsie's This or That, Route 1	1941	DHR Staff: Potentially Eligible, 1996, Criteria Not Listed
016-5040	Terrell Cemetery, Jericho Road	post 1830	Not Evaluated
042-0123	North Anna Battlefield	1864	DHR Staff: Potentially Eligible, 2007 Criterion A
N/A	House, 25006 Jefferson Davis Highway	ca. 1956	N/A
N/A	House, 24459 Jefferson Davis Highway	ca. 1941	N/A
N/A	Chimney and House Ruins, Jefferson Davis Highway	ca. 1900	N/A
N/A	House, 9309 Jericho Road	ca. 1960	N/A
N/A	House, 9329 Jericho Road	ca. 1940	N/A
N/A	House, 2349 Jericho Road	ca. 1936	N/A
N/A	House, Jefferson Davis Highway	ca. 1940	N/A
N/A	House, Jefferson Davis Highway	ca. 1920	N/A



Photo 17: Southwest Oblique of the Esso Gas Station (016-0257), within the Architectural Project Area for the Potential Water Treatment Plant, Parcel 82-A-55.

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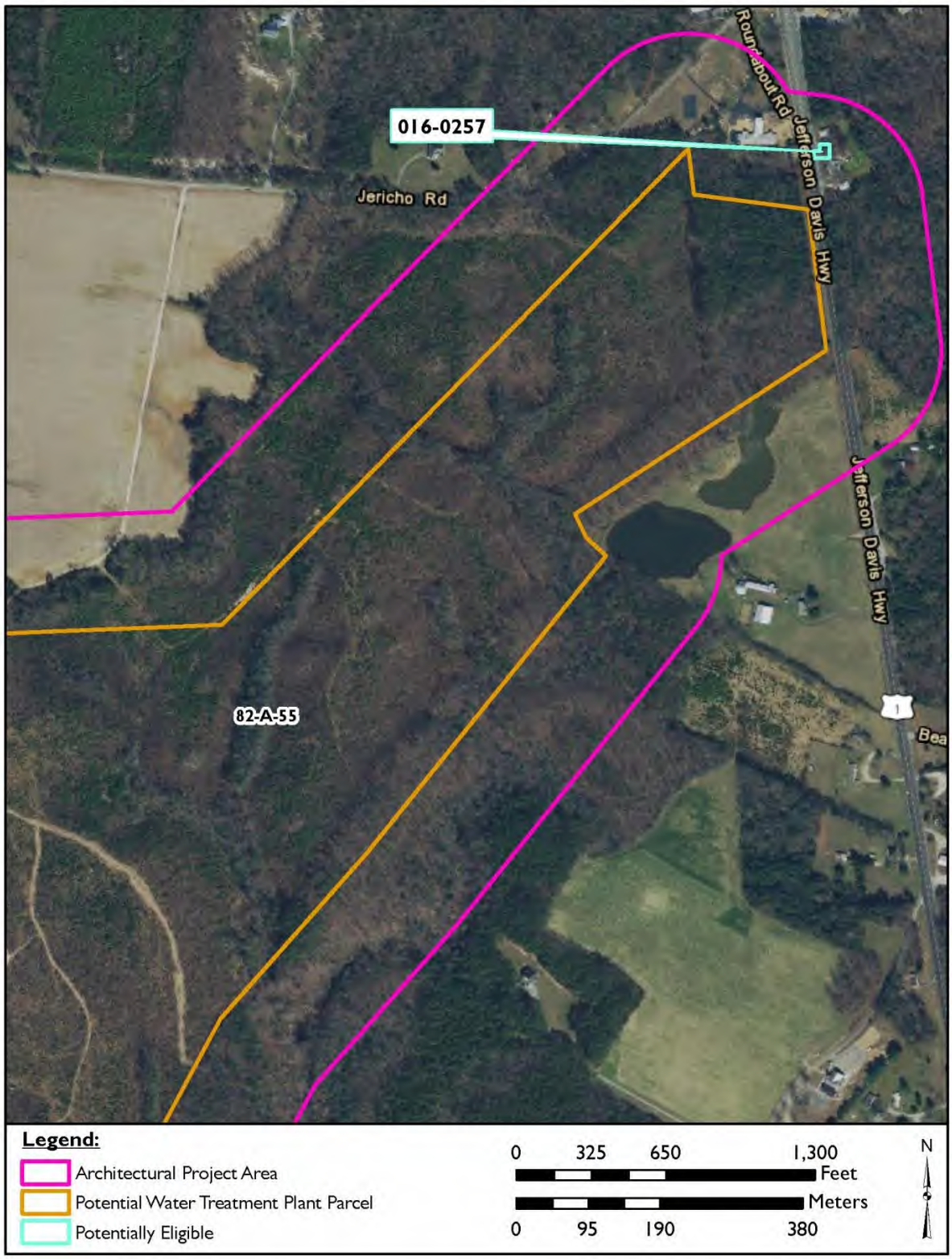


Figure 36: NRHP-Listed, Eligible, and Potentially Eligible Architectural Resources within the Potential Water Treatment Plant, Parcel 82-A-55 Architectural Project Area, Esso Gas Station (016-0257), Map 1 of 2 (VGIN 2017).

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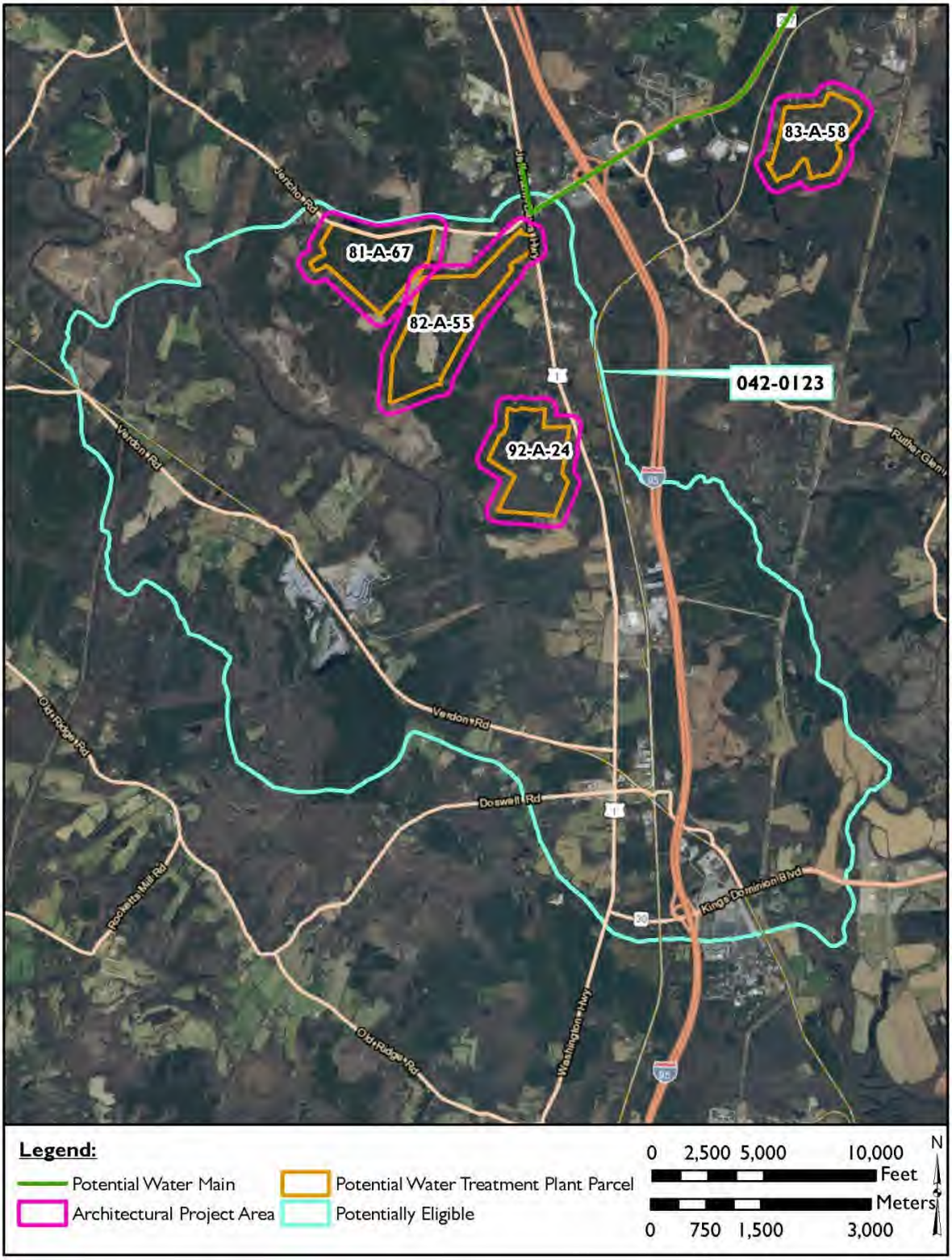


Figure 37: NRHP-Listed, Eligible, and Potentially Eligible Architectural Resources within the Potential Water Treatment Plant, Parcel 82-A-55 Architectural Project Area, North Anna Battlefield (042-0123), Map 2 of 2 (VGIN 2017).

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Photo 18: Example of a Residence within the Architectural Project Area for the Potential Water Treatment Plant, Parcel 82-A-55; House, Jefferson Davis Highway, West Elevation.

Archaeological Phase IA Survey Results

Parcel 82-A-55 lies to the south and east of parcel 81-A-67, near the intersection of Jericho Road with Jefferson Davis Highway (U.S. Route 1). The parcel has a narrow frontage on Route 1, but the potential water treatment plant location within the parcel is located along an access road that extends south from Jericho Road (Figure 38, p. 92). The potential plant location is approximately 3,600 feet (1.1 km) south of Jericho Road. This location lies almost entirely in a generally level farm field, mapped entirely as Class 2e, Kempsville-Emporia Complex soils. These soils are well suited to human occupation, and therefore have a reasonably high probability of containing archaeological remains, though as, discussed previously, subclass "e" soils are somewhat prone to erosion. Numerous previously identified archaeological sites lie in the vicinity of this plant location. Notably sites 44CE0601, 44CE0608, and 44CE0612 are all less than 1,000 feet (304.8 m) from the potential plant. None of these sites have been formally evaluated for NRHP listing, but 44CE0601, a potential slave quarter, was recommended by a previous surveyor for further work. Given the above, the potential water treatment plant location within Parcel 82-A-55 is likely to require Phase IB subsurface archaeological testing, including metal detection as the treatment plant sites both lie within North Anna Battlefield (042-0123). The remainder of the parcel has a similar setting and would also require testing, particularly if plans should impact any of the previously identified sites. Parcel 82-A-55 has a total area of 388.8 acres (157.3 ha), approximately 381 acres (154.2 ha) are suitable for Phase IB testing. However, as discussed, the finalized water treatment plant footprint would occupy only a small portion of this total area.

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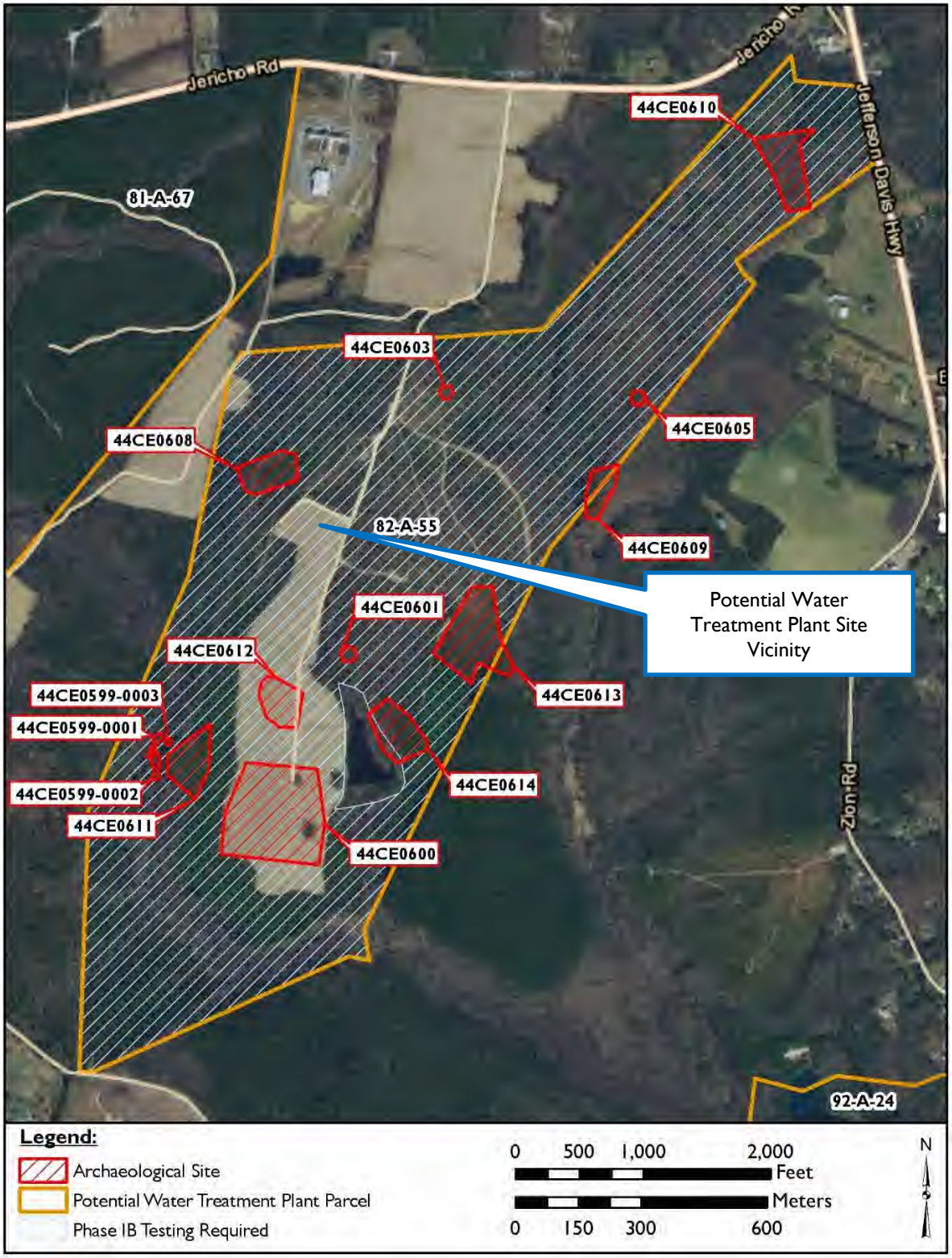


Figure 38: Potential Water Treatment Plant, Parcel 82-A-55 (VGIN 2017).

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Potential Water Treatment Plant, Parcel 83-A-58

Architectural Phase IA Survey Results

There are three resources within the architectural project area of Potential Water Treatment Plant at Parcel 83-A-58, all of which are previously unrecorded resources over 50 years of age (Table 17). All of these buildings are typical, one-story, mid-twentieth-century residences, often with one or more associated outbuildings (Photo 19; Figure 39, p. 94).

Table 17: Architectural Resources Within the Architectural Project Area of the Potential Water Treatment Plant, Parcel 83-A-58.

DHR ID	Name and Address	Date of Construction	Previous Eligibility Determination
N/A	House, 23453 Frye Lane	ca. 1942	N/A
N/A	House, 12229 Dry Bridge Road	ca. 1940	N/A
N/A	House, 12255 Dry Bridge Road	ca. 1960	N/A



Photo 19: Example of a Resource Within the Architectural Project Area for the Potential Water Treatment Plant, Parcel 83-A-58; House, 12255 Dry Bridge Road, Southwest Oblique.

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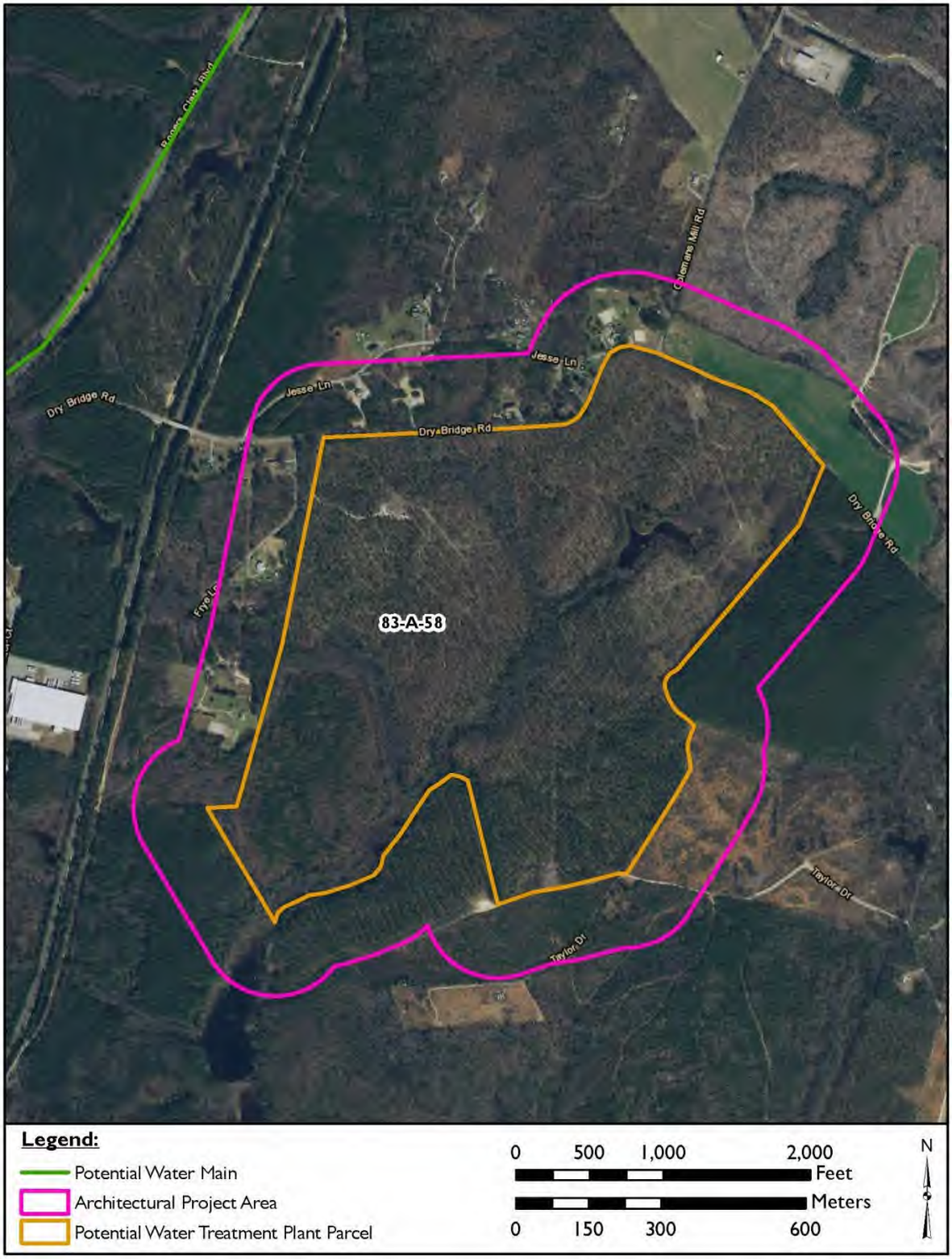


Figure 39: Potential Water Treatment Plant, Parcel 83-A-58 Architectural Project Area (VGIN 2017). Note: There are no NRHP-listed, eligible, or potentially eligible resources within the architectural project area.

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Archaeological Phase IA Survey Results

Parcel 83-A-58 is the only potential water treatment plant parcel located to the east of I-95. This parcel lies on the south side of Dry Bridge Road, approximately 0.5 miles (0.8 km) east of Rogers Clark Boulevard (Virginia Road 207). This parcel contains a single potential water treatment plant location, approximately 400 feet (121.9 m) south of Dry Bridge Road (Figure 40, p. 96). Soils in this area are mapped primarily as Class 2e Kempsville-Slagle complex soils. These soils are reasonably well suited for agriculture and other human activity and as such are reasonably likely to contain cultural remains. The area exhibits some tendency toward erosion, which could impact the preservation of archaeological deposits, should they be present. The nearest previously identified archaeological resources to this area are in a cluster of sites approximately 1,600 feet (487.7 m) to the east, outside the parcel, on the other side of the current CSX railroad (which is itself an architectural resource as the site of the former Fredericksburg, Richmond and Potomac Railroad, 088-5413). As such, this area should be subjected to subsurface testing should it be selected for water treatment plant construction. However, the location is outside the North Anna Battlefield and would not require metal detection. Similar conditions prevail in the remainder of the parcel, with only a small area of drainage being unsuitable for testing should plans be altered. Parcel 83-A-58 has a total area of 219.1 acres (88.7 ha), approximately 196 acres (79.3 ha) are suitable for Phase IB testing. However, as discussed, the finalized water treatment plant footprint would occupy only a small portion of this total area.

Potential Water Treatment Plant, Parcel 92-A-24

Architectural Phase IA Survey Results

There are five resources within the architectural project area of Potential Water Treatment Plant at Parcel 92-A-24, including one previously recorded resource and four previously unrecorded resources over 50 years of age (Table 18, p. 97; Photo 20, p. 97; Figure 41, p. 98). The one previously recorded resource is the North Anna Battlefield (042-0123), which is the location of an 1864 Civil War battle and was determined potentially eligible for listing in the NRHP under Criterion A in 2007.

The four previously unrecorded resources over 50 years in age within a 500-foot (154.2-m) radius of the Potential Water Treatment Plant at Parcel 92-A-24 all date to the mid-twentieth century. Three of the four are one-story, single-family dwellings and the remaining resource is a commercial resource with a main office and several associated outbuildings.

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Figure 40: Potential Water Treatment Plant, Parcel 83-A-58 (VGIN 2017).

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Table 18: Architectural Resources Within the Architectural Project Area of the Potential Water Treatment Plant, Parcel 92-A-24. Potentially eligible, eligible, or listed resources are noted in blue.

DHR ID	Name and Address	Date of Construction	Previous Eligibility Determination
042-0123	North Anna Battlefield	1864	DHR Staff: Potentially Eligible, 2007 Criterion A
N/A	House/Commercial Building, 26140 Jefferson Davis Highway	ca. 1941	N/A
N/A	Commercial, 26145 Jefferson Davis Highway	pre 1966	N/A
N/A	House, 26164 Beverly Circle	ca. 1960	N/A
N/A	House, 26210 Jefferson Davis Highway	ca. 1967	N/A



Photo 20: Example of a Resource Within the Architectural Project Area for the Potential Water Treatment Plant, Parcel 92-A-24; House/Commercial Building, 26140 Jefferson Davis Highway, Southeast Oblique.

Archaeological Phase IA Survey Results

Parcel 92-A-24 is the southernmost of the parcels containing potential water treatment plants, lying near, but without frontage on, Route 1, and located less than 1 mile (1.6 km) north of the North Anna River, Caroline County's southern border (Figure 42, p.99). Within this parcel, one location is being considered for the Water Treatment Plant. The current preferred location for the water treatment plant lies in the northeastern part of the parcel, in gently sloping forest approximately 1,000 feet (304.8 m) west of Route 1. This area appears to be relatively undisturbed, and is mapped almost entirely as containing either class 2e or 3e (dependent on slope) Kempsville soils. The current preferred location, given the lack of apparent disturbance, and relatively good soils, would require Phase IB subsurface testing. This location is within the study area for North Anna Battlefield (042-0123), and would, therefore require metal detection in addition to shovel testing. Taken as a whole, the 280.1-acre (113.4-ha) parcel

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contains 143 acres (57.9 ha) of land suitable for Phase IB testing, including the area of the preferred plant location.

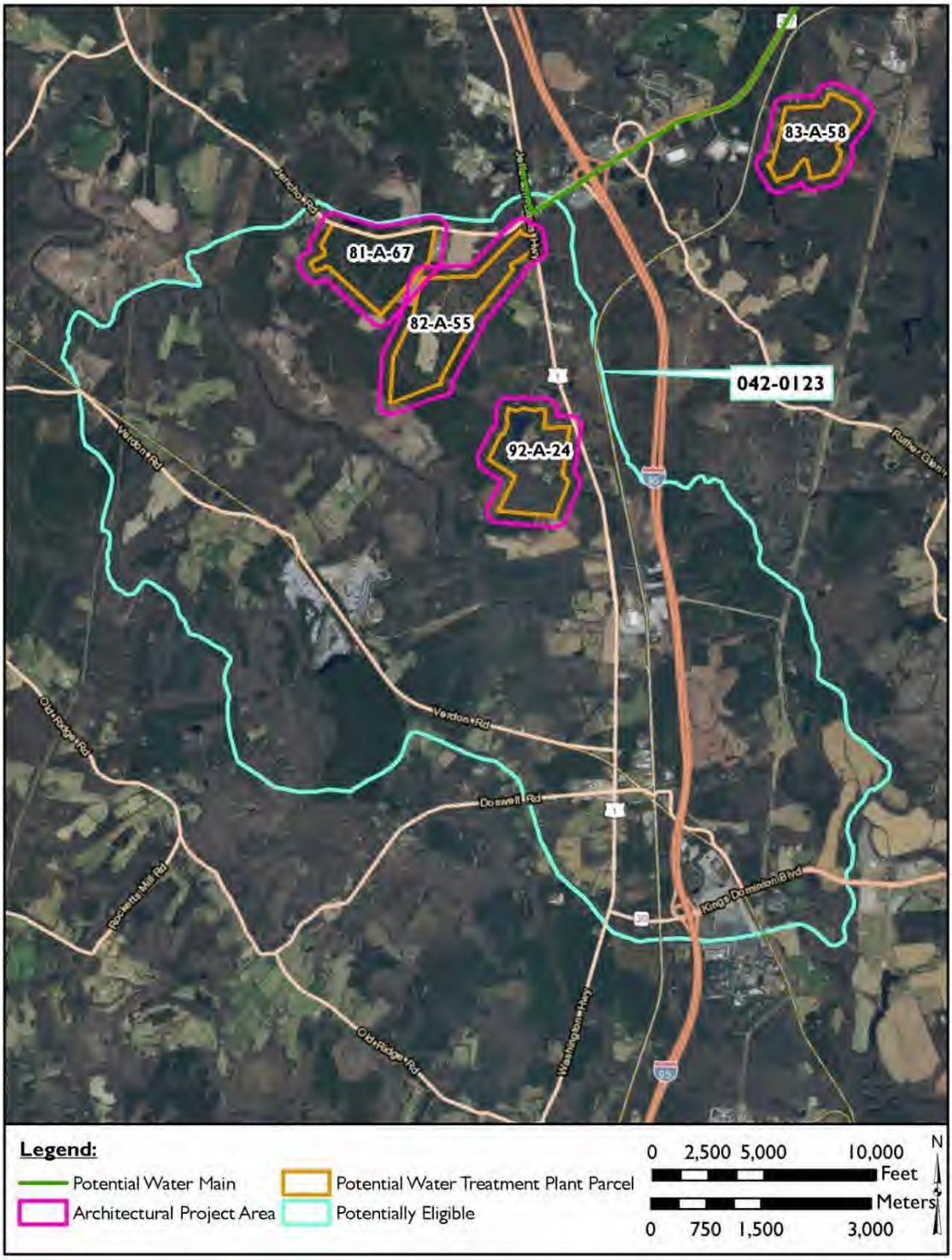


Figure 41: NRHP-Listed, Eligible, and Potentially Eligible Architectural Resources within the Potential Water Treatment Plant, Parcel 92-A-24 Architectural Project Area, North Anna Battlefield (042-0123) (VGIN 2017).

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Figure 42: Potential Water Treatment Plant, Parcel 92-A-24 (VGIN 2017).

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Alternatives Analysis

The Phase IA cultural resources study provided data that was used to compare the different alternatives for each segment (Table 19). Dovetail identified a total of 124 cultural resources within the architectural and archaeological project areas for the potential raw water main, five of which are listed in, or determined eligible or potentially eligible for, the NRHP. During the study, Dovetail noted that the alternative raw water main had slightly fewer cultural resources (n=119), four of which were previously determined potentially eligible or eligible for the NRHP or are NRHP listed.

Of the raw water intake sites, Area 1 has the highest number of identified cultural resources within the architectural and archaeological project areas. At the time of the study, there were seven resources, one of which was determined eligible for the NRHP by DHR staff. Within the project areas for each of the remaining two intake sites are three identified cultural resources, but only Area 3 has a previously determined NRHP-eligible resource, Hayfield (016-0014), which only crosses the northwestern most corner of the architectural project area.

Among the architectural and archaeological project areas for the potential water treatment plants, parcel 82-A-55 had the highest number identified resources (n=27), two of which have been determined potentially eligible for the NRHP by DHR staff. Two of the potential water treatment plant project areas had five or fewer identified cultural resources (parcels 83-A-58 and 92-A-24); of those two, only parcel 92-A-24 has a NRHP-listed, eligible, or potentially eligible resource, the North Anna Battlefield (042-0123), which also spans potential water treatment plant parcels 81-A-67 and 82-A-55.

Table 19: Comparison of Potentially Eligible, Eligible, and Listed Cultural Resources by Project Segment.

Project Segment	Number of Identified Architectural Resources	Number of Identified Archaeological Resources	Number of NRHP-Potentially Eligible, Eligible, and Listed Cultural Resources
Potential Raw Water Main	123	1	5
Alternative Raw Water Main	115	4	4
Raw Water Intake Site, Area 1	3	4	1
Raw Water Intake Site, Area 2	3	0	0
Raw Water Intake Site, Area 3	3	0	1
Water Treatment Plant, Parcel 81-A-67	7	0	2
Water Treatment Plant, Parcel 82-A-55	12	15	2
Water Treatment Plant, Parcel 83-A-58	3	0	0
Water Treatment Plant, Parcel 92-A-24	5	0	1

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SUMMARY AND RECOMMENDATIONS

On behalf of Draper Aden, Dovetail conducted a Phase IA cultural resource reconnaissance study of three potential water intake locations, four water treatment plant locations, a potential raw water main route, and an alternative raw water main route in Caroline County, Virginia. In association with Draper Aden, Caroline County is planning the installation of a water line and associated facilities. The project area for this study comprises three potential water intake areas which cover approximately 880 acres (356.1 ha), four potential water treatment facility locations which cover approximately 1,172 acres (474.3 ha), a potential raw water main route which extends approximately 32.1 miles (51.7 km), and an alternate raw water main route which extend approximately 18.7 miles (30.1 km). The reconnaissance study comprised a visual inspection of the potential and alternate raw water main routes and a visit to the most likely locales for the water treatment facility within the parcels accompanied by representatives from Draper Aden and Hazen and was completed on August 8, 2018, February 26, 2019, and May 30, 2019. The goals of the work were to identify locations within the project area with the potential to contain intact archaeological sites and architectural resources older than 50 years in the project vicinity and make recommendations for any additional investigations and provide data to compare the different alternatives for each segment.

The Phase IA architectural study of the Caroline County Water Supply project included noting all above-ground resources over 50 years in age (1969) within the project's architectural project area. For the potential raw water main and the alternative route for raw water main, the architectural project area is defined as the area adjacent to the water main and is inclusive of any previously recorded resources or previously unrecorded resource 50 years of age or older whose feeling or setting may be impacted by the project. For the potential raw water intake sites and potential water treatment plants the architectural project area is defined as extending 500 feet (152.4 m) from the parcel boundaries. Within the architectural project area, Dovetail identified 50 previously recorded resources, 10 of which have been previously listed in, or determined eligible or potentially eligible for listing in the NRHP and 12 of which have been determined not eligible by DHR staff. The remaining 28 previously recorded resources have not been formally evaluated for inclusion in the NRHP by the DHR. Within the architectural project area for the potential raw water main, alternative route for raw water main, potential raw water intake sites, and potential water treatment plants there are 216 above-ground, previously unrecorded resources that are 50 years of age or older (Table 20, p. 102). Nine resources (016-0011, 016-0032, 016-0153, 016-5014, 016-5087, 016-5176, 042-0123, 088-0061, 500-0001) have received a formal eligibility evaluation and were last surveyed less than five years ago and as such Dovetail **recommends that they will not require a revisit during the Phase IB survey.** Dovetail recommends **that the remaining 257 above-ground resources within the architectural project area may require a Phase IB-level survey.** The list of resources recommended for the Phase IB portion of the project will be refined and likely reduced as the project's limits of disturbance are established.

Eighteen previously recorded archaeological sites are within the project area (44CE0262, 44CE0263, 44CE0264, 44CE0437, 44CE0599-0001, 44CE0599-0002, 44CE0599-0003, 44CE0600, 44CE0601, 44CE0603, 44CE0605, 44CE0608, 44CE0609, 44CE0610, 44CE0611, 44CE0612, 44CE0613, and 44CE0614), none have been evaluated for listing in

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the NRHP by DHR staff. For the two water main routes, the archaeological project area is defined as the area within 25 feet (7.6 m) of the edge of pavement. For the potential raw water intake sites and water treatment plants the archaeological project area includes the entirety of the parcels. The intake areas and parcels containing potential water treatment plants, excluding intake Area 1 (already provisionally eliminated from consideration), encompass a total area of 1,700 acres (688.0 ha). Approximately 350 acres (141.6 ha) of this are considered not suitable for Phase IB survey, leaving 1,350 acres (546.3 ha) or 79.4 percent of the area suitable for further study. However, this area would presumably be reduced upon finalization of plans for ground disturbing activities. The approximately 51 miles (82.1 km) of combined corridor between the two (overlapping) water main routes, are largely disturbed as well, however determining an exact number of disturbed versus undisturbed distance is not practicable. Additional archaeological work at the Phase IB level is recommended involving systematic subsurface testing through the excavation of shovel test pits at 50-foot (15.2-m) intervals across the portions of the project area where ground disturbing activities are planned and where such testing is not precluded by obvious modern disturbance, slope, inundation, or other conditions making excavation impracticable or unsafe. Metal Detection would also be required in those portions of the project area lying within the North Anna Battlefield (042-0123). After such testing recommendations for NRHP eligibility of any sites identified can then be made. Additionally, should any of the previously identified sites remain in the project's limits of disturbance, Phase IB testing will be needed within the site boundaries to assess current conditions within those sites and make appropriate NRHP recommendations.

Dovetail **recommends that all intact soils with less than 15 percent slope, as well as all sites that have been found eligible or not yet evaluated be subjected to subsurface testing.** Within the 1,700 acres (688.0 ha) encompassed by intake and treatment areas currently under consideration approximately 350 acres (141.6 ha) are considered not suitable for Phase IB survey, leaving 1,350 acres (546.3 ha) or 79.4 percent of the area suitable for further study (Table 21, p. 114).

Table 20: Architectural Resources within the Architectural Project Area and Phase IB Survey Recommendations. Potentially eligible, eligible, or listed resources are noted in blue.

DHR ID	Name/Address	Prev. Elig. Status	Recommended for Phase IB	Project Segment
016-0011	Destiny Ministries/Grace Episcopal Church, 4565 Fredericksburg Turnpike	VLR Listing 2018, NRHP Listing 2019; Last Surveyed 2018	No	Alternative Route for Raw Water Main
016-0014	Hayfield, 18173 Tidewater Trail	DHR Staff: Eligible, 2009 Criterion C, Potentially Eligible Criterion A; Last Surveyed 2009	Yes	Alternative Route for Raw Water Main; Pot Raw Intake Site Location 3 (Parcel 4-A-15)
016-0032	Rose Hill/Gay Mont, 23348 Tidewater Trail	VLR Listing, 1972; NRHP Listing, 1972; Last Surveyed 2018	No	Potential Raw Water Main
016-0049	Mount Pleasant No. 3, Nick Minarchi House	Not Evaluated	Yes	Alternative Route for Raw Water Main
016-0050	Captain Brook Farm, Route 2	Not Evaluated	Yes	Alternative Route for Raw Water Main

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DHR ID	Name/Address	Prev. Elig. Status	Recommended for Phase IB	Project Segment
016-0065	Haymount, Route 17	Not Evaluated	Yes	Pot Raw Intake Site Location 1 (Parcel 5-A-8)
016-0072	Yew Spring Farm, Ware Creek Road	Not Evaluated	Yes	Pot Raw Intake Site Location 2 (Parcel 5-A-1)
016-0097	Athen, Route 207	Not Evaluated	Yes	Potential Raw Water Main
016-0104	Campbell's Country Club/Hopewell's Disciples Church, Route 207	Not Evaluated	Yes	Potential Raw Water Main
016-0144	Holly Hill, 15542 Holly Hill Drive	DHR Staff: Not Eligible, 2010; Last Surveyed 2010	Yes	Potential Raw Water Main
016-0150	Magnolia Inn/Mount Olympus, Route 1	Not Evaluated	Yes	Potential Raw Water Main
016-0153	Poplar Grove, 20194 Rogers Clark Highway	DHR Board Determined Not Eligible, 1991; Last Surveyed 2015	No	Potential Raw Water Main
016-0157	Farish House/Hill View, Route 2	Not Evaluated	Yes	Alternative Route for Raw Water Main
016-0169	Jericho Baptist Church, Jericho Road	Not Evaluated	Yes	Water Treatment Plant 81-A-67
016-0187	Carmel Baptist Church, Route 1	DHR Staff: Not Eligible, 1986; Last Surveyed 1991	Yes	Water Treatment Plant 82-A-55
016-0215	Todd's Tavern, Route 2	Not Evaluated	Yes	Alternative Route for Raw Water Main
016-0216	Zion Grove Church and Cemetery, Route 2	Not Evaluated	Yes	Alternative Route for Raw Water Main
016-0257	Esso Gas Station/Elsie's This or That, Route 1	DHR Staff: Potentially Eligible, 1996; Last Surveyed 1996	Yes	Water Treatment Plant 82-A-55
016-0344	Bridge #1013, Campbell Creek, Route 2	DHR Staff: Not Eligible, 1995; Last Surveyed 1995	Yes	Alternative Route for Raw Water Main
016-0349	Fort A.P. Hill Historic District	DHR Staff: Not Eligible, 1994; Last Surveyed 1994	Yes	Potential Raw Water Main
016-0349-0047	General Purpose Warehouse/TT1207, off North Range Road	DHR Staff: Not Eligible, 2005; Last Surveyed 2005	Yes	Potential Raw Water Main
016-0349-0048	Airfield Operations Building/P01201, off North Range Road	DHR Staff: Not Eligible, 2005; Last Surveyed 2005	Yes	Potential Raw Water Main
016-0349-0049	Theater Headquarters Area/SS0137, Killian Road	DHR Staff: Not Eligible, 2005; Last Surveyed 2005	Yes	Potential Raw Water Main

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DHR ID	Name/Address	Prev. Elig. Status	Recommended for Phase IB	Project Segment
016-5014	Jericho School, Jericho Road	NRHP and VLR Listing, 2014, Criteria Not Listed; Last Surveyed 2014	No	Water Treatment Plant 81-A-67
016-5026	George Anderson House, 4390 Buckner Road	Not Evaluated	Yes	Potential Raw Water Main
016-5027	Bridge #1024, Route 207	DHR Staff: Not Eligible, 2006; Last Surveyed 2006	Yes	Potential Raw Water Main
016-5040	Terrell Cemetery, Jericho Road, Jericho Road	Not Evaluated	Yes	Water Treatment Plant 82-A-55
016-5087	Bridge #1026, Route 207 (westbound), spanning CSX Railroad, Rogers Clark Boulevard	DHR Staff: Not Eligible, 2017; Last Surveyed 2017	No	Potential Raw Water Main
016-5091	Fort A.P. Hill Armory, 18272 A.P. Hill Boulevard	DHR Staff: Not Eligible, 2011; Last Surveyed 2011	Yes	Potential Raw Water Main
016-5101	House, 21028 Rogers Clark Boulevard	Not Evaluated	Yes	Potential Raw Water Main
016-5176	Bridge #1025, Rogers Clark Boulevard	DHR Staff: Not Eligible, 2017; Last Surveyed 2017	No	Potential Raw Water Main
042-0123	North Anna Battlefield	DHR Staff: Potentially Eligible, 2007 Criterion A; Last Surveyed 2016	No	Potential Raw Water Main; Water Treatment Plant 81-A-67; Water Treatment Plant 82-A-55; Water Treatment Plant 92-A-24
088-0061	Saint Julien, 9630 Sandy Lane	VLR and NRHP Listing, 1975, Criteria A and C; Last Surveyed 2019	No	Alternative Route for Raw Water Main
171-0002	Glassellton, 302 Main Street	Not Evaluated	Yes	Potential Raw Water Main
171-5001	Bowling Green Historic District	VLR and NRHP Listing, 2003, Criteria A and C; Last Surveyed 2006	Yes	Potential Raw Water Main; Alternative Route for Raw Water Main
171-5001-0128	House, 319 North Main Street	Not Evaluated	Yes	Alternative Route for Raw Water Main
171-5001-0129	House, 329 North Main Street	Not Evaluated	Yes	Alternative Route for Raw Water Main
171-5001-0130	House, 333 North Main Street	Not Evaluated	Yes	Alternative Route for Raw Water Main

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DHR ID	Name/Address	Prev. Elig. Status	Recommended for Phase IB	Project Segment
171-5001-0131	House, 103 East Broddus Avenue	Not Evaluated	Yes	Potential Raw Water Main
171-5001-0132	House, 109 East Broddus Avenue	Not Evaluated	Yes	Potential Raw Water Main
171-5001-0133	House, 111 Broaddus Avenue	Not Evaluated	Yes	Potential Raw Water Main
171-5001-0134	House, 115 East Broddus Avenue	Not Evaluated	Yes	Potential Raw Water Main
171-5001-0135	House, 121 Broaddus Avenue	Not Evaluated	Yes	Potential Raw Water Main
171-5001-0137	House, 125 East Broddus Avenue	Not Evaluated	Yes	Potential Raw Water Main
171-5001-0140	House, 120 East Broddus Avenue	Not Evaluated	Yes	Potential Raw Water Main
171-5001-0141	House, 132 Broaddus Avenue	Not Evaluated	Yes	Potential Raw Water Main
284-0044	Greater Port Royal Historic District	DHR Board: Eligible, 2009, Criteria A and C; Last Surveyed 2013	Yes	Potential Raw Water Main; Pot Raw Intake Site Location 1 (Parcel 5-A-8)
284-5012	House, 25592 A.P. Hill Boulevard	Not Evaluated	Yes	Potential Raw Water Main
284-5013	Port Royal Farm Stand/Commercial Building, 25550 A.P. Hill Boulevard	Not Evaluated	Yes	Potential Raw Water Main
284-5014	Horne's Store & Restaurant, 25532 A.P. Hill Boulevard	Not Evaluated	Yes	Potential Raw Water Main
500-0001	Richmond, Fredericksburg and Potomac Railroad Historic District	DHR Staff: Eligible, 2018, Criterion A; Last Surveyed 2018	No	Potential Raw Water Main
N/A	Service Station, 25577 A.P. Hill Boulevard	N/A	Yes	Potential Raw Water Main
N/A	Port Royal Convenience Store, 25523 A.P. Hill Boulevard	N/A	Yes	Potential Raw Water Main
N/A	J.T.J. Gouldman Farms, 25513 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 25432 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 25404 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 25433 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	Outbuilding, 7306 Edmont Road	N/A	Yes	Potential Raw Water Main
N/A	Restaurant, 18164 A.P. Hill Boulevard	N/A	Yes	Potential Raw Water Main
N/A	Motel, 18138 A.P. Hill Boulevard	N/A	Yes	Potential Raw Water Main

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DHR ID	Name/Address	Prev. Elig. Status	Recommended for Phase IB	Project Segment
N/A	Motel, 18080 A. P. Hill Boulevard	N/A	Yes	Potential Raw Water Main
N/A	Store, 17518 A. P. Hill Boulevard	N/A	Yes	Potential Raw Water Main
N/A	Restaurant, 17468 A. P. Hill Boulevard	N/A	Yes	Potential Raw Water Main
N/A	Auto Dealership, 17398 A. P. Hill Boulevard	N/A	Yes	Potential Raw Water Main
N/A	VFW Bowling Green, 17532 A. P. Hill Boulevard	N/A	Yes	Potential Raw Water Main
N/A	House, 163 Broaddus Avenue	N/A	Yes	Potential Raw Water Main
N/A	House, 163 Broaddus Avenue	N/A	Yes	Potential Raw Water Main
N/A	House, 150 Broaddus Avenue	N/A	Yes	Potential Raw Water Main
N/A	House, 144 Broaddus Avenue	N/A	Yes	Potential Raw Water Main
N/A	Auto, 133 Broaddus Avenue	N/A	Yes	Potential Raw Water Main
N/A	House, 145 Martin Street	N/A	Yes	Potential Raw Water Main
N/A	House, 15478 Rogers Clark Boulevard	N/A	Yes	Potential Raw Water Main
N/A	House, 15490 Rogers Clark Boulevard	N/A	Yes	Potential Raw Water Main
N/A	House, 15489 Rogers Clark Boulevard	N/A	Yes	Potential Raw Water Main
N/A	House, 16044 Chester Lane	N/A	Yes	Potential Raw Water Main
N/A	House, W. Broaddus Avenue	N/A	Yes	Potential Raw Water Main
N/A	House, 16036 Chester Lane	N/A	Yes	Potential Raw Water Main
N/A	House, 16174 Melville Lane	N/A	Yes	Potential Raw Water Main
N/A	House, 16184 Melville Lane	N/A	Yes	Potential Raw Water Main
N/A	House, 16197 Melville Lane	N/A	Yes	Potential Raw Water Main
N/A	House, 16223 Melville Lane	N/A	Yes	Potential Raw Water Main
N/A	House, 16246 Rogers Clark Boulevard	N/A	Yes	Potential Raw Water Main
N/A	House, 16206 Melville Lane	N/A	Yes	Potential Raw Water Main
N/A	Sycamore Hill Farm, 17611 Rogers Clark Boulevard	N/A	Yes	Potential Raw Water Main
N/A	Commercial, 17651 Rogers Clark Boulevard	N/A	Yes	Potential Raw Water Main

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DHR ID	Name/Address	Prev. Elig. Status	Recommended for Phase IB	Project Segment
N/A	House, 17701 Rogers Clark Boulevard	N/A	Yes	Potential Raw Water Main
N/A	Service Station, 18068 Rogers Clark Boulevard	N/A	Yes	Potential Raw Water Main
N/A	House, 18099 Rogers Clark Boulevard	N/A	Yes	Potential Raw Water Main
N/A	Commercial Building, 18126 Rogers Clark Boulevard	N/A	Yes	Potential Raw Water Main
N/A	House, Minor Lane	N/A	Yes	Potential Raw Water Main
N/A	House, 18173 Minor Lane	N/A	Yes	Potential Raw Water Main
N/A	House, 18331 Rogers Clark Boulevard	N/A	Yes	Potential Raw Water Main
N/A	House, 18362 Rogers Clark Boulevard	N/A	Yes	Potential Raw Water Main
N/A	House, 18412 Rogers Clark Boulevard	N/A	Yes	Potential Raw Water Main
N/A	House, 18440 Rogers Clark Boulevard	N/A	Yes	Potential Raw Water Main
N/A	House, 18470 Rogers Clark Boulevard	N/A	Yes	Potential Raw Water Main
N/A	House, 19072 Rogers Clark Boulevard	N/A	Yes	Potential Raw Water Main
N/A	House, 19472 Rogers Clark Boulevard	N/A	Yes	Potential Raw Water Main
N/A	House, Rogers Clark Boulevard	N/A	Yes	Potential Raw Water Main
N/A	House, 20106 Rogers Clark Boulevard	N/A	Yes	Potential Raw Water Main
N/A	House, 22172 Colemans Mill Road	N/A	Yes	Potential Raw Water Main
N/A	House, 23435 Rogers Clark Boulevard	N/A	Yes	Potential Raw Water Main
N/A	Commercial Building, 23804 Rogers Clark Boulevard	N/A	Yes	Potential Raw Water Main
N/A	House, Jefferson Davis Highway	N/A	Yes	Potential Raw Water Main
N/A	House, 22239 Telegraph Road	N/A	Yes	Potential Raw Water Main
N/A	House, 21376 Jefferson Davis Highway	N/A	Yes	Potential Raw Water Main
N/A	House, 21337 Jefferson Davis Highway	N/A	Yes	Potential Raw Water Main
N/A	Service Station and Garage, 21291-21303 Jefferson Davis Highway	N/A	Yes	Potential Raw Water Main
N/A	House, 21308 Jefferson Davis Highway	N/A	Yes	Potential Raw Water Main
N/A	House, 21292 Jefferson Davis Highway	N/A	Yes	Potential Raw Water Main

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DHR ID	Name/Address	Prev. Elig. Status	Recommended for Phase IB	Project Segment
N/A	House, 21274 Jefferson Davis Highway	N/A	Yes	Potential Raw Water Main
N/A	House, 21264 Jefferson Davis Highway	N/A	Yes	Potential Raw Water Main
N/A	House, 22213 Jefferson Davis Highway	N/A	Yes	Potential Raw Water Main
N/A	House, 22002 Jefferson Davis Highway	N/A	Yes	Potential Raw Water Main
N/A	House, 21358 Jefferson Davis Highway	N/A	Yes	Potential Raw Water Main
N/A	House, 25250 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 25226 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	Historic Bridge, North of Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 24255 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 24164 Hazelwood Lane	N/A	Yes	Potential Raw Water Main
N/A	Commercial Building, 23315 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 23219 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 23199 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 23192 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 23059 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 23021 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 23003 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 22559 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 22531 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 22399 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 22303 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 22155 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 22169 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 22153 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 21751 Tidewater Trail	N/A	Yes	Potential Raw Water Main

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DHR ID	Name/Address	Prev. Elig. Status	Recommended for Phase IB	Project Segment
N/A	House, 21627 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	Racefield Farm, 3141 Buckner Road	N/A	Yes	Pot Raw Intake Site Location 1 (Parcel 5-A-8)
N/A	House and Corncrib, 19095 Tidewater Trail	N/A	Yes	Alternative Route for Raw Water Main/ Pot Raw Intake Site Location 3 (Parcel 4-A-15)
N/A	House, 19005 Tidewater Trail	N/A	Yes	Alternative Route for Raw Water Main/ Pot Raw Intake Site Location 3 (Parcel 4-A-15)
N/A	Farm, 18294 Tidewater Trail	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 17437 Tidewater Trail	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 17347 Tidewater Trail	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 16245 Tidewater Trail	N/A	Yes	Alternative Route for Raw Water Main
N/A	Farm, 16132 Tidewater Trail	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 16071 Tidewater Trail	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 15427 Tidewater Trail	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 3460 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 4004 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 4024 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 4217 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 4363 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 4409 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 4402 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 4414 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 4473 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	Commercial Building and Dwelling, 4539 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main

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DHR ID	Name/Address	Prev. Elig. Status	Recommended for Phase IB	Project Segment
N/A	House, 4484 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 4528 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 4606 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 4626 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 5010 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 5056 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 5082 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 5148 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 5174 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 14599 Long Branch Road	N/A	Yes	Alternative Route for Raw Water Main
N/A	Church, 14464 Long Branch Road	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 6088 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 6160 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	Electric Station, Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 6476 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 6488 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 7008 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 7022 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 7094 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 7116 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 7146 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 7166 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	Commercial Building, 7218 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	Auto Service, 7244 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 7370 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main

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DHR ID	Name/Address	Prev. Elig. Status	Recommended for Phase IB	Project Segment
N/A	House, 7376 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 7382 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 7440 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 8198 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 8390 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 8418 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 9199 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 10046 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 11056 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 10332 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 10396 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 11376 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 12020 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 15317 Woodslane Road	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 12571 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 13113 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 13141 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 13922 Farmer Drive	N/A	Yes	Alternative Route for Raw Water Main
N/A	VDOT, 13257 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	VDOT, 13257 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 13956 Farmer Drive	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 13296 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 13328 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 13353 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main

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DHR ID	Name/Address	Prev. Elig. Status	Recommended for Phase IB	Project Segment
N/A	House, 13363 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 13389 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 13415 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 14074 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 14095 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 14110 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 14142 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 14232 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 14256 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 14337 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 14321 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 14330 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 14353 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 14373 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	REC Electric, 14374-14408 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 14408 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 14423 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 14424 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 356 Main Street	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 318 Main Street	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 302 Main Street	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 24251 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 23153 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	House, 22435 Tidewater Trail	N/A	Yes	Potential Raw Water Main
N/A	Dwellings, Southfield Drive	N/A	Yes	Potential Raw Water Main

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DHR ID	Name/Address	Prev. Elig. Status	Recommended for Phase IB	Project Segment
N/A	House, 14577 Long Branch Road	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 9000 Block of Jericho Road	N/A	Yes	Water Treatment Plant 81-A-67
N/A	House, 8207 Jericho Road	N/A	Yes	Water Treatment Plant 81-A-67
N/A	House, 25006 Jefferson Davis Highway	N/A	Yes	Water Treatment Plant 82-A-55
N/A	House, 24459 Jefferson Davis Highway	N/A	Yes	Water Treatment Plant 82-A-55
N/A	House, 23453 Frye Lane	N/A	Yes	Water Treatment Plant 83-A-58
N/A	House, 12229 Dry Bridge Road	N/A	Yes	Water Treatment Plant 83-A-58
N/A	House, 12255 Dry Bridge Road	N/A	Yes	Water Treatment Plant 83-A-58
N/A	House/Commercial Building, 26140 Jefferson Davis Highway	N/A	Yes	Water Treatment Plant 92-A-24
N/A	House, 9309 Jericho Road	N/A	Yes	Water Treatment Plant 82-A-55
N/A	House, 9329 Jericho Road	N/A	Yes	Water Treatment Plant 82-A-55
N/A	House, 9349 Jericho Road	N/A	Yes	Water Treatment Plant 82-A-55
N/A	House, 7656 Jericho Road	N/A	Yes	Water Treatment Plant 81-A-67
N/A	House, 8018 Jericho Road	N/A	Yes	Water Treatment Plant 81-A-67
N/A	Commercial, 26145 Jefferson Davis Highway	N/A	Yes	Water Treatment Plant 91-A-24
N/A	House, 26164 Beverly Circle	N/A	Yes	Water Treatment Plant 91-A-24
N/A	House, 26210 Jefferson Davis Highway	N/A	Yes	Water Treatment Plant 91-A-24
N/A	Corncrib, Skinkers Neck Road	N/A	Yes	Pot Raw Intake Site Location 2 (Parcel 5-A-1)
N/A	House, 2673 Skinkers Neck Road	N/A	Yes	Pot Raw Intake Site Location 2 (Parcel 5-A-1)
N/A	Chimney and House Ruins, Jefferson Davis Highway	N/A	Yes	Water Treatment Plant 82-A-55
N/A	House, Jefferson Davis Highway	N/A	Yes	Water Treatment Plant 82-A-55
N/A	House, Jefferson Davis Highway	N/A	Yes	Water Treatment Plant 82-A-55
N/A	House, 7244 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main

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DHR ID	Name/Address	Prev. Elig. Status	Recommended for Phase IB	Project Segment
N/A	House, 7458 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 7472 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 8432 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 9204 Woodford Road	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 13360 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 14213 Fredericksburg Turnpike	N/A	Yes	Alternative Route for Raw Water Main
N/A	House, 16435 Paige Road	N/A	Yes	Alternative Route for Raw Water Main
N/A	Commercial Building, 25445 Tidewater Trail	N/A	Yes	Potential Raw Water Main

Table 21: Acreage Recommended for Phase IB Archaeological Testing within Each Project Segment.

Project Segment	Total Acreage	Acreage Recommended for Phase IB Testing
Potential Raw Water Main	N/A	N/A
Alternative Raw Water Main	N/A	N/A
Raw Water Intake Site 1	351.9	351.9
Raw Water Intake Site 2	380	242
Raw Water Intake Site 3	148	134.5
Water Treatment Plant 81-A-67	284	254
Water Treatment Plant 82-A-55	388.8	381
Water Treatment Plant 83-A-58	219.1	196
Water Treatment Plant 92-A-24	280.1	143

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APPENDIX A: QUALIFCATIONS OF PRINCIPAL INVESTIGATOR

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DOVETAIL
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D. BRAD HATCH, PHD, RPA

Principal Investigator/Archaeology Division Manager

YEARS EXPERIENCE

With this firm: 8

With other firms: 4

EDUCATION

PhD/Anthropology, 2015

MA/Anthropology and Historical Archaeology, 2009

BA/Historic Preservation, 2007

REGISTRATIONS/QUALIFICATIONS

Registered Professional Archaeologist

Council of Virginia Archaeologists

Secretary of Interior Standards Qualified as Archaeologist and Historian

PUBLICATIONS/PRESENTATIONS/COMMITTEES

Program Co-Chair/Middle Atlantic Archaeological Conference (2017–Present)

Anglo-Native Interaction in Virginia's Potomac River Valley. Paper presented at the Society for Historical Archaeology Conference (2018)

Dairies and Dairying in the Middle Atlantic. Paper presented at the Middle Atlantic Archaeological Conference (2016)

Reassessing the Hallowes Site: Conflict and Settlement in the 17th-century Potomac Valley. *Historical Archaeology* (2014)

Venison Trade and Interaction between English Colonists and Native Americans in Virginia's Potomac River Valley. *Northeast Historical Archaeology* (2012)

Bones, Pans, and Probates: A Faunal Analysis of the Newman's Neck Site (44NB180). *Journal of Middle Atlantic Archaeology* (2011)

EXPERIENCE

Dr. Hatch has over 12 years of experience doing archaeology in the Middle Atlantic region in academic, museum, and cultural resource management (CRM) contexts. His experience ranges from survey and site identification to data recovery excavations on historic and prehistoric sites in Virginia, Maryland, West Virginia, Tennessee, Pennsylvania, Delaware, and North Carolina. Dr. Hatch has been involved with excavations at multiple sites focusing on late prehistoric and contact period Native American sites in Southern Maryland, and the Colonial Encounters project, a reanalysis and synthesis of over 15 sites dating from the early colonial period in the Lower Potomac Valley. Dr. Hatch's primary responsibility for the Colonial Encounters project included the analysis and reporting of the faunal collections from sites in both Maryland and Virginia. His responsibilities at Dovetail include managing projects, writing proposals, tracking budgets, scheduling, and managing the archaeological staff, among other tasks.

SAMPLE PROJECTS

Principal Investigator/Thoburn's Redoubt Interpretive Trail Project (Warren, Virginia). Archaeological studies including testing and metal detecting on the Cedar Creek Battlefield in preparation for parking lot and trail construction.

Principal Investigator/Sunnybrook Farm Solar Project (Halifax, Virginia). Cultural resource studies, staffing, and agency coordination for a proposed solar farm under the Virginia Department of Environmental Quality Permit By Rule process.

Principal Investigator/Buck Knob Virginia State Police Tower Project (Wise, Virginia). Archaeological investigations for a telecommunications tower, including agency coordination.

Project Manager/Greenfield Outbuilding Relocation Project (Botetourt, Virginia). Archaeological investigations and archival research of two nineteenth-century plantation outbuildings related to enslaved occupations on behalf of the County.

Project Manager/Cedar Creek Administrative Building Parking Improvements (Frederick, Virginia). Archaeological studies including shovel testing, test unit excavation, and metal detecting on the Cedar Creek and Belle Grove National Historical Park, under the National Park Service

Principal Investigator/Fall Hill Data Recovery (Fredericksburg, Virginia). Archaeological data recovery and intensive archival research on eighteenth- and nineteenth-century tenant site on the outskirts of Fredericksburg on behalf of VDOT.

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PHASE IB CULTURAL RESOURCE SURVEY OF POTENTIAL WATER INTAKE AND TREATMENT PLANT SITES, CAROLINE COUNTY, VIRGINIA

by

Joseph R. Blondino
and
Mical Tawney

Prepared for

Draper Aden Associates

Prepared by

DOVETAIL
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Phase IB Cultural Resource Survey of Potential Water Intake and Treatment Plant Sites, Caroline County, Virginia

by

Joseph R. Blondino
and
Mical Tawney

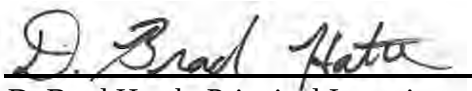
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Dovetail Job #18-054
November 2019



November 19, 2019

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ABSTRACT

On behalf of Draper Aden Associates (Draper Aden), Dovetail Cultural Resource Group (Dovetail) conducted a Phase IB cultural resource survey of a potential raw water intake site, as well as a potential water treatment plant location. The two surveyed locations, totaling approximately 23 acres (9.3 ha), are part of the larger Caroline County Water Supply project. Fieldwork for the survey was carried out from July 29 to August 9, 2019. The goals of the work were to identify archaeological sites over 50 years of age within the archaeological project area, as well as to identify architectural resources in the architectural project area, and to make recommendations on the eligibility of all identified resources for inclusion in the National Register of Historic Places (NRHP). For the purposes of this project, the archaeological project area is defined as the limits of disturbance plus a 50-foot (15.2-m) buffer around the proposed building location and pipeline corridor at the potential raw water intake site and a 100-foot (30.5-m) buffer around the potential water treatment plant, and the architectural project area is defined as the limits of disturbance plus a 500-foot (152.4-m) buffer around the proposed building location and pipeline corridor at the potential raw water intake site and a 1,000-foot (304.8-m) buffer around the potential water treatment plant.

The potential raw water intake site is located along the Rappahannock River approximately 10 miles (16.1 km) southeast of Fredericksburg, Virginia. The intake site was tested with a total of 125 shovel test pits (STPs). One archaeological site, 44CE0914, was identified. Site 44CE0914 is a scatter of lithic debitage dating to an unknown prehistoric period. As a result of the site's low artifact density and disturbance of the deposits by plowing, **site 44CE0914 is recommended as not eligible for inclusion in the NRHP.**

The water treatment plant location is approximately 2.3 miles (3.7 km) south of Interchange 104 on I-95, near Ruther Glen, Virginia. A total of 258 STPs was excavated at the proposed water treatment plant. One artifact was recovered from the STP survey, and controlled metal detector survey resulted in the recovery of eight artifacts. In addition, a large Civil War earthwork likely associated with the Union Army's operations in the area during the actions at the Battle of North Anna was identified. The recovered artifact assemblage and the earthwork were used to define site 44CE0915. Based on the presence of the largely intact earthwork, **site 44CE0915 (architectural resource 016-5199) is recommended as potentially eligible for inclusion in the NRHP under Criteria A, C, and D.**

The architectural study involved identification of all previously recorded and previously unrecorded above-ground resources over 50 years in age located within the architectural project area of the potential raw water intake site and the potential water treatment plant. The architectural survey identified a total of eight resources in the architectural project area that meet the survey criteria. Of those, one resource had been previously recorded with the Virginia Department of Historic Resources (DHR) and seven were newly recorded as part of the current project. Of these resources, one (042-0123) is **recommended to remain potentially eligible for the NRHP**, one (016-5199/44CE0915) is **recommended potentially eligible under Criteria A, C, and D**, and six (016-5192, 016-5193, 016-5195, 016-5196, 016-5197, and 016-5198) are **recommended as not eligible for the NRHP**.

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INTRODUCTION

On behalf of Draper Aden Associates (Draper Aden), Dovetail Cultural Resource Group (Dovetail) conducted a Phase IB cultural resource survey of a potential raw water intake location, as well as a potential water treatment plant location in Caroline County, Virginia (Figure 1, p. 2). In association with Draper Aden, Caroline County is planning the installation of a water line and associated facilities, collectively known as the Caroline County Water Supply project. A cultural resource survey is required for this project due to the involvement of the United States Army Corps of Engineers and the application for a water withdrawal permit from the Virginia Department of Environmental Quality. The project area for this study comprised two separate areas. The potential raw water intake site (Figure 2, p. 3) totals approximately 5 acres (2 ha). The potential water treatment plant is located in the southwestern portion of the county and totals approximately 18 acres (7.3 ha) (Figure 3, p. 4). For the purposes of this project, the archaeological project area is defined as the limits of disturbance plus a 50-foot (15.2-m) buffer around the proposed building location and pipeline corridor at the potential raw water intake site and a 100-foot (30.5-m) buffer around the potential water treatment plant, and the architectural project area is defined as the limits of disturbance plus a 500-foot (152.4-m) buffer around the potential raw water intake site and a 1,000-foot (304.8-m) buffer around the potential water treatment plant. The potential water treatment plant has a larger buffer due to the fact that a tower may be placed on the site, therefore increasing its visual impact on the surrounding landscape. The goals of the work were to identify any previously recorded resources and any previously unrecorded cultural resources over 50 years in age and make recommendations on their National Register of Historic Places (NRHP) eligibility.

The Phase IB cultural resource survey builds upon the results of a Phase IA field reconnaissance and background literature and records review completed in September 2019 on a series of locations being considered for a potential water line and associated facilities (Schnur et al. 2019). The present Phase IB study focused only on the potential raw water intake and potential water treatment plant sites being considered as final preferred locations for the Caroline County Water Supply project facilities. Only data relevant to the Phase IB survey is presented here, and the Phase IA report should be consulted for information on historic context, previous surveys, and previously identified cultural resources.

The Phase IB archaeological survey included systematic shovel testing of a total of approximately 23 acres (9.3 ha). A total of 383 STPs was excavated, and controlled metal detector survey was conducted at the potential water treatment plant site, due to its location within the North Anna Battlefield (042-0123). Archaeological fieldwork was conducted from July 29 to August 9, 2019. The archaeological survey was conducted by Joe Blondino, assisted by Kerry González, Reagan Andersen, Alison Cramer, and Jeff Philips. Brad Hatch served as the Principal Investigator. Dr. Hatch meets or exceeds the Secretary of the Interior (SOI) guidelines for archaeologists (United States Department of Interior [DOI] 1993).

The architectural study included an inspection of the architectural project area. Architectural fieldwork was conducted on July 30 and August 2, 2019 by Mical Tawney and Katherine

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Watts. Ms. Tawney and Ms. Watts meet or exceed the standards established for architectural historian by the SOI.

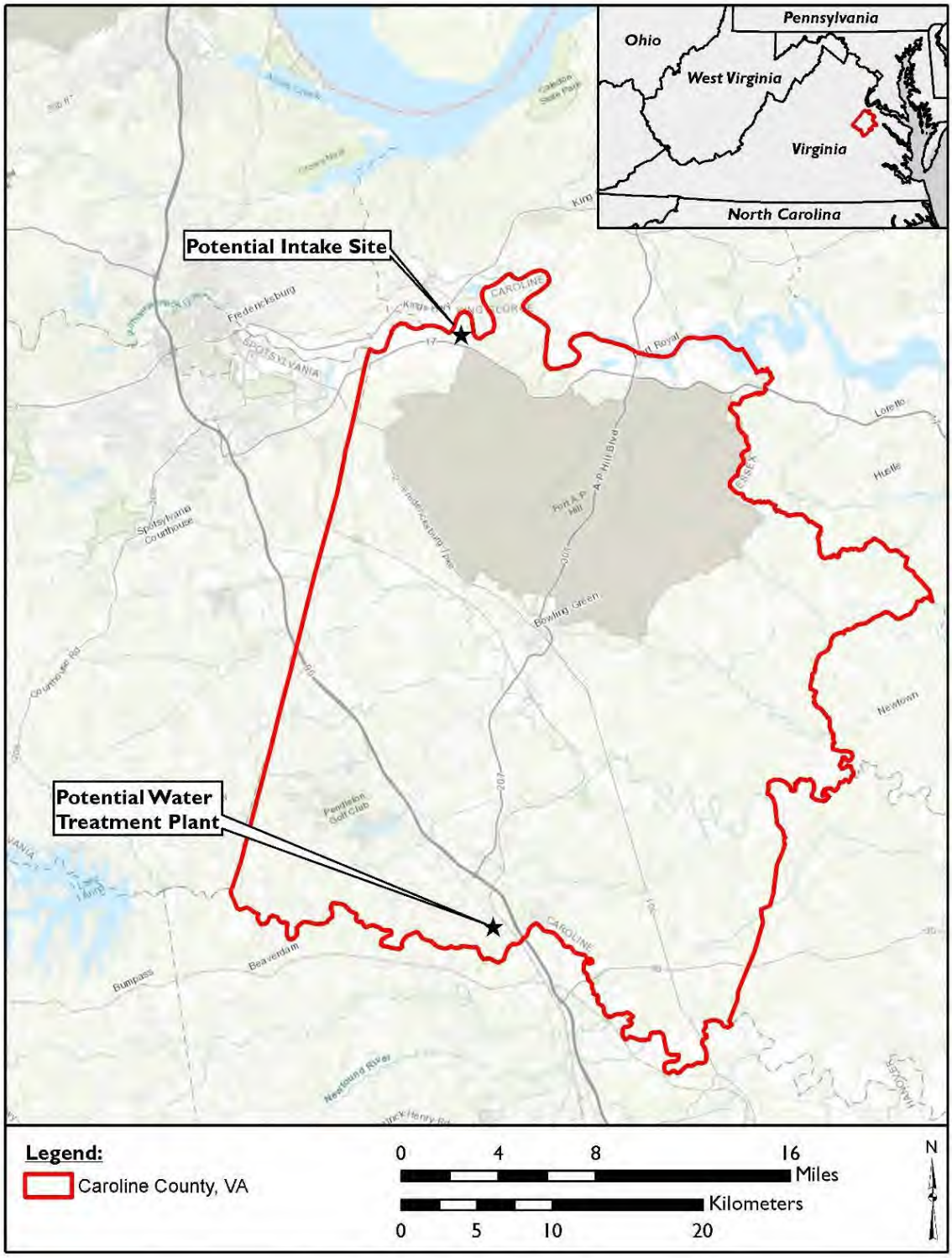


Figure 1: General Project Area Locations within Caroline County, Virginia (Esri 2019a).

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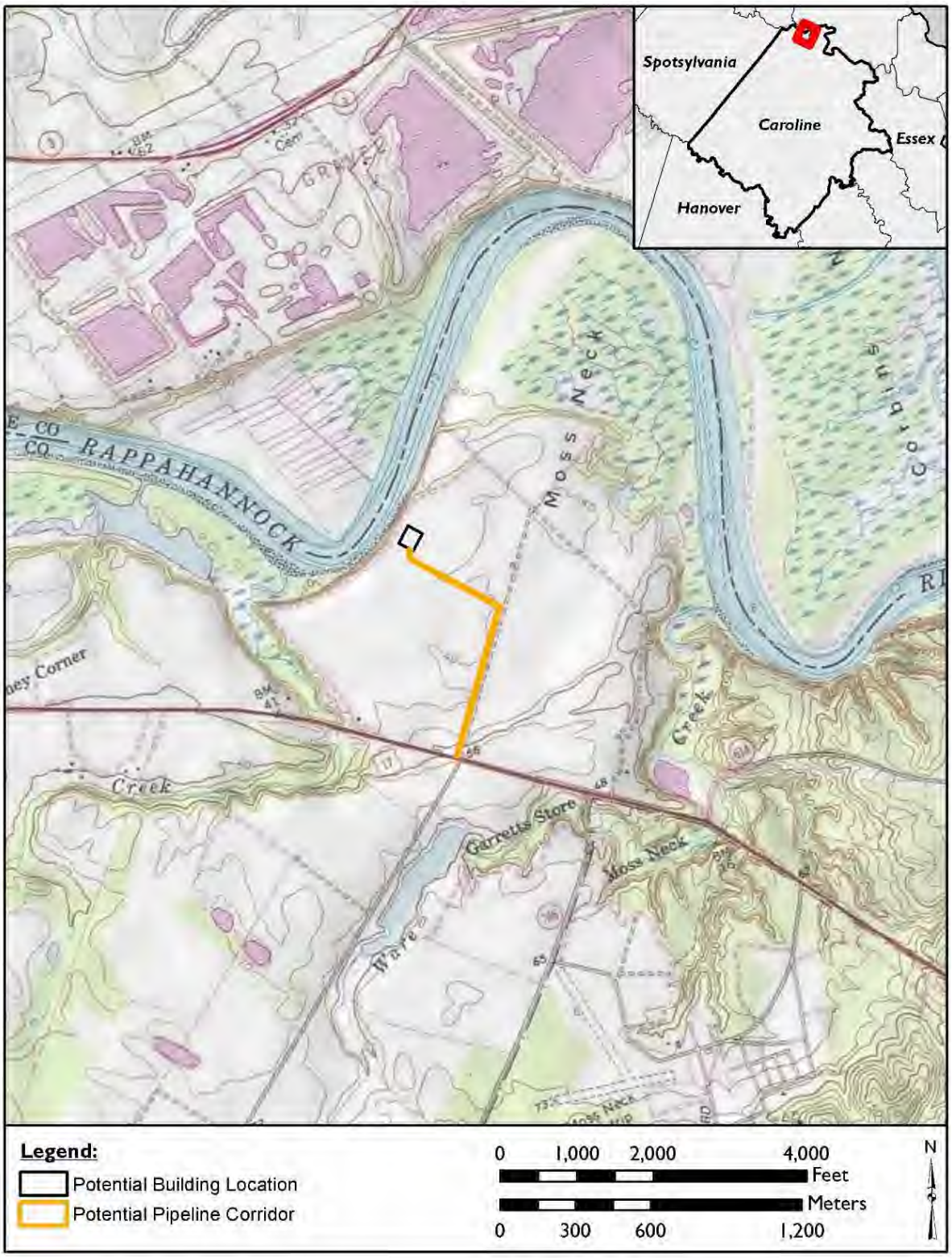


Figure 2: Location of the Potential Raw Water Intake Site, Including the Proposed Building Location and Associated Pipeline Corridor, on the United States Geological Survey (USGS) Caroline County, Virginia, 7.5 Minute Digital Raster Graphic Mosaic (Esri 2019b).

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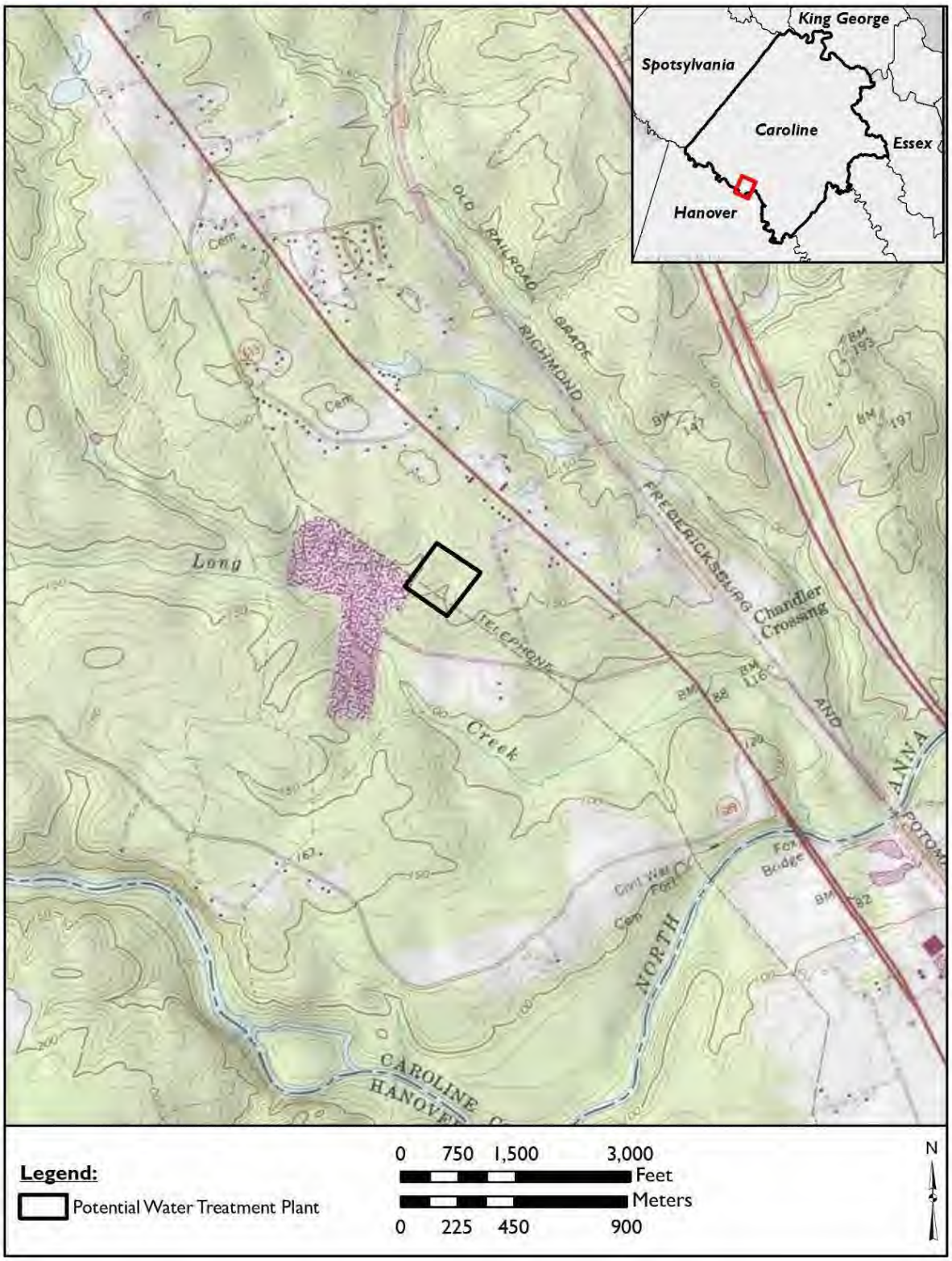


Figure 3: Location of the Potential Water Treatment Plant on the USGS Caroline County, Virginia, 7.5 Minute Digital Raster Graphic Mosaic (Esri 2019b).

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PROJECT AREA DESCRIPTION

The present Phase IB project area comprises two locations in Caroline County, Virginia. The archaeological project area—defined as the entire area to be impacted by construction activities, inclusive of an added buffer zone around each proposed building—consists of two survey areas: a potential raw water intake site and a potential water treatment plant. A 50-foot (15-2-m) buffer was used at the raw water intake site, while a 100-foot (30.5-m) buffer was used at the potential water treatment plant site. The architectural project area is defined as the limits of disturbance plus a 500-foot (152.4-m) buffer around the proposed building location and pipeline corridor at the potential raw water intake site and a 1,000-foot (304.8-m) buffer around the potential water treatment plant. The potential raw water intake site is located in an agricultural field on a high bluff on the south bank of the Rappahannock River (Figure 4, p. 6). At the time of the survey, the proposed building location of the potential raw water intake site was planted in corn (Photo 1, p. 7), while the pipeline corridor leading from the intake site to Route 17 was planted in both corn and soybeans (Photo 2, p. 7). Located to the southwest of the potential raw water intake site are two dwellings, a carport, and two sheds.

The potential water treatment plant is located on a forested portion of a parcel located approximately 24.5 miles (39.4 km) southwest of the potential raw water intake site (Figure 5, p. 8; Photo 3, p. 9). The parcel containing the potential water treatment plant is leased to Martin Marietta Materials, which formerly mined granite for crushed stone in this location. Although the potential water treatment plant location itself was not mined, visible disturbance on the surface in the southern portion of the area indicates that it was used in some fashion during mining operations (Photo 4, p. 9), possibly as a staging area for equipment or a storage area for materials. A road trace runs roughly east-west through the area (Photo 5, p. 10). To the east and southeast of potential water treatment plant, located directly along Jefferson Davis Highway, are several single-family dwellings, commercial buildings, and a church.

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Figure 4: Potential Raw Water Intake Site, Including the Proposed Building Location and Associated Pipeline Corridor, on Aerial Imagery (Virginia Geographic Information Network [VGIN] 2017).

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Photo 1: Cornfield Containing the Potential Raw Water Intake Site, Facing South.



Photo 2: Pipeline Corridor at the Potential Raw Water Intake Site, Facing North from Near U.S. 17.

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Figure 5: Potential Water Treatment Plant on Aerial Imagery (VGIN 2017).

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Photo 3: General View of the Potential Water Treatment Plant Location, Facing Northeast.



Photo 4: Large Pushpiles in Southwestern Portion of the Potential Water Treatment Plant, Facing West.

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Photo 5: Road Trace in the Potential Water Treatment Plant Site, Facing West.

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ENVIRONMENTAL SETTING

The project area is located in Caroline County, Virginia, between the Cities of Fredericksburg and Richmond. Despite its proximity to urban Richmond and increasingly developed and suburban Fredericksburg, Caroline County has maintained a largely rural character. The Caroline County countryside is dominated by agricultural fields and wooded tracts, although the major travel corridors of I-95, U.S. 17, and U.S. 301 pass through the western, northern, and central parts of the county, respectively. The northeastern portion of the county is dominated by the U.S. Army installation at Fort A.P. Hill, which occupies nearly a quarter of the county.

Geology and Topography

Caroline County lies primarily in Virginia's Coastal Plain physiographic province, with the far western portion of the county lying partially in the Piedmont. The Coastal Plain extends from the Fall Line, where the crystalline rocks of the Piedmont meet the unconsolidated sediments of the Coastal Plain, to the Atlantic Ocean, with its general elevation decreasing from west to east as sea level is approached. The area of the potential raw water intake site, in the northern part of Caroline County along the Rappahannock River, is underlain by unconsolidated Quaternary sediments of the Shirley Formation, primarily sand and gravel. The area of the water treatment plant site is underlain by sands and gravels of Pliocene age (Division of Geology and Mineral Resources 2016), although the deeper bedrock comprises a hornblende gneiss quarried just west of the treatment plant site for crushed granite (Sweet 2001). A location just northwest of the potential water treatment plant site has been the subject of ongoing paleontological studies by the Virginia Museum of Natural History. The fossil locality there has produced numerous fossils from both marine and terrestrial animals dating back into the Miocene epoch, including the type specimen of the extinct baleen whale *Eobalaenoptera harrisoni* (The Washington Post 2011).

Hydrology

The potential raw water intake site is situated on a high bluff above the Rappahannock River and is drained directly by the river itself. The Rappahannock flows generally southeast and empties into the Chesapeake Bay, approximately 70 miles (112.7 km) southeast of this portion of the project area, thence into the Atlantic Ocean. The potential water treatment plant site is drained by Long Creek, which empties into the North Anna River approximately 1 mile (1.6 km) south of this portion of the project area. The North Anna River joins the South Anna River approximately 8 miles (12.9 km) southeast of the potential water treatment plant site to form the Pamunkey River. The Pamunkey flows generally southeast before joining the Mattaponi River to form the York River, which empties into the Chesapeake Bay.

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Soils

Fertile, well-drained soils attracted both humans and game over millennia. Moreover, the wild grasses, fruits, and seeds consumed by people both before and after the adoption of agriculture flourished in such settings. As a consequence, numerous archaeologists have cited the correlation between the distribution of level to gently sloping, well-drained, fertile soils and archaeological sites (e.g., Lukezic 1990; Potter 1993; Turner 1976; Ward 1965). Soil scientists classify soils according to natural and artificial fertility and the threat posed by erosion and flooding, among other attributes. Soil Classes 1 and 2 represent the most fertile soils, those best suited for not only agriculture but for a wide range of uses. Of course, soil productivity must be considered in relation to the productivity of the surrounding soils.

The soils at the potential raw water intake site portion of the project area are mapped entirely as the Wickham fine sandy loam. These well-drained Class 2 soils are well suited for occupation from both the historic and prehistoric periods. Two soil types are mapped at the potential water treatment plant site, excluding that area mapped as part of the quarry pits (Table 1). They are both subunits of the Kempsville-Emporia complex, but are differentiated on the basis of slope. Those Kempsville-Emporia soils having a slope between 2 and 6 percent are considered Class 2 for land capability and may contain sites from both the historic and prehistoric periods. The same soils with a slightly greater degree of slope, between 6 and 10 percent, are considered class 3 and, while sites may be located in these areas, they are not ideal locations for occupation from any time period.

Table 1: Soils at the Potential Water Treatment Plant Site (Soil Survey Staff 2019).

Soil	Class	Percentage of Project Area	Characteristics
Kempsville-Emporia complex, 6–10% slopes	3	75.3	Well-drained, derived from loamy marine deposits
Kempsville-Emporia complex, 2–6% slopes	2	23.5	Well-drained, considered prime farmland
Pits, gravel	8	1.1	Quarry pits, topsoil removed and/or disturbed

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SURVEY METHODOLOGY

Archaeological Survey

The goal of the archaeological survey was to identify any archaeological sites located within the project area and make recommendations regarding their eligibility for inclusion in the NRHP. The survey methods employed to meet this goal were chosen with regard to the project's scope (i.e., the project's potential to affect significant resources, should they be present), the potential of the archaeological project area to contain significant archaeological resources, and local field conditions. Based on the rural environmental setting, the archaeological project area was judged to have moderate to high potential for intact archaeological resources.

The survey consisted of subsurface testing throughout the portion of the project area previously determined to have the potential for intact soils during the Phase IA survey. Shovel test pits (STPs) were excavated at 50-foot (15.2-m) intervals along transects across the testable areas. The provenience information for each STP was coded using a trinomial system which included the area number, followed by an alphabetic transect designation, and finally a numerical designation for the STP. For purposes of the present survey, Area 1 corresponded with the potential raw water intake site and Area 2 corresponded with the potential treatment plant site (e.g., STP 1-B-4 is the 4th shovel test located on the B transect in the potential raw water intake site). STPs were not excavated in areas of obvious disturbance or which would not have been suitable for habitation such as drainages or slopes. STPs measured approximately 1.25 feet (38.1 cm) in diameter and were excavated to penetrate at least 0.3 foot (9.1 cm) into sterile subsoil where possible. Shovel test radials were excavated at 25-foot (7.6-m) intervals in cardinal directions along the grid from shovel tests that produced cultural materials.

All soil excavated from STPs passed through 0.25-inch (0.6-cm) hardware mesh cloth. Each natural stratum was given a stratum designation (e.g., I, II, III) in order to delineate stratigraphic relationships. All artifacts were recovered and bagged by stratum to the extent possible. Transect and shovel test designation, level, excavator, date and material recovered were recorded on field tags. Soil conditions, weather information, and notations on disturbances were recorded within field notes.

Due to the location of survey within the potential water treatment plant near landscapes which hosted Civil War military activity during the actions at North Anna in 1864, a metal detector survey was conducted concurrent with the shovel-testing survey across portions of the project area that were not visibly disturbed by grading or other ground-disturbing activities and where vegetation permitted use of the instrument. Where metal detecting was conducted, transects were spaced at 10-foot (3-m) intervals and surveyed using a Fisher Gold Bug metal detector. The area within and immediately adjacent to a newly identified Civil War earthwork (site 44CE0915/016-5199) was given complete coverage using both the Fisher Gold Bug and a Tesoro Cibola metal detector. Metal detecting was conducted in a zig-zag pattern along transects to ensure maximum coverage and was carried out by Dovetail

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staff with extensive experience in the use of metal detectors on military sites. Positive contacts were excavated and the locations of any contacts that yielded historic artifacts were mapped using a handheld GPS.

Laboratory Methodology

All archaeological specimens collected during the Phase I survey were transported to the Dovetail laboratory in Fredericksburg, Virginia for processing and analysis. Prior to washing, each bag was cross-referenced with the field log to confirm provenience information and contents. Stable objects were washed with tap water and a soft brush with special attention paid to edges of ceramics and glass to better aid in identification. After washing, the artifacts were grouped by provenience and placed on a drying rack. Once dry, the artifacts were cataloged for analysis. Specific characteristics were described using currently accepted terminology and were entered into an Access database.

Following the cataloging, all artifacts were prepared for final curation. This was completed according to the Virginia State Collections Management Standards. This process included: one, labeling all artifacts using acryloid B-72 clear lacquer 25 percent solution and archival, acid-free ink pens; two, bagging all artifacts in 4-mil plastic ziplock bags; and three, organizing and labeling each Hollinger box.

Specific ware types and manufacture dates were identified using Adams (2002), Bartoviks (1980), Greer (1970), Nelson (1968), Noël Hume (1991), Pittman et al. (1987), and South (1977). Non-tool prehistoric lithics were identified using Andrefsky (1998), Odell (2004), and Whittaker (1994). Cobbles which exhibited reddening, crazing, or irregular fracture patterns as a result of heating but with no evidence of flake removal or use as abrading or pounding tools, were classified as thermally altered stone (TAS) (Pagoulatos 1992:115–129; Petraglia 2002:241–269). Hafted bifaces and prehistoric ceramics, if recovered, were assigned types using standard regional typologies (i.e., Coe 1964; Custer 1989; Ritchie 1971).

Architectural Survey

The reconnaissance architectural study included an inspection of the architectural project area, defined as the limits of disturbance plus a 500-foot (152.4-m) buffer around the proposed building location and pipeline corridor at the potential raw water intake site and a 1,000-foot (304.8-m) buffer around the potential water treatment plant. The architectural survey was conducted to identify any historic buildings, structures, objects, or districts over 50 years in age within the architectural study area. Each resource was evaluated in regards to Criterion A, for its association with events having a significant contribution to the broad patterns of our history; Criterion B, for its association with people significant in our nation's history; and Criterion C, for its embodiment of distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or possess high artistic values. As part of the current survey, these above-ground resources were not evaluated under Criterion D as architectural resources for its potential to yield information important in history. Criteria considerations were taken into account only where necessary.

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A historic map review provided information on historic land use and area occupants. Maps and historic aerials from the nineteenth and twentieth centuries were consulted. This information provided data on the potential for unrecorded resources in the architectural study area.

The goals of the fieldwork were to identify and locate previously recorded and previously unrecorded above-ground resources over 50 years in age within the architectural project area. Each resource meeting the survey criteria was evaluated for architectural significance and historic and physical integrity. During the architectural work, the project's architectural project area was surveyed through a combination of a vehicular and pedestrian reconnaissance. Identified architectural resources were documented through photographs, written notes, and mapping. This includes buildings, objects, and districts. Digital photos were taken of each resource documenting the primary elevation, oblique angles, and general setting. The information obtained during the survey was then used to update or generate a DHR Virginia Cultural Resource Information System (VCRIS) form, to print archival-quality, color photographs, and to make recommendations on each resource's NRHP potential.

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RESULTS OF THE ARCHAEOLOGICAL SURVEY

The archaeological Phase IB project area contains the potential raw water intake site, which comprises the proposed building location plus a 50-foot (15.2-m) buffer and the associated pipeline corridor leading to U.S. 17, as well as the potential water treatment plant plus a 100-foot (30.5-m) buffer. The two areas are separated by approximately 24.5 miles (39.4 km) and comprise very different environmental settings. The results of testing in each area are discussed separately below. For purposes of the present archaeological survey, Area 1 corresponded with the potential raw water intake site and Area 2 corresponded with the potential treatment plant site

Potential Raw Water Intake Site

The potential raw water intake site comprises approximately 5 acres (2 ha) in an agricultural field along a high bluff of the Rappahannock River southeast of Fredericksburg, Virginia (Photo 6). The area is on the western edge of the inside of a large meander in the river historically known as Moss Neck. The potential raw water intake site also includes an approximately 3,500-foot (1,066.8-m) pipeline corridor leading from the proposed raw water intake site to U.S. 17. At the time of the survey, the potential intake site itself was planted in corn, and the potential pipeline corridor was planted in corn and soybeans. The archaeological survey of the potential raw water intake site included the excavation of 117 STPs along the primary testing grid, as well as an additional eight radial STPs excavated around shovel tests from which artifacts were recovered (Figure 6 and Figure 7, p. 18–19).



Photo 6: Site 44CE0914, Facing Northwest. Treeline marks bank of Rappahannock River.

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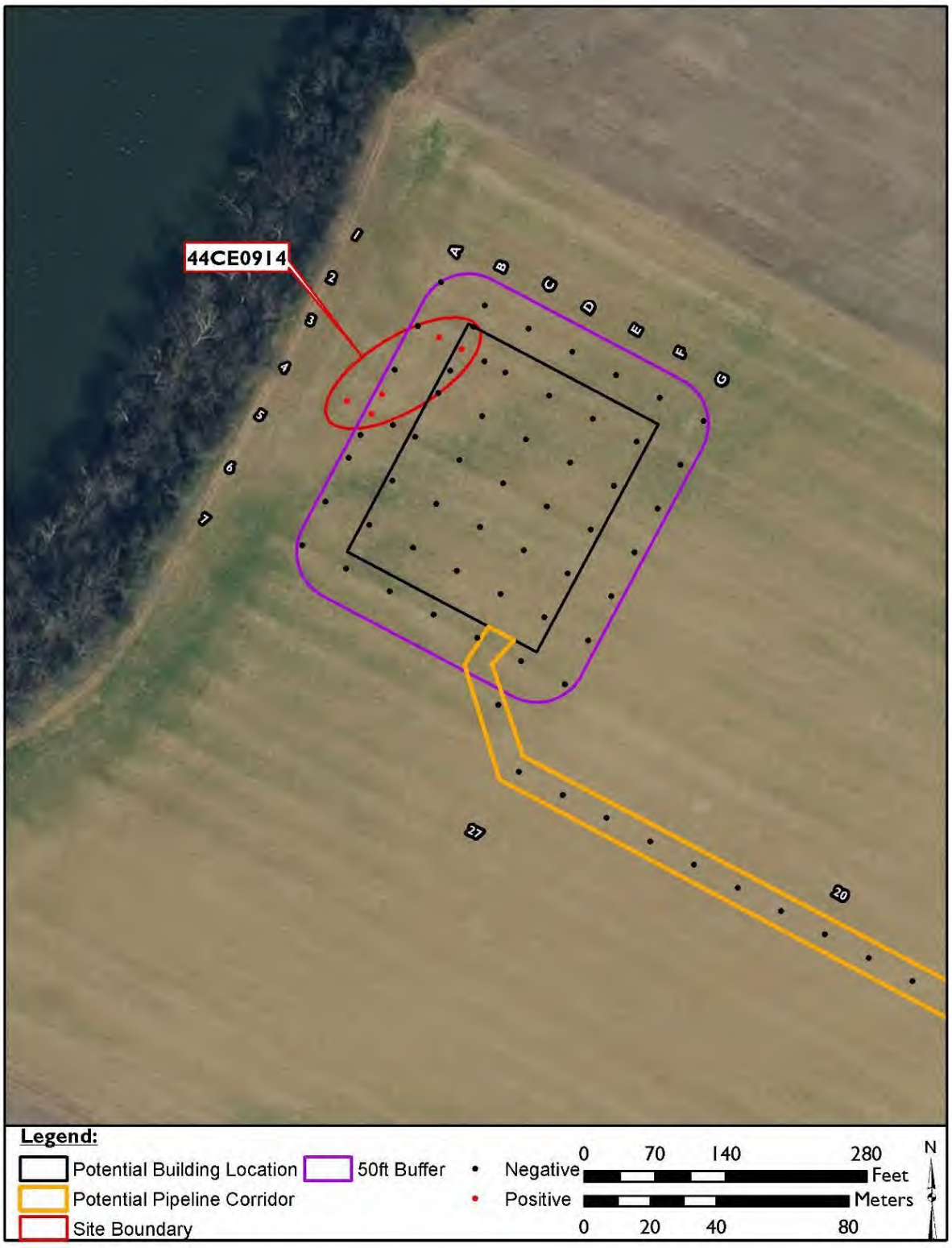


Figure 6: Locations of STPs and Site 44CE0914 in Northern Portion of the Potential Raw Water Intake Site (VGIN 2017).

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Figure 7: Locations of STPs in Southern Portion of the Potential Raw Water Intake Site (VGIN 2017).

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Shovel test profiles within the potential raw water intake site comprised a plow zone over subsoil. STPs averaged 1.1 feet (33.5 cm) in depth, with the deepest shovel test extending 1.8 feet (54.9 cm) below ground surface. The plow zone extended to an average depth of 0.7 feet (21.3 cm). A typical STP profile in the northern portion of the potential raw water intake site consisted of a dark yellowish brown (10YR 4/4) to dark reddish brown (5YR 3/4) sandy loam plow zone overlying a dark yellowish brown 10YR 4/6) sandy loam to yellowish red (5YR 4/6) sandy clay B horizon (Figure 8 and Figure 9, p. 21). In the pipeline corridor section of the potential raw water intake site, a typical profile comprised a dark yellowish brown (10YR 4/4) silt loam overlying a yellowish brown (10YR 5/6) silt loam B horizon (Figure 10, p. 21). A single archaeological site was identified at the potential raw water intake site (Figure 6, p. 18; Figure 11, p. 22).

Site 44CE0914 Description

Site 44CE0914 is a low-density lithic scatter dating to an unknown prehistoric period located in the northern portion of the potential raw water intake site. It was identified on the basis of two positive STPs along the primary testing grid and three positive radial tests. The assemblage from the site comprised five pieces of quartz debitage. No temporally diagnostic artifacts were recovered, and all artifacts were recovered from the plow zone (see Figure 8 and Figure 9, p. 21). Site soils were typical of those observed throughout the potential raw water intake site. No features or intact buried ground surfaces were identified.

Site 44CE0914 Evaluation and Significance

The significance of site 44CE0914 was evaluated in relation to the NRHP eligibility criteria, in particular Criterion D. There are no known significant associations between these deposits and a significant historical event (Criterion A). There are no known associations with significant persons (Criterion B), and the nature of the site deposits preclude them from illustrating distinctive characteristics of a type, period, or method of construction (Criterion C). Because artifact-bearing soils at the site have been disturbed by plowing, and due to the low artifact density, the site is unlikely to contribute important information about the prehistory of Caroline County or the Rappahannock River valley more generally (Criterion D). Therefore, **Dovetail recommends that site 44CE0914 is not eligible for listing in the NRHP.**

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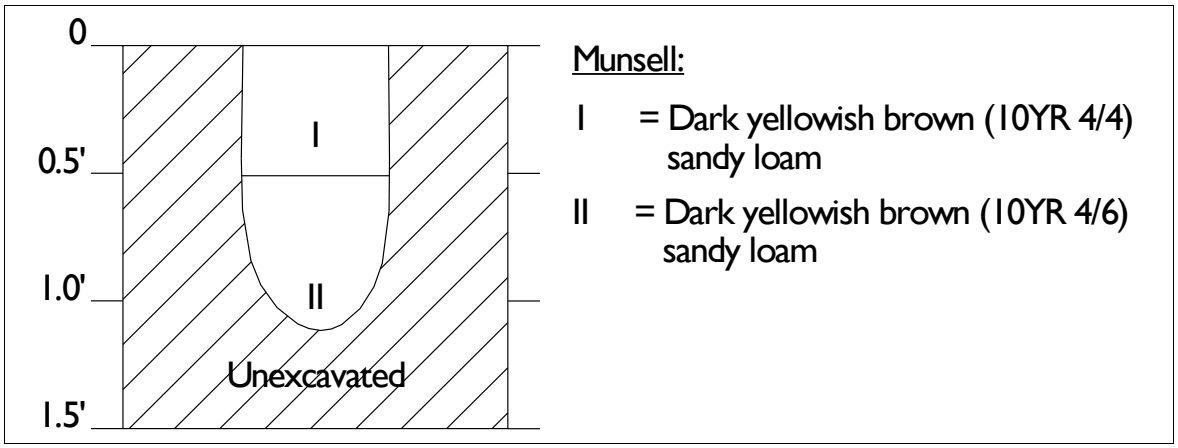


Figure 8: Profile of STP 1-A-4.

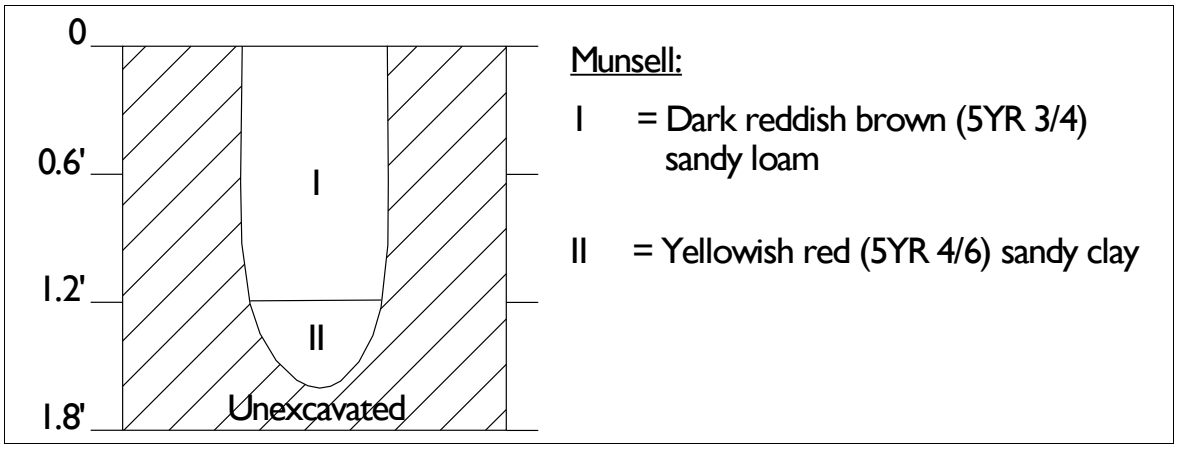


Figure 9: Profile of STP 1-B-2.

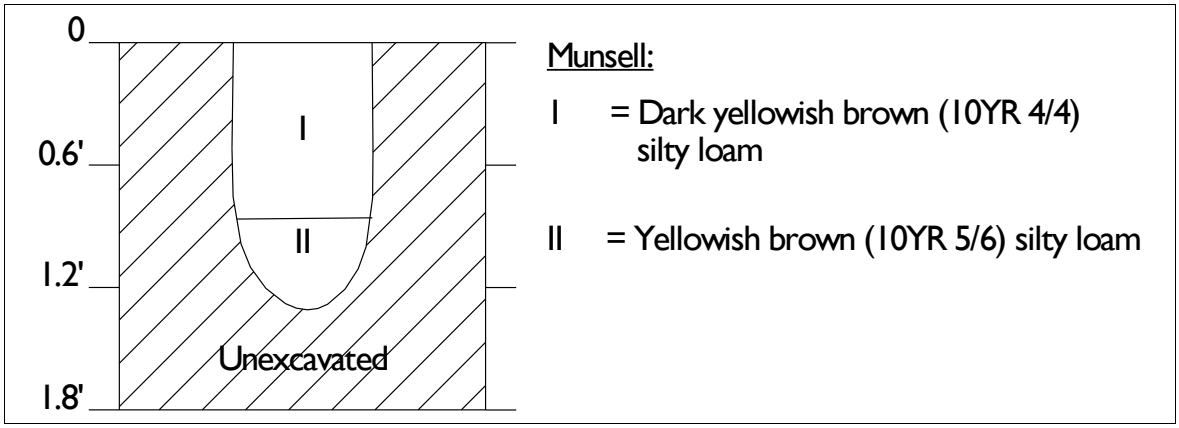


Figure 10: Profile of STP 1-H-21.

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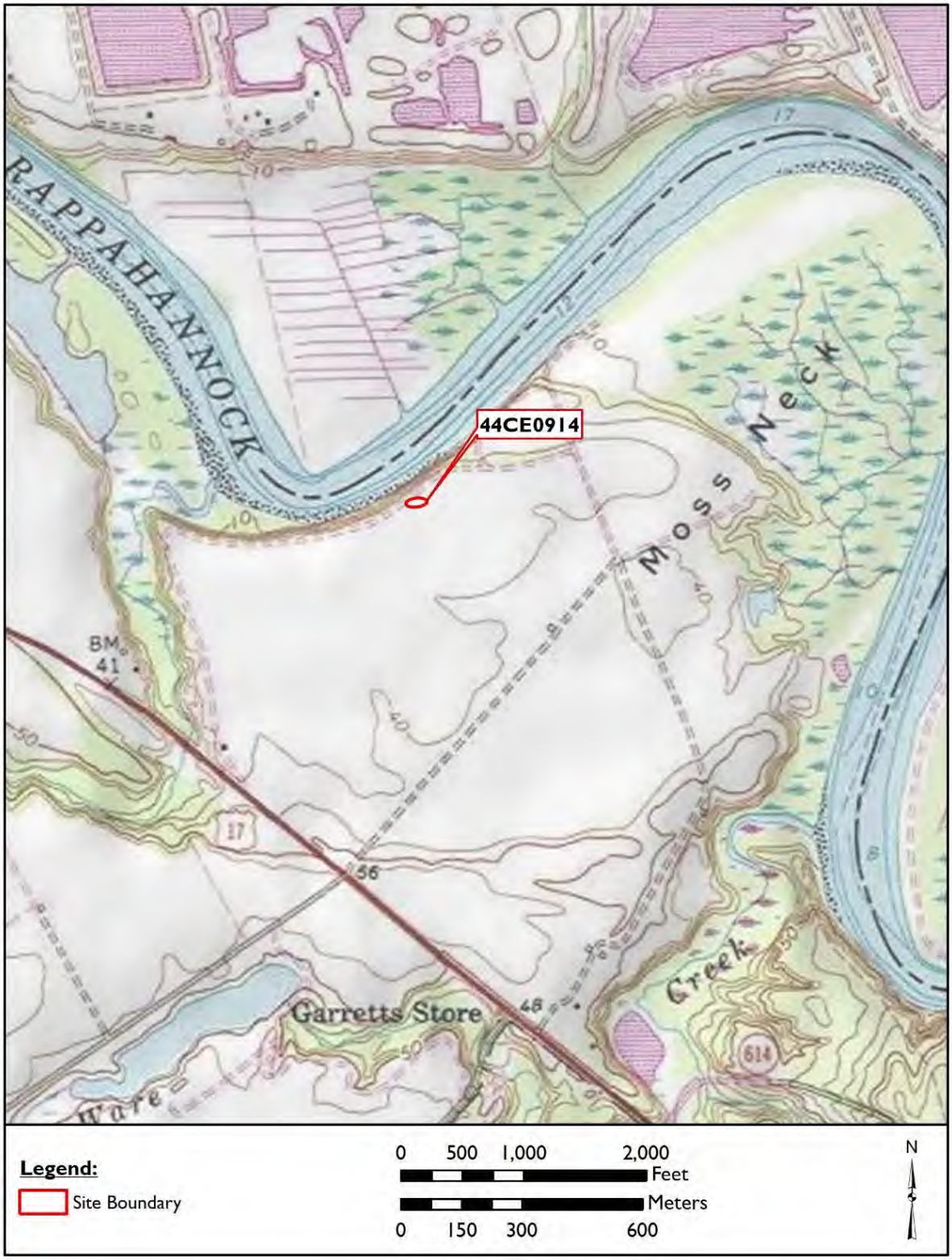


Figure 11: Location of Site 44CE0914 on Topographic Map (Esri 2019b).

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Potential Water Treatment Plant

The potential water treatment plant site is located west of U.S. 1 south of Ruther Glen, Virginia, approximately 24.5 miles (39.4 km) southwest of the potential raw water intake site. It is located in a forested area surrounded to the south and west by an area formerly used by a crushed stone mining operation. An ephemeral drainage runs southwest through the central portion of the potential water treatment plant site, and the slope to another ephemeral drainage characterizes the northwest boundary of the area.

The archaeological survey of the potential water treatment plant site included the excavation of 254 STPs along the primary testing grid, as well as an additional four radial STPs excavated around a positive shovel test (Figure 12, p. 24). Shovel test profiles within the potential water treatment plant site comprised a plow zone over subsoil. STPs averaged 1.0 feet (30.5 cm) in depth, with the deepest shovel test extending 1.7 feet (51.8 cm) below ground surface. The plow zone extended to an average depth of 0.6 feet (18.3 cm). A typical STP profile at the potential water treatment plant site consisted of a yellowish brown (10YR 5/4) to very pale brown (10YR 7/3) sandy loam plow zone overlying a very pale brown (10YR 7/4) sandy loam B horizon (Figure 13 and Figure 14, p. 25). No features or buried surfaces were identified in any of the STPs excavated at the potential water treatment plant site A number of STP locations along the northwestern edge of the potential water treatment plant site were left unexcavated due to slope, while a number of other STP locations were not excavated due to the presence of a drainage or visible disturbance.

In addition to the shovel-testing survey, a metal detector survey was also carried out at the potential water treatment plant site due to the proximity of the survey area to events associated with the 1864 actions at North Anna during the Civil War. The metal detector survey resulted in the recovery of eight artifacts. Seven of these contributed to the identification of an archaeological site 44CE0915, and the remaining one was considered an isolated find (ISF 1). Several other metal detector hits were excavated but discarded in the field because they were clearly modern. The discarded metal detector hits included a dog collar, several shotgun shells, and miscellaneous metal refuse. The isolated find consisted of an iron buckle. Although the buckle might be related to the occupation of nearby site 44CE0915, it was not temporally diagnostic and could not be definitively associated with that site. Isolated finds generally refer to spatially discrete areas with extremely low-density artifact assemblages that result from simple loss or casual or single-episode discard. The probability that further work at isolated finds will contribute significant information to our understanding of the history of an area is extremely low; therefore, by definition, **ISF 1 is not eligible for listing in the NRHP.**

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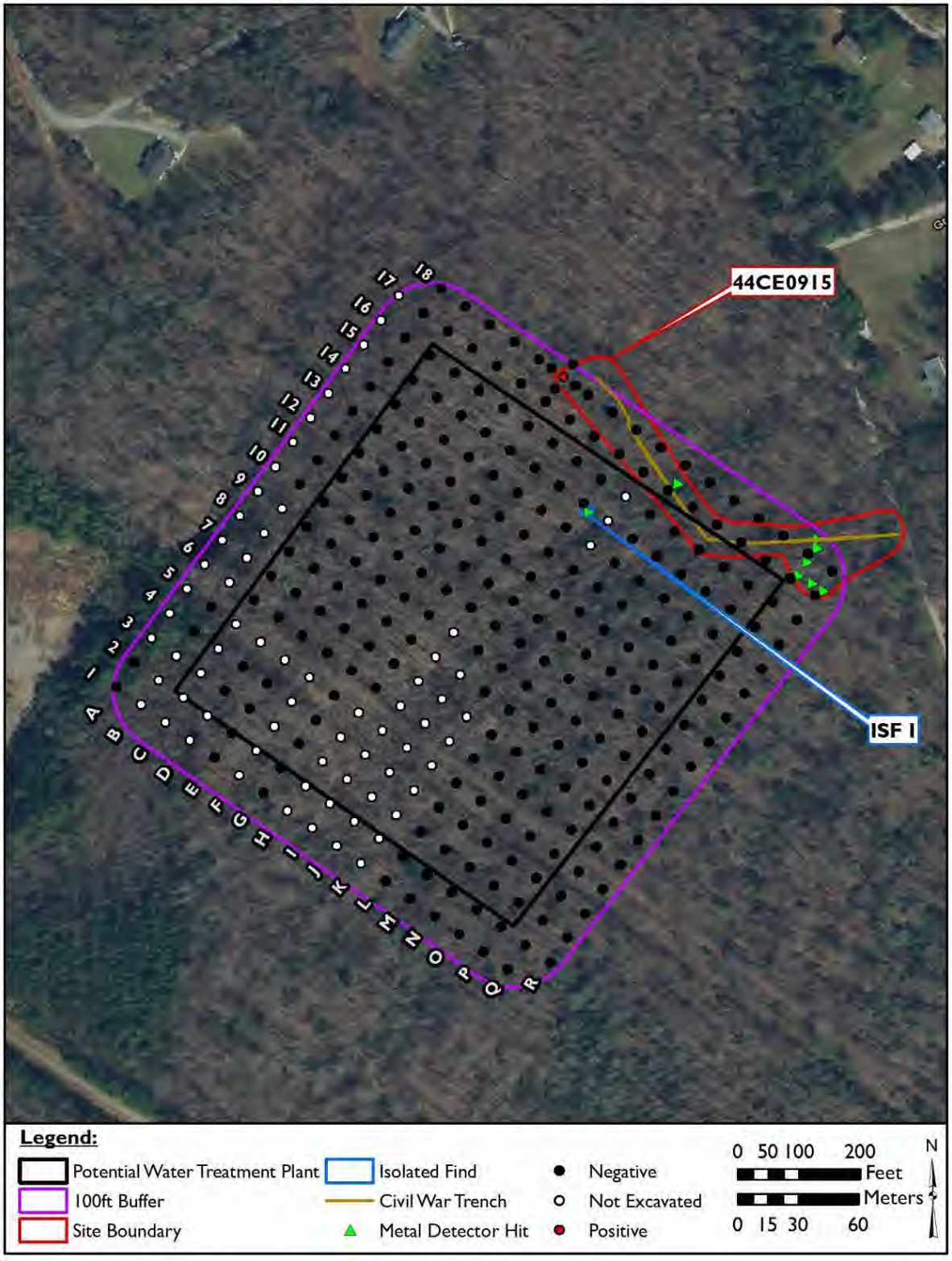


Figure 12: Locations of STPs, Metal Detector Hits, and Site 44CE0915 in the Potential Water Treatment Plant Site (VGIN 2017).

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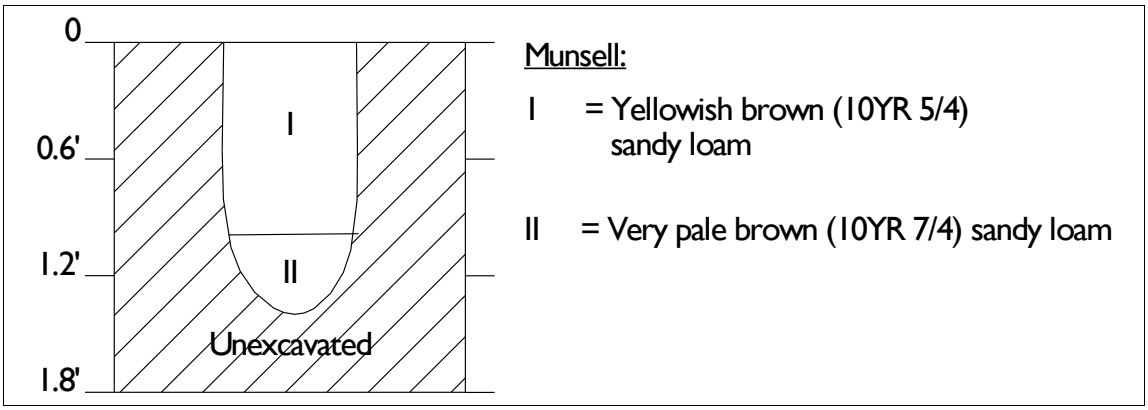


Figure 13: Profile of STP 2-G-18.

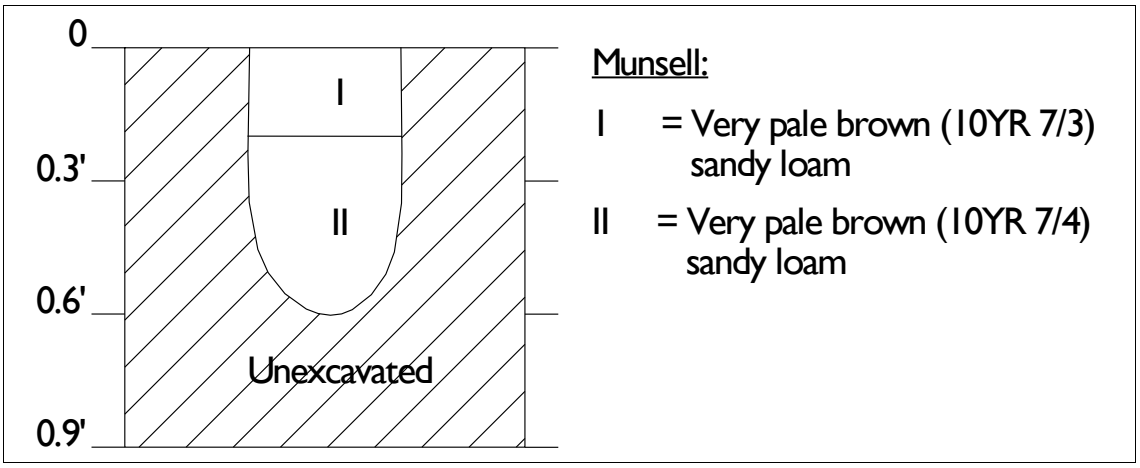


Figure 14: Profile of STP 2-G-2.

Site 44CE0915 Description

Site 44CE0915 (architectural resource 016-5199) was identified on the basis of one positive STP, seven metal detector hits, and the presence of a Civil War earthwork (Figure 15, p. 26). The artifact assemblage from the site consisted of five cut nails, one cut spike, an amorphous lead fragment, and a single sherd of ironstone. The nails and spike were all recovered from a fairly small area near the eastern end of the earthwork and may represent a structure associated with it. Site soils were similar to those seen through the remainder of the potential water treatment plant site, and all artifacts were found within the plow zone (see Figure 13 and Figure 14, p. 25).

The earthwork at site 44CE0915 comprises a typical fortified entrenchment, consisting of a trench excavated to approximately 2 feet (0.6 m) below grade with the excavated soil used to form a defensive berm on the downhill side of the trench (Photo 7 and Photo 8, p. 27). The earthwork at site 44CE0915 extends for approximately 630 feet (192 m) altogether and is interrupted in three locations. The entrenchment appears to be the same one depicted in Michler's 1864 map of North Anna (Figure 16, p. 28; Figure 17, p. 29). The map depicts two separate earthworks, separated by a natural drainage. This drainage coincides with the

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easternmost break in the earthwork at site 44CE0915. A break toward the western end of the earthwork may have accommodated a road also depicted on the Michler map, although no road trace was observed during the field investigations. A third break in the entrenchment was located near its far western end and may represent an artillery emplacement.

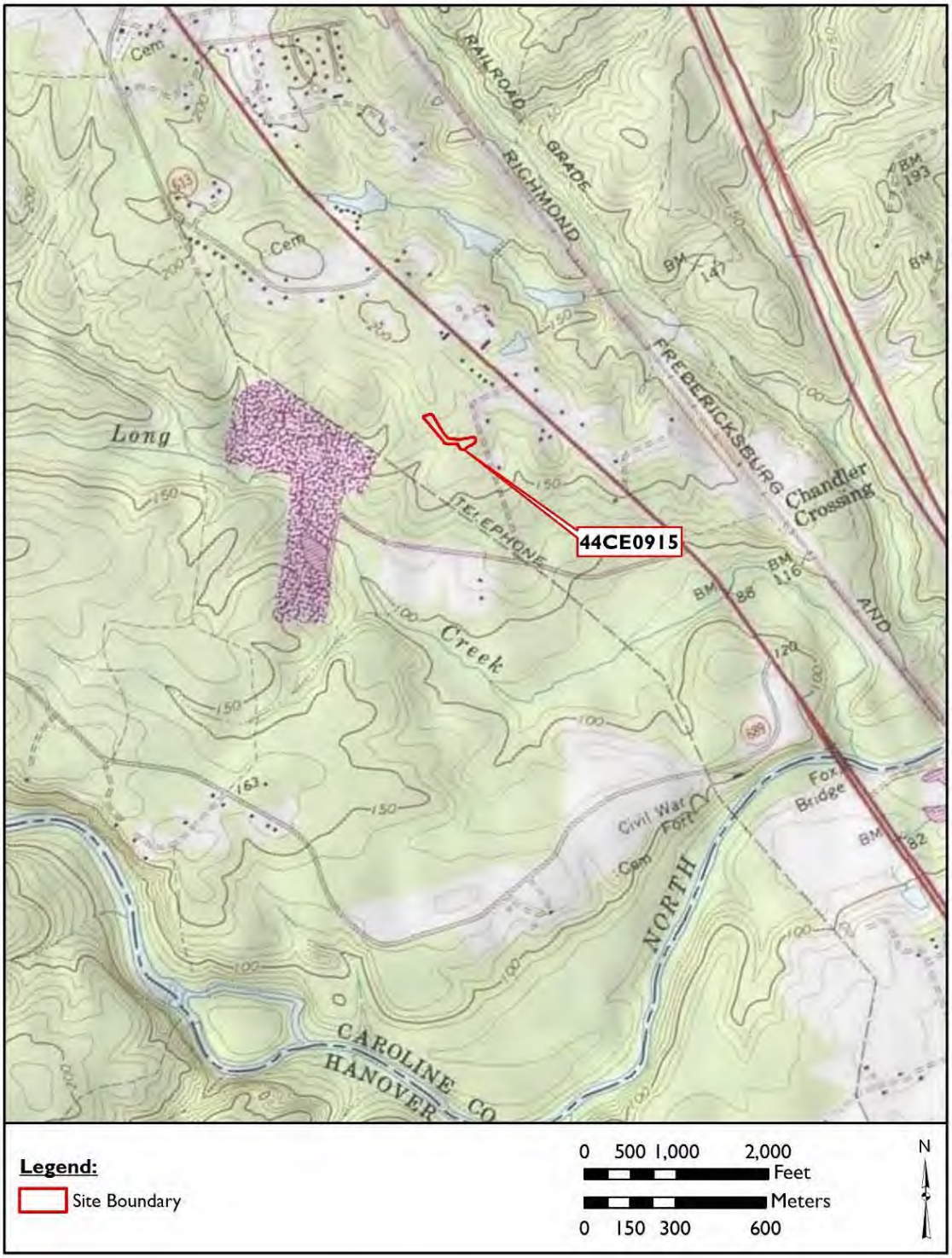


Figure 15: Location of Site 44CE0915 on Topographic Map (Esri 2019b).

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Photo 7: Earthwork at Site 44CE0915, Facing West.



Photo 8: Earthwork at Site 44CE0915, Facing East.

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Figure 16: Portion of Michler's Map of Fortifications in the Vicinity of the North Anna River in May of 1864 (Michler 1867). Red circle indicates earthworks associated with site 44CE0915.

Michler's map does not indicate who occupied the fortifications at site 44CE0915; however, a map created by the American Battlefield Trust shows troops of U.S. Brigadier General Robert O. Tyler's 8th New York Artillery regiment in roughly the location of the site on May 23, 1864. Tyler's unit remained in reserve in this position, behind the troops of Major General David B. Birney throughout the events of that day (Rhea 2000, Scott 1891). By the

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end of the following day, Tyler's men had moved south of Long Creek, and the earthworks at site 44CE0915 were likely never reoccupied.



Figure 17: Location of the Potential Water Treatment Plant Site Overlaid onto Michler Map (Michler 1867; VGIN 2017).

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Site 44CE0915 Evaluation and Significance

The significance of site 44CE0915 was evaluated in relation to the NRHP eligibility criteria. The site is associated with a significant historical event, the Civil War Battle of North Anna in May of 1864 (Criterion A). There are no known direct associations between the site and particular significant persons (Criterion B). The defensive earthworks at the site are well-preserved and, as such, are illustrative of distinctive characteristics of a type, period, or method of construction (Criterion C). An above ground feature, in the form of the earthworks is present at the site, and the possible evidence for an associated structure in the form of a concentration of cut nails suggests that the site has the potential to contribute significant information to our understanding of local and national history during the Civil War (Criterion D). Therefore, **Dovetail recommends that site 44CE0915/016-5199 is potentially eligible for listing in the NRHP under Criteria A, C, and D.**

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RESULTS OF THE ARCHITECTURAL SURVEY

The architectural investigation of the Caroline County Water Supply project involved a reconnaissance survey that identified all previously recorded architectural resources and all previously unrecorded above-ground resources over 50 years in age within the architectural project area, defined as the limits of disturbance plus a 500-foot (152.4-m) buffer around the proposed building location and pipeline corridor at the potential raw water intake site and a 1,000-foot (304.8-m) buffer around the potential water treatment plant. The current survey identified a total of eight resources in the architectural project area that meet the survey criteria, one within the potential raw water intake site architectural project area and seven within the potential water treatment plant project area.

Potential Raw Water Intake Site

Only one resource was identified within the potential raw water intake site architectural project area, a newly recorded single-family dwelling and associated outbuildings known as House and Corn Crib, 19095 Tidewater Trail (016-5192) (Table 2; Figure 18, p. 32). There are two single-family dwellings at 19095 Tidewater Trail. The first house, built in circa 1940, is a one-story, four-bay, cross-gabled house with a concrete-block foundation. The structural system is clad in vinyl and the roof is sheathed in asphalt shingles. Fenestration includes a single-leaf, wood door with two lights and a metal storm door and one-over-one, double-hung-sash, vinyl and metal windows. The other house, built in circa 2011, is a one-and-one-half story, seven-bay, side-gabled house clad in vinyl siding and brick veneer. It features vinyl or fiberglass fenestration. Two sheds and one carport are located to the southeast of the 1940 house. The corn crib, located to the northeast of the 1940 house, has a frame structural system and has mostly fallen down. Heavy vegetation surrounds the building and it is no longer in use. No known significant person or event is associated with the 1940 house and corn crib. The heavy use of replacement materials as well as the disrepair of the corn crib has affected the integrity of the resource. It is for these reasons that the House and Corn Crib are **recommended not eligible for the NRHP**.

Table 2: Newly Recorded Resource Within the Potential Raw Water Intake Site Architectural Project Area.

DHR #	Name/ Address	Date of Construction	Dovetail Recommendation	Photograph
016-5192	House and Corn Crib, 19095 Tidewater Trail	ca. 1940	Not Eligible	

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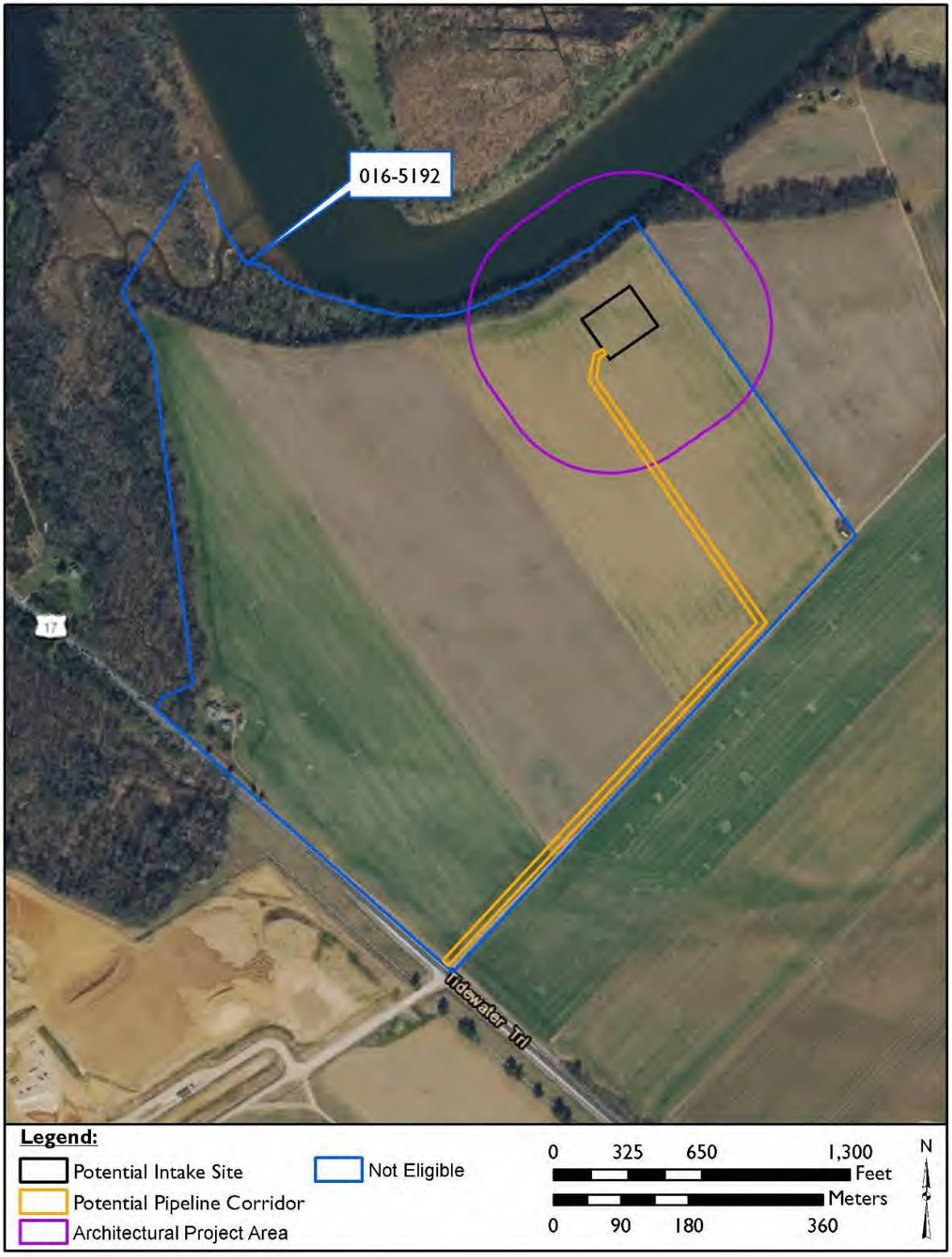


Figure 18: Newly Recorded Architectural Resources Surveyed in the Potential Raw Water Intake Site Architectural Project Area (VGIN 2017).

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Potential Water Treatment Plant

Previously Recorded Resources Not Physically Revisited During the Current Survey

Dovetail identified one previously recorded architectural resource, the North Anna Battlefield (042-0123), within the potential water treatment plant architectural project area that was most recently surveyed less than five years ago (Table 3; Figure 19, p. 34). In accordance with DHR guidelines, it was not physically revisited during this project. The NRHP eligibility of this resource has not changed.

Table 3: Previously Recorded Resource Not Physically Revisited During the Current Survey within the Potential Water Treatment Plant Architectural Project Area.

DHR #	Name	Date	Previous Eligibility Determination	Current NRHP Recommendation
042-0123	North Anna Battlefield	1864	Potentially Eligible, 2016	Remains Potentially Eligible

Newly Identified Resources

A total of six newly recorded resources that meet the NRHP age criteria were identified within the potential water treatment plant architectural project area (Table 4, pg. 35; Figure 20, p. 37). The resources consist of three dwellings, one former dwelling that has been converted into a church, one commercial building, and one Civil War-era earthwork.

The Civil War-era earthwork (016-5199/44CE0915), as discussed in the archaeological site description on page 25, is located at the potential water treatment plant site, approximately 2.3 miles (3.7 km) south of Interchange 104 on I-95. It remains largely intact and runs approximately 630 feet (192 m) long with an average of 2 feet (0.6-m) deep in areas. The earthwork comprises two separate sections, one on either side of a natural drainage. This drainage coincides with the easternmost break in the earthwork. A break toward the western end of the earthwork may have accommodated a road also depicted on the Michler map, although no road trace was observed during the field investigations (Michler 1867). A third break in the entrenchment was located near its far western end and may represent an artillery emplacement. The earthwork is associated with the Union Army's operations in the area during the actions at North Anna, particularly with the U.S Brigadier General Robert O. Tyler's 8th New York Artillery regiment. The North Anna Battlefield (042-0123) is located nearby. Given that this largely intact earthwork is associated with events that took place at the Battle of North Anna during the Civil War, it is **recommended that this resource is potentially eligible for inclusion in the NRHP under Criterion A.** Furthermore, based on its integrity and its representation of a distinctive form of construction, it is **recommended that this resource is potentially eligible for inclusion in the NRHP under Criterion C.** As an architectural resource, this resource was not evaluated under Criterion D. For the evaluation of this resource under Criterion D, see the archaeological write-up on page 25.

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Figure 19: Previously Recorded Resource Not Physically Revisited During Current Survey (VGIN 2017).

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Table 4: Newly Recorded Resources Surveyed During this Effort.

DHR #	Name	Date	Current NRHP Recommendation	
016-5193	Commercial Building, 26140 Jefferson Davis Highway	ca. 1947	Not Eligible	
016-5195	House, 26164 Beverly Circle	ca. 1960	Not Eligible	
016-5196	House, 26210 Jefferson Davis Highway	ca. 1967	Not Eligible	

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DHR #	Name	Date	Current NRHP Recommendation	
016-5197	Church (former house), 26255 Jefferson Davis Highway	ca. 1950	Not Eligible	
016-5198	House, 26296 Jefferson Davis Highway	ca. 1948	Not Eligible	
016-5199 (44CE0915)	Earthwork, Gravel Hill Road	ca. 1864	Potentially Eligible, A and C (see archaeological section for Criterion D recommendations)	

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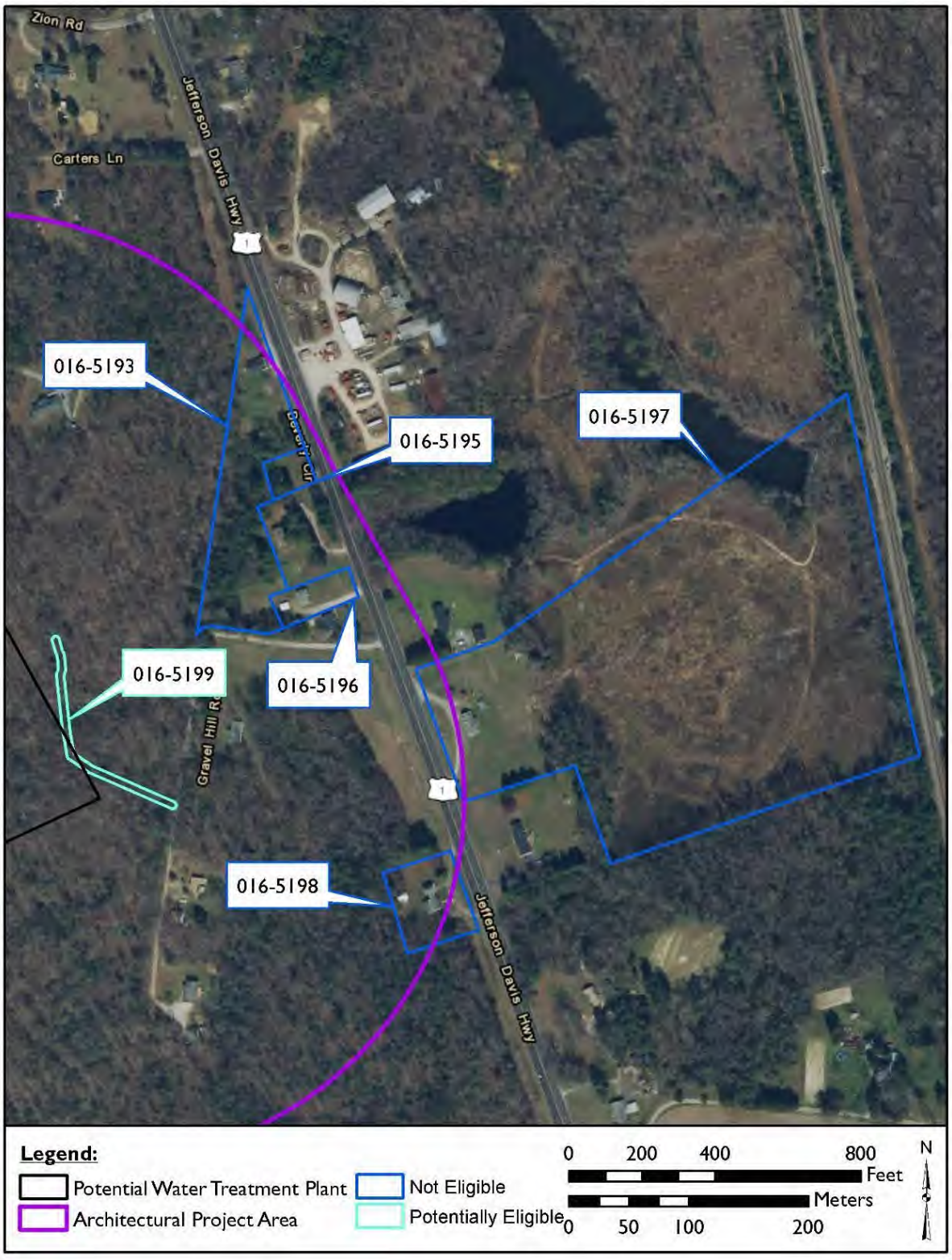


Figure 20: Newly Recorded Architectural Resources Surveyed in the Potential Water Treatment Plant Architectural Project Area (VGIN 2017).

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Three of the newly recorded resources surveyed during this project are single-family dwellings. These single-family dwellings range in construction date from 1948 to 1967 and tend to be one- to one-and-a-half-story, Minimal Traditional- and Ranch-style houses set on poured-concrete or concrete-block foundations, clad in aluminum or vinyl siding, and covered by a gabled roof. The dwellings often lack high levels of decorative embellishment, and it is common for them to be accompanied by outbuildings such as prefabricated sheds, garages, and well houses.

The remaining two newly recorded resources consist of one former single-family dwelling that has been converted to a church and one commercial building. The former single-family dwelling (016-5197) now functions as the Carolina Christian Center and is currently for sale. The building, constructed circa 1950, is in the Cape-Cod form and follows the same architectural pattern as the other dwellings in this region. Several sections of the building have been modified with replacement materials. Several outbuildings, such as a well-house, sheds, a barn, and a carport, are associated with this resource.

The commercial building is located closely along Jefferson Davis Highway. Commercial buildings in the area tend to be simple in design and feature concrete, metal, and vinyl as their main building materials. The commercial building is an abandoned former restaurant and road-side gas station (016-5193). It sits on a concrete block foundation and either has a gable-style roof clad in asphalt siding. The architecture of the building follows the pattern of design for commercial buildings in the area. Furthermore, several areas have been modified with replacement materials.

As a whole, these six resources have undergone modifications and have lost much of their original historic fabric by siding or window replacement, the construction of additions, or modifications of historic elements, such as porches. In addition, they have no outstanding architectural elements and are not the known works of a master. For these reasons, these six newly recorded resources are **recommended not eligible for the NRHP under Criterion C.** They have no known association with a significant event or person and as such are **recommended not eligible for the NRHP under Criteria A or B. As architectural resources, these properties were not evaluated under Criterion D.**

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SUMMARY AND RECOMMENDATIONS

On behalf of Draper Aden, Dovetail conducted a Phase IB cultural resource survey of the Caroline County Water Supply project area between July 29 and August 9, 2019. In association with Draper Aden, Caroline County is planning the installation of a water line and associated facilities, collectively known as the Caroline County Water Supply project. A cultural resource survey is required for this project due to the involvement of the United States Army Corps of Engineers and the application for a water withdrawal permit from the Virginia Department of Environmental Quality. The project area for this study comprised two separate areas in Caroline County, Virginia which are part of the larger Caroline County Water Supply project. The potential raw water intake site, including an associated pipeline corridor leading to U.S. 17, is located in northern Caroline County and totals approximately 5 acres (2 ha). The potential treatment plant site is located in the southwestern portion of the county and totals approximately 18 acres (7.3 ha). The cultural resource survey included archaeological and architectural Phase IB surveys based on the results of a previous Phase IA reconnaissance (Schnur et al. 2019) and coordination with the DHR. The archaeological survey included pedestrian and subsurface survey, supplemented by controlled metal detecting, of the archaeological project area, defined as the limits of disturbance plus a 50-foot (15.2-m) buffer around the proposed building location at the potential raw water intake site and a 100-foot (30.5-m) buffer around the potential water treatment plant. The architectural study area—defined as the limits of disturbance plus a 500-foot (152.4-m) buffer around the proposed building location and pipeline corridor at the potential raw water intake site and a 1,000-foot (304.8-m) buffer around the potential water treatment plant—was also surveyed to identify historic resources over 50 years in age and make recommendations on their NRHP eligibility.

During the archaeological survey, excavation of 383 STPs and recovery of eight artifacts led to the identification of two archaeological sites and one isolated find. Isolated finds generally represent casual or single-episode discard rather than habitation sites or activity areas. As a result, **ISF 1 is, by definition, not eligible for inclusion in the NRHP.** Site 44CE0914 is a low-density scatter of lithic debitage from an unknown period in prehistory. Due to the low number of recovered artifacts and disturbance of the site by historic period plowing, **site 44CE0914 is recommended as not eligible for inclusion in the NRHP.** Site 44CE0915 is a Civil War defensive earthwork and associated artifact deposit associated with the Battle of North Anna in May of 1864. Due to its association with a significant historical event, the presence of a well-preserved earthwork, and overall potential of the site to contribute significant information to our present understanding of events during the Civil War, site **44CE0915 (architectural resource 016-5199) is recommended as potentially eligible for the NRHP under Criteria A, C, and D.**

The architectural survey identified a total of eight resources in the architectural project area that meet the survey criteria for this project (Table 5, p. 40). Of those, one resource was previously recorded with DHR and seven are newly recorded as part of the current project. Six of the resources (016-5192, 016-5193, 016-5195, 016-5196, 016-5197, and 016-5198) are

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recommended not eligible for the NRHP and one resource, the earthwork (016-5199/44CE0915), is **recommended potentially eligible for the NRHP under Criteria A, C, and D.** The North Anna Battlefield (042-0123) is **recommended to remain potentially eligible for the NRHP**.

Table 5: Recommendations for Cultural Resources Identified During the Survey.

DHR #	Name/Address/Site Type	Date of Construction or Site Occupation	Dovetail Recommendation	Project Location
016-5192	House and Corncrib, 19095 Tidewater Trail	ca. 1940	Not Eligible	Potential Raw Water Intake Site
44CE0914	Lithic Scatter, 19095 Tidewater Trail	unknown	Not Eligible	Potential Raw Water Intake Site
016-5193	Commercial Building, 26140 Jefferson Davis Highway	ca. 1947	Not Eligible	Potential Water Treatment Plant
016-5195	House, 26164 Beverly Circle	ca. 1960	Not Eligible	Potential Water Treatment Plant
016-5196	House, 26210 Jefferson Davis Highway	ca. 1967	Not Eligible	Potential Water Treatment Plant
016-5197	House, 26255 Jefferson Davis Highway	ca. 1950	Not Eligible	Potential Water Treatment Plant
016-5198	House, 26296 Jefferson Davis Highway	ca. 1948	Not Eligible	Potential Water Treatment Plant
016-5199, 44CE0915	Earthwork, Gravel Hill Road, Site 44CE0915	ca. 1864	Potentially Eligible Criteria A, C, and D	Potential Water Treatment Plant
042-0123	North Anna Battlefield	ca. 1864	Remain Potentially Eligible	Potential Water Treatment Plant

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APPENDIX A: STP CATALOG

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Area	Transect	STP	Radial	Level	Start Depth (ft)	End Depth (ft)	Soil Description	Comments
1	A	1		I	0.00	0.80	10YR 4/4 dark yellowish brown sandy loam	
1	A	1		II	0.80	1.20	10YR 4/6 dark yellowish brown sandy loam	
1	A	2		I	0.00	0.60	10YR 4/3 brown sandy loam	
1	A	2		II	0.60	1.00	10YR 5/8 yellowish brown sandy loam	
1	A	3		I	0.00	0.75	10YR 4/3 brown sandy loam	
1	A	3		II	0.75	1.15	10YR 5/8 yellowish brown sandy loam	
1	A	4	East	I	0.00	0.70	10YR 4/4 dark yellowish brown sandy loam	
1	A	4	East	II	0.70	1.10	10YR 4/6 dark yellowish brown sandy loam	
1	A	4	North	I	0.00	0.80	10YR 4/4 dark yellowish brown sandy loam	
1	A	4	North	II	0.80	1.10	10YR 4/6 dark yellowish brown sandy loam	
1	A	4	South	I	0.00	0.80	10YR 4/3 brown sandy loam	
1	A	4	South	II	0.80	1.20	10YR 5/8 yellowish brown sandy loam	
1	A	4	West	I	0.00	0.75	10YR 4/3 brown sandy loam	
1	A	4	West	II	0.75	1.20	10YR 5/8 yellowish brown sandy loam	
1	A	4		I	0.00	0.50	10YR 4/4 dark yellowish brown sandy loam	
1	A	4		II	0.50	1.10	10YR 4/6 dark yellowish brown sandy loam	
1	A	5		I	0.00	0.80	10YR 4/3 brown sandy loam	
1	A	5		II	0.80	1.20	10YR 5/8 yellowish brown sandy loam	
1	A	6		I	0.00	0.50	10YR 4/4 dark yellowish brown sandy loam	
1	A	6		II	0.50	1.00	10YR 4/6 dark yellowish brown sandy loam	
1	A	7		I	0.00	0.50	10YR 4/4 dark yellowish brown silty clay loam	
1	A	7		II	0.50	0.90	10YR 5/4 yellowish brown silty clay loam	
1	B	1		I	0.00	0.60	10YR 4/4 dark yellowish brown silty clay loam	
1	B	1		II	0.60	1.25	10YR 5/4 yellowish brown silty clay loam	
1	B	2	East	I	0.00	0.40	10YR 4/4 dark yellowish brown silty clay loam	
1	B	2	East	II	0.40	1.10	10YR 5/4 yellowish brown silty clay loam	
1	B	2	North	I	0.00	0.90	5YR 3/4 dark reddish brown sandy loam	
1	B	2	North	II	0.90	1.30	5YR 4/6 yellowish red sandy clay	
1	B	2	South	I	0.00	1.00	5YR 3/4 dark reddish brown sandy loam	
1	B	2	South	II	1.00	1.40	5YR 4/6 yellowish red sandy clay	
1	B	2	West	I	0.00	0.50	10YR 4/4 dark yellowish brown silty clay loam	
1	B	2	West	II	0.50	1.30	10YR 5/4 yellowish brown silty clay loam	
1	B	2		I	0.00	1.20	5YR 3/4 dark reddish brown sandy loam	
1	B	2		II	1.20	1.60	5YR 4/6 yellowish red sandy clay	
1	B	3		I	0.00	0.60	10YR 4/4 dark yellowish brown silty clay loam	
1	B	3		II	0.60	1.00	10YR 5/4 yellowish brown silty clay loam	
1	B	4		I	0.00	1.00	5YR 3/4 dark reddish brown sandy loam	
1	B	4		II	1.00	1.40	5YR 4/6 yellowish red sandy clay	
1	B	5		I	0.00	0.50	10YR 4/4 dark yellowish brown silty clay loam	
1	B	5		II	0.50	0.90	10YR 5/4 yellowish brown silty clay loam	
1	B	6		I	0.00	0.90	5YR 3/4 dark reddish brown sandy loam	
1	B	6		II	0.90	1.30	5YR 4/6 yellowish red sandy clay	
1	B	7		I	0.00	0.60	10YR 4/4 dark yellowish brown silty clay loam	
1	B	7		II	0.60	0.90	10YR 5/4 yellowish brown silty clay loam	

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Area	Transect	STP	Radial	Level	Start Depth (ft)	End Depth (ft)	Soil Description	Comments
1	C	1		I	0.00	0.90	5YR 3/4 dark reddish brown sandy loam	
1	C	1		II	0.90	1.30	5YR 4/6 yellowish red sandy clay	
1	C	2		I	0.00	0.60	10YR 4/4 dark yellowish brown silty clay loam	
1	C	2		II	0.60	1.20	10YR 5/4 yellowish brown silty clay loam	
1	C	3		I	0.00	1.00	5YR 3/4 dark reddish brown sandy loam	
1	C	3		II	1.00	1.40	5YR 4/6 yellowish red sandy clay	
1	C	4		I	0.00	0.40	10YR 4/4 dark yellowish brown silty clay loam	
1	C	4		II	0.40	0.90	10YR 5/4 yellowish brown silty clay loam	
1	C	5		I	0.00	0.70	5YR 3/4 dark reddish brown sandy loam	
1	C	5		II	0.70	1.10	5YR 4/6 yellowish red sandy clay	
1	C	6		I	0.00	0.60	10YR 4/4 dark yellowish brown silty clay loam	
1	C	6		II	0.60	0.90	10YR 5/4 yellowish brown silty clay loam	
1	C	7		I	0.00	1.40	5YR 3/4 dark reddish brown sandy loam	
1	C	7		II	1.40	1.80	5YR 4/6 yellowish red sandy clay	
1	D	1		I	0.00	0.40	10YR 4/4 dark yellowish brown silty clay loam	
1	D	1		II	0.40	1.00	10YR 5/4 yellowish brown silty clay loam	
1	D	2		I	0.00	0.50	10YR 4/4 dark yellowish brown silty clay loam	
1	D	2		II	0.50	1.00	10YR 5/4 yellowish brown silty clay loam	
1	D	3		I	0.00	0.60	10YR 4/4 dark yellowish brown silty clay loam	
1	D	3		II	0.60	0.80	10YR 5/4 yellowish brown silty clay loam	
1	D	4		I	0.00	0.80	5YR 3/4 dark reddish brown sandy loam	
1	D	4		II	0.80	1.20	5YR 4/6 yellowish red sandy clay	
1	D	5		I	0.00	0.40	10YR 4/4 dark yellowish brown silty clay loam	
1	D	5		II	0.40	0.90	10YR 5/4 yellowish brown silty clay loam	
1	D	6		I	0.00	0.70	5YR 3/4 dark reddish brown sandy loam	
1	D	6		II	0.70	1.10	5YR 4/6 yellowish red sandy clay	
1	D	7		I	0.00	0.60	10YR 4/4 dark yellowish brown silty clay loam	
1	D	7		II	0.60	0.90	10YR 5/4 yellowish brown silty clay loam	
1	E	1		I	0.00	1.00	5YR 3/4 dark reddish brown sandy loam	
1	E	1		II	1.00	1.40	5YR 4/6 yellowish red sandy clay	
1	E	2		I	0.00	0.40	10YR 4/4 dark yellowish brown silty clay loam	
1	E	2		II	0.40	1.00	10YR 5/4 yellowish brown silty clay loam	
1	E	3		I	0.00	0.80	5YR 3/4 dark reddish brown sandy loam	
1	E	3		II	0.80	1.20	5YR 4/6 yellowish red sandy clay	
1	E	4		I	0.00	0.40	10YR 4/4 dark yellowish brown silty clay loam	
1	E	4		II	0.40	0.80	10YR 5/4 yellowish brown silty clay loam	
1	E	5		I	0.00	0.70	5YR 3/4 dark reddish brown sandy loam	
1	E	5		II	0.70	1.10	5YR 4/6 yellowish red sandy clay	
1	E	6		I	0.00	0.50	10YR 4/4 dark yellowish brown silty clay loam	
1	E	6		II	0.50	0.90	10YR 5/4 yellowish brown silty clay loam	
1	E	7		I	0.00	1.00	5YR 3/4 dark reddish brown sandy loam	
1	E	7		II	1.00	1.40	5YR 4/6 yellowish red sandy clay	
1	F	1		I	0.00	0.40	10YR 4/4 dark yellowish brown silty clay loam	
1	F	1		II	0.40	0.90	10YR 5/4 yellowish brown silty clay loam	
1	F	2		I	0.00	0.80	5YR 3/4 dark reddish brown sandy loam	

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Area	Transect	STP	Radial	Level	Start Depth (ft)	End Depth (ft)	Soil Description	Comments
1	F	2		II	0.80	1.20	5YR 4/6 yellowish red sandy clay	
1	F	3		I	0.00	0.40	10YR 4/4 dark yellowish brown silty clay loam	
1	F	3		II	0.40	0.90	10YR 5/4 yellowish brown silty clay loam	
1	F	4		I	0.00	0.80	5YR 3/4 dark reddish brown sandy loam	
1	F	4		II	0.80	1.20	5YR 4/6 yellowish red sandy clay	
1	F	5		I	0.00	0.50	10YR 4/4 dark yellowish brown silty clay loam	
1	F	5		II	0.50	1.00	10YR 5/4 yellowish brown silty clay loam	
1	F	6		I	0.00	0.70	5YR 3/4 dark reddish brown sandy loam	
1	F	6		II	0.70	1.10	5YR 4/6 yellowish red sandy clay	
1	F	7		I	0.00	1.00	5YR 3/4 dark reddish brown sandy loam	
1	F	7		II	1.00	1.40	5YR 4/6 yellowish red sandy clay	
1	G	1		I	0.00	1.20	5YR 3/4 dark reddish brown sandy loam	
1	G	1		II	1.20	1.60	5YR 4/6 yellowish red sandy clay	
1	G	2		I	0.00	0.30	10YR 4/4 dark yellowish brown silty clay loam	
1	G	2		II	0.30	0.80	10YR 5/4 yellowish brown silty clay loam	
1	G	3		I	0.00	0.80	5YR 3/4 dark reddish brown sandy loam	
1	G	3		II	0.80	1.20	5YR 4/6 yellowish red sandy clay	
1	G	4		I	0.00	0.50	10YR 4/4 dark yellowish brown silty clay loam	
1	G	4		II	0.50	0.80	10YR 5/4 yellowish brown silty clay loam	
1	G	5		I	0.00	0.70	5YR 3/4 dark reddish brown sandy loam	
1	G	5		II	0.70	1.10	5YR 4/6 yellowish red sandy clay	
1	G	6		I	0.00	0.50	10YR 4/4 dark yellowish brown silty clay loam	
1	G	6		II	0.50	0.90	10YR 5/4 yellowish brown silty clay loam	
1	G	7		I	0.00	0.50	10YR 4/4 dark yellowish brown silty clay loam	
1	G	7		II	0.50	0.90	10YR 5/4 yellowish brown silty clay loam	
1	H	1					NOT DUG - DISTURBED	near road/utilities
1	H	2		I	0.00	0.50	10YR 4/6 dark yellowish brown sandy loam	
1	H	2		II	0.50	0.85	10YR 5/6 yellowish brown sandy loam	
1	H	3		I	0.00	0.50	10YR 4/4 dark yellowish brown sandy loam	
1	H	3		II	0.50	1.10	10YR 4/6 dark yellowish brown sandy loam	
1	H	4		I	0.00	0.70	10YR 4/4 dark yellowish brown silt loam	
1	H	4		II	0.70	1.10	10YR 5/6 yellowish brown silt loam	
1	H	5		I	0.00	0.60	10YR 4/4 dark yellowish brown sandy loam	
1	H	5		II	0.60	0.90	10YR 4/6 dark yellowish brown sandy loam	
1	H	6		I	0.00	0.65	10YR 4/4 dark yellowish brown silt loam	
1	H	6		II	0.65	0.95	10YR 5/6 yellowish brown silt loam	
1	H	7		I	0.00	0.30	10YR 4/4 dark yellowish brown sandy loam	
1	H	7		II	0.30	0.70	10YR 4/6 dark yellowish brown sandy loam	
1	H	8		I	0.00	0.75	10YR 4/4 dark yellowish brown silt loam	
1	H	8		II	0.75	1.15	10YR 5/6 yellowish brown silt loam	
1	H	9		I	0.00	0.50	10YR 4/4 dark yellowish brown sandy loam	
1	H	9		II	0.50	1.00	10YR 4/6 dark yellowish brown sandy loam	
1	H	10		I	0.00	0.80	10YR 4/4 dark yellowish brown silt loam	
1	H	10		II	0.80	1.20	10YR 5/6 yellowish brown silt loam	
1	H	11		I	0.00	0.60	10YR 4/4 dark yellowish brown sandy loam	

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Area	Transect	STP	Radial	Level	Start Depth (ft)	End Depth (ft)	Soil Description	Comments
1	H	11		II	0.60	1.10	10YR 4/6 dark yellowish brown sandy loam	
1	H	12		I	0.00	0.75	10YR 4/4 dark yellowish brown silt loam	
1	H	12		II	0.75	1.05	10YR 5/6 yellowish brown silt loam	
1	H	13		I	0.00	0.40	10YR 4/4 dark yellowish brown sandy loam	
1	H	13		II	0.40	0.80	10YR 4/6 dark yellowish brown sandy loam	
1	H	14		I	0.00	0.75	10YR 4/4 dark yellowish brown silt loam	
1	H	14		II	0.75	1.05	10YR 5/6 yellowish brown silt loam	
1	H	15		I	0.00	0.60	10YR 4/4 dark yellowish brown sandy loam	
1	H	15		II	0.60	1.10	10YR 4/6 dark yellowish brown sandy loam	
1	H	16		I	0.00	0.80	10YR 4/4 dark yellowish brown silt loam	
1	H	16		II	0.80	1.20	10YR 5/6 yellowish brown silt loam	
1	H	17		I	0.00	0.60	10YR 4/4 dark yellowish brown sandy loam	
1	H	17		II	0.60	1.00	10YR 4/6 dark yellowish brown sandy loam	
1	H	18		I	0.00	0.80	10YR 4/4 dark yellowish brown silt loam	
1	H	18		II	0.80	1.15	10YR 5/6 yellowish brown silt loam	
1	H	19		I	0.00	0.75	10YR 4/4 dark yellowish brown silt loam	
1	H	19		II	0.75	1.15	10YR 5/6 yellowish brown silt loam	
1	H	20		I	0.00	0.60	10YR 4/4 dark yellowish brown sandy loam	
1	H	20		II	0.60	0.90	10YR 4/6 dark yellowish brown sandy loam	
1	H	21		I	0.00	0.85	10YR 4/4 dark yellowish brown silt loam	
1	H	21		II	0.85	1.30	10YR 5/6 yellowish brown silt loam	
1	H	22		I	0.00	0.50	10YR 4/4 dark yellowish brown sandy loam	
1	H	22		II	0.50	0.90	10YR 4/6 dark yellowish brown sandy loam	
1	H	23		I	0.00	0.85	10YR 4/4 dark yellowish brown silt loam	
1	H	23		II	0.85	1.30	10YR 5/6 yellowish brown silt loam	
1	H	24		I	0.00	0.50	10YR 4/4 dark yellowish brown sandy loam	
1	H	24		II	0.50	0.90	10YR 4/6 dark yellowish brown sandy loam	
1	H	25		I	0.00	0.85	10YR 4/4 dark yellowish brown silt loam	
1	H	25		II	0.85	1.30	10YR 5/6 yellowish brown silt loam	
1	H	26		I	0.00	0.60	10YR 4/4 dark yellowish brown sandy loam	
1	H	26		II	0.60	0.80	10YR 4/6 dark yellowish brown sandy loam	
1	H	27		I	0.00	0.70	10YR 4/4 dark yellowish brown silt loam	
1	H	27		II	0.70	1.10	10YR 5/6 yellowish brown silt loam	
1	H	28		I	0.00	0.50	10YR 4/4 dark yellowish brown sandy loam	
1	H	28		II	0.50	0.90	10YR 4/6 dark yellowish brown sandy loam	
1	H	29		I	0.00	0.80	10YR 4/4 dark yellowish brown silt loam	
1	H	29		II	0.80	1.30	10YR 5/6 yellowish brown silt loam	
1	H	30		I	0.00	0.60	10YR 4/4 dark yellowish brown sandy loam	
1	H	30		II	0.60	1.10	10YR 4/6 dark yellowish brown sandy loam	
1	H	31		I	0.00	0.80	10YR 4/4 dark yellowish brown silt loam	
1	H	31		II	0.80	1.20	10YR 5/6 yellowish brown silt loam	
1	H	32		I	0.00	0.50	10YR 4/4 dark yellowish brown sandy loam	
1	H	32		II	0.50	1.00	10YR 4/6 dark yellowish brown sandy loam	
1	H	33		I	0.00	0.75	10YR 4/4 dark yellowish brown silt loam	
1	H	33		II	0.75	1.15	10YR 5/6 yellowish brown silt loam	

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1	H	34		I	0.00	0.30	10YR 4/4 dark yellowish brown sandy loam	disturbed with gravel after .30
1	H	35		I	0.00	0.70	10YR 4/4 dark yellowish brown silt loam	
1	H	35		II	0.70	1.10	10YR 5/6 yellowish brown silt loam	
1	H	36		I	0.00	0.50	10YR 4/4 dark yellowish brown sandy loam	
1	H	36		II	0.50	0.90	10YR 4/6 dark yellowish brown sandy loam	
1	H	37		I	0.00	0.75	10YR 4/4 dark yellowish brown silt loam	
1	H	37		II	0.75	1.15	10YR 5/6 yellowish brown silt loam	
1	H	38		I	0.00	0.30	10YR 4/4 dark yellowish brown sandy loam	disturbed with gravel after .30
1	H	39		I	0.00	0.70	10YR 4/4 dark yellowish brown silt loam	
1	H	39		II	0.70	1.10	10YR 5/6 yellowish brown silt loam	
1	H	40		I	0.00	0.30	10YR 4/4 dark yellowish brown sandy loam	disturbed with gravel after .30
1	H	41		I	0.00	0.75	10YR 4/4 dark yellowish brown silt loam	
1	H	41		II	0.75	1.15	10YR 5/6 yellowish brown silt loam	
1	I	1		I	0.00	0.90	5YR 5/4 reddish brown sandy loam	
1	I	1		II	0.90	1.30	5YR 4/6 yellowish red sandy clay	
1	I	2		I	0.00	0.70	10YR 4/4 dark yellowish brown silty clay loam	
1	I	2		II	0.70	1.00	10YR 5/4 yellowish brown silty clay loam	
1	I	3		I	0.00	0.90	5YR 5/4 reddish brown sandy loam	
1	I	3		II	0.90	1.30	5YR 4/6 yellowish red sandy clay	
1	I	4		I	0.00	0.40	10YR 4/4 dark yellowish brown silty clay loam	
1	I	4		II	0.40	0.80	10YR 5/4 yellowish brown silty clay loam	
1	I	5		I	0.00	0.90	5YR 5/4 reddish brown sandy loam	
1	I	5		II	0.90	1.30	5YR 4/6 yellowish red sandy clay	
1	I	6		I	0.00	0.50	10YR 4/4 dark yellowish brown silty clay loam	
1	I	6		II	0.50	0.80	10YR 5/4 yellowish brown silty clay loam	
1	I	7		I	0.00	0.90	5YR 5/4 reddish brown sandy loam	
1	I	7		II	0.90	1.30	5YR 4/6 yellowish red sandy clay	
1	I	8		I	0.00	0.40	10YR 4/4 dark yellowish brown silty clay loam	
1	I	8		II	0.40	0.80	10YR 5/4 yellowish brown silty clay loam	
1	I	9		I	0.00	0.90	5YR 5/4 reddish brown sandy loam	
1	I	9		II	0.90	1.30	5YR 4/6 yellowish red sandy clay	
1	I	10		I	0.00	0.50	10YR 4/4 dark yellowish brown silty clay loam	
1	I	10		II	0.50	0.80	10YR 5/4 yellowish brown silty clay loam	
1	I	11		I	0.00	0.90	5YR 5/4 reddish brown sandy loam	
1	I	11		II	0.90	1.30	5YR 4/6 yellowish red sandy clay	
1	I	12		I	0.00	0.30	10YR 4/4 dark yellowish brown silty clay loam	
1	I	12		II	0.30	0.70	10YR 5/4 yellowish brown silty clay loam	
1	I	13		I	0.00	0.90	5YR 5/4 reddish brown sandy loam	
1	I	13		II	0.90	1.30	5YR 4/6 yellowish red sandy clay	
1	I	14		I	0.00	0.40	10YR 4/4 dark yellowish brown silty clay loam	
1	I	14		II	0.40	0.80	10YR 5/4 yellowish brown silty clay loam	
1	I	15		I	0.00	0.90	5YR 5/4 reddish brown sandy loam	
1	I	15		II	0.90	1.30	5YR 4/6 yellowish red sandy clay	
1	I	16		I	0.00	0.30	10YR 4/4 dark yellowish brown silty clay loam	
1	I	16		II	0.30	0.60	10YR 5/4 yellowish brown silty clay loam	

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Area	Transect	STP	Radial	Level	Start Depth (ft)	End Depth (ft)	Soil Description	Comments
1	I	17		I	0.00	1.20	5YR 5/4 reddish brown sandy loam	
1	I	17		II	1.20	1.60	5YR 4/6 yellowish red sandy clay	
1	I	18		I	0.00	0.50	10YR 4/4 dark yellowish brown silty clay loam	
1	I	18		II	0.50	0.90	10YR 5/4 yellowish brown silty clay loam	
1	I	19		I	0.00	1.20	5YR 5/4 reddish brown sandy loam	
1	I	19		II	1.20	1.60	5YR 4/6 yellowish red sandy clay	
1	I	20		I	0.00	0.60	10YR 4/4 dark yellowish brown silty clay loam	
1	I	20		II	0.60	1.00	10YR 5/4 yellowish brown silty clay loam	
1	I	21		I	0.00	1.00	5YR 5/4 reddish brown sandy loam	
1	I	21		II	1.00	1.40	5YR 4/6 yellowish red sandy clay	
1	I	22		I	0.00	0.40	10YR 4/4 dark yellowish brown silty clay loam	
1	I	22		II	0.40	0.90	10YR 5/4 yellowish brown silty clay loam	
1	I	23		I	0.00	1.00	5YR 5/4 reddish brown sandy loam	
1	I	23		II	1.00	1.40	5YR 4/6 yellowish red sandy clay	
1	I	24		I	0.00	0.70	10YR 4/4 dark yellowish brown silty clay loam	
1	I	24		II	0.70	1.00	10YR 5/4 yellowish brown silty clay loam	
1	I	25		I	0.00	1.00	5YR 3/4 dark reddish brown sandy loam	
1	I	25		II	1.00	1.40	5YR 4/6 yellowish red sandy clay	
1	I	26		I	0.00	0.50	10YR 4/4 dark yellowish brown silty clay loam	
1	I	26		II	0.50	0.90	10YR 5/4 yellowish brown silty clay loam	
1	I	27		I	0.00	1.00	5YR 3/4 dark reddish brown sandy loam	
1	I	27		II	1.00	1.40	5YR 4/6 yellowish red sandy clay	
1	I	28		I	0.00	0.50	10YR 4/4 dark yellowish brown silty clay loam	
1	I	28		II	0.50	0.80	10YR 5/4 yellowish brown silty clay loam	
2	A	1		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	A	1		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	A	2		I	0.00	0.25	10YR 5/4 yellowish brown sandy loam	
2	A	2		II	0.25	0.95	10YR 7/4 very pale brown sandy loam	root impasse at .95
2	B	4		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	B	4		II	0.40	0.90	10YR 7/4 very pale brown sandy loam	
2	B	5		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	B	5		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	B	10		I	0.00	0.80	10YR 5/4 yellowish brown sandy loam	
2	B	10		II	0.80	1.20	10YR 7/4 very pale brown sandy loam	
2	B	11		I	0.00	0.30	10YR 5/4 yellowish brown sandy loam	
2	B	11		II	0.30	0.70	10YR 7/4 very pale brown sandy loam	root impasse @ .70
2	B	12		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	B	12		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	B	13		I	0.00	1.10	10YR 5/4 yellowish brown sandy loam	
2	B	13		II	1.10	1.50	10YR 7/4 very pale brown sandy loam	
2	B	14		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	B	14		II	0.40	1.00	10YR 7/4 very pale brown sandy loam	
2	B	15		I	0.00	1.10	10YR 5/4 yellowish brown sandy loam	
2	B	15		II	1.10	1.50	10YR 7/4 very pale brown sandy loam	
2	B	16		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	

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2	B	16		II	0.40	0.95	10YR 7/4 very pale brown sandy loam	
2	B	17		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	B	17		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	B	18		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	B	18		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	C	6		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	C	6		II	0.20	0.60	10YR 7/4 very pale brown sandy loam	root impasse @ .60
2	C	7		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	C	7		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	C	8		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	C	8		II	0.40	0.90	10YR 7/4 very pale brown sandy loam	
2	C	9		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	C	9		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	C	10		I	0.00	1.30	10YR 5/4 yellowish brown sandy loam	
2	C	10		II	1.30	1.70	10YR 7/4 very pale brown sandy loam	
2	C	11		I	0.00	0.30	10YR 5/4 yellowish brown sandy loam	
2	C	11		II	0.30	0.75	10YR 7/4 very pale brown sandy loam	
2	C	12		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	C	12		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	C	13		I	0.00	0.60	10YR 5/4 yellowish brown sandy loam	
2	C	13		II	0.60	1.20	10YR 7/4 very pale brown sandy loam	
2	C	14		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	C	14		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	C	15		I	0.00	0.60	10YR 5/4 yellowish brown sandy loam	root impasse @ .60
2	C	16		I	0.00	0.70	10YR 5/4 yellowish brown sandy loam	
2	C	16		II	0.70	1.10	10YR 7/4 very pale brown sandy loam	
2	C	17		I	0.00	0.55	10YR 5/4 yellowish brown sandy loam	
2	C	17		II	0.55	0.85	10YR 7/3 very pale brown sandy loam	
2	C	18		I	0.00	0.70	10YR 5/4 yellowish brown sandy loam	
2	C	18		II	0.70	1.10	10YR 7/4 very pale brown sandy loam	
2	D	3		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	D	3		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	D	4		I	0.00	0.60	10YR 7/4 very pale brown sandy loam	root impasse @ .60
2	D	6		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	root impasse @ .20
2	D	7		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	D	7		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	D	8		I	0.00	0.30	10YR 5/4 yellowish brown sandy loam	
2	D	8		II	0.30	0.80	10YR 7/4 very pale brown sandy loam	
2	D	9		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	D	9		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	D	10		I	0.00	0.55	10YR 7/4 very pale brown sandy loam	root impasse @ .55
2	D	11		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	D	11		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	D	12		I	0.00	0.40	10YR 7/4 very pale brown sandy loam	
2	D	12		II	0.40	0.90	10YR 7/3 very pale brown sandy loam	

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Area	Transect	STP	Radial	Level	Start Depth (ft)	End Depth (ft)	Soil Description	Comments
2	D	13		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	D	13		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	D	14		I	0.00	0.30	10YR 5/4 yellowish brown sandy loam	
2	D	14		II	0.30	0.70	10YR 7/3 very pale brown sandy loam	
2	D	15		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	D	15		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	D	16		I	0.00	0.35	10YR 5/4 yellowish brown sandy loam	
2	D	16		II	0.35	0.85	10YR 7/3 very pale brown sandy loam	
2	D	17		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	D	17		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	D	18		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	D	18		II	0.20	0.80	10YR 7/3 very pale brown sandy loam	
2	E	1		I	0.00	0.30	10YR 5/4 yellowish brown sandy loam	
2	E	1		II	0.30	0.70	10YR 7/4 very pale brown sandy loam	
2	E	2		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	E	2		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	E	3		I	0.00	0.25	10YR 5/4 yellowish brown sandy loam	
2	E	3		II	0.25	1.00	10YR 7/4 very pale brown sandy loam	
2	E	4		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	E	4		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	E	6		I	0.00	0.10	10YR 7/4 very pale brown sandy loam with gravels	gravel impasse - in gravel road
2	E	7		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	E	7		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	E	8		I	0.00	0.45	10YR 5/4 yellowish brown sandy loam	
2	E	8		II	0.45	0.85	10YR 7/4 very pale brown sandy loam	
2	E	9		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	E	9		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	E	10		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	E	10		II	0.20	0.60	10YR 7/4 very pale brown sandy loam	
2	E	11		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	E	11		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	E	12		I	0.00	0.55	10YR 7/4 very pale brown sandy loam	root impasse @ .55
2	E	13		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	E	13		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	E	14		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	E	14		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	E	15		I	0.00	0.20	10YR 5/1 gray sandy loam	
2	E	15		II	0.20	0.80	10YR 5/4 yellowish brown sandy loam	
2	E	16		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	E	16		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	E	17		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	E	17		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	E	18		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	root and rock impasse @ .50
2	F	6		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	F	6		II	0.20	0.60	10YR 7/3 very pale brown sandy loam	

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Area	Transect	STP	Radial	Level	Start Depth (ft)	End Depth (ft)	Soil Description	Comments
2	F	7		I	0.00	0.60	10YR 5/4 yellowish brown sandy loam	
2	F	7		II	0.60	1.00	10YR 7/4 very pale brown sandy loam	
2	F	8		I	0.00	0.60	10YR 5/4 yellowish brown sandy loam	
2	F	8		II	0.60	1.00	10YR 7/4 very pale brown sandy loam	
2	F	9		I	0.00	0.30	10YR 5/4 yellowish brown sandy loam	
2	F	9		II	0.30	0.70	10YR 7/3 very pale brown sandy loam	
2	F	10		I	0.00	0.60	10YR 5/4 yellowish brown sandy loam	
2	F	10		II	0.60	1.00	10YR 7/4 very pale brown sandy loam	
2	F	11		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	F	11		II	0.20	0.60	10YR 7/4 very pale brown sandy loam	
2	F	12		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	F	12		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	F	13		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	F	13		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	F	14		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	F	14		II	0.20	0.65	10YR 7/3 very pale brown sandy loam	
2	F	15		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	F	15		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	F	16		I	0.00	0.35	10YR 5/4 yellowish brown sandy loam	
2	F	16		II	0.35	1.00	10YR 7/4 very pale brown sandy loam	
2	F	17		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	F	17		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	F	18		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	gravel/rock impasse @ .40
2	G	1		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	G	1		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	G	2		I	0.00	0.20	10YR 7/3 very pale brown sandy loam	
2	G	2		II	0.20	0.60	10YR 7/4 very pale brown sandy loam	
2	G	3		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	G	3		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	G	4		I	0.00	0.30	10YR 5/4 yellowish brown sandy loam	
2	G	4		II	0.30	0.90	10YR 7/4 very pale brown sandy loam	
2	G	5		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	G	5		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	G	7		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	G	7		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	G	8		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	G	8		II	0.20	0.70	10YR 7/4 very pale brown sandy loam	
2	G	9		I	0.00	0.80	10YR 5/4 yellowish brown sandy loam	
2	G	9		II	0.80	1.20	10YR 7/4 very pale brown sandy loam	
2	G	10		I	0.00	0.30	10YR 7/3 very pale brown sandy loam	
2	G	10		II	0.30	0.55	10YR 7/4 very pale brown sandy loam	
2	G	11		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	G	11		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	G	12		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	G	12		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	

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2	G	13		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	G	13		I	0.00	0.20	10YR 7/3 very pale brown sandy loam	
2	G	13		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	G	13		II	0.20	0.70	10YR 7/4 very pale brown sandy loam	
2	G	14		I	0.00	0.20	10YR 7/3 very pale brown sandy loam	
2	G	14		II	0.20	0.60	10YR 7/4 very pale brown sandy loam	
2	G	15		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	G	15		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	G	16		I	0.00	0.20	10YR 5/1 gray sandy loam	
2	G	16		II	0.20	0.80	10YR 7/4 very pale brown sandy loam	
2	G	17		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	G	17		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	G	18	East	I	0.00	1.20	10YR 5/4 yellowish brown sandy loam	
2	G	18	East	II	1.20	1.60	10YR 7/4 very pale brown sandy loam	
2	G	18	North	I	0.00	0.70	10YR 5/1 gray sandy loam with gravels	rock impasse @ .70
2	G	18	South	I	0.00	0.25	10YR 5/1 gray sandy loam	
2	G	18	South	II	0.25	0.80	10YR 7/4 very pale brown sandy loam	
2	G	18	West	I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	G	18	West	II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	G	18		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	G	18		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	H	6					NOT DUG - ROAD	
2	H	7		I	0.00	0.30	10YR 5/4 yellowish brown sandy loam	
2	H	7		II	0.30	0.70	10YR 7/4 very pale brown sandy loam	
2	H	8		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	H	8		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	H	9		I	0.00	0.50	10YR 7/4 very pale brown sandy loam	root impasse @ .50
2	H	10		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	H	10		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	H	11		I	0.00	0.30	10YR 5/4 yellowish brown sandy loam	
2	H	11		II	0.30	0.80	10YR 7/4 very pale brown sandy loam	
2	H	12		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	H	12		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	H	13		I	0.00	0.60	10YR 5/4 yellowish brown sandy loam	
2	H	13		II	0.60	1.00	10YR 7/4 very pale brown sandy loam	
2	H	14		I	0.00	0.60	10YR 5/4 yellowish brown sandy loam	
2	H	14		II	0.60	0.90	10YR 7/4 very pale brown sandy loam	
2	H	15		I	0.00	1.10	10YR 5/4 yellowish brown sandy loam	
2	H	15		II	1.10	1.50	10YR 7/4 very pale brown sandy loam	
2	H	16		I	0.00	0.30	10YR 5/4 yellowish brown sandy loam	
2	H	16		II	0.30	0.90	10YR 7/4 very pale brown sandy loam	
2	H	17		I	0.00	1.10	10YR 5/4 yellowish brown sandy loam	
2	H	17		II	1.10	1.50	10YR 7/4 very pale brown sandy loam	
2	H	18		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	H	18		II	0.40	0.80	10YR 7/4 very pale brown sandy loam	root impasse @ .80

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2	I	10		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	I	10		II	0.20	0.60	10YR 7/4 very pale brown sandy loam	
2	I	11		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	I	11		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	I	12		I	0.00	0.30	10YR 7/4 very pale brown sandy loam	root impasse @ .30
2	I	13		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	I	13		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	I	14		I	0.00	0.20	10YR 7/3 very pale brown sandy loam	
2	I	14		II	0.20	0.70	10YR 7/4 very pale brown sandy loam	
2	I	15		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	I	15		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	I	16		I	0.00	0.40	10YR 7/3 very pale brown sandy loam	
2	I	16		II	0.40	1.00	10YR 7/4 very pale brown sandy loam	
2	I	17		I	0.00	1.20	10YR 5/4 yellowish brown sandy loam	
2	I	17		II	1.20	1.60	10YR 7/4 very pale brown sandy loam	
2	I	18		I	0.00	0.20	10YR 5/1 gray sandy loam	
2	I	18		II	0.20	0.95	10YR 7/4 very pale brown sandy loam	
2	J	9		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	J	9		II	0.20	0.60	10YR 7/4 very pale brown sandy loam	
2	J	10		I	0.00	0.60	10YR 5/4 yellowish brown sandy loam	
2	J	10		II	0.60	1.00	10YR 7/4 very pale brown sandy loam	
2	J	11		I	0.00	0.60	10YR 5/4 yellowish brown sandy loam	
2	J	11		II	0.60	1.00	10YR 7/4 very pale brown sandy loam	
2	J	12		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	J	12		II	0.20	0.50	10YR 7/4 very pale brown sandy loam	
2	J	13		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	J	13		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	J	14		I	0.00	0.30	10YR 5/1 gray sandy loam	
2	J	14		II	0.30	1.00	10YR 7/3 very pale brown sandy loam	
2	J	15		I	0.00	0.30	10YR 5/4 yellowish brown sandy loam	
2	J	15		II	0.30	0.70	10YR 7/3 very pale brown sandy loam	
2	J	16		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	J	16		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	J	17		I	0.00	1.10	10YR 5/4 yellowish brown sandy loam	
2	J	17		II	1.10	1.50	10YR 7/4 very pale brown sandy loam	
2	J	18		I	0.00	0.60	10YR 5/4 yellowish brown sandy loam	root impasse @ .60
2	K	8		I	0.00	0.10	10YR 5/4 yellowish brown sandy loam	
2	K	8		II	0.10	0.60	10YR 7/4 very pale brown sandy loam	
2	K	9		I	0.00	0.60	10YR 5/4 yellowish brown sandy loam	
2	K	9		II	0.60	1.00	10YR 7/4 very pale brown sandy loam	
2	K	10		I	0.00	0.30	10YR 5/4 yellowish brown sandy loam	
2	K	10		II	0.30	0.60	10YR 7/4 very pale brown sandy loam	
2	K	11		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	K	11		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	K	12		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	

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2	K	12		II	0.40	0.80	10YR 7/4 very pale brown sandy loam	
2	K	13		I	0.00	0.10	10YR 5/4 yellowish brown sandy loam	
2	K	13		II	0.10	0.40	10YR 7/4 very pale brown sandy loam	
2	K	17		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	K	17		II	0.20	0.60	10YR 7/4 very pale brown sandy loam	root impasse @ .60
2	K	18		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	on top of berm
2	L	1		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	L	1		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	L	2		I	0.00	0.20	10YR 7/4 very pale brown sandy loam	
2	L	2		II	0.20	0.70	10YR 7/3 very pale brown sandy loam	
2	L	3		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	L	3		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	L	4		I	0.00	0.40	10YR 7/4 very pale brown sandy loam	
2	L	4		II	0.40	0.90	10YR 7/3 very pale brown sandy loam	
2	L	5		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	L	5		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	L	6		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	L	6		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	L	7		I	0.00	0.30	10YR 5/4 yellowish brown sandy loam	
2	L	7		II	0.30	0.70	10YR 7/3 very pale brown sandy loam	root impasse @ .70
2	L	8		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	L	8		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	L	9		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	L	9		II	0.40	1.00	10YR 7/3 very pale brown sandy loam	
2	L	10		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	L	10		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	L	11		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	L	11		II	0.50	0.90	10YR 7/3 very pale brown sandy loam	
2	L	12		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	L	12		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	L	13		I	0.00	0.40	10YR 7/3 very pale brown sandy loam	root impasse @ .40
2	L	14		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	L	14		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	L	15		I	0.00	0.60	10YR 7/3 very pale brown sandy loam	root impasse @ .60
2	L	16		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	L	16		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	L	17		I	0.00	0.50	10YR 7/3 very pale brown sandy loam	root impasse @ .50
2	L	18		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	L	18		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	M	1		I	0.00	0.20	10YR 7/4 very pale brown sandy loam	
2	M	1		II	0.20	1.00	10YR 7/3 very pale brown sandy loam	
2	M	2		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	M	2		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	M	3		I	0.00	0.20	10YR 7/4 very pale brown sandy loam	
2	M	3		II	0.20	0.80	10YR 7/3 very pale brown sandy loam	

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2	M	4		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	M	4		II	0.40	0.80	10YR 7/4 very pale brown sandy loam	
2	M	5		I	0.00	0.50	10YR 5/2 grayish brown sandy loam	
2	M	5		II	0.50	0.80	10YR 7/3 very pale brown sandy loam	
2	M	6		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	M	6		II	0.40	0.80	10YR 7/4 very pale brown sandy loam	
2	M	7		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	M	7		II	0.20	0.50	10YR 7/4 very pale brown sandy loam	
2	M	7		III	0.50	0.80	10YR 7/3 very pale brown sandy loam	
2	M	8		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	M	8		II	0.40	0.80	10YR 7/4 very pale brown sandy loam	
2	M	9		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	M	9		II	0.20	0.50	10YR 7/4 very pale brown sandy loam	
2	M	10		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	M	10		II	0.40	0.80	10YR 7/4 very pale brown sandy loam	
2	M	11		I	0.00	0.60	10YR 5/2 grayish brown sandy loam	
2	M	11		II	0.60	0.80	10YR 7/3 very pale brown sandy loam	
2	M	12		I	0.00	0.60	10YR 5/4 yellowish brown sandy loam	
2	M	12		II	0.60	1.00	10YR 7/4 very pale brown sandy loam	
2	M	13		I	0.00	0.50	10YR 5/2 grayish brown sandy loam	
2	M	13		II	0.50	0.80	10YR 7/3 very pale brown sandy loam	
2	M	14		I	0.00	0.60	10YR 5/4 yellowish brown sandy loam	
2	M	14		II	0.60	1.00	10YR 7/4 very pale brown sandy loam	
2	M	15		I	0.00	0.50	10YR 5/2 grayish brown sandy loam	
2	M	15		II	0.50	0.80	10YR 7/3 very pale brown sandy loam	
2	M	16		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	M	16		II	0.40	0.80	10YR 7/4 very pale brown sandy loam	
2	M	17		I	0.00	0.20	10YR 5/2 grayish brown sandy loam	
2	M	17		II	0.20	0.70	10YR 7/3 very pale brown sandy loam	
2	M	18		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	M	18		II	0.40	0.80	10YR 7/4 very pale brown sandy loam	
2	N	1		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	N	1		II	0.20	0.70	10YR 7/4 very pale brown sandy loam	
2	N	2		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	N	2		II	0.40	0.80	10YR 7/4 very pale brown sandy loam	
2	N	3		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	N	3		II	0.20	0.60	10YR 7/4 very pale brown sandy loam	
2	N	4		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	N	4		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	N	5		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	N	5		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	N	6		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	N	6		II	0.20	0.60	10YR 7/4 very pale brown sandy loam	
2	N	6		III	0.60	0.90	10YR 7/3 very pale brown sandy loam	
2	N	7		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	

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Area	Transect	STP	Radial	Level	Start Depth (ft)	End Depth (ft)	Soil Description	Comments
2	N	7		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	N	8		I	0.00	0.60	10YR 5/2 grayish brown sandy loam	
2	N	8		II	0.60	1.00	10YR 7/3 very pale brown sandy loam	
2	N	9		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	N	9		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	N	10		I	0.00	0.40	10YR 5/2 grayish brown sandy loam	
2	N	10		II	0.40	0.90	10YR 7/3 very pale brown sandy loam	
2	N	11		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	N	11		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	N	12		I	0.00	0.30	10YR 5/4 yellowish brown sandy loam	
2	N	12		II	0.30	0.90	10YR 7/4 very pale brown sandy loam	
2	N	13		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	N	13		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	N	14		I	0.00	0.30	10YR 5/1 gray sandy loam	
2	N	14		II	0.30	0.60	10YR 7/4 very pale brown sandy loam	
2	N	15		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	N	15		II	0.40	0.80	10YR 7/4 very pale brown sandy loam	
2	N	16		I	0.00	0.60	10YR 5/2 grayish brown sandy loam	
2	N	16		II	0.60	0.90	10YR 7/3 very pale brown sandy loam	
2	N	17		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	N	17		II	0.40	0.80	10YR 7/4 very pale brown sandy loam	
2	N	18		I	0.00	0.50	10YR 5/2 grayish brown sandy loam	
2	N	18		II	0.50	0.90	10YR 7/3 very pale brown sandy loam	
2	O	1		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	O	1		II	0.40	0.80	10YR 7/4 very pale brown sandy loam	
2	O	2		I	0.00	0.40	10YR 5/2 grayish brown sandy loam	
2	O	2		II	0.40	0.70	10YR 7/3 very pale brown sandy loam	
2	O	3		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	O	3		II	0.40	0.80	10YR 7/4 very pale brown sandy loam	
2	O	4		I	0.00	0.60	10YR 5/4 yellowish brown sandy loam	
2	O	4		II	0.60	1.00	10YR 7/3 very pale brown sandy loam	
2	O	5		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	O	5		II	0.40	0.80	10YR 7/4 very pale brown sandy loam	
2	O	6		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	O	6		II	0.40	0.70	10YR 7/3 very pale brown sandy loam	
2	O	7		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	O	7		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	O	8		I	0.00	0.25	10YR 5/4 yellowish brown sandy loam	
2	O	8		II	0.25	0.60	10YR 7/3 very pale brown sandy loam	
2	O	9		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	O	9		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	O	10		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	O	10		II	0.20	0.60	10YR 7/3 very pale brown sandy loam	
2	O	11		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	O	11		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	

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Area	Transect	STP	Radial	Level	Start Depth (ft)	End Depth (ft)	Soil Description	Comments
2	O	12		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	O	12		II	0.50	0.80	10YR 7/3 very pale brown sandy loam	
2	O	13		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	O	13		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	O	14		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	O	14		II	0.20	0.60	10YR 7/3 very pale brown sandy loam	
2	O	15		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	O	15		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	O	16		I	0.00	0.30	10YR 5/4 yellowish brown sandy loam	
2	O	16		II	0.30	0.80	10YR 7/3 very pale brown sandy loam	
2	O	17		I	0.00	0.60	10YR 5/4 yellowish brown sandy loam	
2	O	17		II	0.60	1.00	10YR 7/4 very pale brown sandy loam	
2	O	18		I	0.00	0.70	10YR 5/4 yellowish brown sandy loam	
2	O	18		II	0.70	1.00	10YR 7/3 very pale brown sandy loam	
2	P	1		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	P	1		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	P	2		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	P	2		II	0.20	0.70	10YR 7/4 very pale brown sandy loam	
2	P	3		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	P	3		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	P	4		I	0.00	0.60	10YR 5/4 yellowish brown sandy loam	
2	P	4		II	0.60	1.00	10YR 7/4 very pale brown sandy loam	
2	P	5		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	P	5		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	P	6		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	P	6		II	0.20	0.50	10YR 7/3 very pale brown sandy loam	
2	P	7		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	P	7		II	0.40	0.80	10YR 7/4 very pale brown sandy loam	
2	P	8		I	0.00	0.30	10YR 5/4 yellowish brown sandy loam	
2	P	8		II	0.30	0.60	10YR 7/3 very pale brown sandy loam	
2	P	9		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	P	9		II	0.40	0.80	10YR 7/4 very pale brown sandy loam	
2	P	10		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	P	10		II	0.40	0.70	10YR 7/3 very pale brown sandy loam	
2	P	11		I	0.00	0.70	10YR 5/4 yellowish brown sandy loam	
2	P	11		II	0.70	1.10	10YR 7/4 very pale brown sandy loam	
2	P	12		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	root impasse @ .40
2	P	13		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	P	13		II	0.40	0.80	10YR 7/4 very pale brown sandy loam	
2	P	14		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	P	14		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	P	15		I	0.00	0.30	10YR 5/4 yellowish brown sandy loam	
2	P	15		II	0.30	0.80	10YR 7/4 very pale brown sandy loam	
2	P	16		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	P	16		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	

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Area	Transect	STP	Radial	Level	Start Depth (ft)	End Depth (ft)	Soil Description	Comments
2	P	17		I	0.00	0.30	10YR 5/4 yellowish brown sandy loam	
2	P	17		II	0.30	0.70	10YR 7/4 very pale brown sandy loam	
2	P	18		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	P	18		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	Q	1		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	Q	1		II	0.20	0.80	10YR 7/4 very pale brown sandy loam	
2	Q	2		I	0.00	1.00	10YR 5/4 yellowish brown sandy loam	
2	Q	2		II	1.00	1.40	10YR 7/4 very pale brown sandy loam	
2	Q	3		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	Q	3		II	0.20	0.80	10YR 7/4 very pale brown sandy loam	
2	Q	4		I	0.00	0.70	10YR 5/4 yellowish brown sandy loam	
2	Q	4		II	0.70	1.10	10YR 7/4 very pale brown sandy loam	
2	Q	5		I	0.00	0.60	10YR 5/4 yellowish brown sandy loam	
2	Q	5		II	0.60	1.00	10YR 7/4 very pale brown sandy loam	
2	Q	6		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	Q	6		II	0.20	0.70	10YR 7/4 very pale brown sandy loam	
2	Q	7		I	0.00	0.60	10YR 5/4 yellowish brown sandy loam	
2	Q	7		II	0.60	1.00	10YR 7/4 very pale brown sandy loam	
2	Q	8		I	0.00	0.10	10YR 5/4 yellowish brown sandy loam	
2	Q	8		II	0.10	0.80	10YR 7/3 very pale brown sandy loam	
2	Q	9		I	0.00	0.70	10YR 5/4 yellowish brown sandy loam	
2	Q	9		II	0.70	1.10	10YR 7/4 very pale brown sandy loam	
2	Q	10		I	0.00	0.30	10YR 5/4 yellowish brown sandy loam with gravels	rock impasse @ .30
2	Q	11		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	Q	11		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	Q	12		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	Q	12		II	0.20	0.40	10YR 7/4 very pale brown sandy loam	
2	Q	13		I	0.00	0.80	10YR 5/4 yellowish brown sandy loam	
2	Q	13		II	0.80	1.20	10YR 7/4 very pale brown sandy loam	
2	Q	14		I	0.00	0.10	10YR 5/1 gray sandy loam	
2	Q	14		II	0.10	0.35	10YR 7/3 very pale brown sandy loam	
2	Q	15		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	Q	15		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	Q	16		I	0.00	0.30	10YR 5/1 gray sandy loam	
2	Q	16		II	0.30	1.00	10YR 7/4 very pale brown sandy loam	
2	Q	17		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	Q	17		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	Q	18		I	0.00	0.60	10YR 5/1 gray sandy loam	
2	Q	18		II	0.60	0.90	10YR 7/4 very pale brown sandy loam	
2	R	1		I	0.00	0.50	10YR 5/4 yellowish brown silty sand	
2	R	1		II	0.50	0.90	10YR 7/4 very pale brown silty sand	
2	R	2		I	0.00	0.40	10YR 5/1 gray sandy loam	
2	R	2		II	0.40	0.80	10YR 7/4 very pale brown sandy loam	
2	R	3		I	0.00	0.70	10YR 5/4 yellowish brown silty sand	
2	R	3		II	0.70	1.10	10YR 7/4 very pale brown silty sand	

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Area	Transect	STP	Radial	Level	Start Depth (ft)	End Depth (ft)	Soil Description	Comments
2	R	4		I	0.00	0.60	10YR 5/4 yellowish brown sandy loam	
2	R	4		II	0.60	1.00	10YR 7/3 very pale brown sandy loam	
2	R	5		I	0.00	0.70	10YR 5/4 yellowish brown silty sand	
2	R	5		II	0.70	1.10	10YR 7/4 very pale brown silty sand	
2	R	6		I	0.00	0.60	10YR 5/4 yellowish brown sandy loam	
2	R	6		II	0.60	1.00	10YR 7/3 very pale brown sandy loam	
2	R	7		I	0.00	0.60	10YR 5/4 yellowish brown silty sand	
2	R	7		II	0.60	1.00	10YR 7/4 very pale brown silty sand	
2	R	8		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	R	8		II	0.20	0.80	10YR 7/3 very pale brown sandy loam	
2	R	9		I	0.00	0.60	10YR 5/4 yellowish brown silty sand	
2	R	9		II	0.60	1.00	10YR 7/4 very pale brown silty sand	
2	R	10		I	0.00	0.10	10YR 5/4 yellowish brown sandy loam	
2	R	10		II	0.10	0.50	10YR 7/3 very pale brown sandy loam	
2	R	11		I	0.00	0.90	10YR 5/4 yellowish brown sandy loam	
2	R	11		II	0.90	1.30	10YR 7/4 very pale brown sandy loam	
2	R	12		I	0.00	0.20	10YR 5/4 yellowish brown sandy loam	
2	R	12		II	0.20	0.70	10YR 7/3 very pale brown sandy loam	
2	R	13		I	0.00	0.50	10YR 5/4 yellowish brown sandy loam	
2	R	13		II	0.50	0.90	10YR 7/4 very pale brown sandy loam	
2	R	14		I	0.00	0.30	10YR 5/4 yellowish brown sandy loam	
2	R	14		II	0.30	0.60	10YR 7/3 very pale brown sandy loam	
2	R	15		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	R	15		II	0.40	0.80	10YR 7/4 very pale brown sandy loam	
2	R	16		I	0.00	0.40	10YR 5/4 yellowish brown sandy loam	
2	R	16		II	0.40	0.80	10YR 7/4 very pale brown sandy loam	
2	R	17		I	0.00	0.10	10YR 5/1 gray sandy loam	
2	R	17		II	0.10	0.80	10YR 7/4 very pale brown sandy loam	
2	R	18		I	0.00	0.70	10YR 5/4 yellowish brown sandy loam	
2	R	18		II	0.70	1.10	10YR 7/4 very pale brown sandy loam	

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APPENDIX B: ARTIFACT CATALOG

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Site	Provenience		Strat	Level	Count	Object	Part	Material	Ware	Manufacture Tech.	Size Class	% Cortex	Comments
44CE0914	STP	1-A-4	I	1	1	Debitage	Whole	Quartz			3	25-49%, Cobble Cortex	Cortical Platform
44CE0914	STP	1-A-4 North	0		1	Debitage	Fragment	Quartz			3	0% Cortex	No Platform
44CE0914	STP	1-A-4 West	I	1	1	Debitage	Broken	Quartz			3	0% Cortex	Platform Intact
44CE0914	STP	1-B-2	I	1	1	Debitage	Fragment	Quartz			3	0% Cortex	No Platform
44CE0914	STP	1-B-2 West	I	1	1	Debitage	Broken	Quartz			4	0% Cortex	No Platform
44CE0915	STP	2-G-18	I	1	1	Hollowware	Body Fragment	Refined Earthenware	Ironstone				Plain
44CE0915	MD Hit	MD-1	I	1	1	Indeterminate	Fragment	Lead		Indeterminate			
44CE0915	MD Hit	MD-3	I	1	1	Nail	Head and Shaft	Iron Alloy		Cut, Machine Cut Head			
44CE0915	MD Hit	MD-4	I	1	2	Nail	Head and Shaft	Iron Alloy		Cut, Machine Cut Head			
44CE0915	MD Hit	MD-5	I	1	1	Nail	Head and Shaft	Iron Alloy		Cut, Machine Cut Head			Burned
44CE0915	MD Hit	MD-6	I	1	1	Nail	Head and Shaft	Iron Alloy		Cut, Machine Cut Head			
44CE0915	MD Hit	MD-7	I	1	1	Nail	Head and Shaft	Iron		Cut, Machine Cut Head			
44CE0915	MD Hit	MD-8	I	1	1	Spike	Complete	Iron		Cut, Machine Cut Head			
ISF 1	MD Hit	MD-2	I	1	1	Buckle	Complete	Iron		Cast			

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APPENDIX C: ARCHAEOLOGICAL SITE FORMS

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Snapshot

Date Generated: September 25, 2019

Site Name: No Data
Site Classification: Terrestrial, open air
Year(s): No Data
Site Type(s): Artifact scatter
Other DHR ID: No Data
Temporary Designation: Site 1

Site Evaluation Status

Not Evaluated

Locational Information

USGS Quad: RAPPAHANNOCK ACADEMY
County/Independent City: Caroline (County)
Physiographic Province: Coastal Plain
Elevation: 45
Aspect: Flat
Drainage: Lower Chesapeake
Slope: 0 - 2
Acreage: 0.390
Landform: Bluff
Ownership Status: Private
Government Entity Name: No Data

Site Components

Component 1

Category: Indeterminate
Site Type: Artifact scatter
Cultural Affiliation: Native American
DHR Time Period: Pre-Contact
Start Year: No Data
End Year: No Data
Comments: No diagnostic artifacts recovered.

Bibliographic Information

Bibliography:
No Data
Informant Data:
No Data

Archaeological site data is protected under the Archaeological Resource Protection Act (ARPA 1979).

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CRM Events

Event Type: Survey:Phase I

Project Staff/Notes:

Field Director: Joseph Blondino

Project Review File Number: No Data

Sponsoring Organization: No Data

Organization/Company: Dovetail CRG

Investigator: Joe Blondino

Survey Date: 8/9/2019

Survey Description:

Phase I archaeological survey of a proposed raw water intake site, pipeline corridor, and water treatment plant site. All locations were tested with STPs excavated at 50-foot intervals with half-interval radials around positive STPs. Water treatment plant site location was also metal detected due to proximity to Civil War action at North Anna.

Current Land Use	Date of Use	Comments
Agricultural field	8/9/2019 12:00:00 AM	No-till agricultural field (formerly plowed/disced)

Threats to Resource: Public Utility Expansion

Site Conditions: Surface Deposits Present But With No Subsurface Integrity

Survey Strategies: Subsurface Testing, Surface Testing

Specimens Collected: Yes

Specimens Observed, Not Collected: No

Artifacts Summary and Diagnostics:

5 pieces quartz debitage

Summary of Specimens Observed, Not Collected:

No Data

Current Curation Repository: Dovetail CRG, Fredericksburg, VA

Permanent Curation Repository: landowner

Field Notes: Yes

Field Notes Repository: Dovetail CRG, Fredericksburg, VA

Photographic Media: Digital

Survey Reports: Yes

Survey Report Information:

Joseph R. Blondino and Mical Tawney. Phase IB Cultural Resource Survey of Proposed Water Intake and Treatment Plant Sites, Caroline County, Virginia. Dovetail Cultural Resource Group, Fredericksburg, Virginia. 2019.

Survey Report Repository: Dovetail CRG, Fredericksburg, VA

DHR Library Reference Number: No Data

Significance Statement: Site appears to have a relatively low artifact density and has been disturbed by plowing.

Surveyor's Eligibility Recommendations: Recommended Not Eligible

Surveyor's NR Criteria Recommendations, : No Data

Surveyor's NR Criteria Considerations: No Data

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Snapshot

Date Generated: September 25, 2019

Site Name: No Data
Site Classification: Terrestrial, open air
Year(s): 1864 - 1864
Site Type(s): Earthworks
Other DHR ID: No Data
Temporary Designation: Site 2

Site Evaluation Status

Not Evaluated

Locational Information

USGS Quad: RUTHER GLEN
County/Independent City: Caroline (County)
Physiographic Province: Coastal Plain
Elevation: 185
Aspect: Facing Southwest
Drainage: Lower Chesapeake
Slope: 2 - 6
Acreage: 1.660
Landform: Ridge Top
Ownership Status: Private
Government Entity Name: No Data

Site Components

Component 1

Category: Military/Defense
Site Type: Earthworks
Cultural Affiliation: Euro-American
DHR Time Period: Civil War
Start Year: 1864
End Year: 1864
Comments: Earthworks are likely associated with action at North Anna.

Bibliographic Information

Bibliography:

Joseph R. Blondino and Mical Tawney. Phase IB Cultural Resource Survey of Proposed Water Intake and Treatment Plant Sites, Caroline County, Virginia. Dovetail Cultural Resource Group, Fredericksburg, Virginia.

Informant Data:

No Data

Archaeological site data is protected under the Archaeological Resource Protection Act (ARPA 1979).

Received by VMRC on March 27, 2020 /lra

CRM Events

Event Type: Survey:Phase I

Project Staff/Notes:

Field Director: Joseph Blondino

Project Review File Number: No Data

Sponsoring Organization: No Data

Organization/Company: Dovetail CRG

Investigator: Joe Blondino

Survey Date: 8/9/2019

Survey Description:

Phase I archaeological survey of a proposed raw water intake site, pipeline corridor, and water treatment plant site. All locations were tested with STPs excavated at 50-foot intervals with half-interval radials around positive STPs. Water treatment plant site location was also metal detected due to proximity to Civil War action at North Anna.

Current Land Use	Date of Use	Comments
Forest	8/9/2019 12:00:00 AM	*No Data*

Threats to Resource: Public Utility Expansion

Site Conditions: Surface Features

Survey Strategies: Historic Map Projection, Metal Detection, Subsurface Testing

Specimens Collected: Yes

Specimens Observed, Not Collected: No

Artifacts Summary and Diagnostics:

6 cut nails
1 cut spike
1 iron buckle
1 unidentified piece of lead

Summary of Specimens Observed, Not Collected:

No Data

Current Curation Repository: Dovetail Cultural Resource Group, Fredericksburg, Virginia

Permanent Curation Repository: landowner

Field Notes: Yes

Field Notes Repository: Dovetail Cultural Resource Group, Fredericksburg, Virginia

Photographic Media: Digital

Survey Reports: Yes

Survey Report Information:

Joseph R. Blondino and Mical Tawney. Phase IB Cultural Resource Survey of Proposed Water Intake and Treatment Plant Sites, Caroline County, Virginia. Dovetail Cultural Resource Group, Fredericksburg, Virginia. 2019.

Survey Report Repository: Dovetail CRG, Fredericksburg, VA

DHR Library Reference Number: No Data

Significance Statement: Site contains well-preserved Civil War earthworks/entrenchments.

Surveyor's Eligibility Recommendations: Recommended Potentially Eligible

Surveyor's NR Criteria Recommendations, : A, D

Surveyor's NR Criteria Considerations: No Data

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APPENDIX D: PRINCIPAL INVESTIGATOR QUALIFICATIONS

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DOVETAIL
CULTURAL RESOURCE GROUP
WWW.DOVETAILCRG.COM

D. BRAD HATCH, PHD, RPA

Principal Investigator/Archaeology Division Manager

YEARS EXPERIENCE

With this firm: 8

With other firms: 4

EDUCATION

PhD/Anthropology, 2015

MA/Anthropology and Historical Archaeology, 2009

BA/Historic Preservation, 2007

REGISTRATIONS/QUALIFICATIONS

Registered Professional Archaeologist

Council of Virginia Archaeologists

Secretary of Interior Standards Qualified as Archaeologist and Historian

PUBLICATIONS/PRESENTATIONS/COMMITTEES

Program Co-Chair/Middle Atlantic Archaeological Conference (2017–Present)

Anglo-Native Interaction in Virginia's Potomac River Valley. Paper presented at the Society for Historical Archaeology Conference (2018)

Dairies and Dairying in the Middle Atlantic. Paper presented at the Middle Atlantic Archaeological Conference (2016)

Reassessing the Hallowes Site: Conflict and Settlement in the 17th-century Potomac Valley. *Historical Archaeology* (2014)

Venison Trade and Interaction between English Colonists and Native Americans in Virginia's Potomac River Valley. *Northeast Historical Archaeology* (2012)

Bones, Pans, and Probates: A Faunal Analysis of the Newman's Neck Site (44NB180). *Journal of Middle Atlantic Archaeology* (2011)

EXPERIENCE

Dr. Hatch has over 12 years of experience doing archaeology in the Middle Atlantic region in academic, museum, and cultural resource management (CRM) contexts. His experience ranges from survey and site identification to data recovery excavations on historic and prehistoric sites in Virginia, Maryland, West Virginia, Tennessee, Pennsylvania, Delaware, and North Carolina. Dr. Hatch has been involved with excavations at multiple sites focusing on late prehistoric and contact period Native American sites in Southern Maryland, and the Colonial Encounters project, a reanalysis and synthesis of over 15 sites dating from the early colonial period in the Lower Potomac Valley. Dr. Hatch's primary responsibility for the Colonial Encounters project included the analysis and reporting of the faunal collections from sites in both Maryland and Virginia. His responsibilities at Dovetail include managing projects, writing proposals, tracking budgets, scheduling, and managing the archaeological staff, among other tasks.

SAMPLE PROJECTS

Principal Investigator/Thoburn's Redoubt Interpretive Trail Project (Warren, Virginia). Archaeological studies including testing and metal detecting on the Cedar Creek Battlefield in preparation for parking lot and trail construction.

Principal Investigator/Sunnybrook Farm Solar Project (Halifax, Virginia). Cultural resource studies, staffing, and agency coordination for a proposed solar farm under the Virginia Department of Environmental Quality Permit By Rule process.

Principal Investigator/Buck Knob Virginia State Police Tower Project (Wise, Virginia). Archaeological investigations for a telecommunications tower, including agency coordination.

Project Manager/Greenfield Outbuilding Relocation Project (Botetourt, Virginia). Archaeological investigations and archival research of two nineteenth-century plantation outbuildings related to enslaved occupations on behalf of the County.

Project Manager/Cedar Creek Administrative Building Parking Improvements (Frederick, Virginia). Archaeological studies including shovel testing, test unit excavation, and metal detecting on the Cedar Creek and Belle Grove National Historical Park, under the National Park Service

Principal Investigator/Fall Hill Data Recovery (Fredericksburg, Virginia). Archaeological data recovery and intensive archival research on eighteenth- and nineteenth-century tenant site on the outskirts of Fredericksburg on behalf of VDOT.

Received by VMRC on March 27, 2020 /lra

Hazen and Sawyer
1555 Roseneath Road
Richmond, VA 23230 • 804.266.1400

October 19, 2023

Allison Major
VWP Permit Writer, Water Division
Virginia Department of Environmental Quality
1111 E. Main Street, Suite 1400
Richmond, VA, 23218

Re: Joint Permit Application (JPA) Number 20-0514; Caroline County Rappahannock River Water Supply Project, Caroline County, Virginia; Request for Additional Information Letter

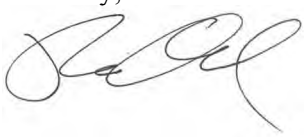
Dear Ms. Major:

On behalf of Caroline County, we are writing in response to the Request for Additional Information letter pertaining to the above-referenced project received from DEQ dated October 3, 2023. In response to that letter, we have provided comment responses and enclosed the items requested by DEQ.

- Responses to DEQ Comments
- Appendix A – Narrative Description of Proposed Impacts

Please contact us with any questions or additional needs regarding this permit application.

Sincerely,



Roger B. Arnold, PE
Senior Associate

cc: J. Schiebel, Caroline County
E. Seavey, Department of Environmental Quality
E. Gallup, Department of Environmental Quality
C. Gorman, Virginia Marine Resources Commission
S. Gazzera, U.S. Army Corps of Engineers
C. Tabor, Hazen and Sawyer

Job no 32380-002

Responses to DEQ Comments

1. *In Appendix D, the applicant provided the Preliminary Jurisdictional Delineation (PJD) approved by the U.S. Army Corp of Engineers (USACE) dated August 28, 2020. In addition, the applicant provided the design plans/cross sections of the stream crossings that have been identified for having permanent impacts. Per the Additional Information Request dated July 12, 2023, and per 9VAC25-690-60 provide the information requested below:*

    a. *Cross-sectional drawings of each proposed impact area (both temporary and permanent) shall include at a minimum a graphic scale, existing structures, existing and proposed elevations, limits of surface water areas, ebb and flood or direction of flow (if applicable), ordinary high water mark in nontidal areas, impact limits, and location of all existing and proposed structures. Profile drawings with this information are required to demonstrate the minimization of impacts. Any application that proposes piping or culverting stream flows shall provide a longitudinal profile of the pipe or culvert position and stream bed thalweg or shall provide spot elevations of the stream thalweg at the beginning and end of the pipe or culvert, extending to a minimum of 10 feet beyond the limits of proposed impact.*

        Response: In addition to plan drawings of the pipeline, profile drawings of significant stream crossings were previously provided to DEQ. As described in Appendix A, many of the other proposed stream crossings involve temporary impacts to small streams (e.g. less than 5 feet wide), some of which are classified as intermittent streams. Based on subsequent discussions with DEQ, final design drawings including plan and profile drawings of the raw water pipeline will be submitted to DEQ prior to construction.

        In addition, please note that the application does not propose culverting of stream flows.

    b. *A narrative description of all impacts proposed (both temporary and permanent) to surface waters, including the type of activity to be conducted in surface waters and any physical alteration to surface waters.*

        Response: Please refer to the enclosed narrative description of proposed impacts in Appendix A.

    c. *Appendix D provided a visual of where the Resource Protection Areas (RPAs) were located, however a written description identifying all upland areas including buffers, wetlands, open water, other surface waters, and compensatory mitigation areas located within the proposed project boundary or permittee-responsible compensatory mitigation areas that are under a deed restriction, conservation easement, restrictive covenant, or other land use protective instrument (i.e., protected areas) was not included. Such description shall include the nature of the prohibited activities within the protected areas and the limits of Chesapeake Bay RPAs as field-verified by the applicant, and if available, the limits as approved by the locality in which the project site is located, unless the proposed use is exempt from the Chesapeake Bay Preservation Area Designation and Management Regulations (9VAC25-830), as additional state or local requirements may apply if the project is located within an RPA.*

Response: The raw water pipeline corridor traverses Fort A.P. Hill, an active U.S. Army base, within the corridor in which U.S. 301 is located. The project also traverses the Pettigrew Wildlife Management Area. Installation of the buried raw water pipeline is not anticipated to have negative impacts to either the Army base or the Pettigrew Wildlife Management Area, and discussions with entities associated with both areas have not expressed concern relative to the project or its proposed installation location. No areas in which deed restrictions, conservation easements, restrictive covenants, or other land use protective instruments are known to be present within the project areas. Additionally, no compensatory mitigation areas or permittee-responsible compensatory mitigation areas are present with the project areas.

Relative to RPA's, per 9VAC25-830-150, construction, installation, and maintenance of water lines owned, permitted, or both, by a local government or regional service authority shall be exempt as long as specific requirements are met. The proposed raw water pipeline meets the exemption requirements for RPA's.

The proposed raw water pump station at the Rappahannock River is located adjacent to the RPA along the river. Disturbance associated with construction of the RPA will remain outside the RPA, and impacts within the RPA are not anticipated.

2. *Commercial Demands:*

   a. *Transit Oriented Development (TOD):*
      i. *Table 3.7 states that "Residential water demand adapted from the Water Master Plan based on a midpoint between TOD and non-TOD scenarios (refer to Table 3-2);*

      ii. *Provide commercial demands reflecting TOD and non-TOD scenarios; and,*

      iii. *The 2008 Caroline County TOD Study is used in the application as justification for future water demands within the 15 year permit term (2038). Please provide the current implementation as a result of this study.*

      iv. *Please provide a timeline in which the TOD will be completed and operational. Specifically, please address what will be completed in the 15 year permit term (i.e., 2038).*

Response: As described in the Transit Oriented Development Study, this project consists of a residential, commercial, and mixed-use development near the Carmel Church area of Caroline County are associated with a high speed rail project. The County's Water Master Plan presents water demand projections with and without the TOD project. Table 1 presents projected commercial demands for TOD and non-TOD scenarios. Based on the anticipated mixed-use development at Carmel Church, the commercial demands associated with the TOD scenario were used as the basis of the water supply project.

Table 1. Summary of Commercial Water Demands With and Without TOD

Demand Category	2028, mgd	2033, mgd	2038, mgd	2043, mgd	2048, mgd
Commercial with TOD	0.63	1.01	1.34	1.42	1.51
Commercial without TOD	0.20	0.31	0.41	0.50	0.58

[1] Water demand projections linearly interpolated from the Water Master Plan.

The project area has been designated as an Urban Development Area (UDA) in Caroline County's Comprehensive Plan, and the property has been zoned as Planned Mixed Use Development (PMUD). The DC to Richmond Southeast High Speed Rail project complete the Final Environmental Impact Statement in May 2019, and the Record of Decision was finalized in September 2019. In addition, the County understands that developers are actively seeking project implementation at the UDA in Carmel Church. In accordance with 9VAC25-780-100, Caroline County is required to plan for water supply for these anticipated needs.

3. *Industrial Demands:*

   a. *Table 3-7 annotation No. 2 states "the average day industrial demands estimated based on maximum day demands provided by anticipated industrial users". Please provide the calculation for how this was determined. In addition, please provide more information on the industrial facilities determined their anticipated water demand.*

   Response: Maximum day water demands were provided by industrial users and converted to average day demands for aggregation with other demand categories. A peaking factor of 1.6, as indicated in Section 3.1, was applied to determine the average day demand for industrial users. For example, the projected maximum day industrial demand in planning year 2038 is 4.2 mgd, and this value was divided by the peaking factor of 1.6 to determine the average day demand of 2.63 mgd listed in Table 3-7.

   b. *Appendix C Section 3.4.4 states that a standard peaking factor was used when calculating the maximum daily withdrawal demand for each of the three (3) projects (Projects Tricycle, Clean Arc, and Tract). Appendix C Section 4.2 appears to apply the peaking factor a second time to the cumulative average (Table 3-7). Was the peaking factor applied two separate times when calculating the peak day demand?*

   Response: The peaking factor was correctly applied when calculating the maximum day industrial demand. The average day demand was first back-calculated based on the maximum day demand estimates provided by industrial users (i.e., the maximum day demand was divided by the peaking factor). This average day demand was then combined with other water use categories (e.g. residential, commercial, etc.). The total maximum day demand was determined by multiplying the total average day demand by the peaking factor; in addition a VDH certification factor of 1.1 was also applied (as described in Section 3.1) for a total multiplier of 1.76.

   Table 2 clarifies projected demands and withdrawals for planning year 2028.

Table 2. Summary of Average and Maximum Day Demands for Planning Year 2038

Category	2038 Average Day	2038 Maximum Day[1]
Caroline County:		
Current Demands	0.58	1.02
Residential	2.47	4.35
Commercial	1.34	2.36
Industrial	2.63	4.63
Bowling Green	0.50	0.88
Total Demand	**7.52**	**13.24**
Total Withdrawal[2]	**7.90**	**13.89**

1. *Maximum day values include a peaking factor of 1.6 and a VDH certification factor of 1.1, for a total multiplier of 1.76.*
2. *Total withdrawal includes an additional 5% allocation for process water use.*

c. *Does the demand include potential water conservation measures implemented by the industrial users, for example, water recycling?*

Response: The industrial demands consider a planned water reuse supply by Caroline County from its wastewater treatment plant, which is intended to offset additional water withdrawals. Water demands were provided by industrial users, who are responsible for considering additional on-site water conservation measures at private facilities when determining water demands.

4. *Provide and update Table 4-2: Summary of Water Withdrawals for Caroline County and the Town of Bowling Green to capture the information requested in questions Two (2) and three (3) above.*

Response: No updates to Table 4-2 are needed at this time. The table above provides an additional summary of demands and withdrawals for planning year 2038 corresponding to the values Table 4-2 in the *Summary of Water Demand Projections*.

Appendix A – Narrative Description of Proposed Impacts

Physical alteration of surface waters will be minimal under the proposed project. This document provides a description of the proposed impacts to surface waters as depicted on the Jurisdictional Waters Impact Map (with Lat and Long provided). An additional summary of the acreage of impacts by impact type is also provided herein.

Permanent Impacts

Permanent impacts to streams will occur only at the proposed raw water intake in the Rappahannock River. Permanent impacts to wetlands will occur at only two locations for raw water pipeline construction where forested wetlands will be converted to non-forested wetlands. These permanent impacts are described as follows.

Streams:

- **Impact site 26 (S-30)** – This site is located in an approximately 350-foot wide portion of the Rappahannock River with the impact site being 50 feet in length. Impact site 26 consists of construction of a raw water intake structure that will result in 1,195 square feet (sf) of permanent impact to the bed of the Rappahannock River. A raw water pipe will be installed from a pump station being constructed in an upland area to the raw water intake structure in the Rappahannock River via trenchless pipe installation.

In summary, permanent impacts to a jurisdictional stream, the Rappahannock River, from construction of a raw water intake structure will occur at impact site 26 and total 1,195 sf (<0.03 acre) of impact.

Wetlands:

- **Impact site 28 (W-9) –** This site consists of permanent conversion of 741 sf (0.02 acre) of forested wetland (PFO1A) to non-forested wetland (PEM) to accommodate a post-construction pipeline access road that will allow for inspection, maintenance, and repair of the raw water infrastructure.
- **Impact site 29 (W-11)** – This site consists of permanent conversion of 433 sf (0.01 acre) of forested wetland (PFO1A) to non-forested wetland to accommodate the aforementioned post-construction access road.

In summary, permanent impacts to jurisdictional wetlands from implementation of the proposed project will occur at two impact sites (impact sites 28 and 29) and total 1,174 sf (0.03 acre) of impact from conversion of forested wetlands to non-forested wetlands to provide a permanent access road in the raw water pipe corridor to allow for inspection, maintenance, and repair access.

It should be noted that the areas of conversion will be returned to original grade upon completion of construction activities and seeded with an appropriate wetland seed mixture in a timely manner upon completion of construction activities in the area in which the wetland is located.

Temporary Impacts

Except for temporary construction impacts associated with installation of the raw water intake structure in the Rappahannock River, temporary impacts to jurisdictional waters of the US will occur from excavation and/or installation of the buried raw water pipeline. The buried raw water pipeline will be installed using open cut pipe installation methods in the wetland and stream areas discussed below. Where feasible, the area of excavation was positioned within the corridor to minimize impacts to any jurisdictional waters of the US.

It should be noted that, where feasible and practicable, the raw water pipeline will be installed via trenchless pipe installation to avoid and/or minimize impacts to jurisdictional waters of the US. The jurisdictional waters not impacted by the proposed project are not included in this narrative description of impacts. Plan and profile drawings of these trenchless stream crossings have been developed and submitted separately.

Streams:

- **Impact site 27 (S-30)** – This site is located in the Rappahannock River, which is a perennial stream. The Rappahannock River at impact site 27 is approximately 350 feet wide and the length of impact is 100 feet. Impact site 27 impacts consist of 7,000 sf of temporary construction access and in-water erosion and sediment control measures via a cofferdam. The cofferdam will allow installation activities of the raw water intake to be performed in the dry, which will prevent disturbed soils or sediments from being released in the Rappahannock River.
- **Impact site 3 (S-1)** – This site comprised of a culvert and 14 feet of an approximately 7-foot wide portion of a perennial stream. Impact site 3 is in the project limits of disturbance, but outside of the area of excavation required for installation of a buried utility service line. No trenching for pipe installation is anticipated within the limits of the stream, and temporary impacts will be limited to vehicle access or installation of temporary erosion and sediment control measures. Impact site 3 consists of temporary construction impacts with the area of disturbance being 98 sf.
- **Impact site 4 (S-2)** – This site is comprised of a culvert and 20 feet of an approximately 11-foot wide portion of a perennial stream. Impact site 4 consists of temporary construction impacts with the disturbance of impact site 4 being outside of the area of excavation required for installation of a buried utility service line. No trenching for pipe installation is anticipated within the limits of the stream, and temporary impacts will be limited to vehicle access or installation of temporary erosion and sediment control measures. The area of disturbance associated with impact site 4 is 220 sf.
- **Impact site 5 (S-3)** – This site is comprised of a culvert and 21 feet of an approximately 9-foot wide portion of a perennial stream. Impact site 5 consists of temporary construction impacts with the disturbance of impact site 5 being outside of the area of excavation required for installation of a buried utility service line. No trenching for pipe installation is anticipated within the limits of the stream, and temporary impacts will be limited to vehicle access or installation of temporary erosion and sediment control measures. The area of disturbance associated with impact site 5 is 189 sf.
- **Impact site 22 (S-29)** – This site consists of temporary construction impacts associated with excavation and installation of a buried utility service line under a perennial stream, Goldenvale Creek. The area of disturbance associated with impact site 22 consists of 52 feet of an approximately 31-foot wide perennial stream with the area of disturbance being 1,612 sf.
- **Impact site 23 (S-7)** – This site consists of temporary construction impacts associated with excavation and installation of a buried utility service line under 50 feet of an approximately 25-

foot wide perennial stream, Mill Creek. The area of disturbance associated with impact site 23 is 1,250 sf.

- **Impact site 6 (S-6)** – This site is comprised of a culvert and 36 feet of an approximately 3-foot wide portion of a perennial stream located between the north and south bound lanes of US 301. Impact site 6 consists of temporary construction impacts with the disturbance of impact site 6 being outside of the area of excavation required for installation of a buried utility service line. No trenching for pipe installation is anticipated within the limits of the stream, and temporary impacts will be limited to vehicle access or installation of temporary erosion and sediment control measures. The area of disturbance associated with impact site 6 is 108 sf.
- **Impact site 8 (S-10)** – This site is comprised of two culverts and 22 feet of an approximately 2-foot wide portion of an intermittent stream between the culverts. Impact site 8 is between the north and south bound lanes of US 301 and consists of temporary construction impacts associated with excavation and installation of a buried raw water pipeline under an intermittent stream. The area of disturbance associated with impact site 8 is 44 sf.
- **Impact site 9 (S-18)** – This site is comprised of a culvert and 18 feet of an approximately 2-foot wide portion of an intermittent stream between the north and south bound lanes of US 301. Impact site 9 consists of temporary construction impacts with the disturbance of impact site 9 being outside of the area of excavation required for installation of a buried raw water pipeline. No trenching for pipe installation is anticipated within the limits of the stream, and temporary impacts will be limited to vehicle access or installation of temporary erosion and sediment control measures. The area of disturbance associated with impact site 9 is 36 sf.
- **Impact site 10 (S-19)** – This site is comprised of two culverts and 4 feet of an approximately 4-foot wide portion of an intermittent stream between the culverts. Impact site 10 is between the north and south bound lanes of US 301 and consists of temporary construction impacts associated with excavation and installation of a buried raw water pipeline under an intermittent stream. The area of disturbance associated with impact site 10 is 16 sf.
- **Impact site 11 (S-21)** – This site is comprised of two culverts and 11 feet of an approximately 2-foot wide portion of an intermittent stream between the culverts. Impact site 11 is between the north and south bound lanes of US 301. Impact site 11 consists of temporary construction impacts with the disturbance of impact site 11 being outside of the area of excavation required for installation of a buried raw water pipeline. No trenching for pipe installation is anticipated within the limits of the stream, and temporary impacts will be limited to vehicle access or installation of temporary erosion and sediment control measures. The area of disturbance associated with impact site 11 is 22 sf.
- **Impact site 13 (S-23)** – This site is comprised of two culverts and 22 feet of an approximately 2-foot wide portion of an intermittent stream between the culverts. Impact site 13 is between the north and south bound lanes of US 301 and consists of temporary construction impacts associated with excavation and installation of the buried raw water pipeline under an intermittent stream. The area of disturbance associated with impact site 13 is 44 sf.
- **Impact site 14 (S-24)** – This site is comprised of two culverts and 29 feet of an approximately 2-foot wide portion of an intermittent stream between the culverts. Impact site 14 is between the north and south bound lanes of US 301 and consists of temporary construction impacts associated with excavation and installation of a buried raw water pipeline under an intermittent stream. The area of disturbance associated with impact site 14 is 58 sf.
- **Impact site 15 (S-26)** – This site is comprised of a culvert and 22 feet of an approximately 5-foot wide portion of an intermittent stream. Impact site 15 consists of temporary construction impacts associated with excavation and installation of the buried raw water pipeline under an intermittent stream. The area of disturbance associated with impact site 15 is 110 sf.
- **Impact site 19 (S-28)** – This site is comprised of a culvert and 33 feet of an approximately 1-foot wide portion of an intermittent stream. An emergent wetland is located immediately upstream, of

which a portion is in the project corridor (impact site 18 [W-20]). Impact site 19 consists of temporary construction impacts associated with excavation and installation of the buried raw water pipeline under an intermittent stream. The area of disturbance associated with impact site 19 is 33 sf.

- **Impact site 12 (S-22)** – This site is comprised of two culverts and 12 feet of an approximately 2-foot wide portion a small portion of a perennial stream between the culverts. Impact site 12 consists of temporary construction impacts with the disturbance of impact site 12 being outside of the area of excavation required for installation of the buried raw water pipeline. No trenching for pipe installation is anticipated within the limits of the stream, and temporary impacts will be limited to vehicle access or installation of temporary erosion and sediment control measures. The area of disturbance associated with impact site 12 is 24 sf.

Areas of temporary disturbance within the stream impact areas will be returned to pre-construction condition with bank stabilization measures employed as needed in a timely manner upon completion of construction activities in the stream impact areas. Total temporary stream impacts from the installation of a buried utility service line consist of 466 feet, 10,864 sf, and 0.25 acre of stream.

Wetlands:

- **Impact site 1 (W-1)** – This site is comprised of a PFO1A forested wetland located along the edge of the limits of disturbance associated with the project. Impact site 1 consists of temporary construction impacts with the disturbance of impact site 1 being outside of the area of excavation required for installation of a buried raw water pipeline. The area of disturbance associated with impact site 1 is 89 sf (0.01 acre).
- **Impact site 2 (W-4)** – This site is comprised of a PFO1A forested wetland located along the edge of the limits of disturbance associated with the project. Impact site 2 consists of temporary construction impacts with the disturbance of impact site 2 being outside of the area of excavation required for installation of a buried raw water pipeline. No trenching for pipe installation is anticipated within the limits of the wetland, and temporary impacts will be limited to vehicle access or installation of temporary erosion and sediment control measures. The area of disturbance associated with impact site 2 is 88 sf (0.01 acre).
- **Impact site 21 (W-9)** – This site is comprised of a PFO1A forested wetland located within a portion of the project corridor. Impact site 21 consists of temporary construction impacts with the disturbance of impact site 21 being outside of the area of excavation required for installation of a buried raw water pipeline and outside of the proposed maintained access corridor. The area of disturbance associated with impact site 21 is 1,426 sf (0.03 acre).
- **Impact site 24 (W-11)** – This site is comprised of a PFO1A forested wetland located within a portion of the project corridor. Impact site 24 consists of temporary construction impacts with the disturbance of impact site 24 being outside of the area of excavation required for installation of a buried utility service line and outside of the proposed maintained access corridor. No trenching for pipe installation is anticipated within the limits of the wetland, and temporary impacts will be limited to vehicle access or installation of temporary erosion and sediment control measures. The area of disturbance associated with impact site 24 is 9,360 sf (0.22 acre).
- **Impact site 7 (W-12)** – This site is comprised of a PEM1E emergent wetland located within a portion of the project corridor. Impact site 7 consists of temporary construction impacts with the disturbance of impact site 7 being outside of the area of excavation required for installation of a buried utility service line and outside of the proposed maintained access corridor. No trenching for pipe installation is anticipated within the limits of the wetland, and temporary impacts will be

limited to vehicle access or installation of temporary erosion and sediment control measures. The area of disturbance associated with impact site 7 is 35 sf (0.01 acre).

- **Impact site 25 (W-16)** – This site is comprised of a PFO1A forested wetland located on the edge of the project corridor. The wetland abuts the downgradient end of a roadside stormwater drainage culvert. Impact site 25 consists of temporary construction impacts with the disturbance of impact site 25 being outside of the area of excavation required for installation of a buried utility service line and outside of the proposed maintained access corridor. No trenching for pipe installation is anticipated within the limits of the wetland, and temporary impacts will be limited to vehicle access or installation of temporary erosion and sediment control measures. The area of disturbance associated with impact site 25 is 42 sf (0.01 acre).
- **Impact site 16 (W-18)** – This site is comprised of a PEM1A emergent wetland that traverses the project corridor downgradient of a roadside stormwater drainage culvert. Impact site 16 consists of temporary construction impacts associated with excavation and installation of a buried utility service line under a wetland. The area of disturbance associated with impact site 16 is 519 sf (0.01 acre).
- **Impact site 17 (W-19)** – This site is comprised of a PEM1A emergent wetland located in a portion of the project corridor and extends downgradient from two roadside stormwater drainage culverts. Impact site 17 consists of temporary construction impacts associated with excavation and installation of a buried utility service line under a wetland. The area of disturbance associated with impact site 17 is 4,176 sf (0.1 acre).
- **Impact site 18 (W-20)** – This site is comprised of a PEM1A emergent wetland that extends downgradient of an intermittent stream (impact site 19[S-28]) in a portion of the project site that is outside of the area of excavation required for installation of a buried utility service line. Impact site 18 consists of temporary construction impacts associated with installation of a buried utility service line under a wetland with the area of disturbance associated with impact site 15 being 157 sf (0.01 acre).
- **Impact site 20 (W-21)** – This site is comprised of a PEM1A emergent wetland that traverses the project corridor downgradient of a roadside stormwater drainage culvert. Impact site 20 consists of temporary construction impacts associated with excavation and installation of a buried utility service line under a wetland. The area of disturbance associated with impact site 20 is 1,911 sf (0.04 acre).

In summary, the temporary wetland impacts associated with the proposed project will be from excavation and/or installation of the buried raw water pipeline under either a forested wetland (PFO1A) or an emergent wetland (PEM). Areas of disturbance within the wetland impact areas will be returned to pre-construction elevation and seeded with an appropriate wetland seed mixture in a timely manner upon completion of construction activities in the impact areas. Upon completion of construction activities, the temporarily impacted wetland areas will be allowed to naturally revegetate. Total temporary wetland impacts from the installation of a buried utility service line consist of 17,803 sf of wetlands comprised of 6,798 sf (0.28 acre) of forested wetland and 11,005 sf (0.17 acre) of emergent wetland.

Hazen and Sawyer
1555 Roseneath Road
Richmond, VA 23230 • 804.266.1400

January 16, 2024

Allison Major
VWP Permit Writer, Water Division
Virginia Department of Environmental Quality
1111 E. Main Street, Suite 1400
Richmond, VA, 23218

Re: Joint Permit Application (JPA) Number 20-0514; Caroline County Rappahannock River Water Supply Project, Caroline County, Virginia; Additional Information

Dear Ms. Major:

On behalf of Caroline County, we are writing in response to your letter pertaining to the above-referenced project received from DEQ on December 15, 2023. In response to that letter, we have provided comment responses and enclosed additional supporting information.

- Responses to DEQ Comments
- Appendix A – Transit Oriented Development Project Information
- Appendix B – Industrial Water Demand Evaluation References
- Appendix C – Public Meeting Notice

Please contact us with any questions or additional needs regarding this permit application.

Sincerely,



Roger B. Arnold, PE
Senior Associate

cc: J. Schiebel, Caroline County
E. Seavey, Department of Environmental Quality
E. Gallup, Department of Environmental Quality
C. Gorman, Virginia Marine Resources Commission
S. Gazzera, U.S. Army Corps of Engineers
C. Tabor, Hazen and Sawyer

Job no 32380-002

Responses to DEQ Comments

1. *The Department requested… that the applicant provide a more robust justification for including the water withdrawal needs as a result of the projected Transit Oriented Development (TOD) project into the demand projections for the 15-year permit term. The applicant stated that they will provide the updated Caroline County Board of Supervisors approved Capital Improvement Plan (CIP) that demonstrates the County's financial commitment in preparation of the TOD project implementation.*

   Response: To further demonstrate the County's commitment to supporting the TOD project, the following additional information is enclosed in **Appendix A** and summarized below. A private developer is responsible for implementation of the TOD project. The project plan for a mixed-use development located adjacent a railway stop known as Carmel Church Station was approved by the County Board of Supervisors in 2010. As described in the County's 2030 Comprehensive Plan (as amended through June 13, 2023), the Board of Supervisors approved the zoning classification for the TOD project property as Planned Mixed Use Development, per the Caroline County Zoning Ordinance.

   - **Board of Supervisors Zoning Approvals** – The Board of Supervisors approved rezoning of the property for the TOD as Planned Mixed Use Development in June 2010. The zoning was updated in November 2020 to provide additional time for a site plan to be submitted. The 2010 rezoning includes a Proffer statement indicating that water and sewer utilities at the property shall be installed by the Owner, and that the Owner shall utilize the County's water and sewer systems.
   - **Caroline County Utilities Capital Improvement Program (CIP)** – While the Owner of the TOD development will be responsible for water and sewer utilities at the site as indicated in the Proffer statement, the County is planning CIP projects to support reliable water and sewer and service to the development. A copy of the County's 2023 CIP is enclosed.
   - **A Brief Synopsis of the Caroline County Commuter Rail Project** – This document provides an overview of the history of the TOD project and the County's role. The document explains that the "Caroline County Board of Supervisors have exercised leadership over a fifteen-year period to build administrative recognition, political support and numerous partnerships to position Carmel Church Station as a geographically defined urban development worth of unparalleled investment that will generate exceptional economic impact."
   - **Carmel Church Station Presentation** – This presentation on behalf of the TOD project developer describes the planned mixed use transit-oriented development at Carmel Church Station. As described in the presentation, "the proffers commit the project to an aggressive program of water efficiency".
   - **Caroline County TOD Study Bubble Plan** – This document describes the land use plan for the TOD project and includes drawings depicting the mixed use development. The Bubble Plan explains that population growth associated with the TOD project is expected by 2030.
   - **Construction Cost Update** – This document describes the anticipated construction cost of the project and the fiscal impact on Caroline County. The County will receive a one-time cash proffer from the developer to fund construction of schools, roads, utilities, and parks, and the County will incur costs associated with public safety and education of residents. This document describes phased construction of the development with completion by 2035 (refer to Table 4.2).

2. *The Department requested… that the applicant provide further clarification on the methodology industrial users used when determining what their water needs would be. In addition, the Department requested that the applicant provide the calculations/methodology that applicant factored when determining the projected maximum daily withdrawal needs for all industrial users.*

   Response: Due to the heat generated by servers, data centers require cooling to maintain the temperature and humidity within the facility at appropriate levels. Water is used at data centers to supply cooling towers which use water evaporation to reject heat from the data center. Water consumption at data center varies depending on the design of the cooling system, the size of the facility, the energy consumption for servers, and the local ambient outdoor temperature and humidity. Due to these variables, cooling system design and estimates of maximum water demands are often based on proprietary analysis and design by data center operators.

   For water supply planning purposes, the County developed industrial water use estimates through a combination of the following steps: (1.) analysis of industry literature and published research on water use at data centers, (2.) coordination between the County's Economic Development department and prospective industrial users, and (3.) review of reported water use rates for existing data centers. These analyses are further described as follows:

   1. ***Analysis of industry literature and published research.*** As described by Siddik et al (2021), "direct water consumption of a data center can be estimated from the heat generation capacity of a data center, which is related to the amount of electricity used". The typical average cooling water requirements of data centers were evaluated and reported by Shehabi et al (2016). In the literature, water consumption by data centers is typically defined as the difference between the water demand and the water discharge, and the total water demand was used for purposes of the proposed water withdrawal rates in the JPA. Day-to-day water use for cooling purposes varies depending on numerous factors, especially the ambient outdoor temperature. Maximum water demands for cooling typically occur during times with high ambient outdoor temperatures, increasing evaporative cooling needs (Zhang, 2022). Adequate water capacity is needed to ensure that servers can run reliably and continuously with sufficient cooling on hot days (Zhang, 2022). For purposes of the JPA, maximum day water demands for evaporative cooling were estimated, and actual water use during other times of year is expected to be lower. It should be noted that Siddik et al (2021) concluded that locating data centers in Virginia would have a lower water footprint impact relative to other areas of the country.
   2. ***Coordination with prospective industrial users.*** The County's Economic Development department coordinated with prospective industrial users to determine anticipated maximum water demands for planning purposes. Water demands were based on the size of proposed facilities, anticipated energy consumption for data servers, and local climatic conditions (i.e., range of temperature and humidity), according to proprietary analyses by data center operators.
   3. ***Review of reported water use rates for existing data centers.*** To further verify industrial water demands, maximum water demands for evaporative cooling were reviewed in comparison to existing data centers. Anticipated maximum day water demands for prospective industries in Caroline County are consistent with reported maximum water use for other existing data centers based on the summary provided by Zhang (2022) and additional sources[1][2][3].

[1] Osaka, 2023. A New Front in the Water Wars. Washington Post.
[2] O'Donnell, 2022. Data Center Water Usage Challenges and Sustainability. Accessed at: https://sensorex.com/data-center-water-usage-challenges/
[3] Barrowclough, 2023. Transforming data centre cooling for a sustainable future. Accessed at: https://datacentremagazine.com/articles/transforming-data-centre-cooling-for-a-sustainable-future

The references containing supporting information used for this analysis are enclosed in **Appendix B**.

The following table presents the anticipated maximum day demand values for industrial cooling purposes during the anticipated permit term in a tabular format. These values are consistent with the analysis presented in the Summary of Water Demand Projections memorandum submitted to DEQ in September 2023.

Summary of Industrial Cooling Water Demands

	Maximum Day Demand (mgd)			
Year	Project Tract	Project Clean Arc	Project Tricycle	Total
2025	0.2	0.2	0	0.4
2026	0.4	0.2	0	0.6
2027	0.6	0.6	0	1.2
2028	0.6	0.6	0	1.2
2029	0.6	0.6	0.4	1.6
2030	0.6	0.6	0.6	1.8
2031	0.6	1	0.6	2.2
2032	0.6	1	0.8	2.4
2033	0.6	1	1.4	3
2034	0.6	1.4	1.4	3.4
2035	0.6	1.4	1.6	3.6
2036	0.6	1.4	1.6	3.6
2037	0.6	1.4	2	4
2038	0.6	1.4	2.2	4.2

3. *Applicant stated that they performed additional public outreach in addition to what was previously provided in the initial Joint Permit Application (JPA). The Department requested a brief summary of the additional public outreach activities.*

Response: Caroline County held a series of meetings with representatives from three community groups in November and December 2023. The purpose of these meetings was for the County to gather input from the community and better understand the perspectives of each group. The County held the following meetings:

- Friends of the Rappahannock – November 20, 2023
- Essex County Conservation Alliance – December 4, 2023
- Rappahannock Tribe – December 11, 2023

In addition, the County has scheduled a public meeting to be held on January 22, 2024. A copy of the County's press release regarding this meeting is enclosed in **Appendix C**.

Caroline County Rappahannock River Water Supply Project
JPA No. 20-0514
January 16, 2024

APPENDIX A

TRANSIT ORIENTED DEVELOPMENT PROJECT INFORMATION

Caroline County, Virginia

Board of Supervisors

Wayne A. Acors
Madison District

Jeff Sili
Bowling Green District

D. M. "Maxie" Rozell, Jr.
Reedy Church District

Bobby Popowicz
Port Royal District

Floyd W. Thomas
Mattaponi District

Percy C. Ashcraft
County Administrator

Caroline County, VA
All-America City
2009

June 28, 2010

Rezoning Request: RZ-08-2009
Applicant: Carmel Church Station
Tax Map Number: 82-12-A/B; 82-9-A; 82-A-89A; 82-17-A/B; 82-18-A; 82-18-B; 92-A-35; 92-A-48; 92-A-49; 92-A-46; 92-A-32; 92-A-33; 92-A-34; 92-3-C; 92-A-31; 92-A-27; 92-A-27C; 92-3-B2

County of Caroline, To-Wit:

At a regular meeting of the Caroline County Board of Supervisors on Tuesday, June 8, 2010, in the Community Services Center, Auditorium, located at 17202 Richmond Turnpike, Milford, Virginia, at the hour of 7:30 p.m.

Present

D.M. "Maxie" Rozell, Jr., Chairman
Floyd Thomas, Vice-Chairman
Wayne A. Acors
Bobby Popowicz
Jeff Sili

On motion by Supervisor Popowicz, seconded by Supervisor Acors, the following rezoning was approved subject to subject to the following modifications to the PUD and general zoning and subdivision regulations:

1.) Sections 2 through 10 of Division 3 of Article XI of the Zoning Ordinance are hereby superseded by the provisions of the GLP, the Phasing Plan, the Proffers, and the Carmel Church Station Development Regulations.

2.) For any other general zoning and/or subdivision regulation that is inconsistent with a provision specifically addressed in the GLP, the Phasing Plan, the Proffers, and/or the Carmel Church Station Development Regulations, the GLP, Phasing Plan, Proffers, and/or Development Regulation(s) shall control.

3.) Any water and/or wastewater distribution treatment facilities approved by the Director of Public Works for the Development shall be deemed to be found consistent with the Comprehensive Plan pursuant to Virginia Code § 15.2-22232.A

212 North Main Street, P. O. Box 447, Bowling Green, Virginia 22427
(804)633-5380 – Telephone (804)633-4970 – Fax
www.visitcaroline.com

RZ-08-2009 – Virginia Land Investments, LLC, Applicant: Request a rezoning of approximately 1,059.3 acres, variously zoned, to PMUD, Planned Mixed Use Development (with a proposed density of 8.2 dwellings per acre [8,659units] and 3.16 million square feet of office, commercial, and industrial space). **Proposed Use**: A mixed use, transit oriented development that is proposed to include a train station and other multi-modal facilities, space for retail/commercial, offices, government agencies, hospitals, universities, hotels, recreational uses, light industry, many types of residential development, and parkland. The properties included in the application are identified as follows:

A. The following tax parcels currently zoned RP, Rural Preservation (with a density of one dwelling unit per ten acres of land): #82 A-89A, Owner, Caroline 225 LLC (1.84 acres); #82-12-A, Owner, Caroline 225 LLC (2.41 acres); #92-A-48, Owner, Caroline 40 LLC (38 acres); #92-A-49, Owner, Caroline 40 LLC (2 acres); #92-A-27, Owner, Caroline 544 LLC (116.60 acres); a portion of #92-A-46, Owner, Ruth O. Beverly (10 acres) and #92-A-31, Owner, Virginia Land Investments LLC (4.18 acres);

B. The following tax parcels currently zoned M-1, Industrial (no specified density): #92-3-B2, Owner, Caroline 544 LLC (3.38 acres); #92-3-C, Owner, Caroline 544 LLC (23.08 acres); #92-A-33, Owner, Caroline 544 LLC (63.33 acres); #92-A-32, Owner, Caroline 544 LLC (16.07 acres); #92-A-27C, Owner, Caroline 544 LLC (3.52 acres); #82-18-A, Owner, Caroline 544 LLC (43.51 acres); #82-9-A, Owner, Caroline 225 LLC (253.24 acres); and #82-17-A, Owner, Ruther Glen Road 80 LLC (79.44 acres);

C. The following parcel currently zoned M-1, Industrial (no specified density) and RP, Rural Preservation (with a density of one dwelling unit per ten acres of land): #92-A-35, Owner, Caroline 544 LLC (398.70 acres).

The properties included in the application are generally located on the immediate east and west sides of I-95, south of Route 207, and north of the North Anna River. The properties, which are designated on the General Land Plan filed with the application as Land Bays A through H (formerly designated as Land Bays 1, 2, 3A, 3B, 3C, 4, 5, and 6), are specifically located as follows:

A. Land Bay A is located west of I-95 approximately 1500' south of the I-95 interchange with Route 207, south of the terminus of the access road into the Flying J located south of Route 207 (Rogers Clark Boulevard) and north of the CSX Railroad right-of-way. Land Bay A is also located to the east of the termination points of Buzzards Bottom Road and Bear Lane.

B. Land Bay B has approximately 800' of frontage on Route 1 and is located approximately 7200' south of the intersection

of Route 1 and Route 207. The Land Bay is east of Route 1 and west of the CSX Railroad right-of-way at the terminus of Route 749 (Pennsylvania Avenue). Land Bay B is also located to the east of the termination point of Route 748 (Opal Lane).

C. Land Bay C is located to the east of Land Bay B and generally west of Land Bays D and E. The CSX Railroad right-of way forms the western boundary of Land Bay C.

D. Land Bay D is bounded on the east by I-95, approximately 5000' south of the I-95 interchange with Route 207, on the north by the CSX Railroad right-of-way, on the west by Land Bay C, and the south by Land Bay E.

E. Land Bay E is bounded on the east by I 95, approximately 10,000' south of the I-95 interchange with Route 207, on the north by Land Bays C and D, on the west by the CSX Railroad right-of-way, and on the south by Land Bay F.

F. Land Bay F is located immediately north of the North Anna River on Route 1 with about 3000' of frontage and west of I-95. Land Bay F has approximately 2500' of frontage on the North Anna River. Land Bay F is bounded on the north by Land Bay E.

G. Land Bay G is located on the east side of I-95 and north of the CSX Railroad right-of-way. Land Bay G is approximately 1500' south of the I-95 interchange with Route 207 on the west side of Route 652 (Ruther Glen Road) with approximately 800' of frontage on Route 652.

H. Land Bay H is located on the east side of I-95 (adjacent to portions of Land Bays D and E) and south of the Holly Ridge Estates subdivision. The Land Bay is on the west side of Route 652 (Ruther Glen Road). The access to Land Bay H is located approximately 8000' south of the Route 652/Route 207 intersection.

Both the 2006 – 2026 Comprehensive Plan and recently adopted 2030 Comprehensive Plan identify the subject areas as being located in the Carmel Church Community Plan of the Primary Growth Area, designated as Planned Mixed Use – Village Core, with a density of 10 – 15 dwelling units with a potential of 9,800 to 14,700 dwelling units, and those portions located east of I-95 and north of the railroad being designated as Heavy Industrial and Office/Industrial for Planned Industrial Area with no designated density.

Voting yea: ***Acors, Popowicz, Rozell, Thomas.***
Voting nay: ***Sill.***

Clerk

The foregoing instrument was acknowledged before me on this 28th day of June, 2010, by Percy C. Ashcraft.

Pamela M. Hall
Notary Public

PAMELA M. HALL
Notary Public
Commonwealth of Virginia
250778
My Commission Expires Jun 30, 2013

My Commission Expires: 6/30/2013

APPLICANT: Thomas F. Thompson
Virginia Land Investments, LLC

The foregoing instrument was acknowledged before me on this 23 day of July, 2010, by Virginia Land Investments, LLC

Elisabeth H. Dwight
Notary Public

ELISABETH HARTSOCK DWIGHT
NOTARY PUBLIC
COMMONWEALTH OF VIRGINIA
Expires 03-31-11
ID# 7139590

My Commission Expires: 3-31-11

CARMEL CHURCH STATION

Proffers
Rezoning Application
Planned Mixed Use Development (PMU)

Virginia Land Investments, LLC, pursuant to the authority granted to it by Caroline 225 LLC c/o Thompson Development LLC, Caroline 40 LLC, Caroline 544 LLC c/o Thompson Development LLC, Ruther Glen Road 80 LLC c/o Thompson Development LLC, Virginia Land Holding 17 LLC c/o Thompson Development LLC, and Virginia Land Investments LLC, fee simple owners ("Owner/Applicant") of the property (the "Property") which is the subject of rezoning application RZ-08-2009 (the "Application"), hereby voluntarily proffer that in the event the Property, having the Tax Map References set forth on Exhibit A, and consisting in total of 1,059 acres +/-, is rezoned by the Board of Supervisors of Caroline County (the "Board") to Planned Mixed Use Development ("PMU"), in substantial accordance with the Application submitted to the County of Caroline, Virginia, dated as of September 18, 2009, and the General Land Plan ("GLP") initially prepared by Bury+Partners, dated as of July 7, 2009, (amended February 24, 2010) then the development of the Property shall be in substantial conformance with the following conditions (the "Proffers") which are voluntarily tendered by the Owner/Applicant pursuant to Section 15.2-2303, of the 1950 Code of Virginia, as amended (the "Code"). These Proffers shall remain applicable to the development of the Property unless and until the amendment or deletion of these Proffers shall be approved by the Board upon application by the Owner/Applicant or its successor or assigns.

GENERAL:

Conformance with Application. The Property shall be developed in substantial conformance with the Application, including the General Land Plan (the "GLP") attached as Exhibit B, and the designated phasing as set forth on the GLP (the "Phasing Plan"). References in these Proffers to the "Land Bays" as a group or individually are references to the areas marked as Land Bays on the GLP.

Recording. The Owner/Applicant will record this proffer statement in the Caroline County Clerk's Office within thirty (30) days of the last to occur:

(i) receiving the notice from the Department of Planning and Community Development of the final approval of the Zoning Application;
(ii) the expiration of the period for appeal of the zoning approval of the Property without the filing of an appeal, or
(iii) if any appeal is filed, the completion of any judicial determinations in connection with such appeal.

Notwithstanding the foregoing, such proffer statement must be filed before any County permit or approval will be issued in connection with the Property.

Successors and Assigns. These Proffers shall be binding upon the heirs, executors, administrators, assigns and successors in interest of the Owner/Applicant. The owners of record of the Property, and the Applicant, do hereby voluntarily proffer all of the conditions stated above, which conditions shall have the effect specified in Section 15.2-2303 of the Code.

Modifications/Amendments. Except as otherwise stated herein, modifications/amendments to these Proffers may only be initiated by the Owner/Applicant, or its successor(s) or assign(s). No other entity is authorized to initiate changes to these Proffers that effect the Property or the obligations or rights of the Owner/Applicant, except that a third-party purchaser may initiate an amendment to these Proffers provided the amendment does not effect the rights and/or obligations of the Owner/Applicant.

Proffer Violations. Any violation of these Proffers by the Owner/Applicant shall preclude the issuance of building permits on portions of the Property owned by the Owner/Applicant or identified successors, but shall not impact individual parcels previously conveyed to third parties for development. Similarly, uncured violations by third party owners shall not be deemed violations by the Owner/Applicant nor interfere with the issuance of building permits on the Property still owned by the Owner/Applicant or identified successors, but shall preclude issuance of building permits on such properties unless such prohibition is specifically waived in writing by the Director of Planning.

Exhibits. The Exhibits attached to these Proffers are incorporated herein by reference.

Definitions. As used herein, the following terms shall mean as follows:

(1) Dwelling Unit (DU): A dwelling unit.

(2) Land Bay: An area of land identified on the GLP and including Land Bays A-H.

(3) (SF): Square Feet.

(4) The Carmel Church Station Regulations (the "Regulations"): the Code of regulations adopted by the Board as part of its approval of the Application, and which control the development of the Property.

(5) Clear glass: A person 2' from the outside of the glass could reasonably read a price tag on an item 2' inside the glass.

DENSITY:

Density. The following are maximum densities for the specified uses permitted in an identified Land Bay. If a use is allowed in the Land Bay, but no maximum density is provided, then the density shall be established through the use of the Regulations. Hotel density is expressed as a number of rooms (units) and is in addition to the "commercial/service" density. Portions of such hotels that are available for use by the public, such as a full service restaurant, shall be subject to the commercial/service density limitations.

A. Land Bay A

(i) Residential Uses (from Appendix A of the Carmel Church Station Development Regulations, Table (A)): 1,930 DU

(ii) Commercial/Service Uses (from Appendix A Table (C)): 723,800 SF

B(1). Land Bay B and C (with Multimodal)

(i) Residential Uses (from Appendix A Table (A)): 2,360 DU

(ii) Commercial/Service Uses (from Appendix A Table (C)): 763,800 SF

(iii) Hotel 250 Units

B(2). Land Bay B and C (with Multimodal including Rail)

(i) Residential Uses (from Appendix A Table (A)): 4,130 DU

(ii) Commercial/Service Uses (from Appendix A Table (C)): 1.4 Million SF

(iii) Hotel: 1,000 Units

C. Land Bay D

(i) Residential Uses (from Appendix A Table (A)): 1,575 DU

(ii) Commercial/Services (from Appendix A Table (C)): 499,200 SF

D. Land Bay E

(i) Residential Uses (from Appendix A Table (A)): 500 DU

(ii) Commercial/Services (from Appendix A Table (C)): 10,000 SF

E. Land Bay F

(i) Commercial/Services (from Appendix A Table (C)): 10,000 SF (within Riverside Park)
(ii) Commercial/Services (from Appendix A Table (C)): 10,000 SF (outside of Riverside Park)
(iii) Residential Uses (from Appendix A Table (A)): 262 DU

F. Land Bay G

(i) Commercial/Service or Light Industrial (from Table 1(C)): 500,000 SF

G. Land Bay H

(i) Residential Uses (from Table 1(A)): 262 DU

(ii) Commercial/Service (from Table 1(C): 10,000 SF

H. Commercial/Service and Residential density from Land Bay B and C can be shifted into such portion of another Land Bay (except Land Bay F) within one half mile of a constructed train station, the normal pedestrian shed for a transit oriented development.

COVENANTS, CONDITIONS AND RESTRICTIONS:

CC&R's. The Owner/Applicant shall prepare and record with respect to the Property certain Covenants, Conditions and Restrictions ("CC&R's") providing for coordinated development of said Property in accord with these Proffers, the GLP, the Regulations, the Design Code (as defined herein), the Caroline County Zoning Ordinance and the Caroline County Subdivision Ordinance. The CC&R's shall provide for a process for the review of the design and placement of each structure on the Property (other than any public or utility structure not bound by the CC&R's), and shall provide that the applicant for a building permit for such structure shall not request such permit until receipt of a determination by the Property's architectural approval body (the "Approval Body") that the proposed structure conforms to the GLP, the Regulations, the applicable Regulatory Plan, and any applicable standards set forth in the Design Code (as defined below). The Owner/Applicant shall not be held responsible for the issuance of any building permit(s) without prior approval by the Approval Body. The CC&R's shall be enforced by the Owner/Applicant or the property owners' association(s) established below.

Home Owner and Commercial Associations. The Owner/Applicant shall prepare and record certain property owner declarations creating home owner and commercial owner associations which shall be responsible for the maintenance of the common areas on the Property, as well as such other duties as the Owner/Applicant shall determine. These documents

shall provide the County with the ability to perform maintenance and obtain payment for such performance in the event that the associations fail to maintain an area or facility open to the public and the County provides such maintenance if the County so desires.

Review and Approval. The Owner/Applicant shall submit the initial CC&R's and the initial association declarations to the County Planning Director for the sole purpose of reviewing for compliance with these Proffers. If the Owner/Applicant has not been notified otherwise within 15 business days of such submittal, the documents shall be deemed approved.

Design and Review. While the Owner/Applicant recognize that the Regulations provide, among other things, minimum development standards, the Owner/Applicant does not intend that the Regulations will provide detailed architectural guidelines or requirements for the Development. Similarly, while important generalities for such items as landscaping, signage or lighting are provided in the Regulations in order to establish the very different character of this development, important details of design have not been finalized.

Prior to the development of Phase I, Owner/Applicant shall convene a "design charrette" to develop a set of detailed guidelines and standards for the entire project (the "Design Code"). The design charrette will include the input of the Owner/Applicant, the Applicant's architect, builders, Caroline County Supervisors, Planning Commissioners, citizens and County staff. The resulting Design Code will be reviewed and approved by the County Director of Planning in conjunction with the Site Plan approval for Phase I. The Director of Planning may seek input from the Planning Commission as he deems necessary.

The Design Code shall establish detailed standards and guidelines for the Development related to architecture, signage, lighting, landscaping and streets, over and above any such standards or regulations required by County regulations. The Design Code is intended to ensure that the Development adheres to the transit oriented development structure and is developed in accordance with the Application, these Proffers, the Carmel Church Station Regulations, the Comprehensive Plan and the Community Plan. In addition, as part of the development of the Design Code, the County may impose additional conditions on any use if, at the time of the approval of this rezoning request, the use was a conditional use under Article XI (Planned Unit Developments) of the Caroline County Zoning Ordinance.

Owner/Applicant shall pay for reasonable costs (not to exceed $10,000) of an architect to attend and participate in the charrette on the County's behalf and assist the County in its review of the Design Code. Such architect shall provide input and review but will not draft the standards.

Owner/Applicant shall pay for reasonable costs (not to exceed $50,000) of such registered design professionals as the County deems necessary to review, on its behalf, and assist the County regarding plans submitted by Owner/Applicant for utility service in connection with the site.

UTILITIES:

Water and Sewer Installation. County water and sewer service on the Property shall be installed by the Owner/Applicant or his agents at the Owners/Applicant's expense.

Loops and Pump Stations. Any interconnections of water lines and installation of pumping station(s) and other elements of connection into the County utilities which meet approval of the Caroline County Public Utilities Department shall be installed by the Owner/Applicant or his agents at the Owner/Applicant's expense.

Phasing Utilities. All such installations shall proceed in accordance with the Water and Wastewater Plan described below provided pursuant to these Proffers.

Reduction of Needs. The Owner/Applicant shall explore the fiscal and physical feasibility of different approaches to reducing the potable water needs of development on the Property as well as the amount of waste water generated from uses on the Property. Such exploration may include mandatory water efficiency devices, utilization of reuse water and purple pipe, waste water mining, storm water harvest, or similar mechanisms. As a result of such study, Owner/Applicant shall develop a Water and Waste Water Plan which will describe the measures to be taken, the anticipated capacity needs associated with each phase, and a phasing plan for the utilities. If necessary, the Owner/Applicant and the County may enter into a contract addressing the creation, ownership, operation and financing of such improvements as well as the creation of any districts necessary.

Modeling. The Owner/Applicant shall submit an engineered water model for the Carmel Church Station project to the County Department of Public Utilities for review and approval at time of submission of the first preliminary site plan for the development. The Department of Public Utilities may require that reasonable and necessary modification be made to the water model before it is approved. Once approved, the site will be developed in accordance with the water model, and no building permits shall be granted until the water model is approved.

Service. The Property shall utilize the County water supply and sanitary systems (subject to the steps taken to reduce needs) provided there are sufficient connections and capacity to meet the Property's requirements. If there are insufficient connections and/or capacity, then the Owner/Applicant shall have the right, but not the obligation to install such components as are necessary to create sufficient capacity for the Property in or to be added to the County system. Such components shall be subject to the County's review and approval, which shall not be unreasonably withheld or delayed. The Owner/Applicant understands

that there may be times when the County cannot meet the utility requirements of the Property because of timing of improvements, construction or fiscal constraints. The County and the Owner/Applicant shall work together to achieve the development goals of the Community Plan without financial burdens to the County taxpayers.

TRANSPORTATION:

Traffic Studies. Because of the scale of the development of the Property, the difficulty of anticipating the actual impact of a multimodal facility and the significant change in assumptions resulting from the construction of a train station, the traffic and transportation studies for the project must be phased. A traffic impact analysis ("TIA") for Phase 1A has been submitted to the County, and has been reviewed by VDOT, and approved by the County in connection with the request for zoning. Other than the development encompassed in Phase 1A, no subdivision and/or development of the Property shall occur unless and until a TIA for that section has been approved by the County.

Necessary Improvements. The Owner/Applicant shall provide the easements for construction, sight distances, turn lanes, and deceleration lanes on the Property or in connection with the Property entrances as and when prescribed, by the traffic studies in order to maintain a LOS D as required by VDOT. The Owner/Applicant shall construct all road improvements internal to the Property and at any of its three planned entrances along Route 1 or its planned entrance at Route 207, as and when prescribed by the TIA to the extent such study shows that development of the Property Phase causes the need for such improvements.

Roadway Standards. The roads shown on the GLP are conceptual and generally located to illustrate the likely layout of the principal internal connections, their intersections with Routes 1 and 207 and the desired railway crossings. The Owner/Applicant will utilize TND Road Standards adopted by Caroline County, to design and construct the roads in the Development, if such standards are adopted. In the absence of such enactment, then the Owner/Applicant shall use the street standards set forth in the Regulations, modified as necessary to allow the acceptance of such streets for public ownership and maintenance. All roads, except for alleys, lanes, and service roads, within the Property, shall be public, with curb lanes, gutter, and sidewalk. If approved by VDOT, the Owner/Applicant may retain the sidewalk and provide for its maintenance and the maintenance of street trees through the homeowner and commercial associations.

Private Roads.

A. Service roads, lanes and alleys shall be private and maintained by the homeowner or commercial association.

B. A road maintenance agreement shall be recorded in the Office of the Circuit Court Clerk of Caroline County for each phase of the Property which contains private roads. Such agreement shall be recorded together with the approved Subdivision plat and a copy of the recorded instrument shall be provided to the County before the release of the final bond.

Interparcel Connections. All other interparcel connections shown on the GLP shall be constructed to the Property line and phased as shown in the Phasing Plan, as updated from time to time and confirmed in connection with the Site Plan and Subdivision approval for any Phase. In the event that the entrance to the Property from Rt. 207 is relocated due to VDOT and/or the County concerns, then Owner/Applicant agrees to support such relocation and utilize the relocated entrance provided that (i) such entrance is provided and extends to the Property and to the road (if any) created by Owner/Applicant for connection, and (ii) that such relocated entrance provides access to the Property at least comparable to the current entrance to Rt. 207.

MultiModal Center.

A. A "multimodal" transportation center provides for the movement of passengers and cargo by more than one method of transport. Utilizing the commercial association or another public or non-profit organization (the "Operator") the Owner/Applicant shall create and operate a multimodal center on the Property. Initially this center will revolve around a "park and ride" parking lot as part of Phase 1A. The park and ride facility will be available while it is reasonably utilized, but may be subject to reasonable fees and may share parking with commercial or civic uses.

B. A permanent facility, integrated with the train station, will be located in Land Bay B or C following commencement of development in these Land Bays and will replace the facility in Land Bay A.

C. The Operator shall operate programs to encourage transportation other than by single occupancy vehicles. Based on fiscal viability and the goal of reducing vehicular miles traveled, the Operator shall assess, and where appropriate implement, programs for:

(i) community bicycle programs,

(ii) ride share programs,

(iii) van programs,

(iv) "Zip Car" or similar shared vehicle programs,

(v) support programs for pedestrians, bicyclists and other forms of alternative transportation,

(vi) Fredericksburg Regional Transit (FRED), GRTC or other service providers to provide service from the Property to the nearest VRE station or

(vii) other bus programs as appropriate

D. Parking for the permanent facility may be integrated with parking for the train station or commercial or civic uses.

E. The Owner/Applicant will construct the parking areas, any bus or van stops, and appropriate facilities for the operation of the facility.

F. The Owner/Applicant may transfer or cause the transfer of such facilities to a government agency or separate non-profit for the continued operation of such facilities.

G. The development shall be designed for internal bus routes, which shall be created as justified by demand and financial feasibility.

SITE DEVELOPMENT AND PHASING:

Phasing Plan.

A. All development shall occur in sequential phases, beginning with Phase 1, as shown on the Phasing Plan. However, because actual phasing will be significantly impacted by the specific mass transportation options available to the site and the then current market for different commercial and residential products, the Owner/Applicant may seek to amend the Phasing Plan, from time to time, by filing a request to amend the Phasing Plan with the Caroline County Director of Planning. The Planning Director shall forward the request, which may include, without limitation, the amendment of phase boundaries, to the Planning Commission, which may approve the request provided it does not substantially modify the existing Phasing Plan. Significant modifications to the Phasing Plan, as determined by the Planning Commission, shall be submitted to the Board for approval, and as required by law.

B. Development following Site Plan and Subdivision Plat approval may occur in a portion of a Phase, and one Phase does not have to be complete before another is begun, provided completion of the earlier phase is being diligently pursued by the Owner/Applicant.

Phasing Traffic Studies. For purposes of phasing traffic studies, a phase shall be the area brought forward for Subdivision or Site Plan (if not

already covered by a Subdivision Plan) approval, and, if requested by the Owner/Applicant, additional areas likely to be developed in conjunction with the area subject to the approval.

Regional Park. Although the Regional Park is included in Phase I, Owner/Applicant shall not be required to provide more than an initial parking area for this park (20 cars) until the 100th building permit is issued and shall not be required to extend utilities to the commercial area of the Park until development of the phase adjoining the Regional Park is commenced.

Phasing the Core. Until completion of the train station and commencement of its operation as a rail stop, if Owner/Applicant includes any portion of the core in a phase proposed for development then such portion shall be designed to achieve not less than 12 dwelling units per acre over the complete period of build-out of such phase.

Coordinating Commercial. Until the Train Station has commenced its operation as a rail stop, no subdivision plan for any Phase or sub-phase of the Property shall be approved unless the total approved subdivision and /or site plans for the Property, including the proposed subdivision plan, include not less than 120 square feet of Commercial/Service Uses from Appendix A, Table (B), (C), (D – provided such entity is not eligible for reduced real estate taxes as a not-for-profit entity), (E) or (F) per dwelling unit (the "Required Commercial Area"). Additionally, until the rail stop at the proposed Train Station has received necessary state and/or federal approvals for operation, and funding for the construction of the Train Station has been identified and secured, except for Phase 1(A), no subdivision plan for a Phase or sub-phase which contains residential dwelling units shall be approved by the County unless, at least , improved pad sites and/or structures have been built in the Required Commercial Area.

DRAINAGE AND STORMWATER MANAGEMENT:

Grading. The Property has significant topographic irregularities. The Owner/Applicant will tailor grading to the designs for each approved Site Plan and Subdivision Plat, and to the extent feasible, will avoid "mass grading." If topsoil is stripped from the Property, topsoil will be replaced in the appropriate areas in accordance with then current Erosion and Sediment Control Standards.

Storm Water Management.

A. Storm water on the Property will be managed through a number of different techniques, including, without limitation, storm water harvesting, low impact development ("LID") techniques, bio swales, constructed wetlands, water features and other similar approaches, in addition to, and to the extent practicable in lieu of, conventional storm water management techniques.

B. Storm water management facilities may be located on private property, on common areas owned by the home owner association or commercial association, or on property owned by public entities when permitted by such entities, provided that all such facilities shall be subject to easements allowing for inspection and maintenance. The homeowner or commercial association shall be responsible for maintenance and upkeep of the facilities located in the common areas and for providing or overseeing the maintenance of facilities located on private or public property. The Owner/Applicant shall provide such maintenance until the responsible association is created.

C. The Owner/Applicant shall record a stormwater maintenance agreement in the office of the Caroline County Clerk and a copy of the recorded instrument shall be provided to Caroline County before bond release.

D. The Owner/Applicant shall provide evidence that the Property is registered with the Virginia Department of Conservation and Recreation for all applicable stormwater discharge permit(s). Should there be conflicts or discrepancies between Caroline County and Virginia stormwater requirements, the more stringent requirements will govern.

RECREATION AND OPEN SPACE:

Setbacks.

A. The Property shall include a 100 foot setback for residential uses along I-95.

B. The Property shall include a 100 foot setback along Route One as specified in the ordinances of Caroline County.

C. Other than along the access road route, Land Bay H shall have a 25 foot setback/natural buffer along the sides of the parcel not facing I-95.

Open Space.

A. Open space will be provided in the forms set forth in the Regulations.

B. The open space on the Property shall, at minimum include the following:

(i) The full RPA's in Land Bay A, B, D, E, F and H, subject to road crossings, trails, utility crossings, permitted

recreational facilities such as boat facilities, and storm water management facilities,

(ii) The minimum required RPA in Land Bay C reflecting such reductions as may be necessary and approved by Caroline County (and subject to any necessary state approvals) in order to construct the train station, the track expansion and other associated improvements, utility crossings and the roads and other connections and storm water management facilities,

(iii) Eighty acres within Land Bay F adjacent to the North Anna River, except for the Cultural Resource Center, an Eco Tourism/Trail Head Center Restaurant and Store, utilities, an HOA storage facility, and other facilities described in these Proffers, and including trails and recreation facilities,

(iv) 19 acres in Land Bay D, in addition to any RPA stream buffer, but including any permanently protected buffer created in the setback along I-95,

(v) 6.75 acres in Land Bay B, in addition to any RPA stream buffer, but including any permanently protected buffer created in the setback along Route One,

(vi) 9.5 acres in Land Bay C, in addition to any stream buffer within 50 feet of the stream centerline,

(vii) In Land Bay A and E, 12.5% of the Land Bay area, not including any RPA stream buffer, but including any permanently protected buffer created in the setback along I-95, and

(viii) In Land Bay H 25% of the Land Bay area, including any stream buffers and any permanently protected buffer created in the setbacks along I-95.

C. Prior to commencing a new phase of the development, Owner/Applicant shall cause all open space in the prior phase, including land otherwise subject to an open space easement, , and which were identified in approved Regulating Plans, Site Plans or Subdivision Plans as permanent open space, to the property owners' association.

3. Recreation Facilities.

A. The Owner/Applicant shall establish a bike and walking trail in Land Bay F. At a minimum such trail shall connect to Land Bay E, Route 1, the likely site of the Cultural Resources Center, the river

and some portion of the historic/archaeological resources within Land Bay F.

B. The Owner/Applicant shall establish a point along the river for canoe and kayak put-in and take-out. Such facility may be accessed by a service road.

C. The Owner/Applicant shall create a system of private facilities and community facilities through such organizations as the YMCA or shared public facilities, such that every resident on the Property has access to a pool, access to a gymnasium providing exercise equipment, access to a reasonable number of basketball, volley ball and tennis courts, and access to playgrounds, provided within the boundaries of the Property which on normal days of usage have sufficient capacity for all desired users. In lieu of meeting this standard for the first 500 DU, the Owner/Applicant shall contribute $50,000 to the construction of a YMCA facility within ten miles of the Property. Such contribution shall be made within ninety days of the passage of the period of appeal of approval of this zoning matter or appeal of any court case filed in connection with such approval without appeal.

Architectural Standards:

1. The Owner/Applicant proffers the following Architectural Standard to apply in all Transect Zones.

   a. Where streetscreens (defined in the Regulations) are required, sight-distance, safety and lighting will be considered when determining their location and height

   b. For residential uses, doors and windows that operate as sliders shall be prohibited along the front of any such building facing a principal street.

   c. If a material other than wood, metal, glass, stone, brick or masonry is to be utilized as exterior facade finishing material, the materials will be from a list approved as part of the Design Code.

   d. Fences along principal or secondary streets (defined in the Regulations) shall be made of painted wood or equivalent composite material, wrought iron, brick or stone. Knee walls and/or retaining walls will be concrete or stucco covered.

   e. Flat roofs will be enclosed by parapets a minimum of 42 inches high, or as otherwise necessary to conceal mechanical equipment, but not to exceed 60". Individual roof screening or louvers may be provided to screen any roof top equipment.

f. Mechanical equipment, whether on the ground or the roof of a building, will be screened so as not to be visible from any street other than alleys and lanes.

2. The Owner/Applicant proffers the following Architectural Standards to apply in specific Transect Zones.

a. T3 Transect Zones

(i) Wall materials on residential buildings shall only be combined horizontally on each façade horizontally, with the heavier material generally below the lighter. Building wall materials for non-residential use or mixed uses may be combined vertically or horizontally.

(ii) All openings including porches, galleries, arcades and windows, with the exception of storefront windows, shall be square or vertical in proportion

(iii) Openings above the first story (as seen from the principal street) shall not exceed fifty (50) percent of the total building wall area, with each façade being calculated independently.

(iv) Pitched roofs, if provided, shall be symmetrically sloped no less than 5:12, except that porches and attached sheds will be sloped no less than 2:12.

b. T4 Transect Zones

(i) Wall materials on residential buildings shall only be combined horizontally on each façade horizontally with the heavier material generally below the lighter. Building wall materials for non-residential use or mixed uses may be combined vertically or horizontally.

(ii) Doors and windows that operate as sliders are prohibited along principal or secondary street frontage.

(iii) Pitched roofs, if provided, shall be symmetrically sloped no less than 5:12, except that porches and attached sheds will be sloped no less than 2:12.

c. T5 Transect Zones

(i) Building wall materials will be only be combined horizontally on each façade, with the heavier generally below the lighter.

(ii) All openings, including porches, galleries, arcades and windows, with the exception to storefronts, shall be squared or vertical in proportion.

(iii) Openings above the 1st floor along principal or secondary street frontage will not exceed 50% of the total building wall area, with each façade being calculated independently.

(iv) Where identified on the Regulating Plan (defined in the Regulations) the facades for retail uses fronting along the principal street will be detailed as storefronts and glazed with clear glass no less than 70% of the area between 3' and 7' of the 1st floor along the street frontage only.

(v) Streetscreens shall be located coplanar with the building façade and built with the same materials as the façade.

(vi) Architectural elements added to a streetscreen will match the same architectural elements of the façade.

(vii) Doors and windows that operate as sliders are prohibited along all street frontage.

(viii) Flat roofs shall be enclosed by parapet walls or slope roofs. Pitched roofs shall be symmetrically sloped no less than 5:12, except that porches and attached structures (sheds) may be no less than 2:12.

(ix) Outdoor storage shall be screened from view of any principal street by a streetscreen. Outdoor storage shall be screened from view of any other street or the first floor of any adjoining property.

d. T6 Transect Zones

(i) Residential building wall materials may be combined on each façade only horizontally, with the heavier generally below the lighter.

(ii) All openings, including porches, galleries, arcades and windows, with the exception to storefronts, shall be squared or vertical in proportion.

(iii) Openings above the 1st floor along principal or secondary street frontage shall not exceed 50% of the total building wall area, with each façade being calculated independently.

(iv) Where identified on the Regulating Plan (as defined in the Regulations) the facades for retail uses fronting along the principle street shall be detailed as storefronts and glazed with clear glass no less than 70% of the area between 3' and 7' of the 1st floor along the street frontage only.

(v) Streetscreens shall be located coplanar with the building façade and built with the same materials as the façade.

(vi) Architectural elements added to a streetscreen shall match the same architectural elements of the façade.

(vii) Doors and windows that operate as sliders are prohibited along all street frontage.

(viii) Flat roofs shall be enclosed by parapet walls or slope roofs. Pitched roofs shall be symmetrically sloped no less than 5:12, except that porches and attached structures (sheds) may be no less than 2:12.

(ix) Outdoor storage shall be screened from view of any principal street by a streetscreen. Outdoor storage shall be screened from view of any other street or the first floor of any adjoining property .

e. Special District Transect Zones

(i) Building wall materials may be combined on each façade only horizontally, with the heavier generally below the lighter.

(ii) All openings, including porches, galleries, arcades and windows, with the exception to storefronts, shall be squared or vertical in proportion.

(iii) All sides of the building shall be of the same material as the primary facade.

(iv) Where identified on the Regulating Plan (as defined in the Regulations) the facades for retail uses fronting along the principal street shall be detailed as storefronts and glazed with clear glass no less than 70% of the area between 3' and 7' of the 1st floor along the street frontage only.

(v) Streetscreens shall be located coplanar with the building facade and built with the same materials as the facade.

(vi) Architectural elements added to a streetscreen shall match the same architectural elements of the facade.

(vii) Doors and windows that operate as sliders are prohibited along all principal or secondary street frontage.

(viii) Flat roofs shall be enclosed by parapet walls or slope roofs. Pitched roofs shall be symmetrically sloped no less than 5:12, except that porches and attached structures (sheds) may be no less than 2:12.

(ix) Outdoor storage shall be screened from view of any principal street by a streetscreen. Outdoor storage shall be screened from view of any other street or the first floor of any adjoining property.

(x) Mechanical equipment, including elevator penthouses, shall be screened from view from all streets.

(xi) Antennas or microwaves used for communication or telecommunication purpose shall be screened from view from all streets including streets that are not within the TND. Mitigated measures are taken in a way to blend antennas for telecommunication purposes with the building material or roof-top landscaping.

(xii) All buildings shall provide equal entrance features for the side of the building facing the principal street and the parking area.

FISCAL:

Cash Proffer. In addition to the above proffers, the Owner/Applicant agrees to a cash proffer in the amount of $5,500.00 per dwelling unit due at the time of building permit issuance, up to a maximum of $36,500,000 total dollars; provided, however, that such maximum shall be lowered to $25,000,000 ($36.5 million and $25 million shall be referred to as the "Maximums"), if 2,000,000 SF of commercial/service development has been achieved (but in no circumstance shall Owner/Applicant be entitled to any refund of amounts paid in excess of the maximum). Provided, however, that the Maximums set forth in this provision shall be reviewed every five (5) years following the issuance of the first building permit in connection herewith and adjusted up or down to reduce the cash proffer per residential unit amount once the revenues from the Project provide a sufficient flow of taxes and fees to pay (i) the on-going costs of services made necessary by the Project, and (ii) create adequate capital funds to construct capital improvements necessary to provide such services to the project and taking into account any special areas, service areas or districts, tax increment areas or commercial development authorities that have been created in connection with the Property, including but not limited to the Service District defined below. Necessary capital improvements shall be those improvements defined under the County's proffer policy as normally resulting from a development project unless shown by Owner/Applicant to be inapplicable.

Road Improvement Fee. In addition to the above proffers, the Owner/Applicant agrees to a cash proffer in the amount of $0.35 per square foot of industrial and commercial space at the time of building permit issuance. Such contribution shall be retained in a dedicated account and used for road improvements in the Carmel Church community.

Adjustments to Fees. The cash proffer of $5,500.00 per dwelling unit and $0.35 per square foot of industrial and commercial space shall be adjusted annually on the anniversary date of the rezoning approval based on the Consumer Price Index (CPI) for the Commonwealth of Virginia as

determined by the U.S. Department of Labor Statistics as provided in Section 15.2-2303.3 of the Code.

Designations of Area. Owner/Applicant supports designation of the Property and surrounding area as an "Urban Development Area" (UDA) pursuant to Virginia Code §15.2-2223.1 et seq. Owner/Applicant will not oppose such designation in the future. Notwithstanding anything to the contrary herein, nor any implication created by the Proffers presented herein, the Owner/Applicant supports the establishment of a "road impact fee service area" pursuant to Virginia Code §15.2-2317 et seq to include the Property and adjusted to give credit for Owner/Applicant's Road Improvement Fee and other Proffered expenditures for the multimodal facility, train station and parking, track expansion and transportation programs, as provided by law. Upon request by the County, the Owner/Applicant will agree to the creation of a service district (the "Service District"), which Service District shall encompass and include the entire Property, for the financing of infrastructure and/or other capital costs necessitated by the development of the Property that are not otherwise paid pursuant to these Proffers.

Library Fee. In order to assist in meeting the academic and intellectual needs of residents of the Property the Owner/Applicant shall contribute $50,000 to construction of a library in the same district as the Property. Such contribution shall be made within ninety days of the passage of the period of appeal of approval of this zoning matter or appeal of any court case filed in connection with such approval without appeal.

LAND FOR COUNTY/PUBLIC USE:

Regional Park. The Owner/Applicant shall dedicate eighty acres of Land Bay F adjacent to the North Anna River, except for (i) a ten acre parcel (and access thereto) for operation of the Ecotourism Center and storage of boats and large vehicles and parking for residents of the Property (ii) such portions required for operation of utility substations, pump stations or other similar facilities and (iii) a parcel not to exceed three (3) acres for yard waste composting (from the Project and the Park), to the County for operation as a public park. The Owner/Applicant shall retain an easement for access to and use of the bike and walking trails and the boat put-in/take-out site as well as the right to locate utility equipment providing service to the Property within this area and dedicate the land in connection therewith to the necessary utilities. Use of the dedicated land shall be limited to use as a public park, except that at the discretion of the County, a portion of the park not exceeding seven (7) acres, may be used as a Cultural Amenity Center.

Library and Auxiliary Government Offices. The Owner/Applicant shall provide the County with a lot in Land Bay A, included in the first Phase of development of the Property for the location of a library and/or an auxiliary County Government building.

The portion of the lot for the County Government building and/or library shall be not less than 75' wide and 100' deep. The building placed on such lot by the County shall be not less than two stories.

If the County determines that it would prefer to locate the County offices and library in the T6 portion of the Property then the Owner/Applicant will work with the County to identify an appropriate location for a combined facility of the County Offices and the library, but because the density of such area is significantly higher, such space shall be a portion of another building or a structure will be designed for subsequent expansion and the Owner/Applicant shall retain the air rights for such structure.

Government Parcel. When requested by the County (but without cost for subdivision approval) the Owner/Applicant shall provide the County with a Parcel in Land Bay H of approximately forty (40) acres. The location and configuration of such parcel shall be subject to the reasonable approval of the County and the Owner/Applicant and result in a usable parcel without cutting off or rendering unusable the balance of Land Bay H. Such parcel may be used for:

- County offices
- Library
- Community Center
- SPCA or animal rescue facility
- District waste transfer station
- An Elementary or Middle School
- Recreational facilities

Utilities and roads shall be extended to the boundary of such site at the same time Owner/Applicant extends them to other development within Land Bay H. If the County desires extension of such roads and utilities prior to that time, such extension shall be at the County's cost and the Owner/Applicant and the County shall work together to identify a mutually acceptable location for such utilities and road. If the school building is certified as not less than LEED Gold and utilizes a façade reasonably approved by the Owner/Applicant then the Owner/Applicant will donate $15,000 toward the school's construction.

"County offices" may include a fire station. If the County determines that it would prefer to locate an elementary school in the T6 portion of the Property then the Owner/Applicant will work with the County to identify an appropriate location for the school, but because the density of such area is significantly higher, such space may be a portion of another building or a structure will be designed for subsequent expansion and the Owner/Applicant shall retain the air rights for such structure. The parties will identify 10 acres of the Property committed to the County as the "Government Parcel" and it will be released to the Owner/Applicant in return for the T6 space.

Train Station. To the extent necessary from the Property owned by the Owner/Applicant, and not sufficiently accommodated by properties already in the railroad right-of-way, the Owner/Applicant shall provide the County with land sufficient to construct a train station and a platform on each side of the tracks or between the tracks as generally located and shown on the GLP. The Owner/Applicant shall retain the air rights for such lot and any building constructed thereon shall be designed to accommodate the use of such right.

Train Station Parking. Upon the construction of the train station proposed on the GLP, the Owner/Applicant shall provide area for the surface parking of not less than 250 automobiles for the multimodal facilities, including the train station. The Owner/Applicant shall be entitled to provide such parking through easements and may reconfigure such parking, move the parking, and/or provide it as part of structured parking, as the Owner/Applicant deems necessary for the development of the Property. Capital for improvements of such parking, as well as operations and maintenance, may be recovered through the charge of reasonable parking fees, comparable to those charged at other parking facilities serving train stations. Such parking facilities may be separated from the station by any natural area required to be preserved in the vicinity of the train station and not more than one block of other uses having commercial uses on their first floor.

Track Right-of-Way. If the Track Dedication Conditions, as defined and listed below, have been satisfied, then the Owner/Applicant shall dedicate sufficient land immediately adjacent to the existing rail right-of-way, to make up the difference between the land currently in the right-of-way and the minimum reasonably necessary to accommodate three through tracks and a fourth by-pass track on the Property to the standards described in the DRPT Amtrak Station Area Planning and Land Use Analysis for Carmel Church Station dated as of August 2008. The "Track Dedication Conditions" shall be:

(i) The Property will have been designated by all applicable Federal, State, CSX, and Amtrak authorities as a site for a train station;

(ii) Funding for constructing all necessary tracks, including the by-pass track shall be within the control of an entity that has committed to such construction;

(iii) All necessary studies, including any required environmental studies and ridership studies, shall have been completed and conclude that the use of the Property as a train station is legal and appropriate;

(iv) CSX shall have granted the right for the three overhead public road crossings, together with crossing rights for any utilities that cannot reasonably be accommodated within such crossings, in exchange

for abandonment of the current surface crossing on the Property and without cost to the Owner/Applicant, and

(v) The Owner/Applicant shall be entitled to retain from such conveyance the necessary rights to construct and dedicate the necessary fee simple or easement rights for the three public road crossings and utility crossings.

AFFORDABLE HOUSING:

Affordable Housing. Not less than five percent of the dwelling units in any Land Bay providing residential dwelling units shall be initially offered for sale or rent at a purchase price or rental such that an individual earning the median wage earned by a school teacher or sheriff's office employee in Caroline County would qualify for a mortgage for such purchase or rental with the minimum deposits or down payment required by lenders normally providing such financing in Caroline County.

To the extent exemption elements of the Regulations dealing with architectural requirements is necessary in order to meet the requirements of this section, such exemption from the County shall be provided so long as:

(i) the elements to be exempted are identified as part of the design guidelines and standards developed at the charrette;
(ii) such exemption is limited to the extent necessary to meet the requirements of this section, and
(iii) the units to which such exemptions is applicable shall be integrated with other housing so that there is not a separate 'section" of affordable housing.

Owner/Applicant
Virginia Land Investments LLC

By _____

State of Virginia

County of Henrico, to wit:

I, Elisabeth H. Dwight, a Notary Public in and for the jurisdiction aforesaid, do hereby certify that Thomas P. Thompson whose name is signed to the foregoing Proffers, has acknowledged the same before me in my County and State as aforesaid.

GIVEN under my hand the 9 day of June 2010.

ELISABETH HARTSOCK DWIGHT
COMMONWEALTH OF VIRGINIA
Expires 03-31-11
ID# 7136930
NOTARY PUBLIC

Elisabeth H. Dwight
Notary Public

My Commission Expires: 3-31-11

LAND BAY G
Phase 1
Phase 8
LAND BAY a
Phase 2
Phase 3
TOD Core
LAND BAY d
Phase 4
LAND BAY c
LAND BAY h
Phase 6
Phase 9
LAND BAY b
Phase 5
Train Station
LAND BAY e
95
Phase 7
Phase 1
LAND BAY f
VICINITY MAP
1" = 2000'
LEGEND:
LAND BAY A
LAND BAY B
LAND BAY C
LAND BAY D
LAND BAY E
LAND BAY F
LAND BAY G
LAND BAY H
TRAIN STATION
GRAPHIC SCALE
CARMEL CHURCH STATION
NEAR I-95, CAROLINE COUNTY
GENERAL LAND PLAN
Bury Partners

Phase	Land Bays	Acres	DU	Commercial/ Service SF	Commercial/ Lt Industrial SF	Hotel Rooms*	Transect (See Definitions below)
1	A	255	390	155,000			T4; T5
	F			10,000			T1
	G				500,000		Special District
2	A	62	400	155,000			T4 outside the Core; T5
3	A, B, C, D	135	1,850	520,000			T4 outside the Core; T5; T6 w/in Core
	B, C					250	
4	C, D	89	1,850	645,000			T4 outside the Core ; T5; T6 w/in Core
	C					150	
5	C, D, E	113	1,910	550,000			T6 w/in Core; w/in LB E: T6 or T5 w/in Core; T4 (for first block beyond Core); T3
	C					350	
6	B	56	690	312,000		250	T6
7	E	106	295	6,000			T3
8	A	103	750	290,000			T5; T4
9	H	140	524	20,000			T3; T4 (along corridor)
	Totals	1,059	8,659	2,663,000	500,000	1,000	

Land Bays	Acres
A	257
B	56
C	135
D	124
E	144
F	124
G	79
H	140

NOTES AND DEFINITIONS

*Hotel rooms in Phase 3 can be postponed to a later phase. Phases 4, 5, 6 can be accelerated into a prior phase or postponed until later phases.

T1 Natural Zone: Consists of mostly undeveloped lands, largely maintained in untended conditions, though such areas may be subject to management plans for programs including biological restoration, proper forest management or the elimination of invasive species.

T2 Rural Zone: Consists of lands in open or cultivated state or sparsely settled. These include woodlands, agricultural lands, grasslands and regulated or dedicated athletic fields and golf courses.

T3 Suburban Zone:Consists of low density suburban residential areas, allowing home occupations as generally permitted under the ordinances of Caroline County. Planting is naturalistic with setbacks relatively deep. Blocks may be large and the roads irregular to accommodate natural conditions.

T4 General Urban Zone: Consists of a mixed-use but primarily residential urban fabric. It has a wide range of building types: single family, patio and townhouses. Setbacks and landscaping are variable. Streets typically define medium-sized blocks.

T5 Urban Center Zone: Consists of higher density mixed-use building types that accommodate retail, offices, townhouses and multifamily. T5 has a tight network of streets with wide sidewalks, regular street tree planting and buildings set close to the frontages.

T6 Urban Core Zone: Consists of the highest density, with the greatest variety of uses, and civic buildings of regional importance. It may have larger blocks; streets have regular street tree planting and buildings set close to the frontage.

Special Districts: Consists of larger structures for commercial industrial, civic or recreation uses. The uses may serve more than the development. The uses may be appropriate for development which is in close proximity to a major transportation network.

CARMEL CHURCH STATION DEVELOPMENT REGULATIONS

ARTICLE 1 Purpose and Intent.

Virginia Land Investment LLC pursuant to its own ownership and authority granted to it by Caroline 225 LLC, Caroline 40 LLC, Caroline 544 LLC, Ruther Glen Road 80 LLC and Virginia Land Holding 17 LLC, (the "Owner") is proposing to rezone 1,059.3 +/- acres (the "Property") from Rural Preservation (RP) and Manufacturing (M-1) to Planned Mixed Use Development (PMUD). The Owner intends to develop the Property as a transit oriented, mixed use development (the "Development"), that will include up to 8,659 residential units, 3.16 million square feet of commercial office and retail space, and light industry, 1,000 hotel rooms and a one hundred twenty acre regional riverfront park.

In order to develop the Property as requested by the Owner, and in a manner consistent with the 2030 Caroline County Comprehensive Plan (the "Plan"), and the Carmel Church Community Plan, dated January 23, 2007, the Board of Supervisors (the "Board") has determined that substantial modifications from the County's PUD and general regulations, as permitted by Article XI of the Caroline County Zoning Ordinance (the "Zoning Ordinance"), are necessary. These modifications, collectively entitled the "Carmel Church Development Regulations" (the "Regulations"), shall set forth the requirements for the consideration, approval, and development of the Property, to ensure that the public purpose of Caroline County Zoning Ordinance and the Caroline County Subdivision Ordinance will be satisfied to at least an equivalent degree.

ARTICLE 2 Definitions of specific terms.

2.1 *Bike Station(s); Scooter Station(s).* A long term storage facility for bicycles and/or scooters and which may also offer bike rental and/or repair.

2.2 *Campus.* An arrangement of buildings and grounds such that multiple buildings may be on a single parcel, but whether on one or multiple parcels, buildings are organized and relate to one another through their relationship with common open spaces rather than street fronts. Hospitals, colleges, research parks, government installations and corporate offices frequently use campus designs for their buildings.

2.3 *Civic Buildings and Uses.* A building or area that may be a common place of destination or gathering for the purpose of providing education, entertainment, fraternalism, worship, or community services to the public such as, but not limited to libraries, cultural centers, museums, center for the arts, town square, post offices, places of worship, community centers, fire stations with community rooms, and schools (public or private).

2.4 *Dwelling, accessory.* An ancillary dwelling with limited use as a family member apartment, guest house (for occasional visits by family or friends), or maid's quarters. Not for rental separate from house.

(i) An accessory dwelling shall not exceed the lesser of twenty-five (25) percent of the total gross floor area (gfa) of the principal dwelling unit or 750 square feet gfa.

(ii) There shall be no more than one accessory dwelling per lot.

(iii) When an accessory building is located in the principal dwelling, the entry to the unit and its design shall be such that the appearance of the building shall remain one-family residence.

(iv) An accessory dwelling shall have the same address as the principal dwelling

(v) This term shall not include a carriage house.

2.5 *Dwelling, carriage house.* A dwelling unit with no more than two (2) bedrooms located above a detached garage on the same lot as a principal dwelling with access by an alley or lane. Not more than 750 square feet gross floor area ("GFA"). May be rented separately from principle building only when principle building is occupied by the owner.

2.6 *Dwelling, quadruple-attached.* One of four (4) attached buildings which are used as single-family dwellings, and which are all located side by side, or with two (2) buildings side by side and two (2) buildings directly behind them. The buildings shall be located on adjoining lots, and separated from each other by a solid wall extending from the lowest floor to the roof and from any other building by space on all other sides.

2.7 *Dwelling, semi-detached.* One of two (2) attached buildings which are used as single-family dwellings and which are all located side by side on adjoining lots, and separated from each other by a solid wall extending from the lowest floor to the roof, and from any other building by space on all other sides.

2.8 *Dwelling, three-family.* A building containing three (3) dwelling units, with two (2) of the dwelling units arranged side by side and situated either above or below the third dwelling unit. If these share a common entrance, this is deemed a multi-family dwelling.

2.9 *Dwelling, triple-attached.* One of three (3) attached buildings which are used as single-family dwellings, located side by side on adjoining lots, separated from each other by a solid wall extending from the lowest floor to the roof and from any other building by space on all other sides.

2.10 *Land Bay.* The areas identified as "land bays" on the General Land Plan for the Development.

2.11 *Live-work unit.* A building containing a commercial unit and a dwelling unit and defined as a "live-work unit" in the International Building Code. The dwelling unit shall be located above the commercial unit. The occupant of the single-family unit does not have to be the owner/occupant of the commercial unit. The floor area for each type of unit, commercial or single-family, excludes any stairs or hallways used to access the unit.

2.12 *Multifamily.* A structure containing more than four dwelling units, without regard to whether such units are rented (eg. apartments) or owned (eg. condominiums).

2.13 *Pedestrian Shed.* An area generally encompassing a five or ten minute walking distance to a designated destination point, such as a park, transit hub, civic building, restaurant, cafe, etc. The maximum length of a pedestrian shed is a circle with a radius of one thousand three hundred and twenty (1,320) feet (the approximate distance of a leisurely five-minute walk), except that the maximum radius of a pedestrian shed on a train station based transit hub is two thousand six hundred forty (2,640) feet (the approximate distance of a ten-minute walk).

2.14 *Primary Building.* The main building on a parcel as determined by its greater size, centralized or destination location and/or enhanced architectural features as compared to other buildings on the parcel.

2.15 *Principal Pedestrian Entrance.* The main point of access for pedestrians into a building.

2.16 *Principal Street.* Where a structure fronts on two streets, the principal street is the street designed, planned, and/or constructed to handle greater projected volumes of travel. If both streets meet this requirement, then the principal street will be assigned based on the number of Principal Pedestrian Entrances facing the street along the block frontage of the building.

2.17 *Regulating Plan.* A development plan that identifies the criteria set forth in Section 3.4 for each phase, or portion thereof, of the Development.

2.18 *Riverside Park.* The regional park located in Land Bay F adjacent to the North Anna River.

2.19 *Sign, directional.* An on-premises sign designed to direct customers to an entrance, drive-through facility or parking area. The directional sign shall not exceed two and one-half (2 ½) feet in height.

2.20 *Sign, tenant.* A wall sign or directory to identify more than one (1) tenant or business located within a building in which the tenant or business does not have a direct/independent entrance to a street and its primary entrance is through the principal entrance to the building. The sign shall be located near the principal entrance to the building and along any secondary entrance from a parking area. This term shall not include a business sign.

2.21 *Street.* A vehicle throughway other than an alley or lane.

2.22 *Streetscape.* A design term that includes all of the elements which constitute the physical makeup of a street and which include, but are not limited to building frontage, street paving, street furniture, landscaping (including trees and other plantings), awnings and marquees, signs and lighting.

2.23 *Streetscreens.* A wall between 3.5 and 8 feet in height and constructed of material matching or complementing adjacent building façades.

2.24 *Transect Zone.* A specific area with its own development requirements as set forth in this Code, and including, but not limited to, density, lot size, open space, types of uses and parking requirements and which include the following designations:

(1) T1, Natural Zone

Mostly undeveloped lands, largely maintained in untended conditions, though such areas may be subject to management plans for programs including biological restoration, proper forest management or the elimination of invasive species.

(2) T2, Rural Zone

Lands in open or cultivated state or sparsely settled. These include woodlands, agricultural lands, grasslands and regulated or dedicated athletic fields and golf courses.

(3) T3, Suburban Zone

Low density suburban residential areas, with naturalistic plantings and setbacks relatively deep. Blocks may be large and the roads irregular to accommodate natural conditions.

(4) T4, General Urban Zone

Mixed-use but primarily urban residential. It has a wide range of building types, including single family and townhouses. Setbacks and landscaping are variable. Streets typically define medium-sized blocks.

(5) T5, Urban Center Zone

Higher density mixed-use building types that accommodate retail, office, townhouse and multifamily uses. Characterized by a tight network of streets with wide sidewalks, regular street tree planting and buildings set close to the frontages.

(6) T6, Urban Core Zone

The highest density, with the greatest variety of uses, and civic buildings of regional importance. Having larger blocks and streets with regular street tree plantings and buildings set close to the frontage.

(7) Special Districts

Having larger structures for commercial industrial, civic or recreation uses, and uses which may serve more than the Development. The uses may be appropriate for development which is in close proximity to a major transportation network

2.25 *Town House.* Single family housing units of at least two stories connected with other units via party walls but with each unit located on a separate lot. The unit may or may not be accompanied by shared ownership of parking spaces or rights in common areas.

2.26 *VDOT.* Means the Virginia Department of Transportation.

2.27 *Village Architect.* A licensed professional qualified to review and approve design concepts and standards as they apply to the design code, proffers and design charrette created by this document.

2.28 *Vista Termination.* A location at the axial conclusion of a thoroughfare. A building identified on a Regulating Plan as being located at a Vista Termination shall be designed to complement the view along the axis though its articulation, elevation and/or location.

ARTICLE 3 Administration.

3.1 Except as expressly permitted herein, no use shall be initiated nor shall any building or structure be constructed, extended enlarged or used on the Property unless in conformance with these Regulations.

3.2 The Property shall be developed in substantial conformance to the Zoning Application, dated September 18, 2009 as amended, including, but not limited to the General Land Plan prepared by Bury+Partners, dated July 7, 2009, as amended (the "GLP"), and the Phasing Plan shown thereon.

3.3 No Land Bay or portion thereof shall be developed until a Regulating Plan, meeting the requirements of these Regulations has been submitted to the County. Once the Regulating Plan is deemed approved by the Director of Planning, the Regulating Plan shall be reviewed and approved by the Planning Commission.

3.4 Contents of a Regulating Plan.

Every Regulating Plan must include the following information for the area proposed for development (unless such information is otherwise being provided to the County through a Subdivision Plan simultaneously submitted to the County in connection with development of such area):

(1) Identified location and layout of all transect zones, including the boundaries lines thereof;

(2) The anticipated area of all Pedestrian Sheds and confirmation that each dwelling component is in at least one Pedestrian Shed;

(3) The proposed traffic circulation pattern, including but not limited to all Primary Streets;

(4) Identification of all Open Park Spaces;

(5) Identification of any Vista Terminations, including the Civic Building and Uses, or other uses proposed at the end of the thoroughfare;

(6) A landscape plan that meets the criteria set forth in Article 11 and also addresses the use of green roofs or green walls;

(7) Identification of criteria required by the Design Code as set forth in Article 13;

(8) Identification of building functions and uses, applicable build-to-lines and allowed encroachments and the landscape elements of the subject portion of the Development.

(9) A plan or report indicating the extent, timing and estimated cost of all on-site and off-site improvements including but not limited to, roads, water, sewer, sanitary sewer, and drainage facilities necessary to construct the proposed development;

(10) A traffic impact analysis.

3.5 In reviewing and deciding whether to approve a Regulating Plan, the Planning Commission may consider whether the Regulating Plan alone, or together with the Subdivision Plan, meets the following criteria:

(1) Whether the Regulating Plan meets the purpose(s) and goals of the Comprehensive Plan and the Community Plan as dated at the date of filing the application for this zoning.

(2) Whether the Regulating Plan satisfies the public purposes of the Caroline County Zoning Ordinance and the Caroline County Subdivision Ordinance to at least an equivalent degree.

(3) Whether the proposed development is compact, pedestrian-oriented and of a mixed-use.

(4) Whether ordinary activities of daily living will occur within walking distance of most dwellings.

(5) Whether the network of thoroughfares shown on the plan are interconnectively designed to disperse and reduce the length of automobile trips.

(6) Whether there are a range of housing types and price levels to accommodate diverse ages and incomes.

(7) Whether appropriate building densities and land uses are provided within walking distance of public transit stops.

(8) Whether civic, institutional, and/or commercial activities are embedded in a village core and not isolated in remote single-use complexes.

(9) When a school is part of the development, whether the school is sized and located to enable children to walk or bicycle to and from the school.

(10) Whether there are a range of open spaces including parks, squares, and playgrounds distributed within the development, and whether appropriate measures exist to protect such spaces in perpetuity.

(11) Whether buildings and landscaping contributes to the physical definition of the thoroughfares as civic places.

(12) Whether the architecture and landscape design are in character with the local climate, topography, history and building practice.

(13) Whether buildings are energy efficient.

(14) Whether civic buildings and public gathering places are provided in locations that reinforce community identity.

(15) Whether civic buildings and uses are distinctive and appropriate for their role.

(16) The relationship and transition between the development proposed by the Regulating Plan and adjacent development(s) and properties.

3.6 After a Regulating Plan has been approved by the Planning Commission, no development or subdivision of any area included in a Regulating Plan may occur until a Site Plan (meeting the criteria of Article XV, Section 14 of the Zoning Ordinance), or a Subdivision Plat (meeting Section 4 of the Subdivision Ordinance) has been approved for such area by the Planning Commission or Planning Department as required by ordinance.

3.7 Notwithstanding any other provision of Article XV, Section 14 of the Zoning Ordinance, two permitted extensions of time allowed under Section 5(e), of Division 1, Article XI of the Zoning Ordinance are hereby granted such that the first site plan for the Property shall be submitted within three (3) years after the date of the zoning approval of the Property pursuant to Zoning Application #_____.

ARTICLE 4 Uses and Development Criteria.

4.1 *Uses Generally*

The uses authorized in the Development and their location are set forth in Appendix A. Should additional by-right or conditional uses be added to the PMU District [Section Article XI, Division 3] of the Zoning Ordinance, such uses shall be permitted as authorized and located in Table 4.1, subject to these Regulations, and other applicable laws.

Table 4.1

PMU Use Categories	Land Bays					
	A and D	B and C	E	F	G	H
By Right PMU Residential	Yes	Yes	Yes	Yes	Yes	Yes
By Right PMU Commercial/Service	Yes	Yes	Yes	Yes	Yes	Yes
PMU Residential Conditional	Yes	Yes	Yes	No	Yes	Yes
PMU Commercial/Service Conditional	Yes	Yes	Yes	No	Yes	Yes
By Right Planned Shopping Center	Yes	Yes	Yes	No	Yes	No
By Right Planned Industrial Park	Yes	yes	No	No	Yes	No
Planned Industrial Park Conditional	Yes	yes	No	No	Yes	No

4.2 *Transect Zones*

Each Land Bay shall be developed utilizing Transect Zones. Each Land Bay shall have the following transect designations, arrayed generally as indicated on the GLP, however final transect designation for any Land Bay or portion thereof shall be shown on the Regulating Plan:

(1) **Land Bay A and D**

(a) Generally T5, however up to 49% of the net developable area may be T4, except that single family detached dwellings shall not be permitted.

(b) At such time as the building permit is issued for the construction of the Train Station shown on the GLP (the "Train Station") is issued, those portions of Land Bay A and Land Bay D within one half mile of the Train Station indicated as the TOD core on the GLP may be designated and developed as T6.

(2) **Land Bay B and C**

(a) T5 except that the following uses shall not be permitted:

i. single family detached dwellings

ii. cemeteries

iii. electric and natural gas/propane substations

iv. manufacture, processing, and fabrication of products, machinery or components

v. contractor's equipment storage yard

vi. airports

vii. truck terminals (other than bus or other public conveyance)

(b) At such time as the building permit for the construction of the Train Station is issued, then all of Land Bay B and C shall be re-designated and developed as T6, and densities from Land Bay A and D may be transferred into this area, resulting in an equivalent density reduction in the initiating Land Bay (A and/or D).

(3) **Land Bay E**

(a) T3, except that the following uses shall not be permitted:

i. cemeteri es (except as accessory uses)

ii. electric and natural gas/propane substations

iii. manufacture, processing, and fabrication of products, machinery or components

iv. contractor's equipment storage yard

v. airports

vi. truck terminals (other than bus or other public conveyance)

(b) The following uses may only occur within one-half mile of the area designated for the proposed Train Station:

(i) bed and breakfast

(ii) churches and other places of worship

(iii) cemeteries (as accessory uses to churches and other places of worship)

(iv) family apartments

(v) efficiency apartments

(vi) colleges and universities

(vii) assisted living facility (adult)

(c) Property within one block of the boundary of Land Bays C and D may be designated as T4.

(d) At such time as the building permit for the construction of the Train Station is issued, those portions of Land Bay E within one half mile of the Train Station may be designated T6 or T5, and densities from Land Bay A and/or D may be transferred into this area, resulting in an equivalent density reduction in the initiating Land Bay (A and/or D).

(4) **Land Bay F**

(a) Outside of the area designated as Riverside Park on the GLP ("Riverside Park"), the same uses allowed in Land Bay E, are allowed subject to the same limitations.

(b) Within Riverside Park, only the following T1 uses shall be permitted:

(i) utility services including, without limitation pump stations, electric and natural gas/propane substations;
(ii) recycling and yard waste management facilities;
(iii) public parks with recreational facilities including without limitation, bike trails, hiking trails, playgrounds, boating facilities, an amphitheater and similar public recreational elements;
(iv) buildings, structures and educational facilities related to historical, natural history and archaeological elements of the region's history;

(v) storage facilities for boats, recreational vehicles, travel trailers and similar large-scale items, and

(vi) a single facility, not exceeding 10,000 SF, which may include a restaurant, a retail store (including food) and/or a convenience store, without gasoline pumps.

(5) **Land Bay G**

Special District with all uses permitted as shown on Appendix A.

(6) **Land Bay H**

(a) T3 except that the following uses shall not be permitted:

(i) cemeteries

(ii) colleges and universities

(iii) temporary construction yards and recycling facilities

(iv) all Commercial/Service Uses (Tables C&E) except (1) restaurants, (2) retail stores, including food, and (3) convenience stores, without gasoline pumps, shall be permitted.

(b) T2 for preserved open spaces

(c) Multifamily units over or within the same structures as Commercial Retail/Office uses are permitted.

4.3 Transect and Use Specific Regulations

The following regulations shall apply to all specific transects and uses as identified in Table 4.1 and shown in Appendix A. In addition, as part of the development of the Design Code, as set forth in Article 12 of these regulations, the County may impose additional conditions on any use if, at the time of the approval of this rezoning request, the use was a conditional use under Article XI (Planned Unit Developments) of the Caroline County Zoning Ordinance.

Table 4.3 Additional Restrictions and Limitations for Specific Uses.

Transect Zone/Use	*T3*	*T4*	*T5, T6, SD-C*
Residential per Appendix Table (A)	Accessory dwelling must be under the same ownership as principal and not exceed 750 square feet.		

Transect Zone/Use	***T3***	***T4***	***T5, T6, SD-C***
Lodging per Appendix Table (B)	1. Food service permitted only from 6:30a.m. to 11:00a.m. 2. Additional parking required for dwelling (one per unit)	1.Food service permitted from 7:00a.m. to 10:00p.m. only. Lodging for greater than 12 rooms prohibited. 2. Additional parking required for dwelling(one per unit)	No restrictions on food service
Office per Appendix Table (C)	Additional parking required for dwelling (none required for live-work unit if parking available on street otherwise one per outside employee) (home occupations-as required under the Zoning Code)	Additional parking required for dwelling (none required for live-work unit if parking available on street otherwise one per outside employee) (home occupations-as required under the Zoning Code)	
Commercial/Industrial Uses per Appendix Table (E)	1. The building area available for Retail Use is restricted to one (1) corner location at the first story for each 300 dwelling units. 2. Restaurants are restricted to no more than 20 seats.	1.The building area available for Retail Use is limited to corner locations, and not more than one (1) per block. 2. Restaurants are restricted to no more than 40 seats.	

ARTICLE 5 General Requirements.

5.1 *Specific requirements for all Transect Zones*

(a) The requirements of this Article shall apply to development within all Transect Zones, except as otherwise set forth herein. Modification or deviation from these requirements may be approved as part of the approval of a proposed Regulating Plan so long as such modification is consistent with the criteria set forth in Section 3.5 and the Comprehensive Plan.

(b) Except in Special District Transect Zones and where campus and/or multifamily uses with approved street orientation are allowed, no more

than one (1) principal building and one (1) accessory building or carriage house shall be permitted per lot.

(c) All lots shall front on a new or existing, state maintained street, except that lots may front on a shared common area provided they are served by an alley or lane.

(d) Setbacks from alleys and lanes shall be measured from the edge of the easement and not the centerline.

(e) Street and parking lot lights shall be designed so as not to glare into any second floor residential use(s). All lighting shall be shielded or downward directed to preserve the night sky.

(f) Outdoor storage shall be screened from view of any public street and/or the ground level of adjoining properties.

5.2 *Encroachments and projections in all Transect Zones*

(a) Encroachments may be approved as part of the Regulating Plan. The following encroachments shall be permitted unless otherwise disapproved during the Regulating Plan or Site Plan approval process.

(i) Awnings and flags (above 8') may encroach the public sidewalk, provided the sidewalk is not within the right-of-way.
(ii) Stoops may encroach 100% of the depth of the setback.
(iii) Open porches and awnings may encroach up to 50% of the depth of the setback.
(iv) Balconies and bay windows may encroach up to 25% of the depth of the setback.

5.3 *Additional regulations for T-3 Transect Zones*

(a) Signs shall not be lit or illuminated.

(b) Average lighting levels for street lights measured at the building frontage shall not exceed 1.0 fc (foot-candles).

(c) All Primary Buildings shall have their Principal Pedestrian Entrance along the street or common area upon which they front.

5.4 *Additional regulations for T-4 Transect Zones*

(a) All Primary Buildings shall have their Principal Pedestrian Entrance along the street or common area upon which they front.

(b) Average lighting levels for street lights measured at the building frontage shall not exceed 2.0 fc (foot-candles).

5.5 *Additional regulations for T-5 Transect Zones*

(a) All Primary Buildings shall have their Principal Pedestrian Entrance along the street or common area upon which they front. For a corner lot, the Principal Pedestrian Entrance shall be along the Principal Street or diagonal to the corner itself.

(b) Facades shall be built parallel to the Principal Street frontage line along a minimum of 70% of its length of the lot. A streetscreen shall be built along the remainder of the length of the lot. Such façade and streetscreen may be interrupted by courtyards, porticos, plazas and parking entrances or similar features, provided that these are integrated into the streetscape to preserve the street wall while allowing useful and/or attractive public or semipublic space.

(c) All parking areas, including parking garages, shall have pedestrian access to the Principal Street except that parking garages set below the average grade of the Principal Street shall be accessed through the building containing the garage.

(d) Average lighting levels measured at the building frontage shall not exceed 5.0 fc (foot-candles).

5.6 *Additional regulations for T-6 Transect Zones*

(a) All Principal Buildings shall have pedestrian access to a street or common area. For a corner lot, the pedestrian access shall be along the Principal Street or diagonal to the corner.

(b) The façade for all buildings shall be built parallel to the Principal Street frontage line along a minimum of 80% of its length of the lot. The remainder of the length shall be a streetscreen. Such façade and streetscreen may be interrupted by courtyards, porticos, plazas and parking entrances or similar features, provided that these are integrated into the streetscape to preserve the street wall while allowing useful and/or attractive public or semipublic space.

(c) All parking areas, including parking garages, shall have pedestrian access to the Principal Street except that parking garages set below the average grade of the Principal Street shall be accessed through the building containing the garage.

(d) Average lighting levels measured at the building, frontage shall not exceed 5.0 fc (foot-candles).

5.7 *Additional regulations for Special District Transect Zones*

(a) All Principal Buildings and parking structures shall have pedestrian access to the street(s) or common areas.

(b) Pedestrian street access for all underground parking areas shall be through the building containing the underground parking area.

(c) Parking areas shall be screened from the Principal Street by a building, streetscreen, or evergreen hedge.

(d) All parking areas, including parking garages, shall have pedestrian access to the Principal Street except that parking garages set below the average grade of the Principal Street shall be accessed through the building containing the garage.

(e) Mechanical equipment, including but not limited to elevator penthouses, shall be screened from view from all public streets.

(f) Antennas or microwaves used for communication or telecommunication purposes shall be screened from view from all streets including streets.

(g) All buildings shall have entrance features for the side of the building equal to those facing the Principal Street and the parking area.

(h) Average lighting levels measured at the building frontage shall not exceed 5.0 fc (foot-candles)

ARTICLE 6 Parking and Loading Requirements.

6.1 *Specific requirements for all Transect Zones*

(a) All parallel parking spaces shall count towards the required number of parking spaces for adjoining propert(ies).

(b) The required parking for all uses within the Transect Zone shall be provided within the specific Transect Zone within 150 feet for a residential use and 500 feet for a non-residential use, or as specifically approved as part of the Site Plan.

(c) A garage, parking court or carport accessory to a residential dwelling may be counted towards the required parking space, however, any portion of a driveway extending past the forward plane of a residence shall not count towards the required number of parking spaces even if the area of the driveway is adequate for a parking space.

(d) Other than parallel parking spaces, all parking spaces shall be accessed by an alley, lane or a street that is not considered a Principal Street.

(e) Parking lots and loading and service areas (not located on the street) shall be screened from Principal Streets by buildings and/or streetscreens.

(f) Loading and service areas shall be connected to parking areas and shall not have direct access from the Principal Streets of the Development; provided that to the extent otherwise permitted by VDOT, temporary and/or permanent loading zones may be established along such streets.

(g) Parking regulations for all Transect Zones

The uses within all transect zones shall comply with the required number of parking spaces as listed in Table 6.2. If a use is not specified in the table, the use nearest approximating such use shall be utilized.

Table 6.2 Parking requirements per use and transect zones

Table E

Parking Required/Uses	*T1, T2, T3*	*T4*	*T5, T6, Special District*
Residential per Appendix Table (A)	2.0 spaces per unit	1.5 spaces per unit	1.0 spaces per unit
Lodging per Appendix Table (B)	1.0 per room	1.0 per room	1.0 per room
Retail/Eating Establishment per Appendix Table (E)	4.0/1000 square feet	4.0/1000 square feet	3.0/1000 square feet
Institutional per Appendix Table (D)	*	*	*
Office per Appendix Table (C)	3.0/1000 square feet	3.0/1000 square feet	2.0/1000 square feet
Cultural/ Entertainment per Appendix Table (F)	*	*	*
Agricultural per Appendix Table (G)	None	None	None
Public/Civic per Appendix Table (H)	*	*	*

* As required pursuant to the Caroline County Zoning Ordinance or specifically reduced as part of the Site Plan approval of any Phase taking into account all relevant factors including, without limitation the availability of transit options, applicable Transportation Demand Management measures in place, applicable demand statistics from the most current edition of the Institute of Traffic Engineers' Parking Generation manual, the source of attendees and whether they would be within walking distance, other public parking available in the vicinity, shared parking, available street parking and such other reasonable factors, with the goals of minimizing excess

on-site parking and maximizing non-automobile transportation use but providing parking adequate to support the use without unreasonable burden on surrounding neighborhoods.

6.2 *Shared parking for specified uses in all Transect Zones*

(a) Only the uses listed in Table 6.3 may apply to the shared parking tabulations.

(b) To determine the total number of spaces to be shared by two (2) categories, add the maximum number for each use and multiply the number by the factor then subtract that difference from the total. *Example*: An office complex and a retail store share a parking lot. The Office use requires 60 spaces and the Retail use requires 40 spaces if they were separate under Table 6.2, total spaces required for both uses is 100; multiply by 1.2 = 120; a difference of 20, therefore, subtract 20 from the original required parking of 100; number of spaces now required for the combined uses is 80. This reflects a 20% sharing factor for these two uses.

(c) When more than two (2) categories in Table 6.3 are to share parking, add the maximum number for each use and multiply the number by the smallest factor then subtract the difference from the total. *Example*: The multiple categories are Residential, Retail, and Cultural. Assume that when you use Table 6.2 for each of these uses individually it shows that you would need 500 spaces. When you look at Table 6.3, the smallest sharing factor is 1.1 (meaning that the least sharing factor when you look at Residential/Retail, (1.2), Retail/Cultural (1.4) and Residential/Cultural (1.1) is the 1.1 or 10%). So the applicable equation is: 500 x 1.1 = 550; 550-500=50; 500-50 = 450 spaces for the lot that supports all three uses.

Table 6.3 Shared Parking Factor

Use with Use/Factor of reduction	*Residential per Appendix Table (A)*	*Lodging per Appendix Table (B)*	*Office per Appendix Table (C)*	*Retail per Appendix Table (E)*	*Cultural/ Entertainment, Institutional or Public/Civic perAppendix Tables (D), (F), (G), (H)*
Residential per Appendix Table (A)	1	1.1	1.4	1.2	1.1
Lodging per	1.1	1	1.7	1.3	1.5

Use with Use/Factor of reduction	*Residential per Appendix Table (A)*	*Lodging per Appendix Table (B)*	*Office per Appendix Table (C)*	*Retail per Appendix Table (E)*	*Cultural/ Entertainment, Institutional or Public/Civic perAppendix Tables (D), (F), (G), (H)*
Appendix Table (B)					
Office per Appendix Table (C)	1.4	1.7	1	1.2	1.4
Retail per Appendix Table (E)	1.2	1.3	1.2	1	1.4
Cultural/entertain-ment, Institutional or Public/Civic per Appendix Tables (D), (F), (G) or (H)	1.1	1.5	1.4	1.4	1

6.3 *Parking and storage facilities for bicycles and scooters for all Transect Zones*

(a) Facilities for the parking and/or storage of bicycles and scooters shall be provided for all uses listed in Table 6.4.

(b) Parking facilities for bikes and scooters must be covered, lit, and visible from public ways or parking areas, but without impeding pedestrian or motor vehicle circulation.

(c) Bicycle racks must support entire bikes (not just one wheel) and enable the user to lock the frame and wheels of the bike with a cable or "U-shaped" lock.

(d) Bike racks shall be installed on sidewalks having five (5) or more feet of clear sidewalk space between the rack and the adjacent roadway.

(e) Bike racks shall be secured so as to prevent the theft thereof.

(f) Bike racks may not be closer than four (4) feet from any fire hydrant, curb ramp, and/or building entrance.

(g) Bike racks shall be distributed along a block and not clustered in one location (i.e., four or five racks distributed along the block rather than a group of four or five racks mid-block in one location).

(h) Bike racks shall be located in areas of high pedestrian activity.

(i) Bike racks shall be located on the same parcel as a proposed use unless otherwise approved as part of the Site Plan review process and provided the racks remain within 500 feet of the proposed use.

(j) Bike Stations and/or Scooter Stations shall be centrally-located near transit stations and lockers. Such facilities shall typically contain the following:

i. Individual lockers for at least half of the bicycles or scooters, and

ii. Enclosed racks in a secure room, or racks are in an area that is monitored by security cameras or guards (within 100 feet) and visible to employees.

(k) Scooter storage, in lieu of a portion of required bicycle storage or in addition thereto, may be approved with the Site Plan approved for any Phase.

Table 6.4 shall determine the number of slots for bicycle parking required per the type of use listed. If a use is not listed, it shall not require a slot for a bicycle or scooter. No more than one half of the slots can be for scooters unless specifically approved as part of the Site Plan approval.

Table 6.4 Parking for Bicycles or Scooter

Use	# of slots required for parking bicycles or scooters
Multifamily units	1 / 10 units
Lodging per Appendix Table (B)	1 / 10 rooms
Office per Appendix Table (C)	1 / 6,000 square feet of office space within one side of a street on a block
Retail/Eating establishment per Appendix Table (E)	1 / 2,000 square feet of retail/eating establishments within one side of a street on a block
Schools – all types	1 / 100 students
Library	1 / 1,500 square feet
Community Building, museum, cultural center	1 / 2,500 square feet
Center for performing arts, auditorium, outdoor pavilion and other public assembly uses	1 / 100 seats
Bus depot, terminal	10

Use	# of slots required for parking bicycles or scooters
Commuter rail/train station	1 / 10 parking spaces required by VRE or Amtrak, minimum of 20
Park	1 / 20 required parking space, minimum of 3 per half acre up to a maximum of 12 if no parking spaces required.

ARTICLE 7 Open Space Requirements.

7.1 *Open space* shall be required as set forth in Table 5.11.

7.2 Each Pedestrian Shed shall contain not less than 5% of its gross land areas as Open or Park Spaces.

Table 5.11 Open Space

Type of Open Space	*Transect Zones*	*Description, Restrictions or Limitations*
Park	T1, T2, & T3	Natural preserves available for unstructured recreation (not requiring formal fields or formal teams) and which includes a landscape of paths, trails, meadows, water bodies, woodlands and open shelters.
Open Space	T1, T2, T3, T4, T5, T6, & Special District	Generally unimproved or restored natural areas serving significant environmental functions (such as habitat or wetlands) or landscaped buffer and edge areas. Bike and/or hiking trails are permitted.
Square	T4, T5, & T6	Areas spatially defined by surrounding building frontages with a landscape consisting of paths, lawns, shrubs, flowers and trees, generally more formal and available for unconstructed recreation and civic purposes.
Plaza	T5 & T6	Areas spatially defined by surrounding building frontages with a landscape consisting of primarily of pavement and optional planters for trees, shrubs and flowers. Uses permitted in area include civic and commercial activities such as farmers market.
Playground/tot-lot	T3, T4, T5, & T6	Fenced areas designed and equipped for recreation of children. May be included with park or greens or as stand alone areas.
Green	T3, T4, & T5	Areas spatially defined by their landscape of

Type of Open Space	*Transect Zones*	*Description, Restrictions or Limitations*
		trees, shrubs, flowers and lawn available for unstructured recreation.
Recreational	T1, T2, T3, T4, T5, T6 & Special District	Areas improved for outdoor recreational activities.

ARTICLE 8 Lot Area and Dimensional Requirements.

8.1 *Lot Area and Dimensional Requirements for Specific Transect Zones*

(1) Lots within each Transect Zone shall comply with the following tables, except that a minor modification or deviation from a specific regulation may be approved by the Director of Planning as part of the Site Plan review process, should the Director find that the modification or deviations meet or exceed the intent of the Regulations.

(2) Height Requirements.

(a) A residential story shall not exceed 10 feet, floor to ceiling.

(b) A commercial/service story shall not exceed 20 ft., floor to ceiling on the first floor and 10 ft. thereafter.

(c) A commercial/service or residential atrium may combine floor heights but will be counted as multiple floors.

(d) English basements that are less tan 50% above the ground level and attics (unoccupied) shall not count as floors.

(e) Industrial and Civic Buildings are subject only to maximum height limitations.

Table 8.1(A) Lot Occupancy This table may require min. & max. Square foot areas, not just lot widths.

Transect Zones	*T1*	*T2*	*T3*	*T4*	*T5*	*T6*	*SD-C*
Lot Width – min/max.	50/none	N/A	60/120	18/120	18/180	18/360	18/none
Max Lot Coverage	60%	N/A	60%	70%	80%	100%	100%

Table 8.1(B) Setbacks, main buildings [these are critical and standard to TOD/TND]

Transect Zones	*T1*	*T2*	*T3*	*T4*	*T5*	*T6*	*SD-C*
Front – min./max.	50/none	N/A	15/30	6 min./20 max	0 min./20 max	0 min/20 max	0 min./none
Side – min./max.	10% of lot width/none	N/A	5/none	* 0 min/none	* 0 min/24 max	* 0 min/24 max	* 0 min/none
Rear – min.	10% of lot	N/A	Either 5%	Either 5% or	Either 5%	Either 5%	Either 5%

	depth		or 18 or greater	18 or greater	or 18 or greater	or 18 or greater	or 18 or greater

* With appropriate provisions for maintenance, repair and reconstruction access.

Table 8.1(C) Setbacks, accessories buildings

Transect Zones	*T1*	*T2*	*T3*	*T4*	*T5*	*T6*	*SD-C*
Front	20 + main bldg.	N/A	20 + main bldg.	20 + main bldg.	20 + main bldg.	20 + main bldg.	N/A
Side	10	N/A	5	*0	*0	*0	N/A
Rear	10	N/A	5	5	5	5	N/A

Table 8.1(D) Heights / Number of Stories

Transect Zones	*T1*	*T2*	*T3*	*T4*	*T5*	*T6*	*SD-C*
Maximum Height	None	N/A	None	None	None	140	140
# of stories – min/max.	None/None	N/A	None/3 max	2 min /4 max	2* min /5 max	2* min / 8 max	1 min / 8 max

* 4 story-minimum in Land Bays 2 and 3A

Table 8.1(E) Building Height to Street Ratio

The building height ratio is the distance between the right-of-way line at the opposite side of the street from the building to the front edge of the building (width) and the distance from the right-of-way line at the opposite side of the street from the building to the top of the building (height). The building may terrace back each story provided the ratio is maintained.

T1	*T2*	*T3*	*T4*	*T5*	*T6*	*SD-C*
N/A	N/A	N/A	N/A	N/A	N/A	3 (height): 2 (width) ratio

ARTICLE 9 Signs.

9.1 *Types of Signs Permitted in TOD*

(1) Each building side shall be treated as independent areas for calculation of maximum permitted signage areas:

(2) For buildings taller than four (4) stories, the building's principal user's sign may have letter or logo heights up to four (4) feet.

(3) One blade sign for each business not to exceed five (5) square feet, may be attached perpendicular to the building façade. There must be at least eight (8) feet of clearance between the bottom of the blade sign and

the sidewalk. The sign may not project more than forty-two (42) inches from the wall.

ARTICLE 10 Streets.

10.1 Streets shall be constructed to the narrowest width and tightest turning radius permitted by VDOT.

10.2 General

(1) All streets, other than lanes and alleys, shall include street trees in and along their rights-of-way.

(2) All residential streets shall, include street lights, at minimum, at their corners.

(3) Streets through commercial areas shall provide street lights throughout the commercial areas.

(4) Alleys and lanes shall have appropriate lighting, which, depending on their length, may include lighting at intersections, garage lighting, or other approaches.

(5) Sidewalks along public streets may be private if maintained by a commercial or homeowner association, provided that public access is assured.

(6) Street, sidewalk and pathway design shall de designed to provide for the safe movement of bicycles, motorized wheelchairs, segways, roller blades and other wheeled transport. Such design may include separate colored lanes on sidewalks for vehicles travelling at less than 15 miles per hour.

10.3 Unless otherwise required by state or local laws or regulations, each street in the Development must meet one of the categories set forth herein and must comply with all standards established for that category.

10.4 Street Categories

(1) **Primary Streets.**

(a) Primary Streets shall be the main street(s) of the Development. They should have the highest volume of traffic within the Development and be the location of the most intense commercial activity. They must be identified as Primary Streets on the Regulatory Plan.

(b) Primary Streets shall have no more than four (4) driving lanes, but service lanes shall be permitted.

(c) Primary Streets may have a median and may function as a boulevard or as a pair of couplets (i.e. double one way streets).

(d) On-street parallel parking shall be permitted on Primary Streets.

(e) Access to courtyards, porticos, parking lots and parking decks may be from Primary Streets, but not to individual lots unless where not accessible from an alley or lane.

(f) Sidewalks along Primary Streets are required.

(g) Round-a-bouts, stop signs or traffic lights may be required when two Primary Streets intersect.

(h) Pedestrian crossings across Primary Streets shall be indentified by brick, stamped-painted asphalt, or similar materials, and shall be slightly raised from street grade. Bulb-outs may be used as a change in materials on corners.

(2) **Village Streets.**

(a) Village streets are intended to provide vehicular access to parking and loading areas for a majority of the commercial and large residential uses.

(b) Direct vehicle access to single family attached units is permitted.

(c) Direct vehicle access to individual lots is restricted if access from an alley or lane is available but access to parking lots, decks, porticos, and courtyards permitted.

(d) Access to alleys and lanes to serve all uses is permitted.

(e) Village streets may have no more than two (2) travel lanes.

(f) A median may be used to restrict access to a village street when near the intersection to a principle street.

(g) Center left lanes are not required but may be necessary when access is near the intersection to a principle street to prevent stacking problems.

(h) Parallel parking is permitted.

(i) On-street angled parking is permitted except when prohibited by VDOT or when determined to be inappropriate by the County.

(j) Sidewalks are required.

(k) Round-a-bout or stop signs may be required when intersecting with another village or neighborhood street.

(l) Pedestrian crossing shall be identified by using brick, stamped-painted asphalt or similar material and slightly raised from the grade of the street. Bulb-outs may be used as well as a change in materials on corners.

(3) **Neighborhood Streets.**

(a) Neighborhood streets are designed to serve small scale multifamily, residential attached and detached units, civic open spaces, and corner commercial areas. These streets are intended to be narrow, quiet and designed for low vehicle speeds.

(b) Neighborhood streets shall have no more than two (2) travel lanes, and may be one-way streets.

(c) Median and center left turn lanes shall be prohibited.

(d) Access to alleys and lanes shall be permitted from neighborhood streets.

(e) Direct vehicle access to all lots is permitted where not available from alleys or lanes.

(f) On-street parallel parking is permitted.

(g) Sidewalks are required.

(h) Round-a-bouts or stop signs may be required when intersecting with another neighborhood street.

(i) Traffic calming devices may be required depending on length of blocks.

(j) Maximum speed limit shall be 25 mph unless VDOT requires a lower maximum speed.

(4) **Rural Streets.**

(a) Rural streets intended to be narrow and designed to serve large single family residential lots or large tract of open space areas. They are not intended to serve high density or intensity areas.

(b) Rural streets shall have no more than two (2) travel lanes.

(c) Use of medians and center left turn lanes shall be required as determined by VDOT.

(d) Direct access for all lots is permitted.

(e) Parallel and on-street angle parking is prohibited.

(f) Rural streets may have sidewalks to access civic open space if within a pedestrian shed.

(g) Maximum speed will be determined by VDOT.

(5) **Alleys and Lanes.**

(a) Private thoroughfares. Lanes are intended to serve residential areas though they may serve corner commercial as well.

(b) Alleys are intended to serve areas with mid-block commercial uses.

(c) Lanes may have a hard surface for at least 18' if two-way with a gravel shoulder of not less than 1' on each side.

(d) Alleys are hard surfaced for their entire easement width, which shall not be less than 20' if two-way.

(e) Alley entrances shall be provided at the minimum width allowed by VDOT.

(f) Stormwater drainage for lanes and alleys may be provided in the center or along one side of the roadway.

10.5 The standards set forth herein may be modified by the Planning Commission during Regulating Plan review as minimally necessary to allow the acceptance of such streets by VDOT.

10.6 Addresses and street names for streets and travel ways in all Transect Zones.

All travel ways and/or streets which provide access to a building will be named, as approved by the Planning Department and any building or unit whose primary access will be via the travel way or street will be assigned an address number to that travel way or street. When the travel way is a secondary access for a residential use and the lot has a carriage house then the carriage house will be assigned an address to the secondary access and the principal resident will have an address of the main street it fronts on even if the secondary access principal resident's vehicle access is from the secondary access.

ARTICLE 11 Landscaping

11.1 Detailed landscaping plans shall be required as part of the Regulating Plan and Site Plan approval process.

11.2 Species of trees to be utilized in the Development shall be approved based on criteria including, but not limited to:

(1) a preferred use of native species

(2) limited impacts on impervious areas and utilities

(3) hardiness, environmental sensitivity, and drought tolerance (unless irrigated with reuse water)

(4) tolerance for local pests and diseases

(5) sustainability benefits. As used in this section, "sustainability benefits" means the benefits the particular landscaping element has for sustainability. These can include the reduction of energy use in adjoining buildings, the shading of streets and parking lots, the creation of habitat, the production of food for humans or animals, the stimulation of beneficial wildlife etc

11.3 Landscaping plans shall include the following minimum standards.

(a) Street trees shall be planted along every street in the Development other than alleys and lanes.

(b) Trees shall be planted evenly along the streets as shown on the Site Plan.

(c) Street trees may be located in the medians of boulevards.

(d) Extensive sod front lawns shall generally be prohibited, and landscaping with art, shrubs and flowers in the front of buildings should be utilized.

(e) No berms or barriers between uses or streets shall be permitted other than hedges, landscaping, and fences.

(f) Extensive landscaping of parking lots shall not be required when screening is provided by buildings and/or streetscreens. Tree canopy to avoid heat island contributions by parking lots and increase the beneficial use or infiltration of storm water shall be required.

(g) In residential areas, seasonal grasses instead of sod lawns shall be permitted and Regulating Plans shall outline where and how vegetables and other cultivation may occur on residential properties.

Because the street level of the core of a town center should be vibrant and the opposite of uniform shopping center signage, the Design Code will include a sign code and may allow a wide range of signage at the street level, including but not limited to sandwich boards, three dimensional signs, tasteful use of color and neon and, in-general, encouragement of creative, vibrant signage.

ARTICLE 12 Design Standards.

12.1 Pursuant to the "Carmel Church Station Proffers," dated _____ (the "Proffers"), and proffered by the Owner in connection with the Application, and as set forth herein, the Owner shall develop a design code (the "Design Code") to establish detailed standards and guidelines for the Development related to architecture, signage, lighting, landscaping and streets. The Design Code shall guide the implementation of those standards, and the general standards set forth in these Regulations, and is intended to ensure that the Development adheres to the transit oriented development structure and is developed in accordance with the Comprehensive Plan and the Community Plan.

12.2 In addition to the foregoing, the Design Code shall also include, at minimum, the following criteria:

(a) an outline of the procedures and contacts for approvals in connection with design and construction within the Development, and

(b) an outline of the procedures and contacts for approvals in connection with the Development's archaeological and environmental programs;

(c) guidelines on the following: (i) appropriate siting of uses with respect to the environmental integrity of the site; (i) proper functional relationships between uses and public spaces and alleys; (iii) scale, mass and height of buildings; (iv) architectural façade treatments; (v) landscaping; (v) signage; (vi) lighting; (viii) treatment of utility and service areas including loading and dumpster areas; (ix) parking lot design, landscaping and screening and (x) control management of construction debris for recycling and mitigation of impacts;

(d) landscape standards as part of the Design Code. The landscape standards shall provide for the number, setbacks, location and types of trees and shrubs along streets, on lots and in common areas.

12.3 The development of the Design Code will take into account adjoining uses, both existing and as contemplated by the Comprehensive Plan. The development of the Design Code will also take into account the future development and potential use of new materials and technologies.

12.4 The Design Code and the Regulating Plans shall permit the planned densification of properties under suitable safeguards. As used herein "planned densification" means the process whereby a use that matches then current market conditions is permitted in a transect or Land Bay, even through a more dense and/or different use is ultimately planned or anticipated for the area (i.e., a garden center may be an initial use in a location where eight story buildings are later to be located; a parking lot may be intended to be replaced by a high density, block with a parking deck or a two story building may be designed so that additional floors may be added later).

12.5 The Design Code shall be developed through a design charrette process. The charette shall include the input of the Owner/Applicant, the Applicant's Architect, builders, Caroline County Supervisors, Planning Commissioners, citizens and County staff. Once approved in accordance with these Regulations, the Design Code shall become a part of these Regulations, and shall not be amended except with approval of the Caroline County Planning Department.

12.6 The Design Code shall include provisions for the approval of modifications based on unusual hardship and/or appropriate reconciliation of site or context conditions, to the extent permitted by state law.

12.7 The Design Code shall be prepared and a copy provided to the County together with the application for the first record plat of the first Land Bay developed.

12.8 Before the sale of any lot or parcel in the Development, the Owner shall establish the position of Village Architect, controlled and funded by the Owner until such time as the position is relinquished to the control and responsibility of the property owners associations. Such position may be on a full or part-time employee or contract basis but shall be fulfilled by an individual licensed in an engineering or architectural program in the United States. The duties of such Village Architect shall include, but not be limited to:

(a) Oversight the programs of Owner and/or the property owners association to assure compliance with the Design Code;

(b) Assisting property owners in complying with the Design Code;

(c) Assisting in the selection of appropriate materials for the use in common areas and public buildings;

(d) Reviewing plans for compliance with the Design Code, initialing such plans, indicating that the plans were so reviewed and noting any standards that have been waived;

12.9 Owner shall apply the Design Code to all structures and uses within the Development, until such time as such function is delegated to one or more property owner associations.

(1) In applying the Design Code, the Owner shall consult the Village Architect.

(2) Any property owner association applying the Design Code shall utilize the Village Architect, and/or the Approval Body proffered to be established by the Owner/Applicant, and defined in the Proffers.

No building permit shall be issued by the County for any structure within the Development until such structure is approved in writing by the Village Architect, or the Approval Body, as the case may be. Such approval shall be accompanied

by the site layout plan, building elevations and landscape plan approved hereunder and shall state that the attached plans have been approved and, that to the best of the knowledge of the approving party after due and appropriate inquiry they comply with the Design Code, the Regulating Plan and the Regulations, and shall note any of the Design Code that have been waived by the approving party.

APPENDIX A

APPENDIX A

Table (A). Residential uses within Transect Zones

Residential Use	*T1*	*T2*	*T3*	*T4*	*T5*	*T6*	*Special District*
Single-Family Detached			Yes				
Duplex			Yes	Yes	Yes		
Semi-detached				Yes	Yes		
Townhouse				Yes	Yes	Yes	
Triplex				Yes	Yes	Yes	
Three-family attached				Yes	Yes	Yes	
Quadruple-attached				Yes	Yes	Yes	
Accessory Dwelling			Yes	Yes	Yes		
Carriage House			Yes	Yes	Yes		
Multifamily			Yes (not exceeding 8 units per lot)	Yes (not exceeding 8 units per lot)	Yes	Yes	
Live-work units			Yes	Yes	Yes	Yes	

Table (B). Lodging Uses Within Transect Zones

Lodging	*T1*	*T2*	*T3*	*T4*	*T5*	*T6*	*Special District*
Bed & Breakfast (up to 5 rooms)			Yes	Yes			
Country Inn (up to 12 rooms)			Yes	Yes	Yes	Yes	
Motel					Yes		
Hotel					Yes	Yes	Yes
School Dormitory			Yes	Yes	Yes	Yes	Yes

Table (C). Office Uses Within Transect Zones

Office Use	*T1*	*T2*	*T3*	*T4*	*T5*	*T6*	*Special District*
Professional Office				Yes	Yes	Yes	Yes
Medical/Dentist Office				Yes	Yes	Yes	Yes
Medical/Dentist Clinic					Yes	Yes	Yes
Bank/Lenders Inst. Without drive-through (except accessed from parking lot or alley)				Yes	Yes	Yes	Yes
Bank/Lender Inst. With drive-through							Yes
Live-work unit			Yes	Yes	Yes	Yes	Yes
Home Occupation			Yes	Yes	Yes	Yes	
Temporary buildings (incidental to construction of permanent buildings)			Yes	Yes	Yes	Yes	Yes
Veterinarian Clinics					Yes	Yes	Yes
Funeral Homes					Yes	Yes	Yes

Table (D). Private Institutional Uses Within Transect Zones

Institutional	*T1*	*T2*	*T3*	*T4*	*T5*	*T6*	*Special District*
Day Care Center			Yes	Yes	Yes	Yes	Yes
Elementary School			Yes	Yes	Yes	Yes	
Middle School			Yes	Yes	Yes	Yes	
High School			Yes	Yes	Yes	Yes	
College/University				Yes	Yes	Yes	Yes
Vocational School				Yes	Yes	Yes	Yes

Institutional	*T1*	*T2*	*T3*	*T4*	*T5*	*T6*	*Special District*
Instruction with studio				Yes	Yes	Yes	Yes
Place of Worship			Yes	Yes	Yes	Yes	Yes
Assisted Living Facility					Yes	Yes	Yes

Table (E). Commercial/Industrial Uses Within Transect Zones

Commerical/ Industrial Uses	*T1*	*T2*	*T3*	*T4*	*T5*	*T6*	*Special District*
Open-Market	Yes*		Yes	Yes	Yes	Yes	Yes
Retail uses				Yes	Yes	Yes	Yes
Vehicle Fuel Sales					Yes		Yes
Automobile Repair					Yes	Yes	Yes
Push Cart	Yes				Yes	Yes	Yes
Kiosk	Yes			Yes	Yes	Yes	Yes
Restaurant	Yes*		Yes	Yes	Yes	Yes	Yes
Carry-out/Café with no drive through			Yes	Yes	Yes	Yes	Yes
Carry-out with drive through					Yes		Yes
Temporary Construction Yard & Recycling Facility			Yes	Yes	Yes	Yes	Yes
Personal Service Establishments (barber and beauty shops, dry cleaners, laundries)				Yes	Yes	Yes	Yes
Convenience stores (without gas pumps)	Yes*			Yes	Yes	Yes	Yes
Convenience stores (with gas pumps)					Yes		
Pet shops					Yes	Yes	Yes
Contractor's					Yes	Yes	Yes

Commerical/ Industrial Uses	*T1*	*T2*	*T3*	*T4*	*T5*	*T6*	*Special District*
Office/Workshop (Indoor)							
Contractor's Office/Workshop (with outdoor storage yard)					Yes		Yes
Repair services (non-auto)					Yes	Yes	Yes
Wholesale businesses					Yes	Yes	Yes
Drug/pharmaceutical laboratories and/or compounding					Yes	Yes	Yes
Manufacturing and/or distribution facilities					Yes	Yes	Yes
Research and development facilities					Yes	Yes	Yes
Printing/engraving house					Yes	Yes	Yes
Airport, helistop, heliport							Yes
Assembly or modular building units							Yes
Moving businesses and storage facilities					Yes	Yes	Yes
Warehouse facilities					Yes	Yes	Yes
Truck Terminals					Yes		Yes

***Only in Land Bay F**

Table (F). Cultural/Entertainment Uses Within Transect Zones

Cultural/ Entertainment	*T1*	*T2*	*T3*	*T4*	*T5*	*T6*	*Special District*
Fountains / Public Art		Yes	Yes	Yes	Yes	Yes	Yes

Cultural/ Entertainment	*T1*	*T2*	*T3*	*T4*	*T5*	*T6*	*Special District*
Library				Yes	Yes	Yes	Yes
Museum					Yes	Yes	Yes
Outdoor Pavilion	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Center for the Arts					Yes	Yes	Yes
Cultural Center	Yes				Yes	Yes	Yes
Movie Theater					Yes	Yes	Yes
Conference Center					Yes	Yes	Yes
Convention Center					Yes	Yes	Yes
Exhibition Center					Yes	Yes	Yes
Bikestation				Yes	Yes	Yes	Yes

Table (G). Agricultural Uses Within Transect Zones

Agricultural Uses	*T1*	*T2*	*T3*	*T4*	*T5*	*T6*	*Special District*
Greenhouse	Yes	Yes	Yes		Yes		Yes
Stable	Yes	Yes					
Rooftop Garden				Yes	Yes	Yes	Yes
Rooftop Greenhouse				Yes	Yes	Yes	Yes
Green Walls			Yes	Yes	Yes	Yes	Yes
Community Gardens	Yes	Yes	Yes	Yes			
Home Occupation			Yes	Yes	Yes	Yes	

Table (H). Public/Civic Uses Within Transect Zones

Public/Civic Uses	*T1*	*T2*	*T3*	*T4*	*T5*	*T6*	*Special District*
Fire/Rescue Station			Yes	Yes	Yes	Yes	Yes
Police Station				Yes	Yes	Yes	Yes
Hospital					Yes	Yes	Yes

Public/Civic Uses	*T1*	*T2*	*T3*	*T4*	*T5*	*T6*	*Special District*
Water/Sewer Treatment Facility	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Water/Sewer Pump Station		Yes	Yes	Yes	Yes	Yes	Yes
MultiModal Facility				Yes	Yes	Yes	Yes
Telecommunication Antennas as an ancillary use to an existing structure or building	Yes	Yes			Yes	Yes	Yes
Public Elementary School				Yes	Yes	Yes	Yes
Public Middle School	Yes*			Yes	Yes	Yes	Yes
Public High School					Yes	Yes	Yes
Public Recreation facilities (indoor and outdoor)	Yes		Yes	Yes	Yes	Yes	Yes
Rooftop or Microgrid Power Production (Wind, Solar or Fuel Cell)			Yes	Yes	Yes	Yes	Yes
Post Office or Facility			Yes	Yes	Yes	Yes	Yes
Government Offices				Yes	Yes	Yes	Yes
Public Library				Yes	Yes	Yes	Yes
Public Utilities/Facilities (other)	Yes	Yes	Yes	Yes	Yes	Yes	Yes

*** Only in Land Bay F**

VIRGINIA: In the Clerk's Office of the Circuit Court of Caroline County. The foregoing instrument was this day presented in the office aforesaid and is, together with the certificate of acknowledgment annexed, admitted to record this 16th day of August, 20 10 12:35 P M. The tax imposed by §58.1-802 of the Code has been paid in the amount of $ 0

Teste: [signature] Clerk

BK 1406 PG 0635

RECORDED IN
COUNTY OF CAROLINE, VA
SUSAN W. MINARCHI
CLERK OF CIRCUIT COURT
FILED Nov 18, 2020
AT 10:41 am
BOOK 01406
START PAGE 0635
END PAGE 0639
INSTRUMENT # 200005271

RAF

VIRGINIA LAND RECORD COVER SHEET

Commonwealth of Virginia VA. CODE §§ 17.1-223, -227.1, -249

FORM A – COVER SHEET CONTENT

Instrument Date: 11/18/2020

Instrument Type: OTHER

Number of Parcels: 0 Number of Pages: 3

[ ] City [X] County CAROLINE
CIRCUIT COURT

Tax Exempt? VIRGINIA/FEDERAL CODE SECTION

[ ] Grantor:

[ ] Grantee:

Business/Name

(Area Above Reserved For Deed Stamp Only)

1 × Grantor: CARLOINE COUNTY

2 × Grantor: BOARD OF SUPERVISORS

1 × Grantee: CARMEL CHURCH STATION, LLC

2 × Grantee: CAROLINE 40, LLC

Grantee Address

Name: CARMEL CHURCH STATION, LLC

Address: 10001 PATTERSON AVE., STE 200

City: RICHMOND State: VA Zip Code: 23238

Consideration: $0.00 Existing Debt: $0.00 Actual Value/Assumed: $0.00

PRIOR INSTRUMENT UNDER § 58.1-803(D):

Original Principal: $0.00 Fair Market Value Increase: $0.00

Original Book No.: Original Page No.: Original Instrument No.:

Prior Recording At: [ ] City [ ] County Percentage In This Jurisdiction:

Book Number: Page Number: Instrument Number:

Parcel Identification Number/Tax Map Number:

Short Property Description:

Current Property Address:

City: State: Zip Code:

Instrument Prepared By: BOARD OF SUPERVISORS Recording Paid By: CARMEL CHURCH STATION LLC

Recording Returned To: LITT THOMPSON

Address: 10001 PATTERSON AVE. #200

City: RICHMOND State: VA Zip Code: 23238

FORM CC-1570 (MASTER, PAGE ONE OF TWO) 10/19

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VIRGINIA LAND RECORD COVER SHEET

Commonwealth of Virginia VA. CODE §§ 17.1-223, -227.1, -249

FORM B – ADDITIONAL GRANTORS/GRANTEES

Instrument Date: 11/18/2020

Instrument Type: OTHER

Number of Parcels: 0 Number of Pages: 3

[ ] City [X] County CAROLINE
CIRCUIT COURT

(Area Above Reserved For Deed Stamp Only)

Grantor Business/Name

Grantor:

Grantor:

Grantor:

Grantor:

Grantor:

Grantor:

Grantor:

Grantor:

Grantee Business/Name

3 × Grantee: CAROLINE 544, LLC

4 × Grantee: CAROLINE 225, LLC

5 × Grantee: CARMEL CHURCH CHURCH STATION TOWNE CENTER, LLC

Grantee:

Grantee:

Grantee:

Grantee:

Grantee:

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Caroline County, Virginia

Board of Supervisors

Jeffrey S. Black
Western Caroline District

Clayton T. Forehand
Madison District

Nancy L. Long
Port Royal District

Jeffery M. Sili
Bowling Green District

Floyd W. Thomas
Mattaponi District

Reginald L. Underwood
Reedy Church District

Charles M. Culley, Jr.
County Administrator

Caroline County, VA
All-America City
2009

Rezoning Request: RZ-05-2020

Owner: Carmel Church Station, LLC; Caroline 40, LLC; Caroline 544, LLC; Caroline 225, LLC; Carmel Church Station Towne Center, LLC

Tax Map Numbers: 82-A-89A; 82-9-A; 82-12-A/B; 82-18-A;82-18-B; 92-A-27; 92A-27C; 92-A-31; 92-A-32; 92-A-33; 92-A-34; 92-A-35; 92-A-48; 92-A-49; 92-3-B2, 92-3-C,

County of Caroline, To-Wit:

At a regular meeting of the Caroline County Board of Supervisors on Tuesday, October 13, 2020, in the Community Services Center, Auditorium, located at 17202 Richmond Turnpike, Milford, Virginia, at the hour of 7:30 p.m.

Present	**Absent**
Floyd Thomas, Vice-Chairman	Jeffery Sili, Chairman
Jeffrey Black	
Clayton Forehand	
Nancy Long	
Reginald Underwood	

On a motion by Supervisor Underwood, seconded by Supervisor Long the following rezoning was approved with the amended language as presented:

RZ-05-2020 – Carmel Church Station, LLC; Caroline 40, LLC; Caroline 544, LLC; Caroline 225, LLC; Carmel Church Station Towne Center, LLC, Owner/Applicant: Request a Rezoning from PMUD, Planned Mixed Use Development (with a density of 8.2 dwellings per acre [8,659 units] and 3.16 million square feet of office, commercial, and industrial space) to PMUD, Planned Mixed Use Development, (with a density of 8.2 dwellings per acre [8,659 units] and 3.16 million square feet of office, commercial, and industrial space) on tax maps 82-A-89A; 82-9-A; 82-12-A/B; 82-18-A;82-18-B; 92-A-27; 92A-27C; 92-A-31; 92-A-32; 92-A-33; 92-A-34; 92-A-35;92-A-48; 92-A-49; 92-3-B2, 92-3-C, consisting of 980 acres, more or less. The properties are generally located on the immediate east and west sides of I-95, south of Route 207, and north of the North Anna River in the Reedy Church Voting District. The 2030 Comprehensive Plan designates this area as being located within the Carmel Church Urban Development Area as Planned Mixed Use. The purpose of this rezoning is to amend Carmel Church Station Development Regulations previously approved with RZ-08-2009, dated June 8, 2010, to modify Article 3.7, Administration, to extend the time for which a site plan for development of the project may be submitted.

To amend Article 3.7 of the Development Regulations for Carmel Church Station as follows:

Notwithstanding any other provision of Article XV, Section 14 of the Zoning Ordinance, the first site plan for the property shall be submitted within five (5) years after the date of zoning amendment approval of the Property pursuant to Zoning Application #RZ-05-2020. No portion of the Property shall be developed, and no building permit may be issued for the Property until after the first site plan for any portion of the Property shall have been submitted.

Voting yea: Black, Forehand, Long, Thomas, Underwood

CLERK: _____

State of: Virginia

County of: Caroline

The foregoing instrument was acknowledged before me this 2nd day of November, 2020, by Charles M. Culley, Jr., County Administrator, on behalf of the Caroline County Board of Supervisors.

Pamela M. Hall
(Signature of Notary Public)

PAMELA M. HALL
Notary Public
Commonwealth of Virginia
Registration No. 250778
My Commission Expires Jun 30, 2021

Notary Public # 250778

My Commission Expires: 6/30/2021

OWNER: _____
Signature

State of: Virginia

County of: Henrico

The foregoing instrument was acknowledged before me this 12 day of November, 2020, by Britt Thompson, member/manager.
(Name)

Elisabeth Hartsock Dwight
(Signature of Notary Public)

ELISABETH HARTSOCK DWIGHT
NOTARY PUBLIC
REG # 7138930
COMMISSION EXPIRES 3-31-23
COMMONWEALTH OF VIRGINIA

Notary Public # 7138930

My Commission Expires: 3-31-2023

INSTRUMENT # 200005271
RECORDED CAROLINE CIRCUIT COURT CLERK'S OFFICE
Nov 18, 2020 AT 10:41 am
SUSAN W. MINARCHI, CLERK by RAF

Priority/Rank	Project Title	Project #	FY 22/23	FY 23/24	FY 24/25	FY 25/26	FY 26/27	Total
1	WATER SUPPLY WELL DEVELOPMENT	DPU-W-16-10	400,000	1,000,000	400,000	400,000	400,000	2,600,000
3	Water Treatment Facility - Pendleton		1,500,000					1,500,000
5	HIGH SCHOOL SYSTEM WELL BUILDINGS (2)	DPU-WW-W-16-01		100,000				100,000
2	Water Tower Painting & Water Mixers	DPU-W-21-03	700,000					700,000
4	Belmont Pump Station Upgrade - submersible pumps	DPU-21-04		175,000				175,000
7	WATER SYSTEM INTER CONNECTION	DPU-W-16-6			500,000	5,000,000	10,000,000	15,500,000
9	RAPPAHANNOCK INTAKE DESIGN	DPU-W-18-6				500,000	500,000	1,000,000
6	Rappahannock Intake & Treatment Facility Property acquisition			1,000,000				1,000,000
								-
								-
10	PENDLETON WATER TOWER* Proffer	DPU-W-09-02			2,100,000			2,100,000
11	LADYSMITH VILLAGE WATER TOWER* Proffer	DPU-W-08-03					2,100,000	2,100,000
8	ECONOLODGE BOOSTER PUMP UPGRADE	DPU-W-16-5			250,000	2,300,000		2,550,000
12	HAYMOUNT WATER SYSTEM** Proffer	DPU-W-94-15A					10,000,000	10,000,000
13	HAYMOUNT WWTP* Proffer	DPW-WW-94-15B					10,000,000	10,000,000
	TOTAL - Infrastructure:		**2,600,000**	**2,275,000**	**3,250,000**	**8,200,000**	**33,000,000**	**49,325,000**
1	Vactor Truck	DPU-EQU-20-01			300,000			300,000
	TOTAL - Equipment:		**-**	**-**	**300,000**	**-**	**-**	**300,000**
		Department Total:	2,600,000	2,275,000	3,550,000	8,200,000	33,000,000	49,625,000

Caroline County Capital Project Request Form

YEAR:	**23 / 24**
DEPARTMENT/AGENCY:	Public Utilities - Infrastructure
PROJECT CODE:	DPU-W-16-10
PROJECT TITLE:	**Water Supply Well Development**
PURPOSE OF REQUEST:	___ NEW x EXISTING ___ REVISED
DEPT. RANK/PRIORITY:	Necessary
PROJECT DESCRIPTION/LOCATION:	Continue well development along the I-95 Corridor with of a goal of an additional 500 gpm or 720,000 gpd
JUSTIFICATION:	Caroline County needs to have additional water supply capacity for economic and development purposes. This is our short term solution and allows for planning for a mid – to long term solution to be developed. Wells are not the answer to our long term water supply.
PROJECT TOTAL:	$3,000,000
REQUEST FOR CURRENT FY:	$400,000
REVENUE SOURCE:	General Fund

CAPTIAL COST SUMMARY

FISCAL YEAR:	22 / 23	23 / 24	24 / 25	25 / 26	26 / 27	BEYOND 27	PROJECT TOTAL
REQUEST:	400,000	1,000,000	400,000	400,000	400,000	400,000	$3,000,000

Are there any changes in operating and/or personnel costs in conjunction with this request?

_____ YES _____ NO X NO CHANGE

DESCRIPTION OF COST INCREASE/DECREASE

DATE: November 18, 2021

SUBMITTED BY: JOSEPH C. SCHIEBEL

SIGNATURE: _____

TITLE: DIRECTOR OF PUBLIC WORKS/UTILITIES

Caroline County Capital Project Request Form

YEAR:	**23 / 24**
DEPARTMENT/AGENCY:	Public Utilities - Infrastructure
PROJECT CODE:	DPU-W-16-10
PROJECT TITLE:	**Water Treatment Facility - Pendleton**
PURPOSE OF REQUEST:	x NEW ___ EXISTING ___ REVISED
DEPT. RANK/PRIORITY:	Necessary
PROJECT DESCRIPTION/LOCATION:	Contruct a water treatment facility for supply wells in the Pendleton sub-division and install two new wells

JUSTIFICATION: The water system has n

PROJECT TOTAL:	$750,000
REQUEST FOR CURRENT FY:	$750,000
REVENUE SOURCE:	General Fund

CAPTIAL COST SUMMARY

FISCAL YEAR:	22 / 23	23 / 24	24 / 25	25 / 26	26 / 27	BEYOND 27	PROJECT TOTAL
REQUEST:	1,500,000						$1,500,000

Are there any changes in operating and/or personnel costs in conjunction with this request?

_____ YES _____ NO X NO CHANGE

DESCRIPTION OF COST INCREASE/DECREASE

DATE: November 18, 2021

SUBMITTED BY: JOSEPH C. SCHIEBEL

SIGNATURE: _____

TITLE: DIRECTOR OF PUBLIC WORKS/UTILITIES

Caroline County Capital Project Request Form

YEAR:	**23 / 24**
DEPARTMENT/AGENCY:	Public Utilities - Infrastructure
PROJECT CODE:	DPU-WW-W-16-01
PROJECT TITLE:	**High School System Well Buildings (2) Upgrade**
PURPOSE OF REQUEST:	___ NEW x EXISTING ___ REVISED
DEPT. RANK/PRIORITY:	Necessary
PROJECT DESCRIPTION/LOCATION:	Both High School System Wells, (High School Tower Well & Bus Maintenance Shop Well) are currently housed by an above ground heated vault. This protects the well, the well piping and electrical from the elements of the outside weather and to allow for the addition of chlorine to the system. It is the intent of this C.I.P. request, to upgrade these the two areas from vaults to walk in prefab well houses such as a Smith-Midland structure. The well house will resemble the facilities in the Carmel Church/ Ladysmith Water System and similar to the Well Housing in the Milford Water System.
JUSTIFICATION:	Replacing the two vault structures that currently house the well's piping, meters, heating source and electrical with a full prefab well house, it will update the facility and its piping, update the electrical, allow space for future chemical injection (chlorine) and allow for additional work area to replace items pertaining to well system. The vault will increase well and water security and increase the level of protection from the environmental elements.
PROJECT TOTAL:	$100,000
REQUEST FOR CURRENT FY:	$100,000
REVENUE SOURCE:	General Fund

CAPTIAL COST SUMMARY

FISCAL YEAR:	22 / 23	23 / 24	24 / 25	25 / 26	26 / 27	BEYOND 27	PROJECT TOTAL
REQUEST:	100,000						$100,000

Are there any changes in operating and/or personnel costs in conjunction with this request?

_____ YES _____ NO X NO CHANGE

DESCRIPTION OF COST INCREASE/DECREASE

DATE: November 18, 2021

SUBMITTED BY: JOSEPH C. SCHIEBEL

SIGNATURE: _____

TITLE: DIRECTOR OF PUBLIC WORKS/UTILITIES

Caroline County Capital Project Request Form

YEAR:	**23 / 24**
DEPARTMENT/AGENCY:	Public Utilities - Infrastructure
PROJECT CODE:	DPU-W-21-03
PROJECT TITLE:	**Water Tower Painting & Mixers**
PURPOSE OF REQUEST:	x NEW ___ EXISTING ___ REVISED
DEPT. RANK/PRIORITY:	Necessary
PROJECT DESCRIPTION/LOCATION:	Removal of existing paint (if necessary), exterior and interior coating of water towers, and installation of water mixing equipment.
JUSTIFICATION:	County water towers need painted at certain age milestones. Mixers will help ensure the quality of drinking water inside the tower. The Water Towers will be added to the maintenance contact and an annual fee will be added to the budget (the first year will be $67,702 with a 5% escalator for every year after)
PROJECT TOTAL:	$700,000
REQUEST FOR CURRENT FY:	$700,000
REVENUE SOURCE:	ARPA Funds / Financed

CAPTIAL COST SUMMARY

FISCAL YEAR:	22 / 23	23 / 24	24 / 25	25 / 26	26 / 27	BEYOND 27	PROJECT TOTAL
REQUEST:	700,000						$700,000

Are there any changes in operating and/or personnel costs in conjunction with this request?

___ YES ___ NO X NO CHANGE

DESCRIPTION OF COST INCREASE/DECREASE

DATE: November 18, 2021

SUBMITTED BY: JOSEPH C. SCHIEBEL

SIGNATURE: _____

TITLE: DIRECTOR OF PUBLIC WORKS/UTILITIES

Caroline County Capital Project Request Form

YEAR:	**23 / 24**
DEPARTMENT/AGENCY:	Public Utilities - Infrastructure
PROJECT CODE:	DPU-W-21-04
PROJECT TITLE:	**Belmont Pump Station Upgrade**
PURPOSE OF REQUEST:	x NEW ___ EXISTING ___ REVISED
DEPT. RANK/PRIORITY:	Necessary
PROJECT DESCRIPTION/LOCATION:	Reconfiguration and retrofit of the Belmont pump station, away from suction lift to submersible pumps, railing and system, to include upgraded lid.
JUSTIFICATION:	The cost of suction lift in operational costs, parts and heating during the winter. Costs will be reduced in parts and man hours and heating cost will be eliminated. Where submersible pumps are rarely pulled due to issues with in the county system, suction lift stations are repaired for obstructions, electrical, hoses, belts, and other issues on a regular weekly basis. Where the county interceptor project will update the South River station to submersibles, delete the VDOT station which is currently suction lift, the remaining suction lift station would be the Belmont station, to remove this suction lift and replace it with submersibles would give uniformity to the system parts.
PROJECT TOTAL:	$175,000
REQUEST FOR CURRENT FY:	$175,000
REVENUE SOURCE:	General Fund

CAPTIAL COST SUMMARY

FISCAL YEAR:	22 / 23	23 / 24	24 / 25	25 / 26	26 / 27	BEYOND 27	PROJECT TOTAL
REQUEST:	175,000						$175,000

Are there any changes in operating and/or personnel costs in conjunction with this request?

_____ YES _____ NO X NO CHANGE

DESCRIPTION OF COST INCREASE/DECREASE

DATE: November 18, 2021

SUBMITTED BY: JOSEPH C. SCHIEBEL

SIGNATURE: _____

TITLE: DIRECTOR OF PUBLIC WORKS/UTILITIES

Caroline County Capital Project Request Form

YEAR:	**23 / 24**
DEPARTMENT/AGENCY:	Public Utilities - Infrastructure
PROJECT CODE:	DPU-W-18-6
PROJECT TITLE:	**Rappahannock River Intake Design & Construction**
PURPOSE OF REQUEST:	___ NEW x EXISTING ___ REVISED
DEPT. RANK/PRIORITY:	Necessary
PROJECT DESCRIPTION/LOCATION:	To Design, and construct a water withdrawal intake on the Rappahannock River to provide up to 18 MGD of raw water to be treated for the public water supply.
JUSTIFICATION:	Caroline County has recently completed the Water Master Plan for Caroline County, wherein the report has determined that the County will need 13 MGD of water over the next 30 years. This water intake site will provide the county with its mid to long range water supply needs.
PROJECT TOTAL:	$1,000,000
REQUEST FOR CURRENT FY:	$0
REVENUE SOURCE:	General Fund

CAPTIAL COST SUMMARY

FISCAL YEAR:	22 / 23	23 / 24	24 / 25	25 / 26	26 / 27	BEYOND 27	PROJECT TOTAL
REQUEST:				500,000	500,000		$1,000,000

Are there any changes in operating and/or personnel costs in conjunction with this request?

_____ YES _____ NO X NO CHANGE

DESCRIPTION OF COST INCREASE/DECREASE

DATE: November 18, 2021

SUBMITTED BY: JOSEPH C. SCHIEBEL

SIGNATURE: _____

TITLE: DIRECTOR OF PUBLIC WORKS/UTILITIES

Caroline County Capital Project Request Form

YEAR:	**23 / 24**
DEPARTMENT/AGENCY:	Public Utilities - Infrastructure
PROJECT CODE:	DPU-W-16-6
PROJECT TITLE:	**Water System Inter Connection**
PURPOSE OF REQUEST:	___ NEW x EXISTING ___ REVISED
DEPT. RANK/PRIORITY:	Necessary
PROJECT DESCRIPTION/LOCATION:	To design and construct a water main to an adjacent localities water system. $500,000 is approved in the current CIP.
JUSTIFICATION:	Caroline County needs to find a mid to long-term water solution to enable economic and development growth. Wells are not the answer to our water shortage and a long-term solution needs to be sought.
PROJECT TOTAL:	$15,500,000
REQUEST FOR CURRENT FY:	$0
REVENUE SOURCE:	General Fund

CAPTIAL COST SUMMARY

FISCAL YEAR:	22 / 23	23 / 24	24 / 25	25 / 26	26 / 27	BEYOND 27	PROJECT TOTAL
REQUEST:			500,000	5,000,000	10,000,000		$15,500,000

Are there any changes in operating and/or personnel costs in conjunction with this request?

___ YES ___ NO X NO CHANGE

DESCRIPTION OF COST INCREASE/DECREASE

DATE: November 18, 2021

SUBMITTED BY: JOSEPH C. SCHIEBEL

SIGNATURE: _____

TITLE: DIRECTOR OF PUBLIC WORKS/UTILITIES

Caroline County Capital Project Request Form

YEAR:	**23 / 24**
DEPARTMENT/AGENCY:	Public Utilities - Infrastructure
PROJECT CODE:	DPU-W-21-2
PROJECT TITLE:	**Rappahannock Intake & Facility Property Acquisition**
PURPOSE OF REQUEST:	___ NEW x EXISTING ___ REVISED
DEPT. RANK/PRIORITY:	Necessary
PROJECT DESCRIPTION/LOCATION:	Acquire necessary property to locate the Rappahannock Intake Facility & Water Treatment Plant
JUSTIFICATION:	Caroline County is currently in the permitted process to withdraw water from the Rappahannock River. The County must secure the necessary property to gain access to the river to construct a intake facility. In addition, during the permitting a site had to be studied for the water treatment facility. As the County has spent a great deal of money
PROJECT TOTAL:	$1,250,000
REQUEST FOR CURRENT FY:	$1,250,000
REVENUE SOURCE:	General Fund

CAPTIAL COST SUMMARY

FISCAL YEAR:	22 / 23	23 / 24	24 / 25	25 / 26	26 / 27	BEYOND 27	PROJECT TOTAL
REQUEST:	1,250,000						$1,250,000

Are there any changes in operating and/or personnel costs in conjunction with this request?

_____ YES _____ NO X NO CHANGE

DESCRIPTION OF COST INCREASE/DECREASE

DATE: November 18, 2021

SUBMITTED BY: JOSEPH C. SCHIEBEL

SIGNATURE: _____

TITLE: DIRECTOR OF PUBLIC WORKS/UTILITIES

Caroline County Capital Project Request Form

YEAR:	**23 / 24**
DEPARTMENT/AGENCY:	Public Utilities - Infrastructure
PROJECT CODE:	DPU-W-09-02
PROJECT TITLE:	**Pendleton Water Tower**
PURPOSE OF REQUEST:	___ NEW x EXISTING ___ REVISED
DEPT. RANK/PRIORITY:	Necessary
PROJECT DESCRIPTION/LOCATION:	The construction of an elevated water tower for the Pendleton Development. This project is required based on population within the development.
JUSTIFICATION:	This project will be constructed to serve Pendleton Development. This project is proffered and ownership and operation will be transferred to Caroline County.
PROJECT TOTAL:	$2,100,000
REQUEST FOR CURRENT FY:	$0
REVENUE SOURCE:	No County funding is required.

CAPTIAL COST SUMMARY

FISCAL YEAR:	22 / 23	23 / 24	24 / 25	25 / 26	26 / 27	BEYOND 27	PROJECT TOTAL
REQUEST:			2,100,000				$2,100,000

Are there any changes in operating and/or personnel costs in conjunction with this request?

_____ YES _____ NO X NO CHANGE

DESCRIPTION OF COST INCREASE/DECREASE

DATE: November 18, 2021

SUBMITTED BY: JOSEPH C. SCHIEBEL

SIGNATURE: _____

TITLE: DIRECTOR OF PUBLIC WORKS/UTILITIES

Caroline County Capital Project Request Form

YEAR:	**23 / 24**
DEPARTMENT/AGENCY:	Public Utilities - Infrastructure
PROJECT CODE:	DPU-W-08-03
PROJECT TITLE:	**Ladysmith Village Water Tower**
PURPOSE OF REQUEST:	___ NEW x EXISTING ___ REVISED
DEPT. RANK/PRIORITY:	Necessary
PROJECT DESCRIPTION/LOCATION:	The construction of an elevated water tower for the Ladysmith Village Development. This project is required based on population within the development.
JUSTIFICATION:	This project will be constructed to serve Ladysmith Village Development. This project is proffered and ownership and operation will be transferred to Caroline County.
PROJECT TOTAL:	$2,100,000
REQUEST FOR CURRENT FY:	$0
REVENUE SOURCE:	No County funding is required.

CAPTIAL COST SUMMARY

FISCAL YEAR:	22 / 23	23 / 24	24 / 25	25 / 26	26 / 27	BEYOND 27	PROJECT TOTAL
REQUEST:					2,100,000		$2,100,000

Are there any changes in operating and/or personnel costs in conjunction with this request?

_____ YES _____ NO X NO CHANGE

DESCRIPTION OF COST INCREASE/DECREASE

DATE: November 18, 2021

SUBMITTED BY: JOSEPH C. SCHIEBEL

SIGNATURE: _____

TITLE: DIRECTOR OF PUBLIC WORKS/UTILITIES

Caroline County Capital Project Request Form

YEAR:	**23 / 24**
DEPARTMENT/AGENCY:	Public Utilities - Infrastructure
PROJECT CODE:	DPU-W-16-5
PROJECT TITLE:	**Econolodge Booster Pump Station Improvement**
PURPOSE OF REQUEST:	___ NEW x EXISTING ___ REVISED
DEPT. RANK/PRIORITY:	Necessary
PROJECT DESCRIPTION/LOCATION:	Upgrade Econolodge booster pump station capabilities.
JUSTIFICATION:	Caroline County needs to upgrade the Econolodge Booster Pump Station, which is over 30 years old, in order to maintain minimum water pressures within the system.
PROJECT TOTAL:	$250,000
REQUEST FOR CURRENT FY:	$0
REVENUE SOURCE:	General Fund

CAPTIAL COST SUMMARY

FISCAL YEAR:	22 / 23	23 / 24	24 / 25	25 / 26	26 / 27	BEYOND 27	PROJECT TOTAL
REQUEST:			250,000				$250,000

Are there any changes in operating and/or personnel costs in conjunction with this request?

_____ YES _____ NO X NO CHANGE

DESCRIPTION OF COST INCREASE/DECREASE

DATE: November 18, 2021

SUBMITTED BY: JOSEPH C. SCHIEBEL

SIGNATURE: _____

TITLE: DIRECTOR OF PUBLIC WORKS/UTILITIES

Caroline County Capital Project Request Form

YEAR:	**23 / 24**
DEPARTMENT/AGENCY:	Public Utilities - Infrastructure
PROJECT CODE:	DPU-W-94-15A
PROJECT TITLE:	**Haymount Water System**
PURPOSE OF REQUEST:	___ NEW x EXISTING ___ REVISED
DEPT. RANK/PRIORITY:	Necessary
PROJECT DESCRIPTION/LOCATION:	The construction of water supply and treatment facilities for the Haymount Development. This project is developer driven and may occur at any time.
JUSTIFICATION:	This project will be constructed to serve the Haymount Development by the Developer. Ownership and operation will be transferred to Caroline County.
PROJECT TOTAL:	$10,000,000
REQUEST FOR CURRENT FY:	$0
REVENUE SOURCE:	No County funding is required.

CAPTIAL COST SUMMARY

FISCAL YEAR:	22 / 23	23 / 24	24 / 25	25 / 26	26 / 27	BEYOND 27	PROJECT TOTAL
REQUEST:						10,000,000	$10,000,000

Are there any changes in operating and/or personnel costs in conjunction with this request?

___ YES ___ NO X NO CHANGE

DESCRIPTION OF COST INCREASE/DECREASE

DATE: November 18, 2021

SUBMITTED BY: JOSEPH C. SCHIEBEL

SIGNATURE: _____

TITLE: DIRECTOR OF PUBLIC WORKS/UTILITIES

Caroline County Capital Project Request Form

YEAR:	**23 / 24**
DEPARTMENT/AGENCY:	Public Utilities - Infrastructure
PROJECT CODE:	DPU-W-94-15B
PROJECT TITLE:	**Haymount WWTP**
PURPOSE OF REQUEST:	___ NEW x EXISTING ___ REVISED
DEPT. RANK/PRIORITY:	Necessary
PROJECT DESCRIPTION/LOCATION:	Construction of a WWTP to serve the Haymount Development. This project is developer driven and may occur at any time.
JUSTIFICATION:	This facility will be constructed to serve the Haymount Development by the Developer. Ownership and operation will be assumed by Caroline County.
PROJECT TOTAL:	$10,000,000
REQUEST FOR CURRENT FY:	$0
REVENUE SOURCE:	No County funding is required.

CAPTIAL COST SUMMARY

FISCAL YEAR:	22 / 23	23 / 24	24 / 25	25 / 26	26 / 27	BEYOND 27	PROJECT TOTAL
REQUEST:						10,000,000	$10,000,000

Are there any changes in operating and/or personnel costs in conjunction with this request?

_____ YES _____ NO X NO CHANGE

DESCRIPTION OF COST INCREASE/DECREASE

DATE: November 18, 2021

SUBMITTED BY: JOSEPH C. SCHIEBEL

SIGNATURE: _____

TITLE: DIRECTOR OF PUBLIC WORKS/UTILITIES

Caroline County Capital Project Request Form

YEAR:	**23 / 24**
DEPARTMENT/AGENCY:	Public Utilities - Equipment
PROJECT CODE:	DPU-EQU-20-01
PROJECT TITLE:	**New Vactor Truck**
PURPOSE OF REQUEST:	x NEW ___ EXISTING ___ REVISED
DEPT. RANK/PRIORITY:	Necessary
PROJECT DESCRIPTION/LOCATION:	Used Vacuum truck designed to pneumatically suck liquids, sludges, slurries, or the like from a location into the tank of the truck
JUSTIFICATION:	Caroline County's existing Vactor truck has significant age and wear. The current truck was purchased many years ago at extremely low price from a neighboring jurisdiction. Due to its age and use, repairs are frequent and costly. It is time to update to a newer, more efficient and capable truck
PROJECT TOTAL:	$300,000
REQUEST FOR CURRENT FY:	$0
REVENUE SOURCE:	General Fund

CAPTIAL COST SUMMARY

FISCAL YEAR:	22 / 23	23 / 24	24 / 25	25 / 26	26 / 27	BEYOND 27	PROJECT TOTAL
REQUEST:			300,000				$300,000

Are there any changes in operating and/or personnel costs in conjunction with this request?

___ YES ___ NO X NO CHANGE

DESCRIPTION OF COST INCREASE/DECREASE

DATE: November 18, 2021

SUBMITTED BY: JOSEPH C. SCHIEBEL

SIGNATURE: _____

TITLE: DIRECTOR OF PUBLIC WORKS/UTILITIES

A Brief Synopsis of the Caroline County Commuter Rail Project: 1100+ Acre Transportation Oriented Development

The Caroline County Board of Supervisors have exercised leadership over a fifteen year period to build administrative recognition, political support and numerous partnerships to position Carmel Church Station as a geographically defined urban development worthy of unparalleled investment that will generate exceptional economic impact.

Caroline County has initiated a TOD project for Carmel Church, Virginia comprising rail, bus, bike, pedestrian and other potential forms of transport that the County believes will assist in the reduction of automobile traffic on I-95 coming from Central Virginia northward, and reduce local and regional traffic growth. The project is anticipated to produce billions of dollars in secondary investment in office, commercial, high tech industrial and retail development.

The project will be developed on what is known as the Thompson Tract, an 1100 acre parcel that has approximately three miles of rail at its western border and is serviced by Interstate 95 on its eastern border, Rt. 1 immediately to its west, Rt. 207 immediately to the north-east, and accessed directly from the Interstate at Interchange 104, Carmel Church. Moreover, adding to this nexus of roads and rail is Interchange 98, six miles south of the site on Interstate 95 which allows for ease of north-bound traffic to access the site from Rt. 1. The site is in Virginia seventy miles south of Washington, DC; Caroline County is regarded as a "strategically safe" distance from the Capital.

Caroline County as the 10th fastest growing County in America in 2005 and the 3rd fastest growing County in Virginia in 2006 has the potential to add either positively or negatively to Virginia's and the National Capital traffic congestion. Caroline would like to be a part of a remedy through the creation of a true TOD that is multimodal, meets human needs of commerce, employment, and recreation, and thereby reduce automobile trips and the need for second automobile ownership both for commuting and for all other travel. It is also conceivable that the success of the multimodal TOD at Carmel Church could lead to future multi-rail and high-speed rail applications that would further benefit the region.

Background: The Caroline County Multimodal Transit-Oriented Development is a culmination of a larger historic planning process that includes a regional approach to meeting the growth and transportation needs of residents in a broad area of impact, as well as a commitment by the Caroline County Board of Supervisors to lead the Community on a dynamic path of defined urban growth to compliment the County's rural traditions. Among those plans and studies that point to the creation of the Carmel Church TOD:

National Capital Planning Commission *Year 2000* Study—The Study, as quoted here from the NCPC history: "In 1961, NCPC produced the influential "Year 2000" plan, proposing a model for long-term regional growth. M-NCPPC then incorporated and expanded on this recommended model in its own comprehensive plan, titled "On Wedges and Corridors."" The wedges and corridors were major traffic corridors that ran from Washington outward. The corridors envisioned in the plan were to be major development areas at least 70 miles away from the District and would be major transportation hubs including multimodal sites that would tie the region together and allow for growth along a TOD design/model. *The Year 2000* Study is an apt description of the Carmel Church TOD project.

Washington, DC/Richmond Rail Corridor Study—Conducted by the Virginia Department of Rail and Public Transportation, 1991, the Study specifically selected the Carmel Church area for a TOD project. This informed Director Wilson to advise the Thompsons to invest in the subject property.

Litt Thompson and Family Purchase Land—In 2003 Robert "Litt" Thompson and the Caroline County Economic Development Director, Gary Wilson, held meetings based on the Washington, DC/Richmond Rail Corridor Study. The decision to purchase the property, and the vision to create Carmel Church Station emerged from those discussions.

Carmel Church Sub-Area Plan—Conducted in 2006 and 2007, the plan recognized the Carmel Church area, and the Thompson Tract specifically, as a rail location suitable for mixed use development. The sub-area plan has been integrated into the Caroline Master Plan. Even prior to the 2006 effort, Caroline Planning specifically included mixed use development for Carmel Church (1994).

Caroline County Land Use Plan—Is Consistent with the Transportation Bill of 2007 linking land use with Transportation planning (Virginia Legislature). Caroline County has already acted on the need and recognized the value of transportation/land use planning integration.

Parsons-Brinkerhoff Study—has identified the elements required for a successful TOD at the Carmel Church site, Thompson Tract. Carmel Church was identified as the proper site for the TOD and specified Thompson Tract.

The Federal Alternative Analysis Study, 2007 was applied for by Economic Development and ultimately funded by a federal appropriation, Federal Transit Administration, of $490,000.

VDOT Study 2008—Based on a $100,000 grant written by the Director of Economic Development, the project's feasibility was confirmed. Carmel Church Station was brought to the attention of VDRPT whereupon that agency conducted an independent study.

VDRPT-- The $100,000+ Department of Rail and Public Transportation study, in consultation with Caroline County Staff, projected high density development at CCS. Feasibility of the project was confirmed, and a rail station location was identified. The project was included in the Statewide Rail Plan.

The site has been rezoned consistent with the VDRPT study of 2008. Caroline County Department of Planning issued a zoning document that received no negative public comment. The Planning process utilized a sub area planning process prior to the site application resulting in a wide understanding of the goals of the project and broad public support.

Statewide Rail Plan 2008—Included the County Project as an official project to be advanced by the Commonwealth**.** VDRPT**.**

Pentagon and GSA Engaging in Location Talks—County representatives have met with Pentagon officials in late 2009 pursuant to attracting Department of Defense investment on the Thompson Rail site, Carmel Church Station. Pentagon staff were highly supportive of the project and interested in establishing further discussions. Pentagon site visit, February 2011 elicited a very positive response.

The GSA has also shown keen interest in the project at Carmel Church. A meeting was held at GSA in Washington, DC, December 2010 with Bob Peck et. al.

An Economic and Fiscal Impact Study by Chmura Economics and Analytics, 2010—concluded that CCS would over a 20 year period of build out create over 25,000 jobs, and provide Caroline County in excess of $55,000,000 in annual revenue upon completion; and over the entire construction period, total County revenue will be over $496,000,000.

VDRPT has stated that they will use a portion of the federal appropriation (2011) for the study of the Richmond-Washington corridor for the CCS project.

VDRPT has stated that a large end user committing to the site will spark a faster pace on the part of the Commonwealth in its support for CCS (2011).

Statewide Rail Plan, 2012, VDRPT has retained the CCS project in the document.

The Alternative Analysis Study Completed in 2014. Identifies the Alternative of direct city to city commuter rail to Washington DC. The direct commuter rail option was voted on by the Board of Supervisors as the Preferred Alternative for development.

VDRPT Letter of Conditions April 9, 2015 VDRPT provided a letter indicating conditions that would trigger Commonwealth involvement and make viable a train station at CCS.

Skip-Stop Station Initiative, 2019 VDRPT has indicated that they are considering Carmel Church Station for a drop and ride commuter rail station whether or not there is a development on the site.

CIT/OST Participation The Center for Innovative Technology, and OST, a technology and development consulting firm, have teamed with the property owners and Caroline County to begin to position Carmel Church Station to realize the goals of establishing a world class Smart City with the latest technology for urban development. CIT/OST, based in Northern Virginia, will position Carmel Church Station to be a host community for federal agencies critical to future technology applications. Check out www.OSTGlobal.com and www.CIT.org .

Prepared By:
Gary R. Wilson
Director, Caroline County
Department of Economic Development & Tourism

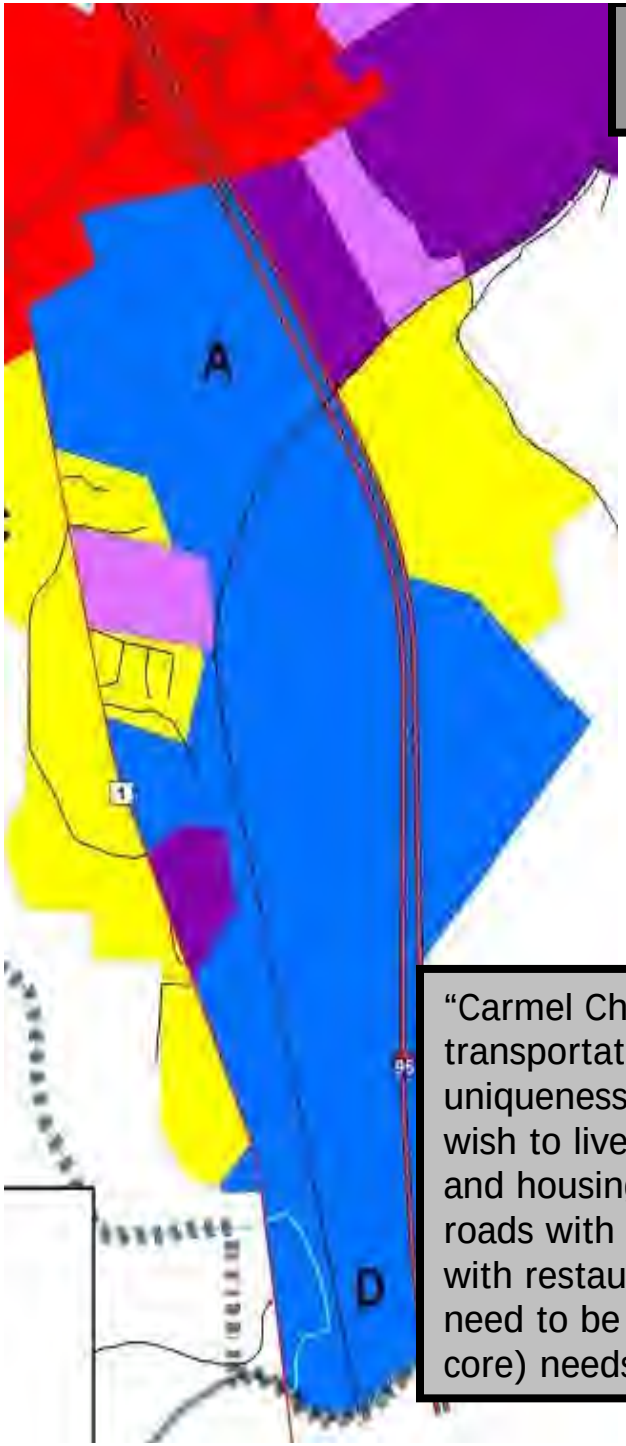
CARMEL CHURCH STATION



Virginia Land Investments LLC

Presented by: Dan Slone
McGuireWoods
Richmond, Virginia

Principals: Litt Thompson
Tommy Thompson

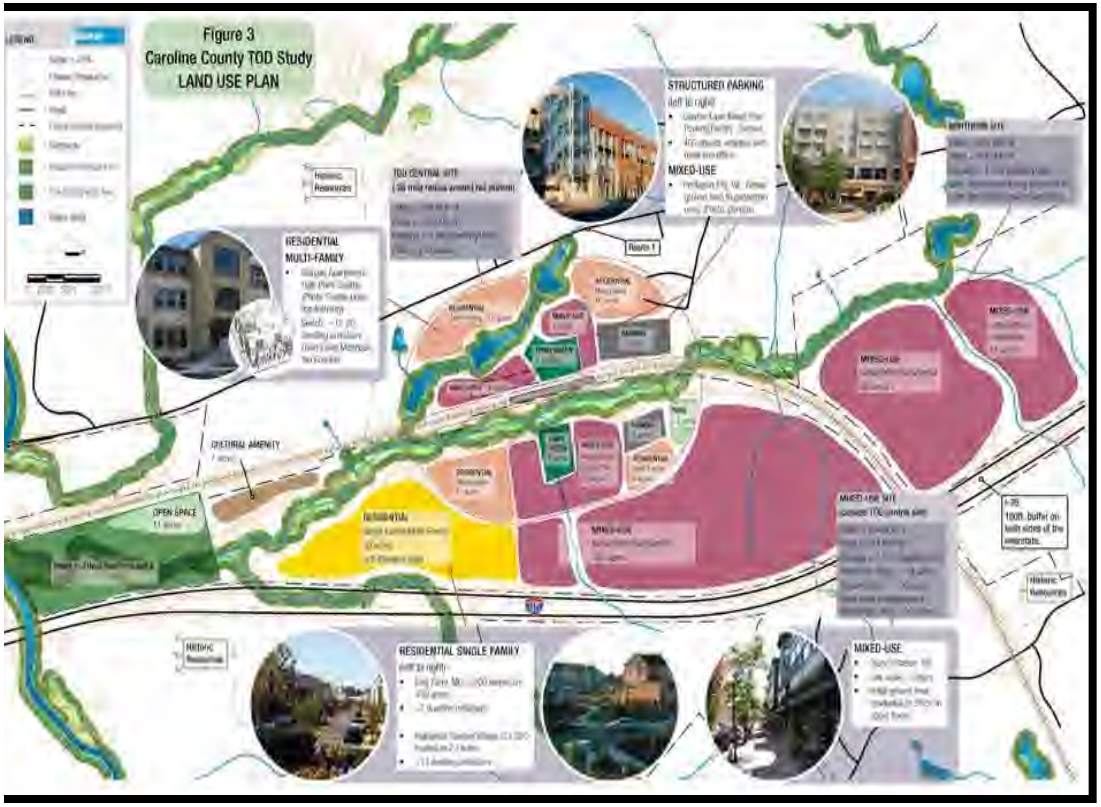


Carmel Church Community Plan

- Citizens Planning Committee creates a plan that calls for land, mostly zoned industrial, to be high-density (10-15 u/a) Mixed-Use with some industrial/office and focused on a train station
  - Use traditional neighborhood development techniques
  - Provide open space, landscaping, sidewalks, street trees, lighting
  - Preserve historic and archaeological sites
  - Provide density, diversity of housing and uses and design
  - Include civic uses and public facilities
  - Provide infrastructure to attract new business
- This plan is made part of the Comprehensive Plan of the County by a unanimous Planning Commission and Board vote

"Carmel Church must inspire a vision of where it belongs today as an important transportation, commercial, business and residential center. To establish a sense of uniqueness and 'place' to Carmel Church, and one in which a variety of people will wish to live, visit, and work, this area must develop a coherent set of business, retail, and housing structures that follow a good quality architectural standard. Distinct roads with residential homes, loft apartments, and other residential styles combined with restaurants and other retail, entertainment, specialty, and convenience stores need to be designed and built. Most importantly however, a Town Center (village core) needs to be established with perhaps a town square area…." pages 39-40

Caroline County Transit Oriented Development Study



- Independent VDOT funded study
- Calls for transit oriented development with integrated residential, office and retail
- Adds concept of hotel, entertainment or destination retail complex
- Five story central core
- Regional park

- Details location, extent and form of residential and commercial development, as well as open space, roads and natural resource protection

DRPT

Virginia Department of Rail & Public Transportation

Amtrak Station Area Planning and Land Use Analysis: Carmel Church Station, Caroline County, August 2008

- Unusual state funded and conducted study
- Endorsed the ideas of Area Plan and TOD Study except:
  - Higher mixed use densities
  - Eight floor buildings in core, surrounded by five floor buildings
  - Office to residential ratio: 20%/80%
  - Large recreation facilities, a school and big box retail opportunities







KEY FEATURES OF PROPOSAL

- Transit Oriented Development
- Pedestrian oriented center
- 6.8-8.9 units/acre
- 11.8% single family detached in later phases
- 3.16 million sq.ft. flexible commercial
- 264 acres of open space
  - 100’ residential setback on I-95
  - 100’ setback on Rt.1
  - Full RPAs except next to station
  - Parks as described in TOD study
  - 120 acre regional park


RURAL
TRANSECT
URBAN
T1 NATURAL ZONE
T2 RURAL ZONE
T3 SUBURBAN ZONE
T4 GENERAL URBAN ZONE
T5 URBAN CENTER ZONE
T6 URBAN CORE ZONE
DA ASSIGNED DISTRICT



USES, DENSITY AND BASIC FORM

- Planned Mixed Use Residential, Commercial/Service, Planned Shopping Center and Planned Industrial Park
- TOD Core: Mixed-use, multifamily; inappropriate uses (e.g. car lots, single family detached) are prohibited
  - Highest density
  - 5-8 story buildings with up to 95% coverage



USES, DENSITY AND BASIC FORM

- North: Mixed-use, multifamily, single family attached
  - Moderate density
  - 4-5 story buildings with 70% to 90% coverage
  - First phase
- South: Regional park, single family detached and attached
  - Low density
  - 3-4 stories with 60% to 70% coverage



USES, DENSITY AND BASIC FORM

•Northeast: Hospital, university, industrial, commercial/service, recreation etc.

- •No residential
- •8 stories with height ratio and 95% coverage

•East: Single family detached with small commercial; if connection across interstate more commercial and attached housing possible

- •Lowest density with 2 u/a and 25% open space (if connection 4 u/a)
- •3-4 stories and 60% to 70% coverage
- •Last phase

FISCAL PERFORMANCE



Land

- 120 acre public, riverfront park with bike and walking trail and canoe take out
- 144 acres of additional project parks and trails
- 13 acre neighborhood school and park
- 1 acre County building and library
- 3 acre train station, multi-modal facility and parking
- 2.1 acres track right-of-way

Fees

- $5,500/unit
- $1,107,000 transportation fee (based on .35/sq.ft. commercial)
- $75,000 green school fee

On-Going Fiscal

- Covers all costs associated with the project, and without any “job cascade”, generates between $10,000 and $15,000 excess benefits per unit
- Create and set up operation of multi-modal facility
- Assess and implement transit program





TRANSPORTATION

- Pedestrian oriented with design to maximize the number of people within walking distance of station
- Designed to encourage bikes, scooters, segways and other non-auto transport
- Required to implement bike share and car share programs when feasible
- Multi-modal from the beginning, using vans and buses and operating with the train station when it is constructed
- Land for train station, parking and track widening
- Adjacent to interstate
- Construct all entrance improvements required by phased studies
- Transportation fee proffer

TOD = A Walkable Neighborhood

People within **a half-mile radius** are **5 times as likely to walk** to a major transit stop than others. Those who live further from a transit node are less likely to bother with the train or bus.

TOD also applies at the **corridor and regional scales.**





CTOD CENTER FOR TRANSIT-ORIENTED DEVELOPMENT

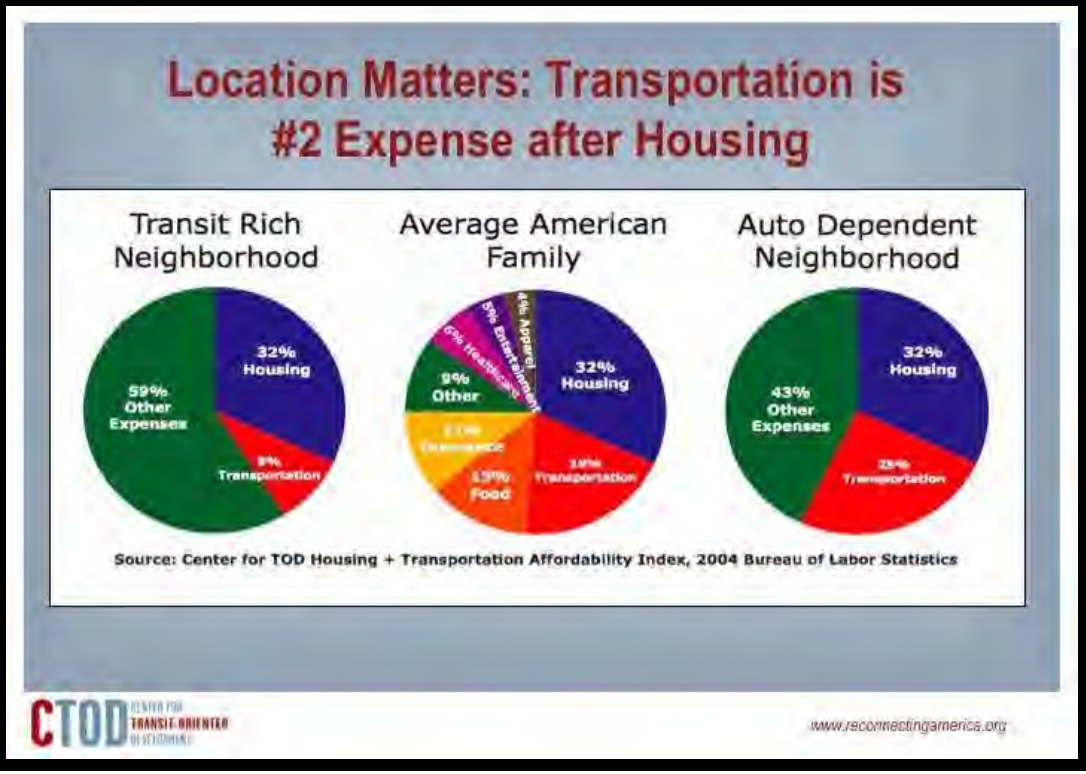
www.reconnectingamerica.org



TRANSIT ORIENTED DEVELOPMENT CODE

- Part of the Development Master Plan
- Form Based Code (Smart Code)
- Requires TND streets
- Uses transect and pedestrian sheds
- Creates pedestrian orientation
- Uses TND approach to parking, alleys, street frontages
- Addresses building height, setbacks, build-to lines, signage, lighting and landscaping
- Applied at the Regulating Plan/Site Plan level





AFFORDABILITY

- Project design allows walking, biking and transit for daily needs, which allows a couple to avoid not only gas costs but the cost of a second car
- Energy and water efficiency allow lower utility costs
- Parks and trails allow free recreation and “café plan” recreation allows individuals to match their needs with the most efficient budget
- At least 5% of the product will be available at a price typically accessible to a teacher or deputy





WATER, WASTE WATER AND STORM WATER

- Proffers commit the Project to an aggressive program of water efficiency, rainwater capture and use, and reuse of waste water
- This program requires less water per unit, avoids the generation of excess waste water and manages the storm water in a manner consistent with emerging regulations of the Commonwealth and EPA
- This program is consistent with the County's approach to future permitting
- Project is less dense than Comp Plan envisions so Public Works can commit less future resources; County has identified multiple future water sources and studies will determine the best one





THINKING ABOUT THE FUTURE

- Residential product mix and phasing is designed to avoid competition with existing single family detached product
- Project utilizes residential products that are currently unavailable in the county
- Project creates commercial product and opportunities that are unavailable in the county
- Project's commercial development and train station will benefit all existing and planned projects in the County
- Project provides the County the ability to attract high quality users such as hospitals, universities, destination commercial and large offices





- According to DRPT, train stations follow riders and residential, so can't just be commercial
- Commercial is flexible and sufficient to meet the County's goal of being competitive at the state level for a broad array of projects
- Large scale users will expect existing, "ready to go zoning", not contingent
- TOD capacity around the train station is assured by product type limitations
- Work on enabling the train station will begin immediately but when the project proceeds depends on funds and market
- Developer and Economic Development office working together to identify users, investors and third party funding for this world class project

BENEFITS

•Consistent with Community Vision, Comp Plan, TOD Study and DRPT Study

•Provides downtown for County

•Billions of dollars of potential economic development

•Tens of millions in property tax revenues

•Thousands of jobs

•Train station and multi-modal center

•Absorb density adjacent to rail and interstate preserving rural character of the balance of the County







BENEFITS

•Adds different types of housing and commercial products rather than competing with existing products

•Regional riverfront park with area for Cultural Amenity Center

•Ability to attract high quality users such as hospitals, universities, destination commercial and large office users

•National profile as sustainable, transit oriented development







CARMEL CHURCH STATION





Caroline TOD Study
Bubble Plan

INTRODUCTION

The Bubble Plan for the Caroline Transit Oriented Development (TOD) study is a representation of the scale and general arrangement of land use that is proposed for the site, including the central TOD site focused on a rail station and the surrounding parcels. The accompanying text explains the assumptions of the plan in terms of land use and access, and it provides phasing notes describing how the site development would transition over time.

The site is the area surrounding the CSX rail line north of the North Anna River and between U.S. Route 1 and Interstate 95. Relative to Caroline County planning documents, this area represents the proposed Town Center and adjacent development for the Carmel Church Area Plan. The Bubble Plan is shown in two graphics, the draft land use plan and the draft circulation plan. A third graphic depicting green infrastructure is also included to identify the low impact site design concepts incorporated at this stage of planning.

The rail station is presented in abstract form in this plan but is assumed to be a 1200' platform on the west side of the existing rail corridor, which would be expanded to three tracks from the existing two. As prior study products have discussed, a siding on the west side of the platform should also be considered to facilitate passenger operations. The rail station is assumed to have overhead walkways connecting the station components and adjacent land use on the east and west sides of the tracks.

LAND USE

The land use in the Bubble Plan is a general concept for planning purposes to allow development and testing of transportation assumptions and advancement of the site design concept. The land use assumptions include levels of residential, retail and office development that are consistent with current projections while also representing transit-supportive densities and design. The scenarios represented in the Bubble Plan reflect assumptions regarding county growth, Carmel Church area growth, density and diversity/design.

County Growth

To ensure that the growth planned for the TOD site is reasonable in the local and regional context, the land use assumptions are based on a share of anticipated growth in population and employment in Caroline County from 2010 to 2030. This time period is chosen as a representative build-out timeframe for which projections are available. The population projections are based on the most recent Virginia Employment Commission forecasts, which have been revised upward in light of actual growth in Caroline County since 2000. The projections indicate approximately 14,000 residents will be added countywide from 2010 to 2030. This is regarded as a conservative estimate, as Caroline's growth rate has been over 3% per year from 2000 to 2006; if sustained, this growth rate would result in close to 10,000 more in population by 2030 than the VEC projection.

Employment growth is more difficult to forecast. The available projections are widely divergent. The existing employment base in Caroline County is small but growing; thus projecting trends in annual growth rates over a long period run the risk of over-projecting since annual percentage rates of growth tend to taper as the employment base grows. For this reason, and in light of the growth objectives for the Carmel Church area, the employment growth assumptions are based on a ratio of 1 job for every 2 persons, which represents a desirable jobs-housing balance.

Carmel Church Area Growth

The Carmel Church area has accounted for about half of recent growth in Caroline County, and the Carmel Church Area Plan indicates that county growth will continue to be focused in this area. To assess a range of development that is well within reason but also represents the possibilities for the area, the residential land use projections assume that the Carmel Church area captures 50-70% of the VEC growth projection for the county. Assigning a current population-to-household ratio to the low estimate and, to the high range, a lower ratio that represents the likelihood of smaller households in the TOD, the range of households utilized for the analysis is 3,000 to 5,000. The employment range is 1,500 to 2,500, which is converted to square footage based on typical ratios for office and retail employment.

The mix of office and retail is approximately equal in terms of employees, which yields a somewhat higher proportion of office square footage. Numerous case studies of TODs were examined to ensure that the assumptions regarding residential, retail and office development are reasonable and to establish reasonable density assumptions. The TOD site is large in scale, but not unprecedented. The 80-acre Monrovia project in the Los Angeles region has a similar land use distribution, and the 95-acre Rio Vista West development in San Diego also has similarities and instructive lessons learned; many other case studies are focused on individual developments within TOD areas and are therefore smaller in scale. The Carmel Church tract is unique in that it offers an opportunity for a transit village to be developed "from scratch" in a strategic position between two urban areas. At the same time, the area is intended to become a regional employment center unto itself. Thus there is not a clear precedent for every assumption and the reasonableness is based on planning judgments, which were confirmed through discussions between the Consultant, County Planning staff, and County Economic Development staff. The resources of the Urban Land Institute were also utilized to research and confirm some of the land use assumptions. As the picture of the area's growth comes together, however, it seems that the residential component represents a higher degree of potential build-out than the commercial component – it is conceivable that with the acres available, the commercial component could double – or more – if supported by market analysis.

Density

The densities assumed for the TOD site and surrounding area are based on minimum densities of 15-20 residential units per acre. The TOD site contains half of the area residential growth in the low-end scenario, or 1,500 units, within approximately 47 acres of residential and 45 acres of mixed use development. The high-range of residential units is assumed to be accommodated via higher densities in the TOD site, which would range up to about 40 units per acre in the TOD.

Outside the TOD area, the residential land uses are assumed to be supportive of bus transit at seven units per acre. These areas are assumed to be developed as single family housing, although townhouses, duplexes and other residential forms could also meet these criteria.

The TOD site also includes a range of approximately 400,000 to 550,000 square feet of office space and 220,000 to 320,000 square feet of retail development. These uses would be vertically integrated in the mixed use tracts totaling 45 acres. This level of commercial development represents employment densities of 17 to 28 employees per acre, which has the potential to go higher if the market would support it.

The same amount of office and retail square footage would also be developed on the larger site at more suburban densities, (approximately 10 employees per acre for the higher projection) on up to 120 acres of land available on the north side of the railroad tracks adjacent to the existing development at the Carmel Church (Exit 104) interchange of I-95. As noted elsewhere, the concept of the greater TOD area

would support substantially more commercial development within the identified footprint if the additional real estate were supported by the market.

Diversity & Design

In addition to density, the key characteristics of TOD include diversity and design. The Carmel Church Town Center, as discussed in the Carmel Church Area Plan, is intended to provide a focal point, which is reflected in the TOD, and mixed uses which may include recreation, culture and/or entertainment. The TOD bubble plan reflects these concepts, designating park and recreational areas at the south end of the study area where the site is narrow and largely taken up with streams and stream buffers. This area also provides access to the North Anna River. This portion of the site is also part of a civil war battlefield area and could lend itself to cultural interpretive sites within and/or adjacent to the recreation area. The Bubble Plan includes a 67-acre park/conservation area with 11 acres of open space for recreational development, with an adjacent 7-acre tract for a cultural amenity such as a visitor/interpretive center related to the area's Civil War history. There is also room on the east side of the railroad tracks, adjacent to Route 1, for a larger entertainment center to be developed (though some existing rural development is in this area at present). The concept of "destination" is an aspect of TODs that is also recognized as contributing to the success of the transit and economic goals of these sites. This potential development is not included in the employment projections or square footage estimates identified for the study site.

Within the TOD, the Bubble Plan is arranged around the streams, stream buffers, and water features of the existing landscape. A Town Green is identified on both sides of the rail station, serving as the focal points for two areas of mixed use development within closest proximity to the rail station. The two greens help provide continuity in the green infrastructure, connecting the station area and surrounding development to green corridors adjacent to the railroad track on the east and west of the proposed town green on the west. The scale of these open space areas is a point of further refinement in the plan.

The 47 acres of mixed use development surrounding the rail station would have vertically integrated retail, office and residential development as described in the Density section. This area could also include a hotel, as is often the case in TOD projects of this scale and diversity. An additional parking area is designated within the TOD on each side of the railroad tracks, in light of the anticipated commuter traffic that may be drawn to the rail station. As addressed in the Phasing portion of this document, the site would initially host more surface parking in closer proximity to the rail station but transition to more structured parking less proximate to the rail station as the TOD site progresses towards build-out.

The Land Use Plan graphic provides some examples of the design and potential appearance of the TOD components. The most critical factor in design is the pedestrian orientation of development, with ample sidewalks, very limited surface parking within developments, and street layouts that accommodate pedestrians. Ground–level development in the mixed use tracts should relate to pedestrian uses as illustrated in the Orenco Station photograph.

Some of the design challenges of this site are also opportunities; there is a network of streams that cannot be developed but can be the spine of a green infrastructure system throughout the site that enhances bicycle and pedestrian mobility while preserving the most critical natural resources of the site. Providing a corridor for wildlife movement in the midst of an otherwise rural area is also an important aspect of the green infrastructure. The site also features rolling hills and some steep slopes. The steep slope areas adjacent to the railroad may provide opportunities for more natural crossing points, minimizing the amount of structure and visual impact involved in providing access across the tracks.

TRANSPORTATION ACCESS

The TOD site and surrounding areas are planned to have multimodal access including rail, roads, walking/biking trails, and local/regional transit.

Trip-Making Assumptions

The initial access plan is based on the amount of traffic that would be generated by the proposed range of land use, as offset by the TOD principles in the site design. Specifically, the mixture of uses, accessibility to rail and other modes, and the density and proximity of site components all contribute to a 10 – 25% reduction in the amount of vehicle traffic that is anticipated to be produced by site development. These reductions reflect the ability of residents, visitors and workers on the site to complete trips as a pedestrian that would require vehicle trips under more traditional suburban land use patterns, and the reductions also reflect the availability of transit. The trip reduction assumptions are based on research from the Urban Land Institute and the Institute for Traffic Engineers trip-generation guidelines for mixed use development. Recent studies by the Urban Land Institute examining the actual post-construction trip reductions in TODs indicates the reductions in vehicle trips are even higher than expected.

The trip reduction assumptions, trip generation results, and impacts to surrounding roadways will all be detailed in the next phase of the study. However, the trip generation was completed based on the current land use scenarios to allow an appropriate representation of the necessary roadway infrastructure in the circulation plan.

Roads

The Circulation Plan graphic illustrates a potential layout of roadways through the site, both primary (4-lane in most cases) and secondary (2-lane), but not including the entire street grid within each development area. The trip generation analysis indicates that three main access points with signals on U.S. Route 1 will be needed, in addition to three smaller unsignalized access points with no out-bound left turns on Route 1. These intersections are illustrated in the Circulation Plan graphic, with appropriate spacing of ½-mile between signalized intersections, interspersed by ¼-mile between signalized and unsignalized intersections. The four through lanes on Route 1 appear to be adequate to handle the additional traffic, but improvements for safety (such as medians) and turning lanes will be needed as the current profile of Route 1 in this area is a four-lane, undivided road.

The circulation plan reflects the need to move traffic between the elements of the site, to provide a logical circulation path for local circulator transit, and the need to minimize crossings of the railroad tracks. The central and southern rail crossings would be developed first, and should be located to utilize the depression of the railroad within the terrain to minimize the scale of overpass bridges.

A final, potential element to the roadway system is a possible bridge across I-95 as shown in the Circulation Plan graphic. This bridge would provide access across to parcels that may provide additional office development opportunities, and if extended to the parallel roads on the east side of I-95, could provide improved local access around the Exit 104 interchange area. The next phase of this study will more closely consider whether this access is needed and how it would affect the viability of the proposed improvements to the Exit 104 interchange in light of proposed development levels.

Walking/Bicycling

As noted under the Diversity & Design heading, a system of green infrastructure is planned for the site to provide resource conservation, recreation, and mobility for non-motorized modes on the site. The site is intended to have extensive bicycle and pedestrian access integrated into the street and neighborhood design in addition to the green infrastructure on the site. This includes pedestrian overpasses at the rail station and other locations of rail and stream crossings, as shown on the Circulation Plan graphic. To promote walk trips, the scale and organization of design in the mixed use

areas should be oriented to the pedestrian, such as walkable block lengths, wide sidewalks along thoroughfares, and pedestrian-oriented uses on street level (restaurants, shops, services, etc.).

Rail

The rail station is an important focal point of the Town Center. Rail service is not fully determined at this time, but current plans to develop faster and more reliable service between Richmond and Washington, D.C. would provide a base level of rail service compatible with the planned development. Specific service plans currently being developed call for 30-minute headways during peak periods. Additional service to be considered for the site is an extension of Virginia Railway Express (VRE) service which currently runs from Fredericksburg to Washington, D.C.; buses from the TOD to Fredericksburg could be provided as an interim service until rail service is established.

Local /Regional Transit

Two main types of transit are planned to complete the multimodal transportation system in the TOD area. First is a local transit circulator that would provide transit within the site, connecting the different components including office park, residential, and recreation areas. This transit would use the primary road system through the site, with a transfer point to regional transit at the rail station. Regional transit is the second type of service; it would make a loop through the site between Route 1 and the rail station with a transfer point at the rail station to streamline operations and minimize travel times for the service. Several regional destinations for the transit service are proposed, including a shuttle to Kings Dominion for both employees and visitors; similar or connected service to the State Fair grounds during events; an extension of the existing route in Caroline County to the Fredericksburg VRE station; and possible service to Richmond, which already has bus service up I-95 to the VRE station in Fredericksburg.

PHASING

The bubble plan represents ultimate build-out of the study site. A plan for phasing is important to the success of the site and particularly to transit usage and viability at the site. The real estate market will largely determine the staging of the major development components, and particularly the rate at which the retail elements are implemented, as the retail components will depend on the existence of residents and office workers in the area. The bubble plan identifies some discrete portions of the TOD site that could be developed in sequence; for example the 8-acre parcel of mixed use development which is closest to Route 1 and the adjacent residential parcel (16 acres) that are along the main spine road into the site would be logical first components to develop. At this early phase, the 9-acre mixed use site adjacent to the rail station might be partially developed as surface parking to promote regional drivers to use the train station and mixed use site. At the same time, outside the TOD, the portion of the single family residential tracts closest to the recreation areas would have market attraction independent of the TOD and could be implemented at an earlier phase once roadway access is established. Also, the access to Route 1 and Route 207 to the north would provide independent viability of the office park areas of the site on the north side of the railroad tracks. Over time, as the western portion and ultimately the eastern portion of the TOD are completed, the surface parking from the early phase would be replaced with structured parking within the mixed use development, and establishment of circulator transit service would be timed to facilitate non-motorized trips within the development area as it approaches a higher level of build-out and parking demand begins to approach or exceed supply.

In summary, the TOD would be anticipated to develop first on the Route 1 side, where the rail station would be located, and there would be some transition from surface parking close to the station and early development to higher value uses as the TOD approaches build-out. The residential and office space parcels outside the TOD would be developed based on market

demand, somewhat independent of the TOD phasing, but the timing of retail development throughout the site will depend on a combination of local demand provided at the site, demand associated with train riders (for example those destined for Kings Dominion), and regional demand.

SELECT SOURCES:

CalTrans Business Transit and Housing Agency, *Statewide Transit Oriented Development Study: Factors for Success in California*, September, 2002. www.dot.ca.gov/hq/MassTrans/Docs-Pdfs/TOD-Study-Final-Rpt.pdf

ITE. *Trip Generation, 7th Edition*. Institute of Traffic Engineers. Washington, DC, 2003

ITE. *Trip Generation Handbook, Second Edition.* Institute of Traffic Engineers. Washington, DC, 2004.

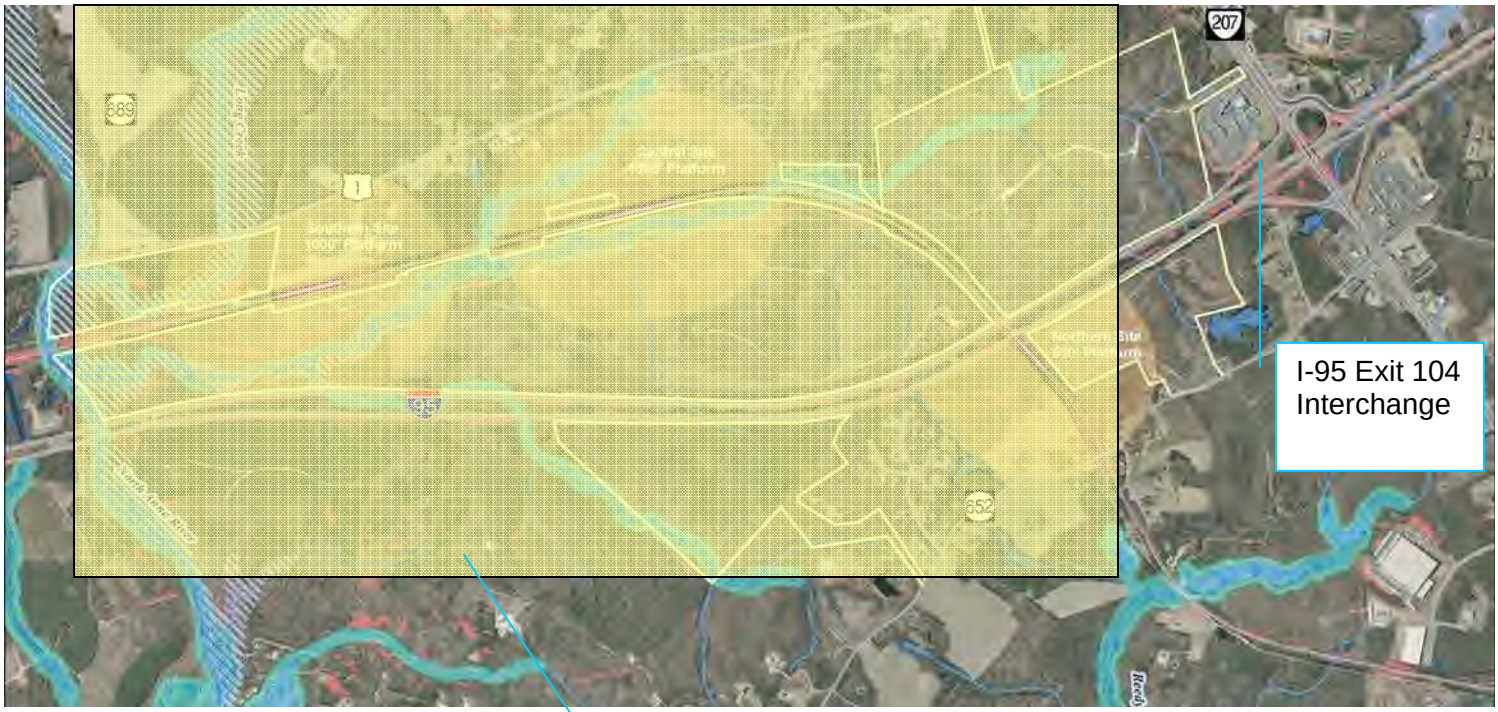
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Shigley, Paul, "With Old Town in fine shape, Monrovia looks to transit future," *California Planning & Development Report,* Volume 23; Issue 3, March 1, 2008.

Baker

Michael Baker Jr., Inc.
June 6, 2008

Study Area Location



DRAFT

Caroline County TOD Study
LAND USE PLAN

LEGEND

- Slope > 25%
- Historic Resources
- Rail Line
- Road
- Parcels
- Wetlands
- Resource Protection Area
- Water

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TOD CENTRAL SITE
(.28 mile radius around rail station)

Low Range
Office Space = 399,600 SF
Retail = 220,000 SF
Multi-Family Housing = 1,500 units

High Range
Office Space = 549,450 SF
Retail = 320,000 SF
Multi-Family Housing = 3,500 units



STRUCTURED PARKING
(left to right)
- Clayton Lane Mixed-Use Parking Facility - Denver
- 400 spaces wrapped with retail and office.

MIXED-USE
- Orenco Station, OR. Relate ground level to pedestrian uses.



NORTHERN SITE

Low Range
Office Space = 199,800 SF
Retail = 220,000 SF

High Range
Office Space = 274,725 SF
Retail = 320,000 SF

Historic Resources

Route 1



RESIDENTIAL
MULTI-FAMILY
- Massachusetts Smart Growth example.
- ~15-20 dwelling units/ acre

RESIDENTIAL
Multi-Family - 17 acres

RESIDENTIAL
Multi-Family
16 acres

MIXED-USE
8 acres

PARKING
11 acres

TOWN GREEN
7.5 acres

MIXED-USE 9 acres

OFFICE/RETAIL
41 acres

OFFICE/RETAIL
83 acres

FUTURE ENTERTAINMENT / DESTINATION RETAIL DEVELOPMENT LOCATION

CULTURAL AMENITY
7 acres

PARK
3.5 acres

PARKING
5 acres

TOWN GREEN
6 acres

MIXED-USE
Retail/Office/ Residential
28 acres

RESIDENTIAL
Multi-Family
6 acres

RESIDENTIAL
Multi-Family
17 acres

OPEN SPACE
11 acres

RESIDENTIAL
Single Family
70 acres
500 Dwelling Units

RESIDENTIAL
Single Family
148 acres
1,000 Dwelling Units

PARK / CONSERVATION AREA
67 acres

Historic Resources

Historic Resources

I-95



RESIDENTIAL SINGLE FAMILY
(left to right)
- King Farm, MD; 3,200 homes on 430 acres.
- ~7 dwelling units/acre
- Highlands' Garden Village, CO; 320 housing units on 27 acres
- ~11 dwelling units/acre

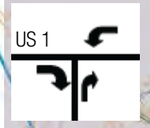


INTERSECTION SPACING ALONG ROUTE 1

- Signalized intersections every ~1/2 mile.
- Limited access points every ~1/4 mile.

ACCESS POINTS LANE CONFIGURATION

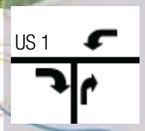
Limited Access Point



Signalized Access Point



Limited Access Point



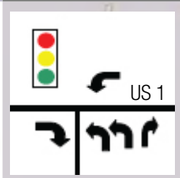
Signalized Access Point



Limited Access Point



Signalized Access Point



Route 1

PEDESTRIAN BRIDGE / STATION THRUWAY

VEHICULAR DROP-OFF FOR STATION

PARKING

PARKING

FUTURE ACCESS TO ENTERTAINMENT / DESTINATION RETAIL

MULTI-USE TRAIL BECOMES PART OF ROAD BRIDGE

MULTI-USE TRAIL BECOMES PART OF ROAD BRIDGE

DESTINATION POINT / MULTI-USE TRAIL TERMINUS

PEDESTRIAN BRIDGE / GATEWAY OPPORTUNITY

I-95

POTENTIAL I-95 CROSSING

DRAFT

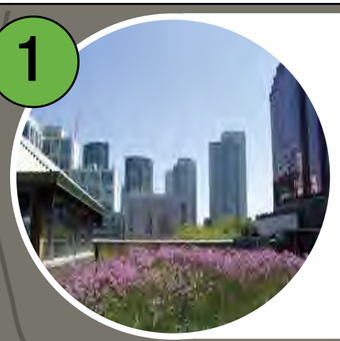
Caroline County TOD Study
CIRCULATION PLAN

LEGEND

- Signalized Access Point
- Limited Access Point
- Potential Roundabout
- Bridge
- Primary Road
- Secondary Road
- Pedestrian Link
- Multi-Use Trail
- Rail Line
- Road
- Parcels
- Wetlands
- Resource Protection Area
- Water

N

0 250 ft 500 ft 1000 ft



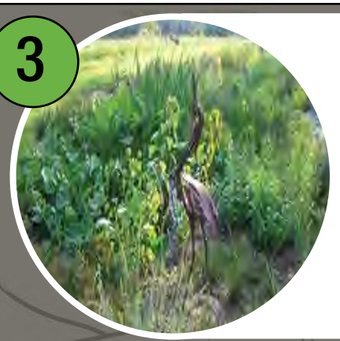
1 MIXED-USE / TOWN GREEN

- Utilize natural conditions.
- Formal park design = Town Green, integrate LID devices.
- Preserve, promote, enhance existing greenspace.
- Provide connections to existing stream corridor. Station circulation includes connection to multi-use trail.
- Incorporate green roofs.
- Implement ROW LID techniques.



2 RESIDENTIAL MULTI-FAMILY

- Higher density condos / townhouses.
- Incorporate inner courtyard designs that function as infiltration gardens.
- Use cisterns.
- Plan green roofs that function as usable open space for residents.
- Capture / reuse rainwater.
- Incorporate graywater systems.
- Implement traffic calming bulb-outs w/ bioretention cells.



3 SMALL-SCALE PARKS

- Incorporate raingardens.
- Landscape design is inspired by the adjacent natural surroundings.
- Incorporate swales, bioretention devices.
- Install educational signage.
- Install permeable pavers, concrete, asphalt for pedestrian walkways.

DRAFT

Caroline County TOD Study
GREEN INFRASTRUCTURE PLAN

LEGEND

- Slope > 25%
- Historic Resources
- Rail Line
- Green Infrastructure Links
- Multi-use Trail
- Wetlands
- Resource Protection Area
- Water

Baker

N



4 RESIDENTIAL SINGLE FAMILY

- Select permeable pavers for driveways.
- Incorporate permeable materials into parking lane design.
- Incorporate bioswales in yard / lawn design to increase the amount of infiltration. Utilize rain barrels as an irrigation source.
- Integrate pocket parks / playgrounds though out the neighborhood. Utilize LID devices.



5 OFFICE / RETAIL

- Incorporate permeable hardscape materials in parking lots.
- Utilize LID devices in the ROW.
- Incorporate bioswales, bioretention in landscape design of office buildings.
- Use native species where possible.
- Limit footprint of building and impervious services.
- Limit site disturbance and conserve natural habitats.



6 CONSERVATION AREAS

- Ribbons of greenways utilize existing natural conditions / stream route.
- Multi-use trail for pedestrians and bicycles follow conservations area.
- Constructed wetlands.
- Preserve natural habitats especially at the southern most point - create park.
- Park will serve as a destination point for development and an environmental educational opportunity.

Date 1/15/2014



The Economic and Fiscal Impact of Carmel Church Station on Caroline County, Virginia

The Carmel Church Station development is expected to create 13,762 jobs and $2.3 billion in annual economic impact in Caroline County, Virginia upon completion in 2035. The construction of the project is expected to support 13,834 cumulative jobs during the 20-year development period. The cumulative economic impact from 2015 to 2035 is estimated to reach $22.7 billion. Upon completion, the county is expected to collect $66.1 million a year from real estate, personal property, and other taxes from businesses and residents located at Carmel Church Station. Meanwhile, the county will also incur $40.8 million a year in additional expenses to provide public services for the businesses and residents located in Carmel Church Station. Thus, the net fiscal gain for Caroline County is expected to be positive at $25.3 million per year after project completion. The local fiscal impact is positive every year for the development period, having a cumulative positive value of $235.9 million from 2015 to 2035.

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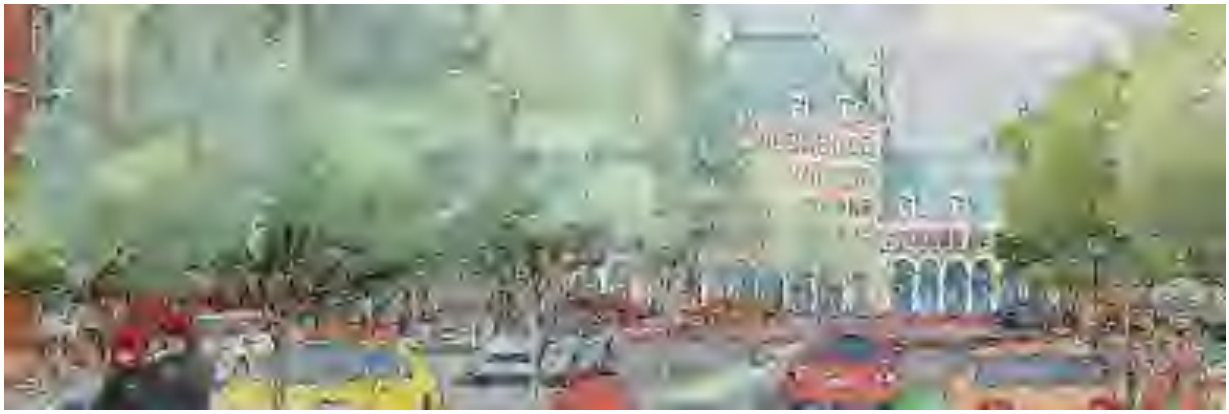
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PREPARED FOR

Washington DC South @Carmel Church Station



11/01/2019

Construction Cost Update

Carmel Church Station

CHMURA
Economics & Analytics

Carmel Church Station (CCS) is a proposed mixed-used development in Caroline County, Virginia. The current plans for the project call for the development of one million square feet (SF) of retail space and restaurants, 1.6 million square feet of office space, 600,000 square feet of industrial/manufacturing space, 1,000 hotel rooms, and 8,659 residential units.

In 2014, Chmura Economics & Analytics (Chmura) completed an economic and fiscal impact analysis of Carmel Church Station in Caroline County.[1] The study estimated that the overall construction cost of the project from 2015 to 2034, measured in nominal dollars, would be $3.76 billion.

This report provides an updated estimate of the construction cost of the project, assuming the construction would start in 2020 and last for 20 years until 2039. In this estimation, Chmura performed the following two calculations:

1. Use the actual price indexes for the construction industry from 2015 to 2019 to estimate the construction cost of CCS in 2019 fixed dollars.

2. Use the projected price indexes for the construction industry to estimate the nominal construction cost of CCS from 2020 to 2039.

Estimated Construction Cost of Carmel Church Station (Nominal $Million)

Year	Residential	Retail & Restaurants	Office	Light Industry	Hotel	Total
2020	$148.2	$9.0	$14.0	$4.6	$2.7	$178.5
2021	$152.8	$9.2	$14.4	$4.7	$2.8	$183.9
2022	$157.6	$9.5	$14.8	$4.8	$2.9	$189.6
2023	$162.5	$9.7	$15.2	$4.9	$3.0	$195.3
2024	$167.6	$10.0	$15.6	$5.0	$3.0	$201.3
2025	$172.8	$10.3	$16.0	$5.2	$3.1	$207.4
2026	$178.2	$10.6	$16.5	$5.3	$3.2	$213.7
2027	$183.8	$10.8	$16.9	$5.4	$3.3	$220.3
2028	$189.5	$11.1	$17.4	$5.6	$3.4	$227.0
2029	$195.4	$11.4	$17.8	$5.7	$3.5	$233.9
2030	$201.5	$11.7	$18.3	$5.9	$3.6	$241.0
2031	$207.8	$12.1	$18.8	$6.0	$3.7	$248.4
2032	$214.3	$12.4	$19.3	$6.2	$3.8	$256.0
2033	$221.0	$12.7	$19.9	$6.3	$3.9	$263.8
2034	$227.9	$13.1	$20.4	$6.5	$4.0	$271.8
2035	$235.0	$13.4	$20.9	$6.7	$4.1	$280.1
2036	$242.3	$13.8	$21.5	$6.8	$4.2	$288.7
2037	$249.9	$14.2	$22.1	$7.0	$4.3	$297.5
2038	$257.7	$14.5	$22.7	$7.2	$4.4	$306.5
2039	$265.8	$14.9	$23.3	$7.4	$4.5	$315.9
Total	**$4,031.7**	**$234.6**	**$366.0**	**$117.1**	**$71.1**	**$4,820.5**

Source: Chmura Economic & Analytics

Chmura estimated that **the total construction cost for Carmel Church Station, from 2020 to 2039, would be $4.82 billion**, measured in nominal dollars. To arrive at this estimate, the following assumptions were used:

- From 2015 to 2019, the price change for residential construction was 4.2% per year, while price changes for commercial and industrial construction were 3.4% and 3.5% per year, respectively.[2] Those reflected actual price changes from 2015 to 2019.
- The average construction cost for retail and commercial properties is $175.2/SF in 2019, up from $153.4/SF in 2015.
- The average construction cost for industrial property is $148.0/SF in 2019, up from $128.8/SF in 2015.
- The average construction cost for residential property is $331,919 per unit in 2019, up from $281,147 per unit in 2015.
- The average construction cost for a hotel room is $53,123 per room in 2019, up from $46,499 per room in 2015.

From 2019 to 2039, the construction price change for residential units is projected to be 3.1% per year, while price changes for commercial and industrial construction are projected to be 2.7% and 2.6% per year, respectively.[3] For residential construction, this price projection reflects the annual price change over the last twenty years, from 1999 to 2019. For commercial and industrial construction, those price projections reflect the annual price change since 2006 and 2007, respectively.[4] Chmura chose to use long-term price indexes as the projected price changes because long-term indexes include price changes during the economic recession of 2007 to 2009. With construction spanning twenty years for Carmel Church Station, long-term price indexes, rather than those from 2015 to 2019, are better indicators of construction price changes in the future.

[1] Source: The Economic and Fiscal Impact of Carmel Church Station on Caroline County, Virginia, prepared by Chmura Economics & Analytics, January 2014.

[2] Source: Construction Price Indexes, Census Bureau, https://www.census.gov/construction/cpi/. Producer Price Index for Nonresidential Building Construction. Bureau of Labor Statistics, https://www.bls.gov/ppi/ppinrbc.htm

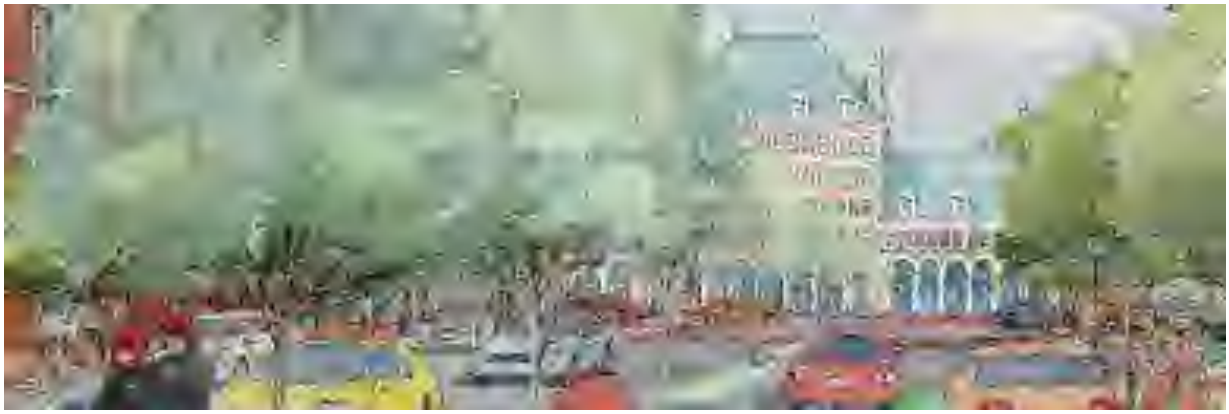
[3] Ibid.

[4] 2006 and 2007 are the earliest years for which such price data are available.

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11/01/2019

Construction Cost Update

Carmel Church Station-New Zoning

CHMURA
Economics & Analytics

Carmel Church Station (CCS) is a proposed mixed-used development in Caroline County, Virginia. The current plans for the project call for the development of one million square feet (SF) of retail space and restaurants, 1.6 million square feet of office space, 600,000 square feet of industrial/manufacturing space, 1,000 hotel rooms, and 8,659 residential units.

In October 2019, Caroline County Department of Economic Development stated that "the County would be amendable to the zoning of an additional 15 million square feet of land for commercial/industrial use."

This report provides an estimate of the construction cost of the newly zoned development, assuming the construction would start in 2020 and last for 20 years until 2039. In addition, it is assumed that 13 million SF of space will be for office and other commercial properties, and 2 million SF will be for industrial use.

In this analysis, Chmura used the previous studies of Carmel Chmura Station to form the assumption to estimate the construction cost of the new zoning.[1] Chmura estimated that **the total construction cost of the newly zoned development, from 2020 to 2039, would be $3.44 billion, measured in nominal dollar**s.

In reaching the above estimate, the following assumptions were used:

- The average construction cost for office and other commercial properties is $175.2/SF in 2019.
- The average construction cost for industrial property is $148.0/SF in 2019.

Estimated Construction Cost of Additional Zoning at CCS (Current $Million)

Year	Office/Commercial	Light Industry	Total
Year	$117.0	$15.2	$132.1
2020	$120.1	$15.6	$135.7
2021	$123.4	$16.0	$139.3
2022	$126.7	$16.4	$143.1
2023	$130.1	$16.8	$146.9
2024	$133.6	$17.2	$150.9
2025	$137.3	$17.7	$154.9
2026	$141.0	$18.1	$159.1
2027	$144.8	$18.6	$163.4
2028	$148.7	$19.1	$167.8
2029	$152.7	$19.6	$172.3
2030	$156.8	$20.1	$176.9
2031	$161.1	$20.6	$181.7
2032	$165.4	$21.1	$186.5
2033	$169.9	$21.6	$191.6
2034	$174.5	$22.2	$196.7
2035	$179.2	$22.8	$202.0
2036	$184.1	$23.3	$207.4
2037	$189.1	$23.9	$213.0
2038	$194.2	$24.6	$218.7
Total	**$3,049.7**	**$390.2**	**$3,439.9**

Source: Chmura Economic & Analytics

From 2019 to 2039, the construction price change for residential units is projected to be 3.1% per year, while price changes for commercial and industrial construction are projected to be 2.7% and 2.6% per year, respectively.[2] For residential construction, this price projection reflects the annual price change over the last twenty years, from 1999 to 2019. For commercial and industrial construction, those price projections reflect the annual price change since 2006 and 2007, respectively.[3] Chmura chose to use long-term price indexes as the projected price changes because long-term indexes include price changes during the economic recession of 2007 to 2009. With construction spanning twenty years for Carmel Church Station, long-term price indexes are better indicators of construction price changes in the future.

[1] Source: Construction Cost Update for Carmel Church Station, prepared by Chmura Economics & Analytics, November 2019

[2] Source: Construction Price Indexes, Census Bureau, https://www.census.gov/construction/cpi/. Producer Price Index for Nonresidential Building Construction. Bureau of Labor Statistics, https://www.bls.gov/ppi/ppinrbc.htm

[3] 2006 and 2007 are the earliest years for which such price data are available.

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1. Executive Summary

Carmel Church Station (CCS), currently in the proposal phase, will be a mixed-use, transit-oriented development situated in Caroline County. The site location encompasses approximately 1,100 acres of land along I-95. The current plans for the project call for the development of one million square feet of retail space and restaurants, 1,560,000 square feet of office space, 600,000 square feet of industrial/manufacturing space, 1,000 hotel rooms, and 8,659 residential units. A project of this magnitude is expected to have a significant and positive impact on the economy and fiscal budget for Caroline County.

In 2010, Chmura Economics & Analytics (Chmura) conducted an economic and fiscal impact study of CCS in Caroline County.[1] An update of the 2010 study is necessary due to the following changes:

- The project schedule has been moved to 2015 through 2035. The original benchmark year of 2032 needed to be updated to 2035, taking inflation into consideration.
- The Chmura 2010 study was based on 2009 county tax rates. Since then, the county has increased its real estate tax rate from 0.53% to 0.72%, while reducing personal property tax rate from 6.25% to 3.5%.
- An updated IMPLAN model is used that reflects the most recent economic situation in Caroline County. The economic multipliers are larger than those in Chmura 2010 study.

Using the latest IMPLAN Pro model to estimate the total economic and fiscal impacts of this project, Chmura found that:

- Upon project completion, spending within CCS will support 13,762 jobs both within the development and elsewhere in Caroline County.
- Each dollar spent at CCS businesses will have a $0.28 ripple effect throughout the county. Each job located at CCS will support an additional 0.18 jobs in the county.
- Upon completion, the project will result in $66.1 million per year in county revenue. Over the construction and development period from 2014 through 2035, total county revenue from the project will be $590.4 million.
- The project will have a net annual fiscal impact on Caroline County of $25.3 million upon completion in 2035.
- The cumulative net fiscal impact on Caroline County from 2014 through 2035 is $235.9 million. In fact, the project has a net positive fiscal impact each year during its development phase.
- Total project construction spending is estimated at $3.76 billion, which will generate $2.72 billion of economic impact in Caroline County during its development phase.
- During the 20-year construction and development period, 13,834 cumulative jobs will be created or supported in Caroline County.

[1] Source: The Economic and Fiscal Impact of Carmel Church Station on Caroline County, Virginia, prepared for Virginia Land Investments, by Chmura Economics & Analytics, June 21, 2010. This is referred to as the Chmura 2010 Study in this report.

2. Background

Virginia Land Investments has proposed the Carmel Church Station (CCS) project: a mixed-use, transit-oriented development on approximately 1,100 acres of land located along Interstate 95 (I-95) in Caroline County, Virginia.

Focusing on the new trend of transit-oriented developments, CCS will be a progressive community in which to live, work, and play. This new development will feature an inter-city rail station, a regional park along the North Anna River, and a blend of different housing types, shopping options, and employment opportunities. All of this will be maintained in a sustainable environment to assure energy efficiencies and minimal negative impact on the environment.

The location of CCS within Caroline County provides advantages that will underpin its anticipated success. Caroline County offers a rural lifestyle with access to the nation's capital, and it is one of the most vibrant economic regions in the country. The CCS location is situated on I-95 between Richmond, VA and Washington, D.C. The train station in CCS will afford a walkable and convenient option for residents, employees, and visitors who want to visit or commute to Richmond or Washington and avoid the traffic congestion on I-95.

In 2010, Chmura Economics & Analytics (Chmura) conducted an economic and fiscal impact study of CCS in Caroline County based on the latest project plan approved by the Caroline County Planning Commission in April 2010. An update of the 2010 study is necessary due to the following changes:

- The project schedule has been moved to 2015 through 2035. The benchmark year needed updating to 2035, considering inflation.
- Since 2010, the county has increased its real estate tax rate from 0.53% to 0.72%, while reducing the personal property tax rate from 6.25% to 3.5%.
- An updated IMPLAN model is used that reflects current economic conditions in Caroline County. The economic multipliers are larger than those in Chmura 2010 study.

This rest of this report is organized in the following manner:

- Section 3 briefly describes the Chmura methodology for the economic and fiscal impact analysis
- Section 4 details the project plan and timeline
- Section 5 discusses the economic impact resulting from construction and the ongoing operation of CCS
- Section 6 analyzes the fiscal impact of the project on the county with regard to additional revenue and expenses
- Section 7 provides a conclusion

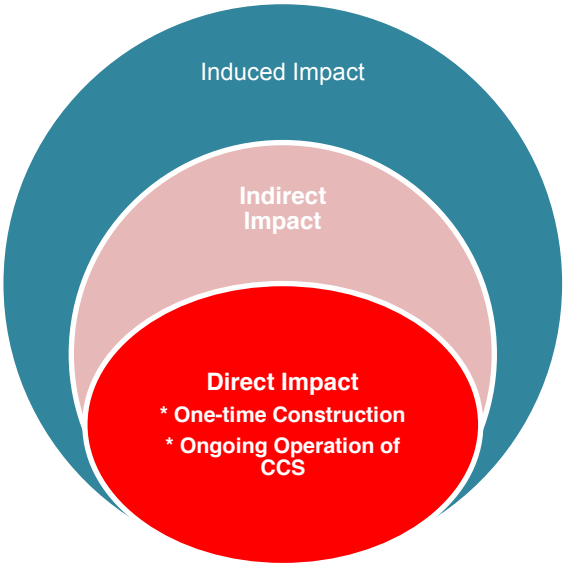
3. Methodology

The economic impact of the Carmel Church Station project comes from the following two sources: (1) the one-time economic impact from construction activities, and (2) ongoing operation such as the spending activities of businesses and residents located within the development.

These components constitute the direct economic impact of Carmel Church Station on Caroline County. The total economic impact will also include the economic ripple effects from the direct impact. Ripple effects, categorized as indirect and induced impacts (see Appendix 1 for definitions), measure the secondary benefits generated by CCS construction and its ongoing operation. These effects include the benefits for the many local businesses supporting CCS construction and operation phases, such as suppliers to local construction companies, and local businesses that cater to employees working in CCS.

The indirect and induced effects are estimated with IMPLAN Pro software after the direct impact is determined. Total construction spending and operational revenue are input into the various IMPLAN model sectors to estimate both the indirect and induced impacts for each sector. Those impacts are eventually aggregated to reach the estimated overall economic impact of CCS. Figure 3.1 illustrates the economic impact framework.

Figure 3.1: Economic Impact Analysis Framework



This study also estimates the fiscal effect of Carmel Church Station on Caroline County government entities. As development proceeds, the county can collect recordation taxes and one-time cash proffers. After completion, the county will continue to collect tax revenue from the following sources within CCS:

- Real estate and personal property taxes from commercial and residential properties
- Sales, meals, and lodging taxes from retail, restaurants, and hotels
- Machinery and tools tax from industry property
- Business, professional, occupational licenses tax (BPOL) from all eligible businesses

The current tax rates for the county are used to estimate tax revenue even though the rates may change in the future. The county would also incur costs to provide education, fire protection, public safety, and other services to workers and residents in CCS. Since education costs are one of the largest expense items for the county, Chmura first analyzes the household patterns and the number of school-age children living in CCS. Based on the household patterns and education cost per pupil, Chmura estimates the total education cost associated with CCS development. For other costs such as public safety, social services, and general administration, Chmura utilizes a per capita approach to estimate total county costs.

By comparing both county cost and tax revenue, it then can be determined whether the CCS development is fiscally positive for Caroline County, and to what extent.

4. Carmel Church Station Development

Commercial, industrial, and residential properties are included in the proposed CCS development. The initial plan for CCS is presented in Table 4.1. The project spans 20 years, from commencement of construction in 2015 to its completion in 2035. When it is complete, the project will host 1,000,000 square feet (SF) of retail space that is planned to include grocery stores, clothing stores, pharmacies, and home improvement stores. Also included are 80,000 SF of restaurant space. In addition to retail and restaurants, CCS will also offer 1,560,000 SF of office space and 600,000 SF of industrial/manufacturing space. Finally, multiple hotels with a total of 1,000 rooms are included in this plan.

Table 4.1: Plans for Carmel Church Station

	Square Footage	Units
Commercial		
Grocery	160,000	
Clothing	60,000	
Drug	100,000	
Home Improvement	100,000	
Misc. Retail	500,000	
Restaurants	80,000	
Total Retail & Restaurants	1,000,000	
Office	1,560,000	
Industrial	600,000	
Total Commercial Square Footage	**3,160,000**	
Hotel		1,000
Residential		
Apartment		2,500
Condos		2,500
Townhomes		2,500
Single Family Dwelling		1,159
Total Residential		**8,659**

Source: Virginia Land Investments

Since a mixed-used development aims to bring work and retail close to their residents, minimizing dependence on automobiles, another important component of CCS is its residential development. The plan for CCS includes 8,659 residential units, allocated among apartments, condos, townhomes, and single-family dwellings.

The entire project will be completed over a 20-year period from 2015 to 2034. The first year of full operation will be 2035. The total project construction spending is estimated to be $3.76 billion in nominal dollars. To arrive at this estimate, the following assumptions were used:

- The unit construction cost is assumed to increase 2.5% per year
- The average construction cost for retail and commercial properties is $153.40/SF in 2015
- The average construction cost for industrial/manufacturing property is $128.80/SF in 2015
- The average construction cost for residential property is $281,147 per unit in 2015
- The average construction cost for a hotel is $46,499 per room in 2015

The construction cost assumptions for CCS are consistent with other studies Chmura has conducted in the Richmond metropolitan area, with slight differences attributable to locations and timing of construction. In this

update, Chmura uses the construction cost assumption from the Chmura 2010 study, adjusted for inflation to arrive at 2015 figures.

The total project construction spending of $3.76 billion is assumed to be evenly spread during the construction phase. Table 4.2 provides the construction outlays by year.

Table 4.2: Estimated Construction Cost (Current $Million)

Year	Residential	Retail & Restaurants	Office	Light Industry	Hotel	Total
2015	$121.7	$7.7	$12.0	$3.9	$2.3	$147.5
2016	$124.7	$7.9	$12.3	$4.0	$2.4	$151.2
2017	$127.8	$8.1	$12.6	$4.1	$2.4	$154.9
2018	$131.0	$8.3	$12.9	$4.2	$2.5	$158.8
2019	$134.2	$8.5	$13.2	$4.3	$2.6	$162.7
2020	$137.6	$8.7	$13.5	$4.4	$2.6	$166.7
2021	$141.0	$8.9	$13.9	$4.5	$2.7	$170.9
2022	$144.5	$9.1	$14.2	$4.6	$2.8	$175.1
2023	$148.0	$9.3	$14.5	$4.7	$2.8	$179.4
2024	$151.7	$9.6	$14.9	$4.8	$2.9	$183.9
2025	$155.5	$9.8	$15.3	$4.9	$3.0	$188.4
2026	$159.3	$10.0	$15.7	$5.1	$3.0	$193.1
2027	$163.3	$10.3	$16.0	$5.2	$3.1	$197.9
2028	$167.3	$10.5	$16.4	$5.3	$3.2	$202.8
2029	$171.4	$10.8	$16.8	$5.4	$3.3	$207.8
2030	$175.7	$11.1	$17.3	$5.6	$3.4	$213.0
2031	$180.0	$11.3	$17.7	$5.7	$3.4	$218.2
2032	$184.5	$11.6	$18.1	$5.9	$3.5	$223.6
2033	$189.1	$11.9	$18.6	$6.0	$3.6	$229.2
2034	$193.8	$12.2	$19.0	$6.2	$3.7	$234.9
Total	**$3,102.1**	**$195.4**	**$304.8**	**$98.5**	**$59.3**	**$3,760.1**

Source: Virginia Land Investments

The greater part of construction spending is for residential units, accounting for 82.5% ($3.10 billion) of project spending. Office and retail construction will account for 8.1% and 5.2% of construction spending, respectively. The rest is allocated to industrial/manufacturing properties (2.6%) and hotels (1.6%).

5. Economic Impact of Carmel Church Station

In this section, the one-time construction impact from the development is shown, followed by an analysis of the impact of the ongoing operation of the project's commercial and residential components. Lastly, the overall impact of the project is summarized by year, providing the foundation for the fiscal analysis.

5.1. One-time Economic Impact from Construction Spending

The construction of CCS will create jobs in construction and related industries in Caroline County and the surrounding area. As a result, CCS construction spending will bring more business to local suppliers and construction companies.[2] In addition, area restaurants and shops will benefit as construction workers spend money at local establishments.[3]

The total construction spending of the project is estimated to be $3.76 billion. This spending is spread evenly over a span of twenty years. The construction outlays include site development, construction of the structures, and professional fees such as architecture and engineering fees and other soft costs. Construction spending was entered into IMPLAN software to estimate job creation and the ripple economic effects of related construction activities.

The model shows that from 2015 through 2034, a total of $2.18 billion will be directly spent in Caroline County to support the construction of Carmel Church Station (Table 5.1).[4] In 2015, for example, yearly construction spending will be $85.5 million, directly creating 577 jobs in construction trades in Caroline County. The indirect impact for 2015 is expected to result in $8.2 million in additional sales and 46 additional jobs in industries supporting construction, such as truck transportation and utilities. The induced impact is projected to total $13.0 million and 68 jobs in Caroline County in 2015. The induced jobs, which are generated when construction workers spend their income in the area, will be concentrated in consumer services-related industries such as restaurants, healthcare, and retail stores.

[2] This is commonly referred to as an indirect impact.
[3] This is commonly referred to as an induced impact.
[4] This number is smaller than the $3.76 billion total project cost because some spending will occur in businesses outside Caroline County. Chmura uses the IMPLAN model to estimate the percentage of construction spending that will leak out of the county.

Table 5.1: Economic Impact of Construction of Carmel Church Station (2015-2035, Nominal $)								
	Spending ($Million)				Employment			
Year	Direct	Indirect	Induced	Total	Direct	Indirect	Induced	Total
2015	$85.5	$8.2	$13.0	$106.7	577	46	68	692
2016	$87.6	$8.4	$13.3	$109.3	577	46	68	692
2017	$89.8	$8.6	$13.7	$112.0	577	46	68	692
2018	$92.0	$8.8	$14.0	$114.8	577	46	68	692
2019	$94.3	$9.0	$14.3	$117.7	577	46	68	692
2020	$96.6	$9.3	$14.7	$120.6	577	46	68	692
2021	$99.0	$9.5	$15.1	$123.6	577	46	68	692
2022	$101.4	$9.7	$15.4	$126.6	577	46	68	692
2023	$104.0	$10.0	$15.8	$129.8	577	46	68	692
2024	$106.5	$10.2	$16.2	$133.0	577	46	68	692
2025	$109.2	$10.5	$16.6	$136.3	577	46	68	692
2026	$111.9	$10.7	$17.0	$139.6	577	46	68	692
2027	$114.6	$11.0	$17.4	$143.1	577	46	68	692
2028	$117.5	$11.3	$17.9	$146.6	577	46	68	692
2029	$120.4	$11.6	$18.3	$150.3	577	46	68	692
2030	$123.4	$11.8	$18.8	$154.0	577	46	68	692
2031	$126.4	$12.1	$19.2	$157.8	577	46	68	692
2032	$129.6	$12.4	$19.7	$161.7	577	46	68	692
2033	$132.8	$12.7	$20.2	$165.7	577	46	68	692
2034	$136.1	$13.1	$20.7	$169.8	577	46	68	692
Total (2015-2034)	**$2,178.4**	**$209.1**	**$331.5**	**$2,719.0**	**11,550**	**915**	**1,369**	**13,834**
Annual Average (2015-2034)	**$108.9**	**$10.5**	**$16.6**	**$135.9**	**577**	**46**	**68**	**692**

Source: Virginia Land Investments and IMPLAN Pro 2012

Overall, during the 20-year construction phase, Carmel Church Station is expected to generate a total of $2.72 billion in economic impact for Caroline County businesses. This economic impact averages $135.9 million in spending and 692 jobs per year for the 2015 through 2034 project cycle.

5.2. Ongoing Economic Impact of CCS Development

This section analyzes the total ongoing spending and employment effects of CCS, based on the economic impact of a fully-built CCS in 2035. The next section (Section 5.3) presents the economic impact for the years 2015 through 2034, as different components of CCS are completed and come into operation each year.

New businesses have an economic ripple effect in a local economy. Consider a restaurant as an example. As sales increase, the restaurant purchases more local supplies from grocery stores or farmers. As a result, the output (sales) of the underpinning businesses also increases. In this example, the restaurant will need to hire additional workers to meet rising demand.[5] As the income of the restaurant workers rise, their consumption increases, further enhancing spending effects in the area.[6]

[5] This is commonly referred as an indirect impact.
[6] This is commonly referred as an induced impact.

Table 5.2 presents the total output and employment from the ongoing operation of CCS beginning in 2035. When all components are operating, all businesses located in the development are estimated to have direct economic sales of $1.77 billion. Of the commercial components, the largest contributor to economic output will come from office space, which is expected to generate annual direct sales of $837.9 million. The manufacturing industries located in CCS are expected to generate $452.3 million in sales annually, while the remaining direct sales are expected to come from retail merchants, restaurants, and hotels. In addition, the apartments located in CCS are expected to generate $33.9 million in annual sales in the form of rental income. The total direct impact of CCS is estimated to be $1.81 billion in 2035.

Table 5.2: Annual Economic Impact of Carmel Church Station (2035 Onward)

	Spending ($Million)				Employment			
	Direct	Indirect	Induced	Total	Direct	Indirect	Induced	Total
Grocery Store	$42.2	$2.3	$1.9	$46.3	391	9	7	408
Clothing	$39.6	$4.4	$1.5	$45.5	372	20	7	398
Drug Store	$28.3	$1.6	$1.4	$31.3	322	11	9	342
Home Improvement Store	$47.1	$3.0	$2.1	$52.2	390	15	10	415
Misc. Retail	$235.6	$8.0	$10.0	$253.6	2,781	45	52	2,878
Restaurant	$60.3	$10.7	$7.2	$78.1	580	47	30	657
Office	$837.9	$93.1	$127.0	$1,057.9	5,278	579	551	6,408
Industry	$452.3	$139.6	$45.3	$637.3	1,226	319	244	1,788
Hotel	$28.9	$8.7	$2.1	$39.6	183	46	10	239
Total Commercial	**$1,772.1**	**$271.3**	**$198.5**	**$2,241.9**	**11,524**	**1,091**	**920**	**13,534**
Apartment	$33.9	$4.8	$1.2	$39.9	131	14	4	148
Condominium	$0.0	$8.0	$2.0	$10.0	0	23	7	30
Townhouse	$0.0	$8.0	$2.0	$10.0	0	23	7	30
Single Family Dwelling	$0.0	$5.6	$1.4	$7.0	0	16	5	21
Total Residential	**$33.9**	**$26.5**	**$6.5**	**$67.0**	**131**	**76**	**22**	**228**
Total CCS	**$1,806.0**	**$297.8**	**$205.0**	**$2,308.9**	**11,654**	**1,167**	**941**	**13,762**

Source: Virginia Land Investments and IMPLAN 2012

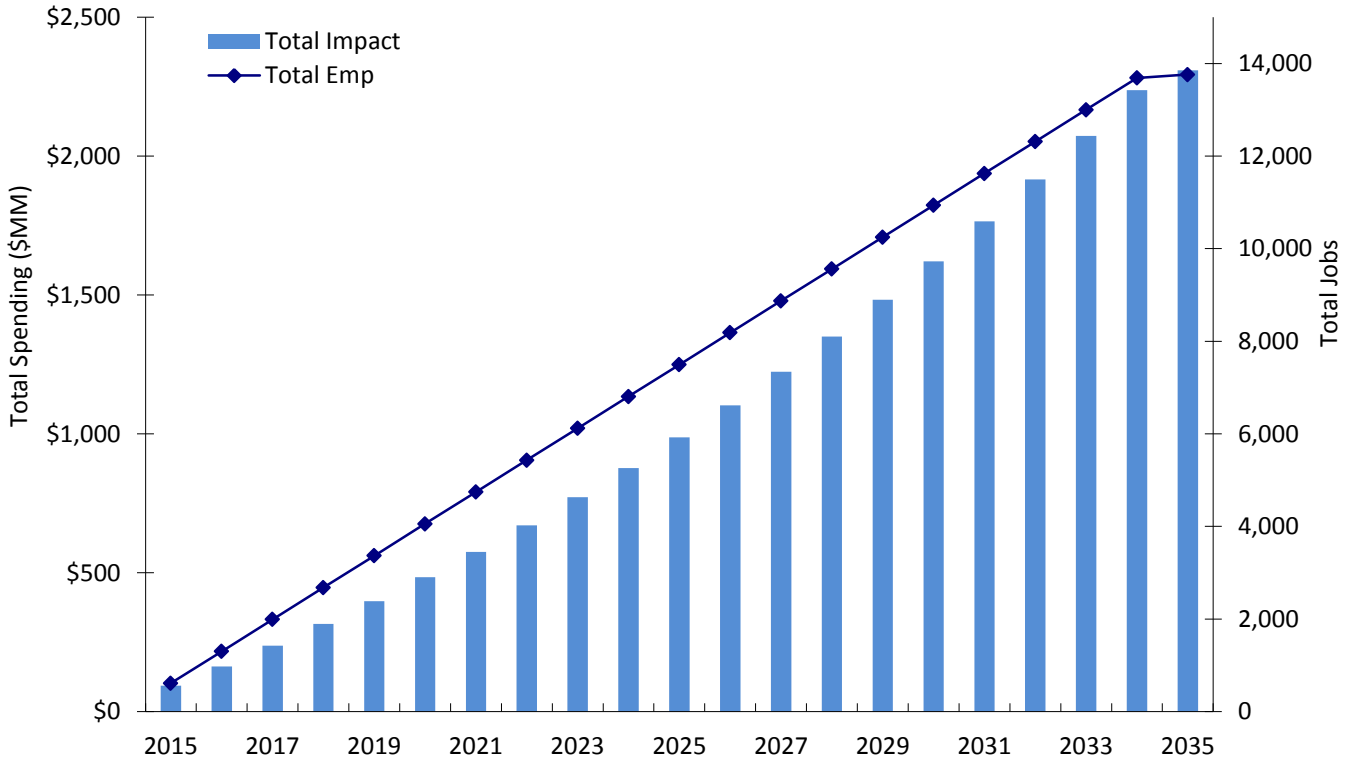
In addition to direct spending, CCS will create new jobs in Caroline County. It is estimated that 11,654 people will be directly employed by CCS establishments, with the largest component (5,278) working in offices. Other jobs in CCS establishments will include those in the manufacturing industry (1,226), restaurants (580), and various retail establishments.

The indirect and induced impacts measure the extent to which other businesses in the county benefit from CCS operation. The indirect and induced effects normally occur during the same year of the direct impact. The indirect impact of $297.8 million and 1,167 jobs represents increased spending and employment for county businesses supporting the operation of Carmel Church Station. Some examples are local suppliers to retailers, local banks with CCS businesses as their customers, and local landscape companies hired to maintain the property. The induced impact of $205.0 million and 941 jobs is the result of increased spending from local consumers who are employed by CCS businesses. Beneficiary businesses include hospitals, doctor's offices, and other retailers and restaurants throughout the county. On average, one dollar spent at CCS businesses is expected to have a $0.28 ripple effect throughout the county. One job located in CCS will support an additional 0.18 jobs in the county.

5.3. Economic Impact over Time

Given that construction, commercial, and residential operations overlap, the economic impact of CCS will gradually escalate to its fully-built level (Figure 5.1). Since total construction spending is assumed to be split evenly during the construction phase, the economic impact over time will expand at a steady pace. Between 2015 and 2034, the economic impact is derived from both construction spending and ongoing operation of the residential and commercial properties. After 2035, the impact will stabilize.

Figure 5.1: CCS Economic Impact Summary: Spending and Employment



Source: Chmura Economics & Analytics

6. Fiscal Impact on Caroline County

In addition to creating thousands of jobs and injecting millions of dollars into the county's economy, CCS will also produce significant tax revenue for Caroline County after it is complete. Major revenue sources from this project for the county government come from the following taxes: real estate, tangible (personal) property, machinery and tools, sales, meals, lodging, and BPOL. In addition, Caroline County will benefit from a one-time cash proffer from the developer, and realize recordation tax revenue as properties transfer. However, the county will also incur costs in the areas of public safety and education for workers and residents of CCS. Therefore, tax revenue and service costs of CCS operation are both calculated to determine the net fiscal impact of this project on the county.

6.1. Real Estate Tax and Tangible Personal Property Tax

In 2013, Caroline County taxed real estate at $0.72 per $100 of assessed value. The tangible personal property tax rate is $3.50 per $100 of assessed value.[7] Caroline County uses fair market value as the base for real estate property assessments. In this report, the estimated assessed value for real estate property is assumed to be the construction cost.[8] The estimated assessed value for personal property tax is estimated as follows. For residential households, it is assumed that each household has 1.5 vehicles. The assessed value for each vehicle is estimated to be $9,723 in 2035. The estimated assessed value of tangible personal property for commercial properties is assumed to be 2.7% of the assessed real property tax.[9]

Table 6.1: Property Tax Breakdown (2035 Onward)

Component	Size	Total Assessed Value	Real Estate Tax	Personal Property Tax
Grocery Store	160,000	$80,976,691	$583,032	$76,216
Clothing	60,000	$30,366,259	$218,637	$28,581
Drug Store	100,000	$50,610,432	$364,395	$47,635
Home Improvement Store	100,000	$50,610,432	$364,395	$47,635
Misc. Retail	500,000	$253,052,160	$1,821,976	$238,174
Restaurant	80,000	$40,488,346	$291,516	$38,108
Office	1,560,000	$789,522,738	$5,684,564	$743,102
Industry	600,000	$255,076,577	$1,836,551	$240,079
Hotel	1,000	$153,457,578	$1,104,895	$144,435
Total Commercial	**3,161,000**	**$1,704,161,213**	**$12,269,961**	**$1,603,964**
	Number of Unit	Assessed Value Per Unit	Real Estate Tax	Personal Property Tax
Apartment	2,500	$770,678,117	$5,548,882	$1,301,552
Condominium	2,500	$1,300,519,323	$9,363,739	$1,301,552
Townhouse	2,500	$1,445,021,470	$10,404,155	$1,301,552
Single Family Dwelling	1,159	$1,060,693,926	$7,636,996	$603,400
Total Residential	**8,659**	**$4,576,912,836**	**$32,953,772**	**$4,508,057**
Total Property Tax			$45,223,733	$6,112,021
Minus Current Tax Estimate		$4,389,300	$59,558	
Net Property Tax			**$45,164,175**	**$6,112,021**

Source: Virginia Land Investments, Caroline County, and Chmura Economics & Analytics

[7] In the 2010 Chmura Study, the real estate tax rate was $0.53 per $100 of assessed value and tangible personal property tax rate was $6.25 per $100 of assessed value. Those changes resulted in a significant increase in real estate tax revenue and a decrease in personal property tax revenue.

[8] The assessed value for residential property is based on estimated sales price, with 95% assessment ratio.

[9] Those assumptions are from the 2010 Chmura study, adjusted for inflation when necessary.

Table 6.1 details the real estate and personal property tax estimates from the CCS development upon full completion in 2035. The annual real estate taxes from commercial properties at CCS are estimated to be $12.3 million, while the estimated annual real estate tax from residential properties is $33.0 million. Currently, the total assessed value of land amounts to $4.4 million. This translates to an annual revenue loss of $59,558 for the county in 2035. As a result, the net real estate tax for the county is $45.2 million in 2035.

The personal property tax for commercial properties, including taxes on cars, trucks, and office equipment is estimated to be $1.6 million in 2035. The personal property tax associated with residential properties, derived from cars owned by households in CCS, is estimated to be $4.5 million in 2035.The total real estate and personal property tax is thus estimated to be $51.3 million in 2035.

Caroline County also collects a recordation tax for real estate sales. The current tax rate is 8.3 cents per $100 transaction value. Chmura applies this rate on the estimated sales value of residential units in CCS. Based on the construction schedule, there are 433 units of new houses for sale each year. As a result, the total recordation tax is estimated to be $0.18 million in 2015 and $0.30 million in 2035, assuming housing prices appreciate at the rate of the consumer price index.

6.2. Other Commercial Taxes from CCS

The Virginia state sales tax is 5.3%—1% of which is returned to the county by the state. The sales tax is levied on the purchase of goods but not services. In this study, a 1% tax rate is applied to sales at restaurants, hotels, and retail shops located at CCS to arrive at the sales tax estimate. The total sales tax from all operations in 2035 is estimated to be $4.8 million (Table 6.2).

Table 6.2: Other Commercial Taxes (2035 Onward)

	Local Sales Tax	Meal Tax	Lodging Tax	BPOL Tax	Machinery & Tools Tax
Grocery Store	$422,144			$63,322	
Clothing	$395,760			$59,364	
Drug Store	$282,686			$42,403	
Home Improvement Store	$471,143			$70,671	
Misc. Retail	$2,355,714			$353,357	
Restaurant	$603,063	$2,412,251		$90,459	
Hotel	$288,905		$1,444,524	$43,336	
Office				$2,848,793	
Industry					$2,208,695
Total	**$4,819,414**	**$2,412,251**	**$1,444,524**	**$3,571,706**	**$2,208,695**

Source: Virginia Land Investments, County of Caroline, and Chmura

As of 2013, Caroline County had a 4% meals tax, which is applied to restaurant sales. The total meals tax from restaurants in 2035 is estimated to be $2.4 million. Caroline County also has a 5% lodging tax, which is applied to hotel receipts. The total lodging tax from hotels in 2035 is estimated to be $1.4 million.

Caroline County has a business, professional, and occupational license (BPOL) tax, which is applied to retail and service businesses at different rates. As of 2013, the BPOL tax rate for retailers was $0.15 per $100 of gross receipts. This rate was $0.12 for contractors, $0.19 for personal services, and $0.49 for professional businesses. All retail, restaurants, and lodging businesses are subject to the retail BPOL tax rate, as are office businesses, which are assumed to be half professional services and half personal services. As a result, the total BPOL taxes from all businesses located in CCS is estimated to be $3.6 million in 2035.

Caroline County also has a machinery and tools tax which is applied to manufacturers and is based on the assessed value of their machines and equipment. Since the assessed equipment values of the potential manufacturing industries in CCS are not available, Chmura utilized a per capita approach. In the 2010 Chmura study, it is estimated that the average machinery and tools tax per worker is $965. Applying this base amount as a guide for manufacturing industries that may locate in CCS, it is estimated that the machinery and tools tax in 2035 will be $2.2 million.

Overall, all taxes derived from the commercial operation of CCS are estimated to be $14.5 million in 2035. Measured in 2013 dollars, total taxes from commercial operation are projected to be $8.3 million.

6.3. Cash Proffer Impact

Caroline County has a cash proffer policy for both residential and commercial development—termed impact fees and road improvement fees. The cash proffer is paid when the building permits for CCS are obtained and is primarily used to build schools, roads, and parks. The preliminary impact fees for residential developments are $5,500 per dwelling unit, due at the time of building permit issuance, but the total amount is limited to $36.5 million. The maximum limit is lowered to $25.0 million if one million square feet of commercial space is built. For industrial and commercial developments, there is a road improvement fee paid to Caroline County at $0.35 per square foot. Cash proffers are adjusted each year based on the consumer price index.

Based on the above cash proffer formula and the construction schedule outlined in section 4, the total impact fees from the residential development are estimated to be $25.0 million. Under the current construction schedule, the development will reach 1.0 million SF in commercial/industrial development in 2021; however, the accumulated impact through 2018 is $18.9 million. As a result, Caroline County will continue to collect impact fees up to $25.0 million when this maximum is reached in 2024. In addition, the total road improvement fees are estimated to be $1.5 million from 2015 to 2034, averaging over $70,000 per year.

Overall, the total cash proffer from CCS is estimated to be $26.4 million from 2015 to 2034. Most of the revenue will be paid to the county during the first half of the construction phase, as building permits are issued each year for the completed site construction.

6.4. Tax Revenue Summary

When the development is fully operational in 2035, CCS is expected to generate annual revenue of $66.1 million for Caroline County (Table 6.3). Of this amount, $45.2 million is expected from real estate tax, $6.1 million from personal property tax, $4.8 million from sales tax, and the rest from meals, lodging, BPOL, recordation, and machinery and tools taxes. During the years of construction, Caroline County will also receive cash proffers. Since the development will come into operation in different phases, the county will see increased tax revenue each year. Table 6.3 outlines the county tax revenue from CCS operation from 2015 to 2035.

Table 6.3: County Fiscal Revenue Summary (Annual 2015-2035, $Million)											
Year	Proffer	Real Estate	Personal Property	Sales	Meal	Lodging	BPOL	Machinery & Tools	Recordation	Total Taxes	Cumulative Total Tax
2015	$2.4	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$2.4	$2.4
2016	$2.5	$1.3	$0.2	$0.1	$0.1	$0.0	$0.1	$0.1	$0.2	$4.6	$7.0
2017	$2.6	$2.7	$0.4	$0.3	$0.1	$0.1	$0.2	$0.1	$0.2	$6.7	$13.7
2018	$2.6	$4.2	$0.6	$0.4	$0.2	$0.1	$0.3	$0.2	$0.2	$8.9	$22.6
2019	$2.7	$5.7	$0.8	$0.6	$0.3	$0.2	$0.4	$0.3	$0.2	$11.2	$33.8
2020	$2.8	$7.3	$1.0	$0.8	$0.4	$0.2	$0.6	$0.4	$0.2	$13.6	$47.3
2021	$2.8	$9.0	$1.2	$1.0	$0.5	$0.3	$0.7	$0.4	$0.2	$16.1	$63.4
2022	$2.9	$10.7	$1.4	$1.1	$0.6	$0.3	$0.8	$0.5	$0.2	$18.7	$82.1
2023	$3.0	$12.6	$1.7	$1.3	$0.7	$0.4	$1.0	$0.6	$0.2	$21.5	$103.6
2024	$1.4	$14.5	$2.0	$1.5	$0.8	$0.5	$1.1	$0.7	$0.2	$22.7	$126.2
2025	$0.1	$16.5	$2.2	$1.8	$0.9	$0.5	$1.3	$0.8	$0.2	$24.3	$150.5
2026	$0.1	$18.6	$2.5	$2.0	$1.0	$0.6	$1.5	$0.9	$0.2	$27.3	$177.9
2027	$0.1	$20.8	$2.8	$2.2	$1.1	$0.7	$1.6	$1.0	$0.2	$30.5	$208.4
2028	$0.1	$23.1	$3.1	$2.5	$1.2	$0.7	$1.8	$1.1	$0.2	$33.9	$242.3
2029	$0.1	$25.5	$3.4	$2.7	$1.4	$0.8	$2.0	$1.2	$0.2	$37.4	$279.7
2030	$0.1	$28.0	$3.8	$3.0	$1.5	$0.9	$2.2	$1.4	$0.3	$41.0	$320.7
2031	$0.1	$30.6	$4.1	$3.3	$1.6	$1.0	$2.4	$1.5	$0.3	$44.8	$365.5
2032	$0.1	$33.3	$4.5	$3.5	$1.8	$1.1	$2.6	$1.6	$0.3	$48.8	$414.2
2033	$0.1	$36.1	$4.9	$3.8	$1.9	$1.2	$2.9	$1.8	$0.3	$52.9	$467.1
2034	$0.1	$39.1	$5.3	$4.2	$2.1	$1.2	$3.1	$1.9	$0.3	$57.2	$524.3
2035	$0.0	$45.2	$6.1	$4.8	$2.4	$1.4	$3.6	$2.2	$0.3	$66.1	$590.4
Total	**$26.4**	**$384.5**	**$52.0**	**$41.0**	**$20.5**	**$12.3**	**$30.4**	**$18.8**	**$4.6**	**$590.4**	

Source: Chmura Economics & Analytics

The tax revenue generated from the Carmel Church Station project is significant for Caroline County. In fiscal year (FY) 2012, the total revenue for the county was $40.3 million.[10] The future annual tax revenue from CCS, discounted to FY2012, is estimated to be $35.1 million. This project can potentially increase the county revenue by 87% from its current level.

6.5. Estimating Resident Population of CCS

Based on the Census Bureau 2007-2011 estimates from the American Community Survey, the average household size in Caroline County is 2.68.[11] The average household size within CCS is expected to be smaller, as the county average includes a large number of single-family households. Since the majority of residential units in CCS are apartments, condos, and townhouses, the development is expected to attract empty-nesters or active retirees. Chmura assumes that single-family dwellings in CCS average 2.63 persons per household and the remaining residential units average 2.37 persons per household. The average household size in CCS is estimated to be 2.42. The total number of residents in CCS is estimated to be 20,918 when construction is complete.[12]

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[10] Source: Caroline County Virginia Fiscal Year 2013-2014 Adopted Budget. Available at: http://www.visitcaroline.com/adoptedfy14budget.pdf.

[11] Source: U.S. Census, http://factfinder2.census.gov/faces/nav/jsf/pages/community_facts.xhtml.

[12] Those are the same assumptions as the 2010 Chmura study.

The number of school-age children in CCS is expected to be smaller than in similar developments of single-family housing in other parts of the county. Studies have found that the number of school-age children in a Transit-Oriented Development (TOD) is smaller than other mixed-used developments. For example, a 2008 TOD study of 32 developments around the country found the average number of school-age children ranged from 0.00 to 0.12 per household. The developments in the referenced study averaged about 1.45 bedrooms per unit. For Carmel Church Station, the average number of bedrooms is between 2 and 3. Other studies on TOD suggest that the average number of school-age children is 0.06 per bedroom. Since the average residence size in CCS is expected to be between 2 and 3, the average number of school-age children per household in CCS is estimated to be 0.14. As a result, the number of school-age children in CCS is estimated to be 1,191.

6.6. Additional County Costs for CCS Residents and Workers

Ongoing operation of CCS, which includes retail and residential properties, are estimated to generate $66.3 million in annual tax revenue in 2035 (including sales, real estate, and personal property taxes) for the county. However, the county will incur additional costs to provide public safety services, water, and sewage services for residents and businesses located in CCS. Public education will also be provided for school-age children who move into the neighborhood.

Chmura utilizes a per-capita approach to estimate the additional county cost in all budget categories except education. Only expenditures from the general fund are counted as incremental costs to the county.

In a mixed-use project, both new employees and residents result in additional cost for the county. Chmura first estimates the county cost per employee and county cost per resident, excluding expenditures for education. To allocate county expenses among residents and employees, Chmura assumes that 100% of the following expenditures are for the residents: health and welfare; parks, recreation, and library; and community and economic development. For other expenditures, 16% is allocated for employees and 84% is allocated for residents. Based on the Fiscal Year (FY) 2013 adopted county budget (Table 6.4), excluding education, the annual county cost per employee is estimated to be $536.50 and the county cost per resident is estimated to be $669 according to the FY2013 cost structure for Caroline County.

Table 6.4: Caroline County Budget

	2013 Proposed Budget	% Designated for Employees	% Designated for Resident
General Government	$2,934,202	16%	84%
Judicial Administration	$1,225,479	16%	84%
Public Safety	$11,215,178	16%	84%
Public Works	$2,788,241	16%	84%
Health and Welfare	$621,984	0%	100%
Education	$0	0%	100%
Parks, Recreation & Library	$692,494	0%	100%
Community Development	$1,279,692	0%	100%
Non-departmental	$1,185,905	0%	100%
School Enrollment	4,340	County Cost Per Student	$2,584

Source: Caroline County

The total number of residents in this development is estimated to be 20,918. This project will also host 11,654 employees. Allowing a cost appreciation of 2.5% per year, the total county cost, excluding education, is estimated to be $35.5 million in 2035.

Based on the FY2013 proposed county budget, the net county cost for educating each student is calculated to be $2,584. CCS is estimated to house 1,191 school-age children. As a result, the county cost to educate these children is estimated to be $3.1 million, based on 2013 dollars. Allowing a cost appreciation of 2.5% per year, the total county cost, excluding education, is estimated to be $5.4 million in 2035.

Adding education and other incremental county costs together, the total cost for all county services provided to CCS residents and employees will be $40.8 million in 2035, after the project is complete.

6.7. Net Fiscal Impact for Caroline County

As operation begins for the residential and commercial properties, Caroline County will collect tax revenue from CCS. Meanwhile, it will also incur additional costs. The local fiscal impact is positive for all years. Notably, the fiscal impact will increase as more properties begin operating. The continuing operation of Carmel Church Station is expected to result in a net $25.3 million annual gain in revenue for Caroline County when the project is complete in 2035.

Table 6.5: County Fiscal Impact by Year (Annual $Million)

Year	County Revenue	County Cost	Net Revenue Per Year	Cumulative Net Revenue
2015	$2.4	$0.3	$2.2	$2.2
2016	$4.6	$1.5	$3.1	$5.3
2017	$6.7	$2.7	$3.9	$9.2
2018	$8.9	$4.1	$4.8	$14.0
2019	$11.2	$5.5	$5.7	$19.7
2020	$13.6	$6.9	$6.7	$26.4
2021	$16.1	$8.4	$7.6	$34.0
2022	$18.7	$10.0	$8.7	$42.7
2023	$21.5	$11.7	$9.8	$52.5
2024	$22.7	$13.4	$9.2	$61.7
2025	$24.3	$15.3	$9.0	$70.8
2026	$27.3	$17.2	$10.2	$80.9
2027	$30.5	$19.1	$11.4	$92.3
2028	$33.9	$21.2	$12.7	$105.0
2029	$37.4	$23.4	$14.0	$119.0
2030	$41.0	$25.7	$15.3	$134.3
2031	$44.8	$28.0	$16.8	$151.1
2032	$48.8	$30.5	$18.3	$169.4
2033	$52.9	$33.0	$19.8	$189.2
2034	$57.2	$35.7	$21.5	$210.7
2035	$66.1	$40.8	$25.3	$235.9

Source: Chmura Economics & Analytics

The cumulative net revenue for Caroline County in the twenty-year construction period is shown in Table 6.6. By the year 2035, this amount is estimated to be $235.9 million.

Table 6.6: County Fiscal Impact by Year (Cumulative $Million)

Year	County Revenue	County Cost	Net Revenue Per Year
2015	$2.4	$0.3	$2.2
2016	$7.0	$1.8	$5.3
2017	$13.7	$4.5	$9.2
2018	$22.6	$8.6	$14.0
2019	$33.8	$14.0	$19.7
2020	$47.3	$20.9	$26.4
2021	$63.4	$29.4	$34.0
2022	$82.1	$39.4	$42.7
2023	$103.6	$51.1	$52.5
2024	$126.2	$64.5	$61.7
2025	$150.5	$79.8	$70.8
2026	$177.9	$96.9	$80.9
2027	$208.4	$116.1	$92.3
2028	$242.3	$137.3	$105.0
2029	$279.7	$160.7	$119.0
2030	$320.7	$186.4	$134.3
2031	$365.5	$214.4	$151.1
2032	$414.2	$244.8	$169.4
2033	$467.1	$277.9	$189.2
2034	$524.3	$313.6	$210.7
2035	$590.4	$354.5	$235.9

Source: Chmura Economics & Analytics

7. Conclusion

The construction and ongoing operation of Carmel Church Station in Caroline County will inject millions of dollars into the local economy every year and provide jobs for workers in construction, retail, personal services, and professional services. The county will also reap considerable fiscal benefits from this project. It is estimated that when the project is complete, the county will receive tax benefits totaling $66.1 million per year, while paying $40.8 million to provide services for residents and businesses at Carmel Church Station. As a result, the CCS development will be fiscally positive for Caroline County not only upon completion, but also for each year of its development. The findings of this study are summarized in Table 7.1.

Table 7.1: Annual Economic and Fiscal Impact Summary

	Spending ($Million)		Employment		Fiscal Impact ($ Million)		
Year	Direct	Total Impact	Direct	Total	County Revenue	County Cost	Net Revenue
2015	$79.4	$93.1	526	616	$2.4	$0.3	$2.2
2016	$134.4	$163.2	1,109	1,304	$4.6	$1.5	$3.1
2017	$192.5	$237.2	1,692	1,992	$6.7	$2.7	$3.9
2018	$253.8	$315.3	2,275	2,680	$8.9	$4.1	$4.8
2019	$318.4	$397.6	2,857	3,368	$11.2	$5.5	$5.7
2020	$386.3	$484.3	3,440	4,056	$13.6	$6.9	$6.7
2021	$457.7	$575.3	4,023	4,744	$16.1	$8.4	$7.6
2022	$532.8	$671.0	4,605	5,432	$18.7	$10.0	$8.7
2023	$611.5	$771.4	5,188	6,121	$21.5	$11.7	$9.8
2024	$694.1	$876.8	5,771	6,809	$22.7	$13.4	$9.2
2025	$780.7	$987.2	6,354	7,497	$24.3	$15.3	$9.0
2026	$871.3	$1,102.8	6,936	8,185	$27.3	$17.2	$10.2
2027	$966.2	$1,223.8	7,519	8,873	$30.5	$19.1	$11.4
2028	$1,065.4	$1,350.4	8,102	9,561	$33.9	$21.2	$12.7
2029	$1,169.1	$1,482.7	8,684	10,249	$37.4	$23.4	$14.0
2030	$1,277.5	$1,620.9	9,267	10,937	$41.0	$25.7	$15.3
2031	$1,390.7	$1,765.3	9,850	11,625	$44.8	$28.0	$16.8
2032	$1,508.8	$1,916.0	10,433	12,314	$48.8	$30.5	$18.3
2033	$1,632.0	$2,073.2	11,015	13,002	$52.9	$33.0	$19.8
2034	$1,760.4	$2,237.1	11,598	13,690	$57.2	$35.7	$21.5
2035	$1,806.0	$2,308.9	11,654	13,762	$66.1	$40.8	$25.3
Total (2015-2035)	**$17,889.0**	**$22,653.5**			**$590.4**	**$354.5**	**$235.9**

Source: Chmura Economics & Analytics

The summary of the cumulative economic and fiscal impact is listed in Table 7.2.

Table 7.2: Cumulative Economic and Fiscal Impact Summary

	Spending ($Million)		Fiscal Impact ($ Million)		
Year	Direct	Total Impact	County Revenue	County Cost	Net Revenue
2015	$79.4	$93.1	$2.4	$0.3	$2.2
2016	$213.9	$256.2	$7.0	$1.8	$5.3
2017	$406.4	$493.5	$13.7	$4.5	$9.2
2018	$660.2	$808.8	$22.6	$8.6	$14.0
2019	$978.6	$1,206.4	$33.8	$14.0	$19.7
2020	$1,364.9	$1,690.7	$47.3	$20.9	$26.4
2021	$1,822.6	$2,266.0	$63.4	$29.4	$34.0
2022	$2,355.4	$2,937.1	$82.1	$39.4	$42.7
2023	$2,966.9	$3,708.5	$103.6	$51.1	$52.5
2024	$3,661.0	$4,585.3	$126.2	$64.5	$61.7
2025	$4,441.6	$5,572.5	$150.5	$79.8	$70.8
2026	$5,312.9	$6,675.3	$177.9	$96.9	$80.9
2027	$6,279.1	$7,899.1	$208.4	$116.1	$92.3
2028	$7,344.5	$9,249.4	$242.3	$137.3	$105.0
2029	$8,513.7	$10,732.1	$279.7	$160.7	$119.0
2030	$9,791.1	$12,353.0	$320.7	$186.4	$134.3
2031	$11,181.8	$14,118.3	$365.5	$214.4	$151.1
2032	$12,690.6	$16,034.3	$414.2	$244.8	$169.4
2033	$14,322.5	$18,107.5	$467.1	$277.9	$189.2
2034	$16,083.0	$20,344.6	$524.3	$313.6	$210.7
2035	$17,889.0	$22,653.5	$590.4	$354.5	$235.9

Employment number should not be presented as cumulative number

Source: Chmura Economics & Analytics

Appendix 1: Glossary

Transit-oriented Development (TOD)—a mixed-use residential or commercial area designed to maximize the access to public transportation. A TOD neighborhood typically has a center with a train station, metro station, or bus stop, surrounded by relatively high density development.

IMPLAN Professional—an economic impact assessment modeling system. It allows the user to build economic models to estimate the impacts of economic changes in states, counties, or communities. It was created in the 1970s by the Forestry Service and is widely used by economists to estimate the impact of specific events on the overall economy.

Input-Output Analysis—an examination of business-business and business-consumer economic relationships capturing all monetary transactions in a given period, allowing one to calculate the effects of a change in an economic activity on the entire economy (impact analysis).

Economic Impact—total economic activity generated by a project or operation. It is typically measured in economic spending and job creation. Economic impacts include direct, indirect, and induced impacts.

Fiscal Impact—the effect of a project or operation on the fiscal situations of state or local governments. It is typically measured in the tax revenues and government costs resulting from the project or operation.

Direct Impact—economic activity generated by a project or operation. For construction, this represents activity of the contractor; for operations, this represents activity by tenants of the property.

Overhead—construction inputs not provided by the contractor.

Indirect Impact—secondary economic activity that is generated by a project or operation. An example might be a new office building generating demand for parking garages.

Induced (Household) Impact—economic activity generated by household income resulting from direct and indirect impacts.

Multiplier—the cumulative impacts of a unit change in economic activity on the entire economy.

Appendix 2: Data Breakdown by Year

The yearly details of construction cost, construction impact, and tax revenue have been provided in the body of the report. The following three tables show the planned yearly breakdown of the construction schedule, the impact of CCS ongoing operation, and county cost.

Table A1: Detailed Construction Schedule (Annual)

Year	New Residential Unit	New Commercial Space (SF)	Cumulative Residential Unit	Cumulative Commercial Space SF)
2015	433	158,000	433	158,000
2016	433	158,000	866	316,000
2017	433	158,000	1,299	474,000
2018	433	158,000	1,732	632,000
2019	433	158,000	2,165	790,000
2020	433	158,000	2,598	948,000
2021	433	158,000	3,031	1,106,000
2022	433	158,000	3,464	1,264,000
2023	433	158,000	3,897	1,422,000
2024	433	158,000	4,330	1,580,000
2025	433	158,000	4,762	1,738,000
2026	433	158,000	5,195	1,896,000
2027	433	158,000	5,628	2,054,000
2028	433	158,000	6,061	2,212,000
2029	433	158,000	6,494	2,370,000
2030	433	158,000	6,927	2,528,000
2031	433	158,000	7,360	2,686,000
2032	433	158,000	7,793	2,844,000
2033	433	158,000	8,226	3,002,000
2034	433	158,000	8,659	3,160,000
2035	0	0	8,659	3,160,000

Source: Virginia Land Investments

Table A2: Detailed Table in Section 5.2-CCS Ongoing Operation (Annual Impact $Million)						
Year	Direct Impact of CCS Operation	Indirect/Induced Impact	Total Impact of Operation	Direct Employment of CCS	Indirect/Induced Employment Impact	Total Employment of CCS
2015	$0.0	$0.0	$0.0	0	0	0
2016	$53.0	$14.8	$67.8	583	105	688
2017	$109.1	$30.4	$139.5	1,165	211	1,376
2018	$168.3	$46.9	$215.2	1,748	316	2,064
2019	$230.8	$64.3	$295.0	2,331	422	2,752
2020	$296.5	$82.6	$379.1	2,914	527	3,441
2021	$365.7	$101.8	$467.6	3,496	632	4,129
2022	$438.5	$122.1	$560.6	4,079	738	4,817
2023	$514.9	$143.4	$658.3	4,662	843	5,505
2024	$595.1	$165.7	$760.8	5,244	949	6,193
2025	$679.2	$189.1	$868.3	5,827	1,054	6,881
2026	$767.4	$213.7	$981.0	6,410	1,159	7,569
2027	$859.6	$239.3	$1,099.0	6,993	1,265	8,257
2028	$956.2	$266.2	$1,222.5	7,575	1,370	8,946
2029	$1,057.3	$294.4	$1,351.6	8,158	1,476	9,634
2030	$1,162.9	$323.8	$1,486.6	8,741	1,581	10,322
2031	$1,273.2	$354.5	$1,627.7	9,324	1,686	11,010
2032	$1,388.4	$386.6	$1,774.9	9,906	1,792	11,698
2033	$1,508.6	$420.0	$1,928.6	10,489	1,897	12,386
2034	$1,634.0	$455.0	$2,089.0	11,072	2,003	13,074
2035	$1,806.0	$502.9	$2,308.9	11,654	2,108	13,762
Source: Chmura Economics & Analytics						

Table A3: Detailed Table in Section 5.2-CCS Ongoing Operation (Cumulative Impact, $Million)			
Year	Direct Impact of CCS Operation	Indirect/Induced Impact	Total Impact of Operation
2015	$0.0	$0.0	$0.0
2016	$53.0	$14.8	$67.8
2017	$162.2	$45.2	$207.3
2018	$330.5	$92.0	$422.5
2019	$561.3	$156.3	$717.6
2020	$857.8	$238.8	$1,096.7
2021	$1,223.6	$340.7	$1,564.2
2022	$1,662.1	$462.8	$2,124.8
2023	$2,177.0	$606.1	$2,783.1
2024	$2,772.1	$771.8	$3,543.9
2025	$3,451.3	$960.9	$4,412.3
2026	$4,218.7	$1,174.6	$5,393.3
2027	$5,078.3	$1,413.9	$6,492.3
2028	$6,034.6	$1,680.2	$7,714.7
2029	$7,091.8	$1,974.6	$9,066.4
2030	$8,254.7	$2,298.3	$10,553.0
2031	$9,527.8	$2,652.8	$12,180.6
2032	$10,916.2	$3,039.4	$13,955.6
2033	$12,424.8	$3,459.4	$15,884.2
2034	$14,058.8	$3,914.4	$17,973.2
2035	$15,864.9	$4,417.2	$20,282.1

Employment number should not be presented as cumulative number

Source: Chmura Economics & Analytics

Table A4: Detailed Table in Section 6.5-County Cost (Annual, $Million)						
Year	Number of Workers in CCS	Number of Residents CCS	Number of Students CCS	Employment/Resident Cost	Education Cost	Total County Cost
2015	526	0	0	$0.3	$0.0	$0.3
2016	1,109	1,046	60	$1.3	$0.2	$1.5
2017	1,692	2,092	119	$2.4	$0.3	$2.7
2018	2,275	3,138	179	$3.6	$0.5	$4.1
2019	2,857	4,184	238	$4.8	$0.7	$5.5
2020	3,440	5,229	298	$6.0	$0.9	$6.9
2021	4,023	6,275	357	$7.4	$1.1	$8.4
2022	4,605	7,321	417	$8.7	$1.3	$10.0
2023	5,188	8,367	476	$10.2	$1.5	$11.7
2024	5,771	9,413	536	$11.7	$1.7	$13.4
2025	6,354	10,459	595	$13.3	$2.0	$15.3
2026	6,936	11,505	655	$14.9	$2.2	$17.2
2027	7,519	12,551	714	$16.7	$2.5	$19.1
2028	8,102	13,596	774	$18.5	$2.7	$21.2
2029	8,684	14,642	833	$20.4	$3.0	$23.4
2030	9,267	15,688	893	$22.3	$3.3	$25.7
2031	9,850	16,734	952	$24.4	$3.6	$28.0
2032	10,433	17,780	1,012	$26.5	$4.0	$30.5
2033	11,015	18,826	1,072	$28.7	$4.3	$33.0
2034	11,598	19,872	1,131	$31.1	$4.7	$35.7
2035	11,654	20,918	1,191	$35.5	$5.4	$40.8

Source: Chmura Economics & Analytics

Table A5: Detailed Table in Section 6.5-County Cost (Cumulative $Million)			
Year	Employment/Resident Cost	Education Cost	Total County Cost
2015	$0.3	$0.0	$0.3
2016	$1.6	$0.2	$1.8
2017	$4.0	$0.5	$4.5
2018	$7.6	$1.0	$8.6
2019	$12.4	$1.7	$14.0
2020	$18.4	$2.5	$20.9
2021	$25.8	$3.6	$29.4
2022	$34.5	$4.9	$39.4
2023	$44.7	$6.4	$51.1
2024	$56.4	$8.1	$64.5
2025	$69.7	$10.1	$79.8
2026	$84.7	$12.3	$96.9
2027	$101.3	$14.8	$116.1
2028	$119.8	$17.5	$137.3
2029	$140.2	$20.5	$160.7
2030	$162.5	$23.9	$186.4
2031	$186.9	$27.5	$214.4
2032	$213.4	$31.5	$244.8
2033	$242.1	$35.8	$277.9
2034	$273.2	$40.4	$313.6
2035	$308.6	$45.8	$354.5

Employment, resident and student number should not be presented as cumulative numbers

Source: Chmura Economics & Analytics

Caroline County Rappahannock River Water Supply Project
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APPENDIX B

INDUSTRIAL WATER DEMAND EVALUATION REFERENCES

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Article

The Water Footprint of Data Centers

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Abstract: The internet and associated Information and Communications Technologies (ICT) are diffusing at an astounding pace. As data centers (DCs) proliferate to accommodate this rising demand, their environmental impacts grow too. While the energy efficiency of DCs has been researched extensively, their water footprint (WF) has so far received little to no attention. This article conducts a preliminary WF accounting for cooling and energy consumption in DCs. The WF of DCs is estimated to be between 1047 and 151,061 m^3/TJ. Outbound DC data traffic generates a WF of 1–205 liters per gigabyte (roughly equal to the WF of 1 kg of tomatos at the higher end). It is found that, typically, energy consumption constitues by far the greatest share of DC WF, but the level of uncertainty associated with the WF of different energy sources used by DCs makes a comprehensive assessment of DCs' water use efficiency very challenging. Much better understanding of DC WF is urgently needed if a meaningful evaluation of this rapidly spreading service technology is to be gleaned and response measures are to be put into effect.

Keywords: water footprint; data center; water; water-energy nexus; water use

1. Introduction

The world is experiencing an era of dramatic socio-technical change. The internet and associated information and communications technologies (ICT) have been diffusing at an astounding pace. In 2001, 8% of humanity was online, but by 2013, 38% were [1]. Not only is the Internet being adopted quickly, but global data traffic is rising at an exponential rate: 100 gigabytes/second (GB/s) in 2002,

2000 GB/s in 2007, and 28,875 GB/s in 2013 [2]. This change has been facilitated by a rapid deployment of data centers (DCs) to store, retrieve, and transmit information.

DCs have increased in number and sophistication, enabling the rapid adoption of Internet use and, more recently, the use of cloud-based services and mobile Internet access. DCs are amongst the most rapidly-growing electricity consumers. The installed base of servers worldwide has grown from just under 5 million in 1996, to 30 million in 2007 [3]. In the US, between 2013 and 2020 DC energy use is predicted to rise by 53% to 139 billion kilowatt-hours (kWh) [4].

Simultaneous to this information revolution, the world is also experiencing rapidly-rising environmental stress. Alongside the implications of climate change, many freshwater and other natural systems are losing the ability to maintain their ecological functions while simultaneously being compelled to service humanity's growing needs. Such stresses are imposing new constraints on both public and private sector decision-making. These systems and the human systems for controling energy and water are highly inter-linked and exhibit reinforcing feedbacks. Using more energy increases the use of water, which in turn increases energy use even further [5]. Global energy use is set to rise by 35%–40% [6,7] and electricity by 70% by 2035 [8]. As a result, global water withdrawals for thermal electricity are set to rise by 40% [8] and water consumption by more than 100% by 2050 [9]. Globally, the energy sector will likely see an increase in the annual water footprint (WF) between 37% and 66% by 2035 with WF per unit energy produced rising between 5% and 10% [10]. In the United States and Europe, 50% and 43% of freshwater withdrawals respectively are used for cooling purposes in electricity generation [8]. Such rising demand means that energy and water consumers are in tight competition for resources. The spread of DCs and their growing energy use compete alongside the established players.

Worldwide, DCs accounted for 1.1%–1.5% of all electricity use in 2010 [11]. ICT end-user-equipment and infrastructure accounted for 7.7% of the total EU-27 electricity use in 2011 [12]. DCs and telecommunication networks themselves accounted for 1.9% of electricity consumption, but this is set to rise 35% between 2011 and 2020, with the the ICT sector serving as the greatest driver for electricity consumption growth [12]. This rise in DC electricity consumption, coupled with concerns about energy systems' greenhouse gas emissions, has promoted interest in their energy efficiency. DCs can reduce energy use in the broader economy enough to offset their own energy use [13]. The application of ICT-based efficiency applications in other sectors, as well as the dematerialization of economic activity through the application of ICT, will deliver reductions in the EU's net energy consumption even under business-as-usual scenarios without a push for ICT-based efficiency [14]. Without such a push, however, ICT may not have a positive effect on net CO_2 emissions [14].

Reviewing the literature on DC energy efficiency, Koomey [11] finds the rapid diffusion of volume servers to be the main driver of DC electricity use. He argues that while large DCs can reap the greatest efficiencies, measures applied to the servers themselves have the greatest efficiency improvement potential because most DCs are still small and medium sized. Additionally, the growth rate of DC electricity use had slowed to 56% in the 2005–2010 period, relative to the 2000–2005 period which saw a doubling [11]. Koomey finds that this drop was mainly due to lower-than-expected installed server base as opposed to energy efficiency improvements. These points highlight the role of server manufacturers and other suppliers in reducing DC environmental footprints on top of innovations by DC operators themselves. Studies of particular interest in this area are the lifecycle assessments of data

centres, which broadly indicate that electricity production forms the major part of DC impacts [15,16]. A series of studies also consider the cooling technologies applied and their impacts [17–19].

In the context of reducing DC carbon emissions, Masanet *et al.* [20] developed a formal model for determining DC electricity demand. They identified characteristics of low-carbon DCs, providing insight into the factors driving DC carbon performance which revolve mainly around energy efficiency. This is one among several publications dealing with the carbon emissions or renewables in relation to DCs. In particular, the literature is rich with new algorithms for optimizing workload distribution among data centres [21–29] and server electricity demand optimization [30,31]. Some publications have also highlighted the role of geographic location or siting in carbon emissions and energy use optimization [32–34].

Carbon emissions are only one form of environmental impact. Ignoring the impacts of DCs on water resources could lead to the partial displacement of impacts from the climate to water. Such a dynamic can take place when shifting from non-renewable to renewable energy sources [35]. Evaluating different energy sources along multiple criteria of environmental footprint, Hadian and Madani [35] find that even if an energy technology has a low carbon footprint, it cannot be considered "green" or "sustainable" unless its other footprints (*i.e.*, water and land use footprints), together with cost, compare favourably to other energy technologies. Assessing the sustainability of DCs should take a similar approach. Namely, evaluating multiple criteria, in order to give a better understanding of the trade-offs involved with siting and cooling technology. Without a comprehensive assessment of the water impacts of energy soruces, our understanding of the resource use efficiency of DCs remains incomplete.

Even in terms of energy efficiency, much work remains to be done. The EU Commission's Joint Research Center reported that within the EU, DCs are subject to only six "Green ICT" measures (one mandatory) which they see as inadequate [12]. 31% of data-center-related companies report on their water usage while 21% report on CO_2 emissions [36]. Global Reporting Initiative data indicate that in the computer, as well as in the telecommunications, sector 64% report on water withdrawals by source [37]. Very few however report on total water discharge, recycling rates, waters affected by discharge, runoff or withdrawal, and associated biodiversity impacts [37]. Reporting will have to increase and be comminucated more widely for a better understanding of not just DC energy efficiency, but their overall environmental footprint and sustainability.

In terms of the water efficiency of DCs, very little has been published. Even the extremely detailed handbooks on cooling technologies published by the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE), give very little guidance on water efficiency in DC cooling systems. To the authors' knowledge, the Hewlett-Packard's (HP) Sustainable IT Ecosystem Laboratory was the first to publish work dealing directly with DCs' impacts on water [38]. They consider the infrastructure, in particular the cooling systems' water use, and opportunities for water savings through building design and different cooling solutions. They find that a 1 megawatt (MW) DC can consume 18,000 gallons (68 m^3) of water a day for cooling and provide guidance on managing water-energy trade-offs. They also consider opportunities for electricity use reductions, focusing on the energy use of direct and indirect water usage [39]. In Bash *et al.* [40], as part of the ongoing work at HP, this method was incorporated into a broader "cloud sustainability dashboard". Frachtenberg [41], building on previous work in thermal design and high-efficiency DCs, published on the engineering principles for reducing environmental footprint deployed in the Facebook's Open Compute Project. Ren [42], building on the vast body of literature on load distribution algorithms, developed a "software approach" which

highlighted non-structural (soft) engineering solutions for water use optimization. This came in the form of an algorithm distributing workload between DCs that minimizes electricity costs, maximizes renewables use, and maximizes water efficiency across different times and locations. The team at HP have also developed methods to combine supply- and demand-side optimization to address energy use, carbon emissions, and water consumption [43]. The Green Grid has published on the topic of water use in DCs and, of greatest import, has developed the Water Use Effectiveness (WUE_{source}) metric which takes the indirect form of water use arising from electricity use into account [44]. This will be explored in more detail alongside water footprint below.

To be able to understand the water impacts of DCs, consistent water metrics should be applied, otherwise comparisons are invalid [5]. While water metrics such as withdrawal, consumption, and footprint are commonly used for evaluating the impacts of different processes on water resources, the literature has failed to use them consistently, making the resulting values incomparable in many cases [5]. Water use is a generic term referring to the use of water resources in human processes. It can be quantified by the following metrics. "Water withdrawal" measures the total freshwater input into a process. "Water consumption" measures the volume of total water input that has become unavailable for reuse due to evaporative losses, incorporation into a product, or transfer to another catchment. Water withdrawals can affect the environment through reduced water availability but this is not necessarily the case, particularly when good quality water is returned to the environment quickly. Likewise, water consumption implies reduced water availability but does not capture the environmental impact of polluted (but not consumed) water being returned to the environment. To overcome these issues Water Footprint (WF) [45] can be used as a comprehensive metric [5,10].

WF measures the quantity of freshwater consumed and polluted and is divided into blue, green, and grey water footprint [41]. Blue footprint covers the volume of freshwater (surface or groundwater) consumed. Green footprint covers the volume of rainwater consumed—rainwater being water that does not become run-off at the field level. The grey footprint is an indicator of water pollution and is defined "as the volume of freshwater that is required to assimilate the load of pollutants given natural background concentrations and existing ambient water quality standards" [46]. Ideally, WF also covers the full lifecycle of a process capturing both the direct (on-site) and indirect form of WF [46]. As such, WF offers the most comprehensive scoping of the measurement of impacts on water resources out of the metrics considered, as well as avoiding the problems associated with only considering water withdrawals or consumption. However, WF has not yet been used for measuring the water impacts of DCs. Thus, the objective of this article is to address this gap in the literature.

WF has a well-systematized measurement methodology which includes water used for energy use on top of on-site water use, and is broadly accepted as the standard for water use accounting. This makes it a valuable metric for assessing trade-offs in the water use of different cooling systems, their performance in different climatic conditions, and the indirect WF of the energy sources which are here taken together to define the WF of DCs. Equipped with this understanding further research can begin compiling comparable data and benchmarks applicable to efforts at minimizing the environmental footprint of our information-heavy societies.

Below, the application of WF in the water use component of the WUE will be developed and the question of the units of DC WF will be discussed. This will be followed by a review of DC structure and the likely sources of WF for each component. Subsequently, generic issues in WF of electricity and WF

of cooling technologies are considered, taking particular notice of WF uncertainties and associated trade-offs. Next, using reported energy source values, the WF range for Apple's DCs is calculated. Then, the uncertainties in the WF of energy will be highlighted. These uncertainties make decisions on the cooling technology difficult in the context of a dataset on different cooling technologies for a DC in Phoenix, Arizona. As a penultimate step, taking the above-mentioned considerations into account, a rough calculation for the global average WUE of DCs as well as a WF per outbound GB is performed. Finally, caveats, trade-off management principles, and potential corporate and governmental policy responses to deliver DC WF sustainability innovations are discussed. Although sources of blue, green, and grey WF throughout the lifecycle and supply chain of a DC will be identified, this "first-step" study into the WF of DCs will largely be limited to direct consumptive blue WF and indirect consumptive blue WF because of data and comparability constraints.

2. Water Footprint for Measuring Water Use Efficiency

Emerging as the industry standard in measuring DC water use is Water Use Effectiveness (WUE), as developed by the Green Grid [44]. It is defined as the total facility water use divided by the energy going solely to the IT equipment. A higher WUE indicates a more water-intensive DC (IT equipment energy is a proxy measure for DCs' product. More detail on why this is the case is given later in this section).

$$WUE = \frac{Total\ Facility\ Water\ Use}{IT\ Equipment\ Energy} \quad (1)$$

While WUE differs somewhat from the WF, WF can be used to inform the WUEs Total Facility Water Use. Using WF as a metric for water use is helpful, particularly for avoiding the limitations of "withdrawals" or "consumption" as metrics. The Green Grid guidance on measuring total facility water use in WUE calls for the inclusion of consumptive water use in humidification, cooling, and in the production of energy. WF can account for all of these while opening the possibility for a broader WF account which can include green and grey WF along the full life-cycle and supply chain. Unlike WF, WUE, explicitly, does not take into account the full lifecycle [44] but does come in a second form, which captures indirect water use:

$$WUE_{source} = \frac{Total\ Facility\ Water\ Use + Water\ use\ of\ source\ energy}{IT\ Equipment\ Energy} \quad (2)$$

The reason for truncating the supply chain in the WUE to just energy is two-fold: firstly, servers have extremely complex supply chains with producers rarely, if ever, measuring and disclosing water use. This makes it prohibitiveley difficult to find accurate and not-double-counted values for server components. Secondly, the supply chain usually encompasses the greatest part of the WF of any process [46]. Subsequently, indirect WF is important to consider since often simple adjustments in the supply chain can dramatically reduce WF. However, including the full supply chain, and not just the WF of source energy, would grow DC's WF enormously and subsequently the differences in the design and operation of the DC would be, proportionally, much smaller as opposed to differences in supply [44]. Full life-cycle and supply chain WF helpfully indicate how to supply DC water conscientiously.

In respect of the operation of DCs, a narrowed scope can however be more helpful. The point here, as with the units of measurement discussed below, is that different measures provide different

information useful in different contexts. Confusion between these measures should be avoided by clear scoping. This study will focus on direct WF in cooling technology and indirect WF from energy use, in order to be applicable to WUE while indicating how WF could expand the remit of WUE.

WF is always expressed as a volume of water over some unit, such as number of products, quantity of energy, or time [46]. The question of which units will be used to express the WF of DCs is not immediately answerable since the product of DCs is debatable. Arguably, DCs offer information and communication services, as evidenced by Service Level Agreements or Quality of Service agreements (contracts many data centres sign with customers) [47–50].

This topic has been helpfully addressed by an international taskforce dealing with this question in the context of energy and greenhouse gas efficiency [51]. In defining DC energy productivity it recommends following the example set by the Green Grid: "useful work that a DC produces based on the amount of energy it consumes. 'Useful work' is a sum of tasks that are completed in a specified period of time, where each task is weighted based on a specified relative value" [51]. While the taskforce recommends that DCs self-assess what counts as useful work and what the relative weightings of different tasks are, it also provides guidance on proxy measures. Three proxy measures identified by the taskforce as particularly promising are:

- *Network traffic (bits) per kilowatt-hour:* Outbound bits/DC energy use
- *Weighted CPU utilization*: (SPECint_rate × CPU utilization)/DC energy use
- *IT equipment energy efficiency (ITEE) × IT equipment utilization (ITEU)*: (Benchmark performance/rated power) × (IT energy/IT rated energy) [52]

where network traffic per kilowatt-hour measures how many bits (binary digits) are transmitted out of the data centre per kilowatt-hour of energy used by the whole DC.

Weighted CPU utilization gives another measure of the effectiveness of the IT equipment, but is based on a test of certain parts of the IT equipment as maintained by the Standard Performance Evaluation Corporation (SPEC). A set of programs are run on the servers and the speed at which they are run is measured. This value measures the amount of useful work that *can* be done by the IT equipment. Multiplied by the ratio of IT equipment actually used, this gives a sense of how much useful work *is* being done.

The ITEE × ITEU measures the IT equipment's energy efficiency multiplied by the utilization of the IT equipment. Rated power and rated energy simply mean the capacity of the equipment as given by the producer on the equipment specification.

The metrics from the international taskforce mentioned above, could be converted into use for a WF. In such a case WF could be expressed as:

$$DCWF_{bits} = \frac{Volume\ of\ Water}{Outbound\ Bits} \tag{3}$$

$$DCWF_{SPECint_rate} = \frac{Volume\ of\ Water}{\text{SPECint_rate} \times \text{CPU utilization}} \tag{4}$$

The ITEE × ITEU could not be converted in the same way because IT equipment is not rated for water use as the IT equipment itself does not directly use water. While future studies could use these units, they do entail serious challenges as values for bits and SPECint_rate are rarely readily available.

Therefore, a simpler, less data-limited, method for approximating the useful work done in a DC is power use effectiveness (PUE), as developed by the Green Grid [44]. In this metric, work done is represented simply by the electricity going to the IT equipment. This metric is much more readily available and more useful if one does not want to exhaustively determine how efficient the IT equipment and software itself is but rather how efficient the surrounding DC infrastructure is; including heating, ventilation, and air conditioning (HVAC). Here DC operators have more control and can deliver environmental innovation more readily.

Clearly, the question of the denominator of the WF is a challenging one. As with WF scoping above, it is wise to deploy different measures for different research objectives. Overall, however, it can be seen that WF can be used easily in WUE as a good measure of total facility water use. Clearly, WF is also compatible with IT equipment energy use as a proxy for useful work done. Later, values for DC WF will be expressed in the above formulae (*i.e.*, WF and WUE) and units (*i.e.*, per IT energy used and per outbound bits).

3. Data Center Structure and Water Footprint of Its Components

Figure 1 depicts a schematic of the components of a typical DC. It highlights some of the key drivers of DC WF which are elaborated below: IT equipment; heating, ventilation, and air conditioning (HVAC) systems; climatic conditions (psychrometrics); uninterruptible power supply equipment; and the energy source portfolio. After a brief overview of each component's function and typical mechanism for generating water footprint, a more detailed review of uncertainties involved in the WF of energy use and HVAC systems follows.

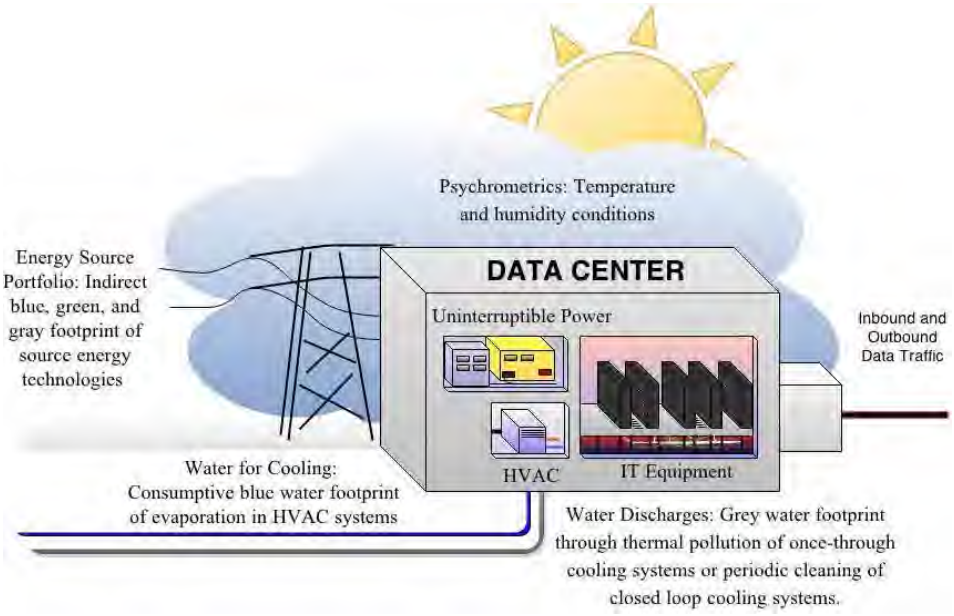


Figure 1. DC components and DC WF drivers: HVAC, Climate, and Energy Sources.

3.1. IT Equipment and Uniterruptible Power Supply

IT equipment covers a DC's servers and communications equipment. Servers store and process data while the communications equipment sends and receives it. This component is "mission-critical", meaning that proper functioning must be absolutely guaranteed. A serious failure of the IT equipment

could entirely halt businesses reliant on data traffic (e.g., a bank that could no longer process financial transactions). Such a failure would most likely mean that the data centre has violated its contracts with its customers and, hence, would be obliged to pay substantial penalties. DC operators seeking to deliver environmental-friendly innovations are then looking for ways to reduce the environmental footprint without placing continued service provision at risk.

IT equipment does not directly consume water. It does, however, directly consume electricity. In order to guarantee the continued supply of electricity (even in case of grid supply failure), DCs are typically equipped with uninterruptible power supply equipment. This includes a switch which immediately turns on backup generators. Uninterruptible power supply is also responsible for transforming grid electricity to a form applicable in the DC. Importantly, power conversion efficiency improvements can play an important part of reducing electricity use and, hence, indirect WF.

During operation, IT equipment releases a lot of waste heat which, if not removed, will accumulate and cause the IT equipment to overheat and break down. The high cooling load for a DC can be between five and 10 times that of a office or a meeting room [52]. Greenberg *et al.*'s study of energy use in 22 DCs shows great variation in DC energy use going to HVAC, servers, and other functions, with IT equipment typically accounting for the largest share of energy use. HVAC is in second place, followed by conversion efficiency in power supply [53]. No definitive values exist due to the lack of measurement and reporting but a typical ratio of total facility energy use over IT equipment energy use is around 2 [54]. This means that IT equipment typically uses half of the energy going to the facility as a whole; the other half going to HVAC, power conversion losses, lighting, and other uses. As mentioned above, larger facilities often have better ratios.

3.2. Direct WF—HVAC

HVAC includes all the technologies monitoring and maintaining temperature and humidity within the DC at levels deemed appropriate to the functioning of the IT equipment. Temperature affects the efficiency of IT equipment components and can cause overheating. Low humidity can cause static buildup and sparks, while high humidity can cause dew to collect on and disrupt circuits. ASHRAE gives the following guidance on appropriate temperature and humidity (psychrometric conditions) for IT equipment: "a temperature range of 18–27 °C (64–81 °F), a dew point range of 5–15 °C (41–59 °F), and a maximum relative humidity of 60% for DC environments" [55]. ASHRAE also provides looser, "allowable" ranges and is encouraging DC operators to consider operating in less stringent conditions to save energy and reduce environmental footprints. This is one of the more convenient innovations to implement for DC operators seeking to reduce environmental footprints.

In order to achieve these conditions HVAC systems use many varied components but typically they employ a vapor-compression cycle and have three key components: the chiller, coolant loop (cycling water or a refrigerant), and airflow control (how cool air is distributed to the IT equipment) [44,55,56]. The vapor-compression cycle uses the thermal dynamics of coolant vaporization to extract heat from one place and compression to release it in another. When pressurizing the coolant, it releases heat and when vaporizing, it absorbs it.

The chiller includes the main components used to facilitate this process. Compressors pressurise the coolant. Condensers remove the heat the coolant releases using water and/or ambient air. Flow control

mechanisms ensure the correct pressures in different parts of the cycle. In evaporators the coolant vaporization absorbs heat from air which is then distributed to the IT equipment by the airflow control (the fans, ducts, false-floor, convection currents in the room with the IT equipment, or otherwise). Thereby, the IT equipment is kept from overheating [56].

As mentioned, condensers can be cooled by air or water. This distinction is important to consider in the context of WF. Broadly speaking, water-cooled condensers are less energy intensive as water can cool the condensers more effectively than air [57,58]. For example, a Pacific Gas and Electric (PG&E) Co. study found that in a typical 100,000 m^2 building in California, air-cooled condensers used 440,000 kWh while water-cooled condensers used only 190,000 kWh per year [59]. The question of whether air- or water-cooled condensers have a lower water use is addressed in more detail in [59] and in the example from Phoenix towards the end of this paper.

In dry conditions, HVAC systems can also employ evaporative cooling, where raising the humidity of air lowers the temperature. Although, in general, there are evaporative losses whenever water is used (e.g., water-cooled condensers evaporate some of the coolant in cooling towers to improve cooling), evaporative cooling is a key driver of blue WF. HVAC systems also generate grey WF through water pollution via expelling hot water to the environment if they are once-through cooling systems without a cooling pond and through the discharges of dirty water for cleaning and replacing water in the coolant loop. For more detail on the chemical use in HVAC systems refer to [57] whose values could be used to determine grey WF. As mentioned in the introduction, grey WF is not addressed here beyond indicating the need to study it further. Finally, but very importantly, HVAC systems also generate indirect WF through the electricity they consume for compressors, sensors, and control systems.

3.3. Psychrometrics: Temperature and Humidity

Psychrometrics examines the physical and thermal characteristics of mixtures of gas and vapor. In the context of DCs it is useful in managing the relationships between air temperature and humidity. A greater deviation in the DC's environment from the standards necessary for the IT equipment means that the HVAC has more temperature and humidity control to do. That greater workload generates a greater WF through the evaporation of water and/or the consumption of electricity (indirect WF). ASHRAE [56] offers detailed understandings of the relation between climate and cooling and the Green Grid provides geographic maps of where free cooling and air-side economization can serve as an effective cooling option [57]. In air-side economization, the returning, warm coolant is first passed through a condenser exposed to outside air before being cooled further. In free cooling, outside air is filtered and directly used to cool the IT equipment. This is already prevalent in approximately 50% of DCs in the United States [60]. While the Green Grid's maps are a useful tool, they should also be subject to the uncertainties arising from climate change. This is important particularly when siting and designing DCs which are expected to be operational for many decades.

Metzger *et al.* [61] conduct a bin analysis of four cooling technologies (individually and in combination with others) by their climate appropriateness and energy use reduction as compared to just a typical direct exapansion (DX) air-conditioning. While that study focused on energy reductions as indicators of efficiency, varying WF between these technological options should also be considered. The uncertainties involved in this are discussed in an example later in this paper.

The technology options in the Metzger *et al*. study are: (1) direct expansion (DX): typically an off-the-shelf Computer Room Air Conditioning (CRAC) unit; (2) air-side economizer: outside air is used for cooling after treatment for air quality and humidity; (3) direct evaporative cooling: evaporation into air lowers its temperature; and (4) multistage indirect evaporative cooling: two cooling systems are connected to deliver cooling and humidity control. Seven combinations of these technologies are identified, defining seven cooling strategies. In Figure 2, the zones identifying under which temperature and humidity each cooling strategy is effective are mapped onto the psychrometric chart. In the middle of the chart is the ASHRAE recommended environment for IT equipment.

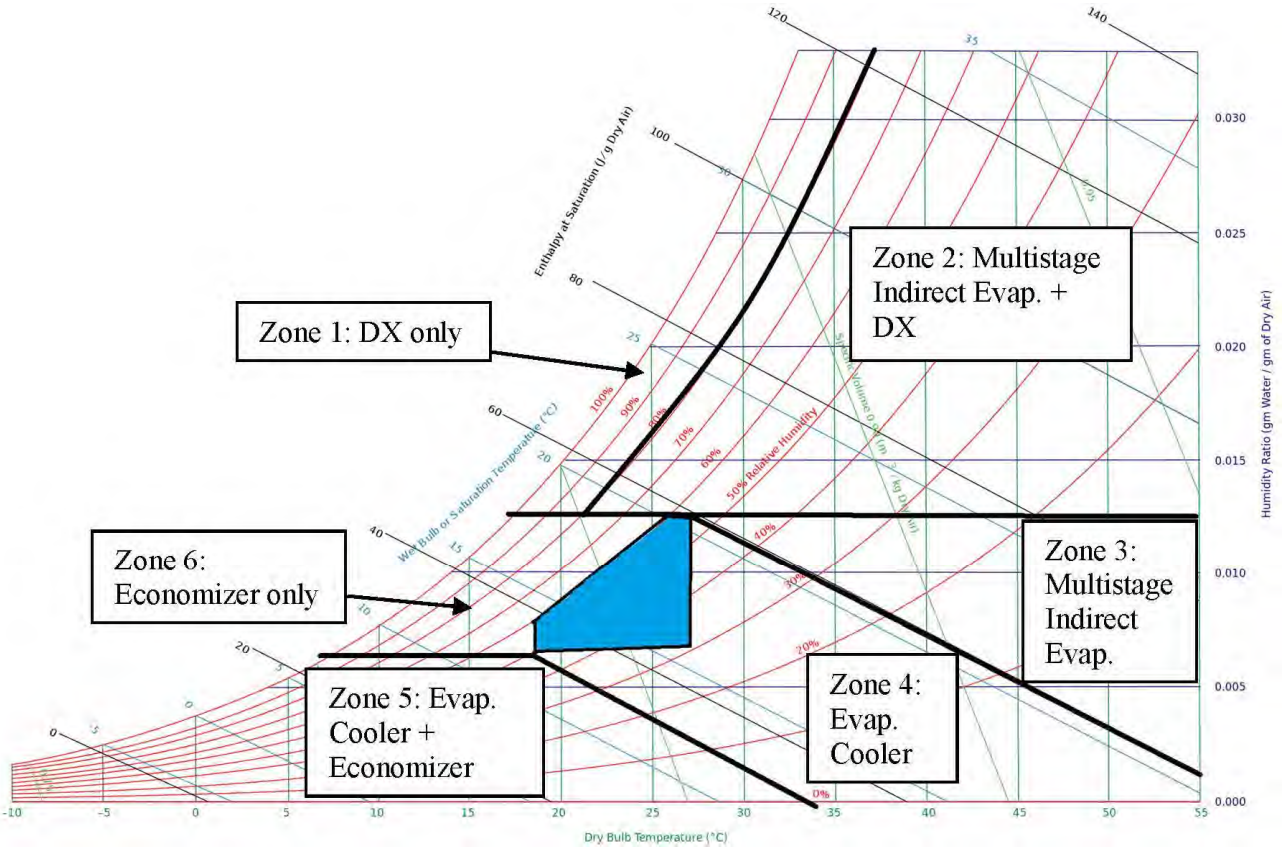


Figure 2. Psychrometric chart displaying bin zones for the recommended envelope and alternative cooling strategies (after [61]). The blue zone represents the ASHRAE "recommended" temperature and humidity for IT equipment. The psychrometric chart is taken from [62].

For environments with >80% relative humidity and >15 °C dewpoint, DX is still the best option. With >15 °C dewpoint and <80% relative humidity, adding multistage indirect evaporation can reduce energy consumption. In environments with the ASHRAE recommended absolute humidity but below recommended temperature, air-side economizers can deliver the required cooling by themselves with great reductions in energy use. At a lower humidity ratio, an evaporative cooler should be used in combination with air economizers. For 5.5–15 °C wet-bulb temperature at lower than recommended relative humidity the evaporative cooler can deliver recommended air conditioning alone by the cooling effect of directly evaporating water into the air. Finally for >15 °C wet-bulb temperature and <15 °C

dew point the multistage indirect evaporation alone will reduce energy use because it can reduce temperature without changing the humidity.

3.4. Indirect WF—Energy Source

Energy consumed by DCs during operation, is a key driver of DC WF. Determining the WF of the energy consumed by DCs (WF_{source}) can be done by determining the WF of each energy source in the electricity generation portfolio and then calculating a portfolio-share weighted average to get a a WF per unit of electricity supplied. The WF_{source} is then multiplied by the amount of energy used to get the WF of energy used.

$$WF_{Source} = \sum_{i=1}^{n} (WFE_i \times TS_i) \quad (5)$$

where n is the number of energy sources in the energy supply portfiolio, WFE_i is WF per unit of energy produced by energy technology i, and TS_i is the percentage share of energy technology i in the total electricity supplied.

The energy source portfolio therefore determines the WF for the electricity used in the DC. This means that to reduce WF, DC can look for energy sources with a low WF as well as improving energy use efficiency, which reduces the amount of energy used in a DC and thereby also the indirect WF.

The most common electrical components of a DC and their relation to energy efficiency are reviewed in depth in Report to Congress on Server and DC Energy Efficiency [13] among many other publications dealing with this [13,44,53,63]. According to Miller [64], typical measures for reducing electricity are to: reduce power conversion efficiency losses, optimize airflow, economize on outside air, relax temperature and humidity standards, and centralize controls and sensors. Further energy efficiency measures for DCs are given by the Green Grid [57], US Department of Energy [65], and Environmental Protection Agency [66].

Regarding green WF, DCs typically do not interact with rainwater (green WF). That being said, it is worth briefly noting that large facilities may have substantial outdoor areas on campus which may generate green WF. Apple reports on changes in landscaping at one of their campuses which reduces green WF [67]. While the method for calculating the water footprint of DC energy source is relatively simple, large uncertainties remain in practice which are addressed in the section below.

4. Uncertainty Ranges in Determining the Water Footprint of Source Energy

Figure 3 depicts WF per unit of electricity output as sorted by the range minimum [68]. The values reflect consumptive blue WF for fuel supply, construction, and operation.

Wind is clearly the least water intensive, and firewood and hydropower the most intensive. However, large ranges (Figure 3) in most other technologies indicate large uncertainty and variability. Therefore, understanding the particularities of each case of a technology is required for accurate WFE accounting. For example, all technologies except wind, photovoltaic, and firewood include 1000 $m^3 \cdot TJ_e^{-1}$ as a value in the range. It is likely that method of operation, its efficiency, location, regulatory and psychrometric setting, or other factors could at times overtake the energy technology itself as dominant drivers of WFE. The overlap between nuclear and many fossil fuels could be explained by the common reliance on steam

turbines and associated uses of water. It is then possible that the steam turbine system's WF is a greater driver of the energy generation technologies WF than the feedstock (e.g., coal or nuclear). Some further division and granular analysis of the dominant technologies employed per electricity type and their accompanying WFs would be helpful. It is also important to note that these values are the most up to date, but do not reflect the full WF account, which would also include the green and grey WF. Slightly older values for the full water footprint of energy technologies can be found in [10].

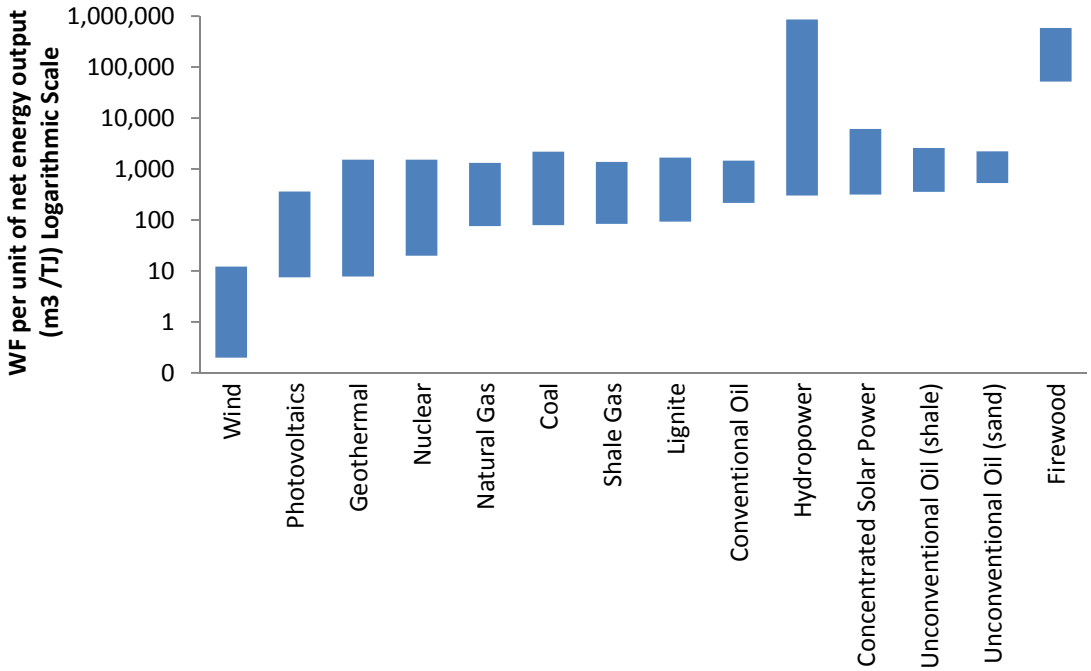


Figure 3. The consumptive WF per unit of electricity output for different energy sources for the total production chain of electricity (after [68]).

That being said, WF must be assigned to each generation technology, but it is important that as much detail as possible is given for the particular energy supply facility. Without such specific information, uncertainty will propagate through the WF assessment making it more difficult to decide on optimal technology choices. To highlight this, the above ranges will be carried into the subsequent analyses, showing how these uncertainties make decision between WF reduction strategies difficult.

Other than for backup, most DC operators will not invest in their own electricity generation technology and will, therefore, simply purchase electricity from the grid. Figure 4 shows the estimated WF of electricity in a few sample regions around the world. The ranges have been calculated based on the technological mix in each country or area [6,69–71] with respect to the recent energy WF estimations of Mekonnen *et al*. [68] using the the WF_{source} equation. The figure therefore shows the WF of an average unit of electricity output to the grids in those areas. The WF of electricity varies by the mix of more and less water intensive electricity generation technologies and their associated uncertainty ranges. In particular, low-share, high-WF sources like biofuels and hydroenergy can drive WF_{source} disproportionately.

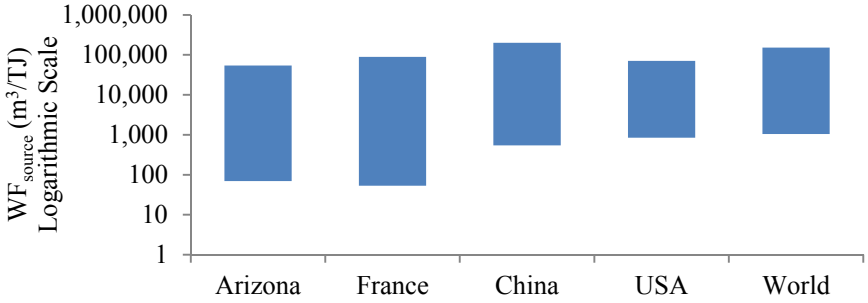


Figure 4. Consumptive WF per unit of energy in different locations.

This relationship comes through particularly with the difference between the WF_{source} of France and the US. France relies much more on nuclear than the US. In the US, fossil fuels account for the majority of energy production. As seen above, nuclear's range minimum is clearly below that of the fossil fuels. This allows France to enjoy a lower WF_{source} range minimum. However, France's range maximum is well above that of the US. This could not be explained by the large share of nuclear, since nuclear's range maximum is similar to that of the fossil fuels. France has a substantially larger share of energy coming from hydro than the US does. This drives France's WF_{source} maximum well above that of the US.

Apple Inc., in operating its large DCs, provides an interesting case of DC operators adopting environmental innovations because it claims to be ambitiously pursuing environmental sustainability, including a zero carbon emissions policy, clean water programme, and others [69]. Apple has been building its own electricity generation capacities and reports a successful decarbonization of its DCs [69]. It also reports that the introduction of a new water reusing cooling system at the Maiden, North Carolina DC has reduced water consumption by 20%. Simultaneously, however, Apple reports it has seen a rise in water consumption in its DCs as a result of growing server room cooling load.

Figure 5 shows the calculated WF_{source} associated with Apple's DCs based on their energy mixes as shown in Table 1. Apple facilities in Newark, Prineville, and Reno have a relatively low WF. The Newark facility still purchases all of its electricity from the grid. This is done through California's Direct Access Program where consumers can buy renewable energy directly from generators. Although this means Apple can buy electricity to meet its zero carbon emissions policy, the exact electricity supply portfolio is not clear and so neither is the range of the WF. As a proxy, California's renewables mix was used here to give a rough indication of what the values could be in this case [72]. The USA's WF_{source} is replicated here to give a benchmark.

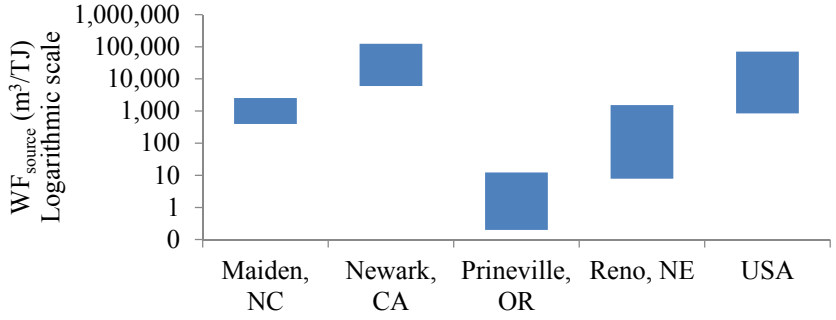


Figure 5. WF_{source} for Apple's DCs. Values are per unit of electricity as opposed to the total WF of electricity consumed annually.

Table 1. Apple Data Centers' energy sources. Values are based on Apple's 2014 Environmental Footprint Report [67].

Location	Electricity (TJ/Year)	Biogas (from Landfill)	Solar	Grid Electricity	Wind	Geothermal
Maiden, North Carolina	576	47% *	53%			
Newark, California	443			100% **		
Prineville, Oregon	65				100%	
Reno, Nevada	11					100%

* WF of Biogas from landfill: 833.3–4166.6 m^3/TJ [73], ** Apple reports that it purchases all electricity from renewable energy generators under California's Direct Access Program.

In pursuing its zero carbon strategy and investing in its own generating capacity, Apple has reaped the co-benefit of reduced WF. This however, is not the case in Newark, if its electricity supply portfolio is the same as California's renewables mix which has a substantial bioenergy share (11.5%). Therefore, the WF associated with that electricity comes out higher than the that for the US weighted average.

While the range for the Newark facility is already large, it does not include the uncertainties associated with the share of renewables in the energy mix. Retrospectively it is possible to fix the portfolio shares but these are not definite indicators of the future mix as it is subject to variablity in solar and wind energy supply, as well as the regulatory and policy uncertainty surrounding renewable energy.

To ascertain the total WF of electricity for each facility, the above WF of energy values would have to be multiplied by the amount of electricity each facility uses. This would still not yield the total WF of DC as the direct WF of each facility (particularly the WF of HVAC) would still have to be added. Uncertainties in that stage of the WF account are considered below for a DC in Phoenix, Arizona as an example.

4.1. Uncertain WFs of HVAC Systems

As discussed throughout, in order to understand the WF of DCs both direct and indirect WF should be taken into account. Thus, in addition to the indirect WF of DCs through energy use, one needs to quanitify the WF of different HVAC systems. This can be done by reviewing different HVAC systems' energy use and WF in a given climate.

Figure 6 shows four different options for a DC cooling unit with a capacity of 36,000 cubic feet per minute (61,164 m^3/min) operating on a DC in Phoenix, Arizona as compared by their direct and indirect WF. All options use outside air economization. They vary by two factors: (1) air- or water-cooled condensers and (2) direct evaporation or no evaporation. Direct evaporation is equivalent to the direct evaporative cooling option in Metzger *et al*. [61]. The third option, "no evaporation or air-cooled condenser" is essentially equivalent to the direct expansion option in the Metzger study. As expected from the Metzger *et al.* findings, the HVAC systems employing evaporative cooling use less electricity in the dry Arizona climate. Also, as expected, the water-cooled systems use less electricity.

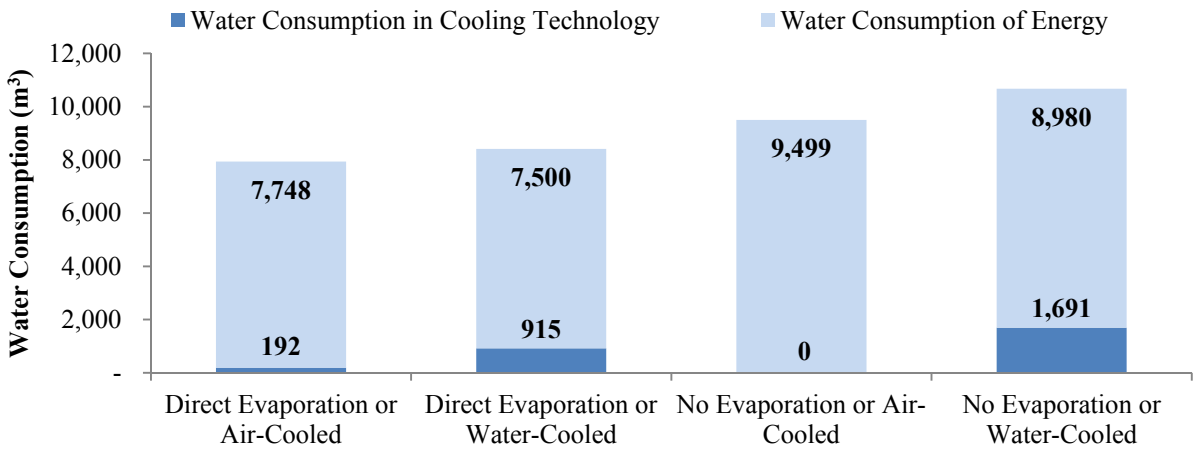


Figure 6. Annual water consumption of different cooling technologies in a DC cooling technology with a capacity of 61,164 m^3/min, based on inlet supply temperature to servers of 27 °C in Phoenix, Arizona. (After Vokoun [74] who reports United Metals Products values. Vokoun uses National Renewable Energy Laboratory (NREL) figures for the water consumption for electricity production (8254 m^3/TJ) [75]. Note that NREL is using only evaporative water consumption not WF).

When considering the values in Figure 6, some cooling systems appear to be less water intensive in terms of direct water consumption, but because of greater electricity demand, end up with greater total water consumption. In particular, while the "air cooled condensers/no evaporation" option has no direct WF, it requires significantly more electricity to achieve the same cooling. The WF of generating this additional electricity more than neutralizes the gains of not having a direct footprint. Thus, the 'direct evaporation/air cooled condenser' option has the lowest water consumption.

Figure 7 shows the annual WF of HVAC including direct and indirect WF as calculated with the WF_{source} range determined for Arizona above multiplied by the electricity consumption for the different HVAC options. At the low end of Arizona's WF_{source} range (70 m^3/TJ), the 'no evaporation/air-cooled condenser' comes out with the lowest footprint. This is despite the less efficient air-cooled condenser, and the lack of evaporative cooling (most appropriate to a dry climate) generating the greatest electricity use of all four options. At the high end (540,544 m^3/TJ), "direct evaporation/water-cooled chiller" comes out with the lowest footprint. This runs counter to the result of the water consumption figures from NREL (8254 m^3/TJ), where "direct evaporation/air-cooled condenser" came out best. These differences are indicative of the proportions in play. As the WF of electricity rises, the relative impact of electricity consumption over direct water consumption on WF rises. Subsequently, it becomes apparent that the uncertainty range involved in determining the WF_{source} hinders a definitive recommendation on which HVAC technology has the lowest total WF, hence which technologies can provide environmental innovations most readily.

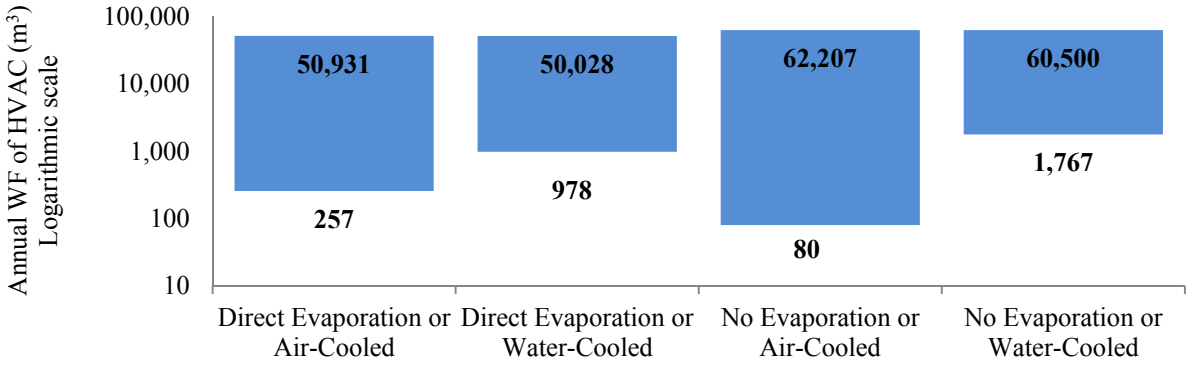


Figure 7. Annual WF of different HVAC systems. The direct water consumption values are taken from Vokoun [74] and added to Arizona WF of energy ranges from Figure 4.

The dataset from Vokoun used in these calculations has at least two important limitations. Firstly, the data comes from one firm (United Metal Products) [74]. The data are therefore dependant on that firm's designs and are not necessarily representative of evaporative, air and water cooled chiller technologies in general. There is substantial variability between designs which is another source of uncertainty that must be acknowledged. Secondly, the above data do not include the grey water footprint that is associated with water cooling. This could again skew the HVAC system choice recommendation.

4.2. Water Footprint of Data Centres and Data Centre Outbound Traffic

This section provides a rough calculation of the WF of DCs. This is done by summing the WF of the energy consumed in DCs with the direct WF from HVAC systems.

To get the WF of total energy used by DCs, Koomey's values for worldwide DC energy use in 2010 were applied (732,240–978,480 TJ/year) [11]. The range was multiplied by the WF_{source} range for the global average energy portfolio (1047–150,317 m^3/TJ) as calculated for Figure 4. This gives the range 767–147,082 million cubic meters (mcm) for the annual WF of energy consumed by DCs. As a point of referance, the top end of the range is comparable with Italy's WF of 130,000 mcm/year, and the bottom end of the range is comparable with the 650 mcm/year WF of the Bahamas [76].

Using Vokoun's data on the water consumption in Arizona's HVAC systems we can roughly calculate an uncertainty range for the WF of HVAC systems. This is done by dividing the HVAC water consumption by the HVAC electricity consumption. Given the electricity consumed by HVAC we can, thereby, establish a rough ratio between that and the direct WF of HVAC. This gives us a range of 0–1554 m^3/TJ. Although, Sharma *et al.*'s [39] reported linear relationship of around 0.5 m^3/TJ, for a water-cooled chiller it is compatible with this range, but it is at the very low end. This could imply that the distribution of values within the range are skewed towards the lower end.

To get the annual WF of DC HVAC systems, the above range is multiplied by the share of energy going to DC infrastructure annually in 2010 (as reported by Koomey: 331,200–468,720 TJ) [11]. This is an impefect metric as it includes lighting and other electricity uses in DCs but is used here as a rough proxy measure. This gives the range 0–728 (mcm) per annum for the direct WF of HVAC. This is a much smaller value than for the WF of DC energy use.

Added together the WF of HVAC and the WF of energy used in DCs gives us the range 767–147,810 mcm per annum for all the world's DCs. Dividing this value by the useful work done by DCs will give us values comparable between DCs. Firstly, we can again divide by the total energy used in DCs thereby resulting in the WUE_{source} ranging from 1047 to 151,061 m^3/TJ. Importantly, this value is much higher than the 787 m^3/TJ reported by the Sharma *et al*. [38], and differs because of the use of WF accounting.

As discussed with regards to units of measurement, the range for annual WF of worldwide DC is divided by the outbound data traffic for which Cisco Systems, Inc. values were used [2]. Only 23.3% of all DC data traffic (3.1 zettabytes per year) actually goes to other DCs or to users giving us the value 722 exabytes (EB) outbound traffic per year in 2013. Dividing the above calculated values for annual DC WF gives us the range: 1–205 mcm/EB or liters per gigabyte of data sent out of DCs. The high end of the range is comparable to the WF of a kilogramme of tomatoes which is 214 litres [77], reflecting the high but overlooked water effects of data use and communcation.

5. Caveats for Policy and Innovation Recommendations

The three key uncertainties involved in determining the WF of DCs and recommending innovations towards reducing environmental footprint are: WF of electricity, psychrometrics, and WF of HVAC.

Due to the very high energy use in DCs, and broad tendency for IT equipment to use half or more of the total energy in a DC, indirect WF (WF of electricity) is typically much larger than direct WF. Therefore, the first focus for reducing DC WF should be on air-side economization and energy efficiency. Helpfully, this yields the important co-benefit of reduced operating costs going to electricity and reduced greenhouse gas emissions. If at least these three criteria are considered (*i.e.*, cost, water, and carbon footprint), then DC innovation should remain strongly focused on energy efficiency. Also, given the possibility, investing in less water-intensive electricity generation technologies can dramatically reduce DC WF as seen in the case for Apple's DCs.

Secondly, attention should be given to the choice of HVAC technology. Under high WF_{source}, HVACs with direct WF as opposed to those without any, can reduce total WF as seen in the case of the DC in Phoenix. On the other hand, under a very low WF_{source}, switching away from HVAC systems with direct WF can reduce DC WF. This technology decision, however, would have to be made with a more detailed understanding of the relative performances of different designs in different climates.

With regards to the WF values calculated for worldwide DCs above, the share of energy going to HVAC and the WF of HVAC remain very uncertain as specific values were not available. The proxy measure used was based on one simple dataset from one location. As such it should be interpreted very cautiously but does provide reaffirmation that the direct WF is relatively small compared to the WF_{source}. Consequently, the focus for WF reduction broadly remains on energy efficiency.

DC location choice can also greatly impact its WF. With regards to reducing WF, DC siting is subject to considerations of WF_{source} (if purchasing from grid) and psychrometric conditions in different possible locations. In this optimization, it is important to note that if a given amount of electricity is being bought from the grid, the WF of that electricity has a linear relationship with the total DC WF, assuming that the energy supply portfolio does not change by the amount of energy supplied. As in the case of Apple's DCs, the total amount of energy used does not necessarily affect WF_{source}. However, this linearity will

not necessarily hold when directly purchasing from generators. Relative prices or supply constraints from sources with a lower WF may make DCs buy a share of electricity from higher WF sources. The amount of energy used can affect the technology shares and, hence, WF_{source}. Thus, higher electricity consumption increases total WF which may be non-linearily greater because of the need to buy from energy sources with a higher WF.

Additionally, in considering siting, deviation from psychrometric conditions amenable to IT equipment is likely to display a non-linear relationship with the total WF. Such deviations imply not only changes in the amount of work needed to be done by HVAC (*i.e.*, HVAC WF and energy consumption), but also the kinds of systems that can or must be deployed. This would be particuarly pronounced when crossing psychrometric envelopes in which free cooling with outside air is effective. Large DC operators such as Facebook, Google, and others therefore are building their new DCs in cold climates where outdoor air is most easily exploited [78–80]. As provided in the Green Grid and other sources, this psychrometric deviation is quantified by the average number of hours in a year where outside air has the psychrometric values appropriate to IT equipment cooling. Different locations have different frequency distributions for that number of hours and hence imply the possibility of non-linearity in the relationship between deviation of average psychrometric conditions and amount of energy and water used on HVAC. Possible siting trade-offs then include circumstances where an increase in WF_{source} at an alternative location may much more than offset the total WF increase by a much more air-side-economization-friendly climate. These difficulties in defining the relationships between the key uncertainties and DC WF make definitive decision-support difficult without the specific values which are generally challenging to come by.

For a given DC, the uncertainties are reducible when exploring specific options for the siting, design, and build stages of a DC. Once the operational phase has begun, reporting on a facility's WF (and related carbon footprint and other environmental performance criteria) becomes possible with a reasonable degree of accuracy and can be validated by a third party should the desire to do so arise. Noting that site-specific uncertainty can be reduced, a number of corporate and regulatory/policy responses could reduce uncertainty for generic assessments, and boost innovation and best practice.

It is fundamental that firms collaborate in the development of leading industry standards such as the WUE. As a parallel activity, standardization, monitoring, and reporting templates for DC WF should be created. Currently, corporate sustainability frameworks, such as the Global Reporting Initiative (GRI) are not fit for purpose in this regard [37]. Standardized WF and WUE could be, summarily, introduced into the corresponding GRI methodology with a corresponding reporting template. This would improve knowledge of the water use in average DCs. It would also allow firms that rely upon DC service provision to select DC service suppliers by environmental performance, as well as cost and other metrics. Additionally, this would allow for the creation of a performance league table rewarding first mover advantage while calling attention to laggards, and enticing firms to improve performance.

More ambitiously, WF reduction methodologies and implementation solutions (including HVAC technologies, design solutions, and siting) could be built into the licensing or permitting frameworks for DCs. Implementing industry best practice in the form of "best available techniques (BAT)" is a standard feature of industrial installations throughout Europe in respect of how they are regulated under the Industrial Emissions Directive [81]. Though it is not suggested that DCs be regulated under this Directive, modest versions of BAT reference documents (BREFs) specifically designed for DCs would

appear to be sensible given their growing contribution to energy and water resource use. Much of the content of BREFs would come from industry in any event as an exemplar of sectoral best practice.

6. Conclusions

Given the rising use of DCs coupled with rising environmental stress, substantially more attention should be paid to the WF of DCs. To do this, all three factors of WF_{source}, psychrometrics, and HVAC must be considered. In particular, more research and disclosure is needed to understand the relative performance of different DCs, the energy and water intensity of different HVAC technologies in different climates, and the water intensity of electricity generation. Large uncertainties remain in the quantification of the values necessary for addressing trade-offs involved in DC design, siting, and operation. These uncertainties also mean that the values determined in this paper should be considered with caution and are more indicative of the uncertainties involved than a definite quantitification of WF values. Building on the work done here, further research for determining WF of data traffic could develop interesting insights into the WF of the Internet and the associated virtual water flows.

In order for such values and understandings to develop, consistent metrics and methodologies need to be applied. WF offers a systematic approach for understanding the water impacts of DCs and can be applied in WUE and WUE_{source}. Different metrics yield different recommendations for reducing water footprint. When considering direct WF, the focus is on HVAC: evaporation for humidification and cooling, and the gray WF from heat pollution and chemical discharge. When we include the indirect WF, electricity use takes over as the biggest driver of DC WF. The focus then shifts to less water-intensive energy sources and boosting energy efficiency of both IT equipment as well as the facility more broadly. As seen in the comparison of different HVAC systems at a DC in Phoenix, systems which came out unfavourably when only considering direct WF can deliver a lower total WF when WF_{source} is included. Determining which HVAC system is the best requires a consideration of the psychrometry of the data center given its cooling needs, its (changing) climatic environment, and the energy and water performance of the HVAC systems.

Future studies in this area should seek to reduce the uncertainties surrounding the WF of electricity and provide a more systematic understanding of HVAC systems' direct and indirect WF. Although, having considered other sources, this study has been limited to one simple dataset on different HVAC systems operating in Phoenix, because very little data can be found for the WF of DCs, or even HVAC systems, generally. More data for the water and energy performance of different HVAC systems in different climates would provide a better basis on which to develop trade-off management principles. Future studies should also consider expanding the scope of analysis to include a quantification of other parts of the DC supply chain and also to consider the grey and green WF in much more depth than the mention these factors recieved here. Apple, for example, reports on changes in landscaping which have led to reductions in green WF. While Apple and other large firms have environmental reporting, most DCs are small and have little to no reporting on environmental footprints. Although academia, industry, and the public sector have started making such efforts, much work remains to be done.

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Author Contributions

All authors have contributed equally to the realization of this research, albeit in different ways. The research question was concieved by Kaveh Madani who lead the study team. Bora Ristic was responsible for data collection and analysis, interpretation of results, and writing. Kaveh Madani and Zen Makuch both contributed substantially to improving the analysis and with suggestions for improvement in the manuscript. All authors have read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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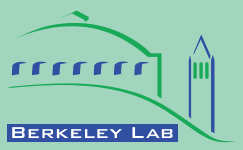
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United States Data Center Energy Usage Report

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Version Updates

- 6/27/16: Original report posted
- 7/12/16: Equation 3 updated to read “m*(1-u)” instead of “m*u”
- 8/2/16: Duplicate Figure 5 removed

Executive Summary

This report estimates historical data center electricity consumption back to 2000, relying on previous studies and historical shipment data, and forecasts consumption out to 2020 based on new trends and the most recent data available. Figure ES-1 provides an estimate of total U.S. data center electricity use (servers, storage, network equipment, and infrastructure) from 2000-2020. In 2014, data centers in the U.S. consumed an estimated 70 billion kWh, representing about 1.8% of total U.S. electricity consumption. Current study results show data center electricity consumption increased by about 4% from 2010-2014, a large shift from the 24% percent increase estimated from 2005-2010 and the nearly 90% increase estimated from 2000-2005. Energy use is expected to continue slightly increasing in the near future, increasing 4% from 2014-2020, the same rate as the past five years. Based on current trend estimates, U.S. data centers are projected to consume approximately 73 billion kWh in 2020.

Many factors contribute to the overall energy trends found in this report, though the most conspicuous change may be the reduced growth in the number of servers operating in data centers. While shipments of new servers into data centers continue to grow every year, the growth rate has diminished over the past 15 years. From 2000-2005, server shipments increased by 15% each year resulting in a near doubling of servers operating in data centers. From 2005-2010, the annual shipment increase fell to 5%, partially driven by a conspicuous drop in 2009 shipments (most likely from the economic recession), as well as from the emergence of server virtualization across that 5-year period. The annual growth in server shipments further dropped after 2010 to 3% and that growth rate is now expected to continue through 2020. This 3% annual growth rate coincides with the rise in very large “hyperscale” data centers and an increased popularity of moving previously localized data center activity to colocation or cloud facilities. In fact, nearly all server shipment growth since 2010 occurred in servers destined for large hyperscale data centers, where servers are often configured for maximum productivity and operated at high utilization rates, resulting in fewer servers needed in the hyperscale data centers than would be required to provide the same services in traditional, smaller, data centers.

Along with total server count, the power demand for each server has also changed. While server power requirements were observed to be increasing from 2000-2005, power demand appears to have stayed fairly constant since 2005. Additionally, servers are improving in their power scaling abilities, thus reducing power draw during idle periods or when at low utilization. Efficiency improvements in storage, network and infrastructure also influence the electricity estimates in this report. Storage devices are becoming more efficient on a per-drive basis, with the growth in drive storage capacity projected to outpace increases in data storage demand by 2020, ultimately reducing the number of physical drives needed throughout data centers. Recent estimates of network port power consumption are now much lower than estimates from the past decade. Increased awareness in data center infrastructure operations (e.g. cooling) has resulted in improved efficiency across data center types, though the most significant infrastructure impact observed in this report is the recent growth in hyperscale data centers that are often innovatively designed to maximum infrastructure efficiency.

The combination of these efficiency trends has resulted in a relatively steady U.S data center electricity demand over the past 5 years, with little growth expected for the remainder of this decade. It is important to note that this near constant electricity demand across the decade is occurring while simultaneously meeting a drastic increase in demand for data center services; data center electricity use would be significantly higher without these energy efficiency improvements. A counterfactual scenario was created for this study that estimates what data center energy consumption would have been if industry energy-savings efforts were halted in 2010. For this scenario, the follow metrics remain static at 2010 industry-wide levels from 2010-2020:

- Average server utilization
- Server power scaling at low utilization
- Average power draw of hard disk drives
- Average power draw of network ports
- Average infrastructure efficiency (i.e., PUE)

The resulting electricity demand, shown in Figure ES-1, indicates that more than 600 additional billion kWh would have been required across the decade.

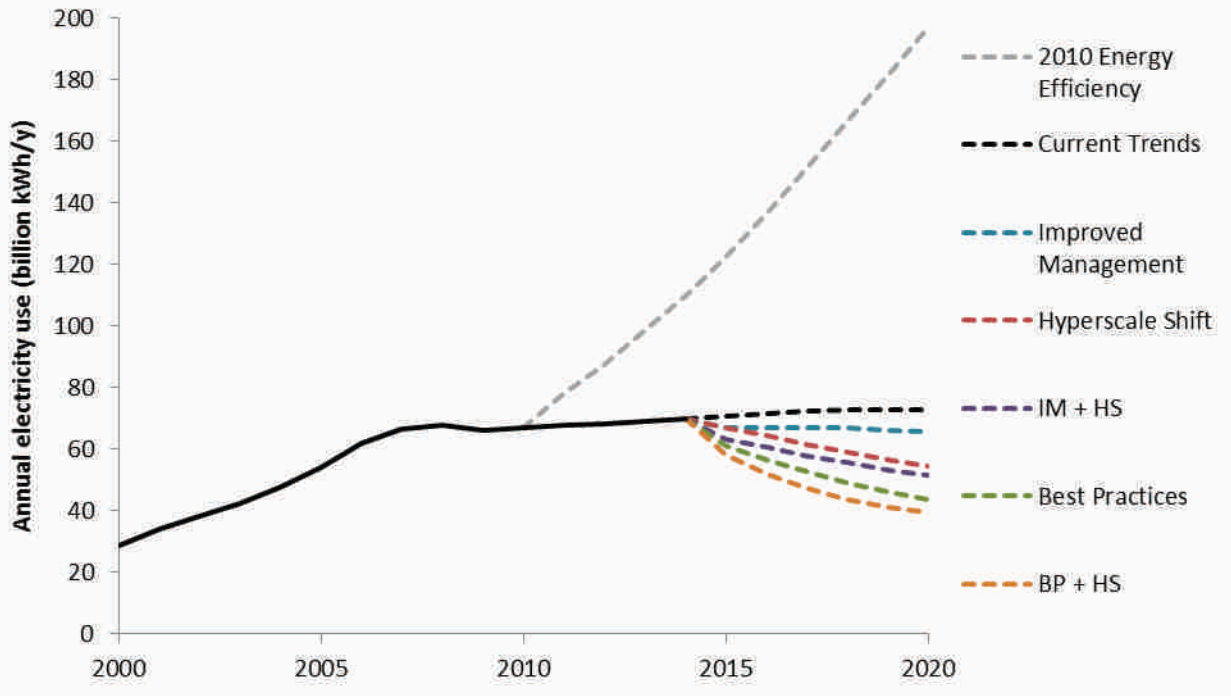


Figure ES-1 Projected Data Center Total Electricity Use

Estimates include energy used for servers, storage, network equipment, and infrastructure in all U.S. data centers. The solid line represents historical estimates from 2000-2014 and the dashed lines represent five projection scenarios through 2020; Current Trends, Improved Management (IM), Best Practices (BP), Hyperscale Shift (HS), and the static 2010 Energy Efficiency counterfactual.

Note that this scenario does not halt the technological advancements of the computing industry in terms of performance, and therefore metrics such as computational performance (i.e., computations/second per server), the electrical efficiency of computations (i.e., computations per kWh), storage capacity (i.e., TB per drive), and port speeds (i.e., Gb per port) are all assumed to progress as normal. See Section 2.3.5 in the main body of this report for more details regarding the assumptions in this counterfactual scenario.

Along with the considerable energy efficiency resource already achieved, there are additional energy efficiency strategies and technologies that could significantly reduce data center electricity use below the approximately 73 billion kWh demand projected in 2020. Many of these efficiency strategies are already successfully employed in some data centers while others are emerging technologies that will be commercially available in the near future. Recently observed efficiency trends are incorporated into a "current trends" scenario. The potential impact from a more aggressive adoption of the energy efficiency strategies is explored through additional projections that apply a combination of the three following efficiency scenarios:

- The "improved management" scenario includes energy-efficiency improvements beyond current trends that are either operational or technological changes that require minimal capital investment. This scenario represents a focus on improving the least efficient components of the data center stock by employing practices already commonly used in data centers.

- The "best practices" scenario represents the efficiency gains that can be obtained through the widespread adoption the most efficient technologies and best management practices applicable to each data center type. This scenario focuses on maximizing the efficiency of each type of data center facility.

- The "hyperscale shift" scenario represents an aggressive shift of data center activity from smaller data centers to larger data centers. While the current trend scenario already incorporates some movement towards more server use in large data centers, this scenario assumes the majority of servers in the remaining small data centers are also relocated.

In addition to applying each of these scenarios independently, two additional scenarios demonstrate the combination of a "hyperscale shift" scenario in conjunction with either the "improved operation" or "best practices" scenario. Figure ES-1 shows that these five scenarios yield an annual saving in 2020 up to 33 billion kWh, representing a 45% reduction in electricity demand when compared to current efficiency trends.

1 Introduction

Data centers primarily contain electronic equipment used for data processing (servers), data storage (storage equipment), and communications (network equipment). Collectively, this equipment processes, stores, and transmits digital information and is known as “information technology” (IT) equipment. Data centers also usually contain specialized power conversion and backup equipment to maintain reliable, high-quality, power as well as environmental control equipment to maintain the proper temperature and humidity for the IT equipment.

As our economy and society continue to shift towards increased digital information management, data centers have become ubiquitous – they are found in nearly every sector of the economy – and are essential to the function of communication, business, academic, and governmental systems. All but the smallest companies have some kind of data center needs, and larger companies often have tens, or even hundreds, of data centers. Smaller data centers are commonly located within large commercial buildings, while larger data centers tend to be buildings constructed specifically for their use that can be up to several hundred thousand square feet in size. Universities, municipalities, and government institutions also use and operate data centers for information management and communication functions.

The energy used by the nation’s servers and data centers is significant. In a 2007 Report to Congress,[1] the data center sector was estimated to have consumed about 61 billion kilowatt-hours (kWh) in 2006 (1.5 percent of total U.S. electricity consumption) for a total electricity cost of about $4.5 billion (2006 dollars). This estimated level of electricity consumption is similar to the amount of electricity consumed by approximately 5.8 million average U.S. households. The electricity use of the nation’s servers and data centers in 2006 was more than double the electricity that was estimated to have been consumed for this purpose in 2000. The accompanying methodology article[2] to the 2007 Report, published in 2011 with updated methods and inputs, estimated 2008 data center electricity demand to be 69 billion kWh, 1.8% of total U.S. electricity sales. Another study published in 2011[3] revealed that electricity use by U.S. data centers in 2010 constituted about 2% of overall electricity use in that year, and that the rate of growth in energy use slowed significantly in the period 2005-2010, compared to 2000-2005. This trend was likely a result of the 2008-09 economic crisis and the increased adoption of virtualization and other energy efficiency practices in the data center industry.[3] This report provides updated estimates of current data center energy use, updated historical estimates of energy use back to the year 2000, and projections for energy use through 2020.

1.1 Report Scope

This report builds on previous modeling efforts and updates key inputs to the data center model used in the 2007 Environmental Protection Agency Report to Congress on Server and Data Center Efficiency, Public law 109-4311.[1] The scope of this report includes updates to the following sections from the 2007 study:

- Trends in Growth and Energy Use Associated with Servers and Data Centers in the U.S.

- Potential Energy and Cost Savings through Improved Energy Efficiency

Additionally, this report provides the following insights as outlined in the North American Energy Security and Infrastructure Act of 2015:[4]

1. A comparison and gap analysis of the estimates and projections contained in the original report with new data regarding the period from 2008 through 2015;
2. An analysis considering the impact of information technologies, including virtualization and cloud computing, in the public and private sectors;
3. An evaluation of the impact of the combination of cloud platforms, mobile devices, social media, and big data on data center energy usage;
4. An evaluation of water usage in data centers and recommendations for reductions in such water usage; and
5. Updated projections and recommendations for best practices through fiscal year 2020.

1.2 Report Organization

This report serves as an update to the 2007 Environmental Protection Agency Report to Congress on Server and Data Center Efficiency, Public law 109-4311[1] (henceforth referred in this study as the 2007 Report). The 2007 Report provides detailed background information such as data center equipment layout and cooling configurations, which are therefore not discussed here. Rather, this report focuses on new trends and data available since the 2007 Report, methodology of the current estimate, and details of the new results and findings. Chapter 2 of this report describes the methodology used for the current energy and water use estimates. Although the current methodology follows the framework presented in the 2007 Report, recent trends such as the proliferation of “unbranded” servers and storage equipment, also referred to as “self-assembled,” “whitebox,” or original design manufacturer (ODM) servers require additional data input and characterization. Unbranded servers are associated with the increasing number of very large “hyperscale” data centers and often bypass large, branded server vendors (e.g. Hewlett-Packard, Dell) by being bought directly from the manufacturing companies that build servers (e.g., Quanta, Wistron, and Foxcom). See Chapter 2 for a more detailed description of unbranded servers. Chapter 3 of the report is devoted to the discussion of servers and data centers owned and operated by the federal government. Chapter 4 describes a number of key trends observed in the data center industry, such as server consolidation, colocation, and the shift to cloud-based platforms. These trends, along with energy efficiency strategies, are used to generate alternative energy use projection scenarios out to the year 2020. While rapid growth in the Internet industry has resulted in significant direct energy use in data centers, it can also indirectly impact certain resources in other sectors and possibly promote other efficiencies in society that were previously not achievable. These observations are discussed in Chapter 5. Finally, Chapter 6 provides suggestions for future research to address challenges that have been identified but not addressed in this report, which could improve future energy use estimates in such a rapidly evolving industry with little publically available data.

2 Estimates of U.S. Data Center Energy Use

2.1 Methodology Overview

The 2007 Report provided a series of data center energy use projections for 2007-2011 developed for five different efficiency scenarios. Detailed assumptions used for those efficiency measures in each scenario can be found in Brown et al. (2007),[1] while the modeling algorithms developed for these energy use projections are presented in Masanet et al. (2011).[2] Additional studies were conducted by Koomey[3 5 6] to assess the growth in data center electricity use from 2000 to 2010 for the U.S. and the world, using methods similar to the 2007 Report. The 2010 data center electricity use estimated by Koomey (2011) most closely aligns with the "improved operation scenario" projection in the 2007 Report.

The current study differs from previous work in its categorization of IT equipment and types of data centers. The number of data center space types has been expanded from the 2007 Report to account for hyperscale data centers, which are large warehouse-sized data centers that have emerged with the growth in cloud platforms, mobile devices, social media, and big data. Previously considered size-based space types are now disaggregated into two categories: "internal" data centers and "service provider" data centers. Internal data centers represent traditional facilities that support businesses and institutions while service provider data centers account for the more specialized facilities that provide the core services of businesses, such as communication and social media companies. New server classifications are added to distinguish between servers that only contain one processor socket ("1S") and those that contain 2 or more ("2S+"). Additionally, the new server classifications distinguish between servers that are branded and sold by global computer companies (e.g., Dell, Hewlett-Packard, IBM), and servers that bypass these brand vendors in the supply chain and are bought directly from the manufacturing companies that build servers (e.g., Quanta, Wistron, and Foxconn), often by large Internet companies and typically for use in hyperscale data centers, as shown in Figure 1. The latter is defined in this report as "unbranded" servers and the former as "branded" servers. These categories are associated with different usage and data center type placement assumptions, as described in Section 2.2. The current study also includes updates to previous storage power consumption estimates, which are now derived from terabyte shipment data and disaggregated into hard disk drive (HDD) and solid-state drive (SSD) categories. Network consumption is now estimated through a combination of switch port shipment data of various speeds and port power consumption from publically available data and published literature. The equipment types (servers, storage, and networking) modeled in this study are shown in Figure 2.

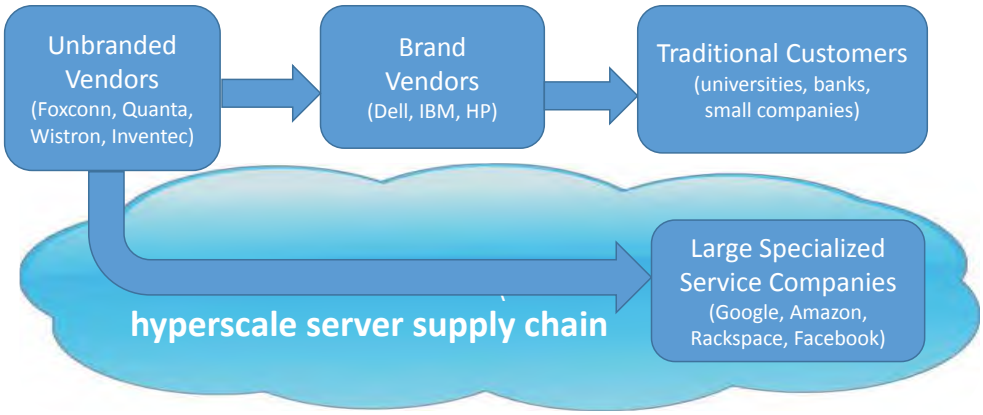


Figure 1. Volume Server Supply Chain

Similar to previous U.S. data center energy estimates,[1 2 3 4 5] this study uses data provided by the market research firm International Data Corporation (IDC) to derive numbers of data center servers, as well as storage and network equipment, installed in the United States. Power draw assumptions are then applied to the estimated installed base of equipment to determine overall IT equipment energy consumption. IT equipment is disaggregated across various data center space types, each of which has an associated power use effectiveness (PUE) value. The PUE, when multiplied by equipment power consumption, gives an estimate of the total power needed to run the data center, including the data center infrastructure (i.e. cooling, lighting, controls).

Figure 3 shows a schematic of this modeling approach, and Section 2.2 discusses data sources in more detail.

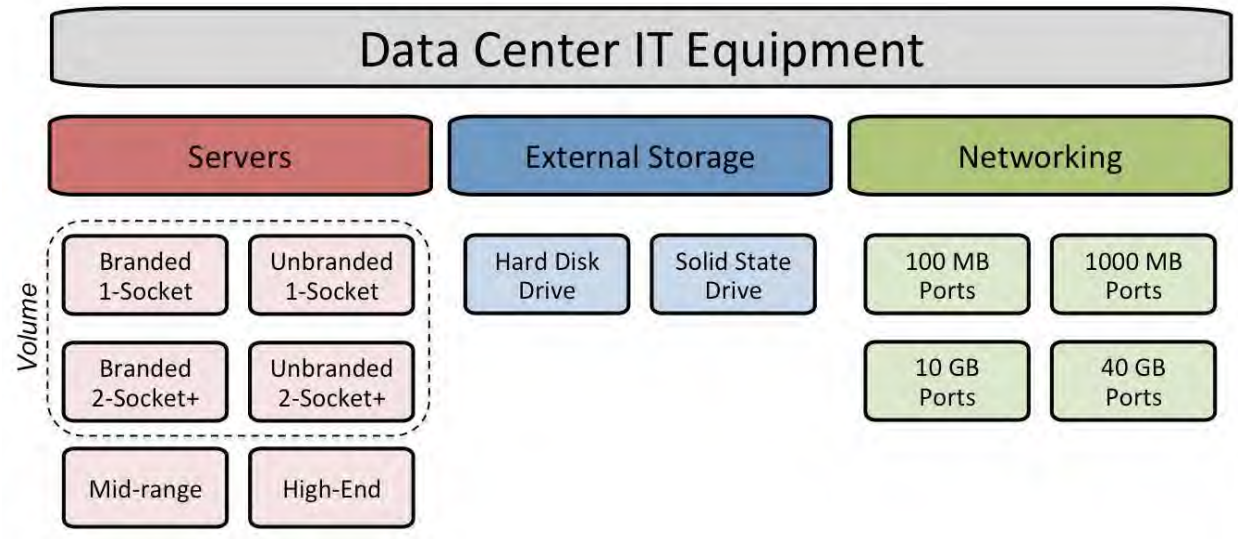


Figure 2. Equipment Types Modeled in Energy Estimation

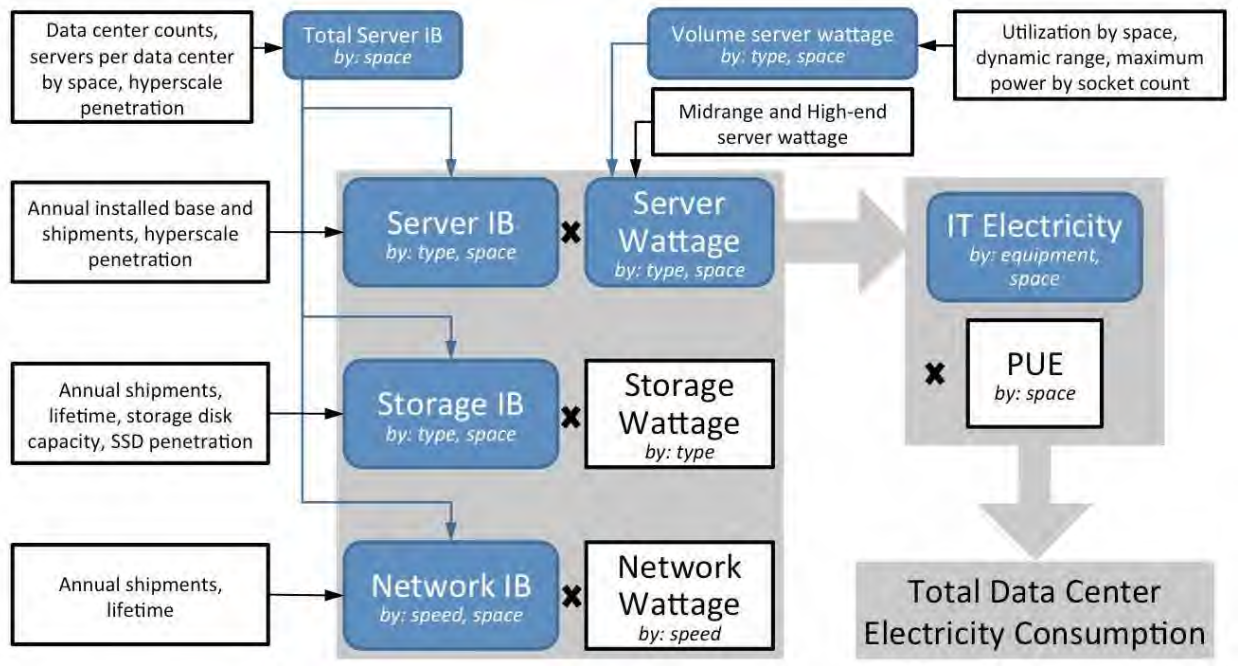


Figure 3. Schematic of Modeling Approach

2.2 Data

2.2.1 IDC Worldwide Trackers[7]

IDC's Worldwide Quarterly Server, Storage, and Network trackers were used as the basis for many equipment estimates in this study. Data was obtained in 2014 Q4, and therefore all values beyond 2014 are considered forecasts. These trackers include historical and forecasted shipments for each equipment type, as well as installed base estimates for servers.[8] [9] [10] [11] This data is referred throughout the report as "IDC data"

2.2.2 SPEC Database[15]

The SPEC Power benchmark suite, created by the Standard Performance Evaluation Corporation (SPEC), measures power and performance of servers. SPECpower_ssj2008 is an industry-standard benchmark application that has been used since 2007, with users self-submitting results to a database that is reviewed and released to the public quarterly. Data from 2007 to 2015 Q4 was used in this study, and will be referred to as "the SPEC database".

2.2.3 SERT[12] *Database*

The Server Efficiency Rating Tool (SERT) was created by SPEC for the U.S. Environmental Protection Agency's (EPA) ENERGY STAR program. This tool uses a set of synthetic worklets to test discrete system components, providing detailed power consumption data at different load levels. Data from this tool is submitted to the EPA by manufacturers, and is collected and maintained by the Information Technology Industry Council (ITI). Data collected by ITI through March 2016 was used in this report, and will be referred to as "the SERT database".

2.3 IT and Infrastructure Equipment Estimates

2.3.1 Server Energy Use

Server Installed Base

Estimates for the U.S. installed base of servers are based on IDC's "Worldwide Quarterly Server Tracker – Installed Base",[11] which contains annual data for historical (2006-2014) and forecasted (2014-2018) server shipments and installed base of servers. These numbers are provided for each of the three primary server classes (volume, midrange, and high-end) as well as by processor count (1S or 2S+). The three server classes are an IDC taxonomy based on average sales value, with volume, midrange, and high-end servers representing < $25,000, $25,000-$250,000, and >$250,000, respectively. Volume servers typically contain x86 processors and represent the overwhelming majority of servers in data centers. High-end servers are often large RISC-based systems that operate on Unix and include many high-performance computing supercomputers. Midrange servers can contain aspects of both volume and high-end servers. The installed base estimates were extended from 2018 to 2020 using the compound annual growth rate (CAGR) of the installed base from 2014-2018, the years for which IDC has forecasted installed base growth.

Each of the 1S and 2S+ categories for volume servers is further disaggregated into "branded" and "unbranded" classes using additional data provided by IDC and assumptions about future penetration of hyperscale data centers. First, the percent of all servers located in hyperscale data centers from 2000-2020 is estimated. (See discussion in Section 2.2.4.) Then, a sigmoid curve shape (i.e., "S-shape") is applied to estimate the penetration of unbranded servers within hyperscale data centers over time. Resulting unbranded installed base estimates for 2000-2020 are calibrated to (1) estimates for 2008-2010, which were provided through communications with IDC[13], and (2) IDC historical server shipment data for 2010-2014, which included disaggregation by vendor type.[8] The assumed hyperscale data center server capacity, sigmoid curve, data-based estimates, and resulting installed base are shown in Figure 4.

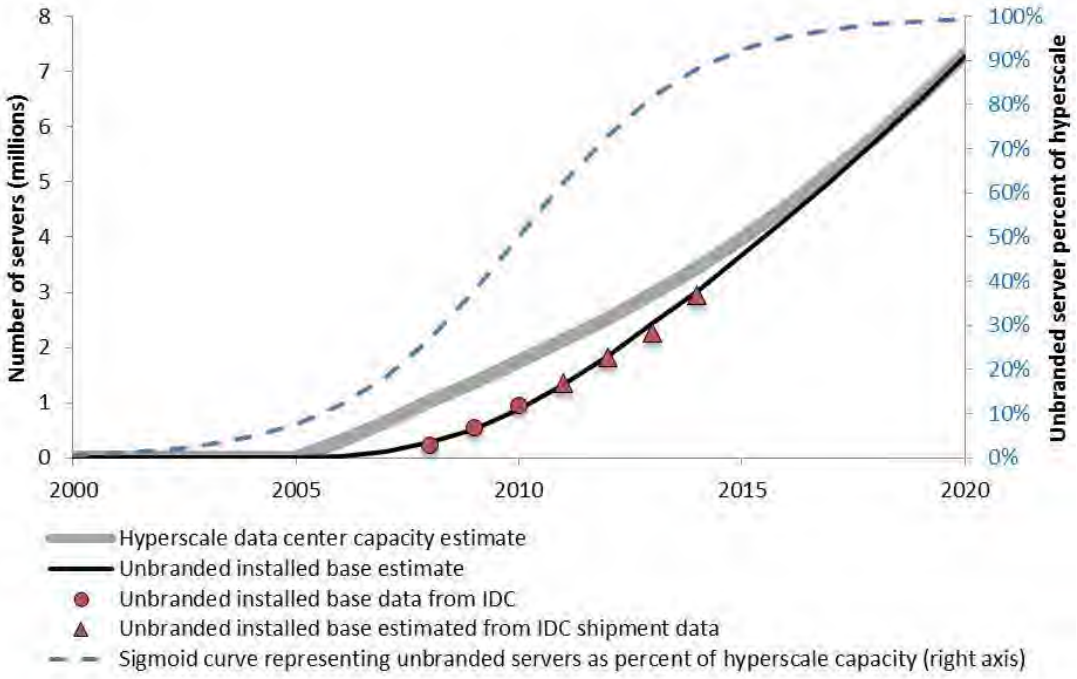


Figure 4. Unbranded Server Installed Base and Underlying Assumptions

Figure 5 shows the current and projected total server count for 2000-2020 estimated in this study, as well as server count estimates from the 2007 Report and from Koomey (2011). The 2007 Report projected much higher server counts than other estimates, with growth from 2007-2011 following the same trend as 2000-2007, due to these estimates being made prior to the 2008 financial crisis that greatly affected sales. Data from Koomey (2011) is similar to the current study's branded server estimates, with server installed base leveling off then slightly decreasing after 2007. Similarity between these two estimates is expected, as unbranded servers were not being explicitly tracked by IDC at the time of the Koomey (2011) study. Figure 6 shows the volume server installed base estimates from the current study disaggregated by processor count (1S or 2S+) and vendor type (branded or unbranded).

Server installed base and shipment data provided by IDC was also used to determine the approximate lifetime of servers. Observation of data showed that for any given year, the number of servers in the installed base was more than the sum of the previous 4 years' shipments, but less than the previous 5. The exact portion of the 5th year's shipments that were still in the installed base was found using Equation 1. For 2006-2020, this portion averaged 0.4, with very little deviation, indicating an approximate server lifetime of 4.4 years. This value was later used during storage and network installed base calculations based on a report from The Green Grid, which estimates that servers, storage, and network equipment all have a lifetime of 3-5 years.[14]

Equation 1

$$f = \frac{IB_y - \sum_{i=y-3}^{y} S_i}{S_{y-4}}$$

Where f = fraction of 5th year shipments in installed base
IBy = installed base in year y
Sy = shipments in year y

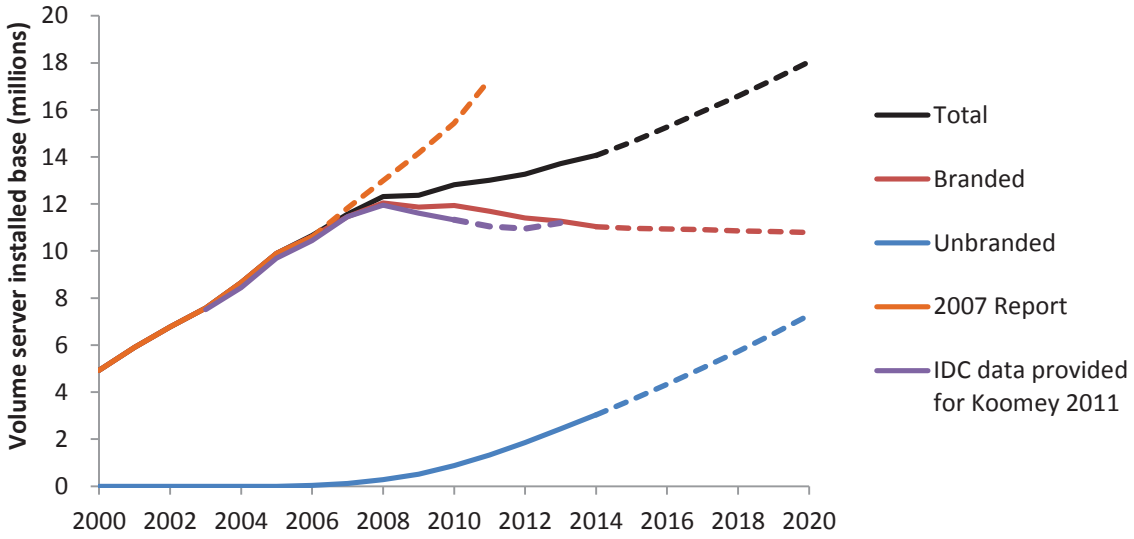


Figure 5. Total Volume Server Installed Base Estimates from Three Studies

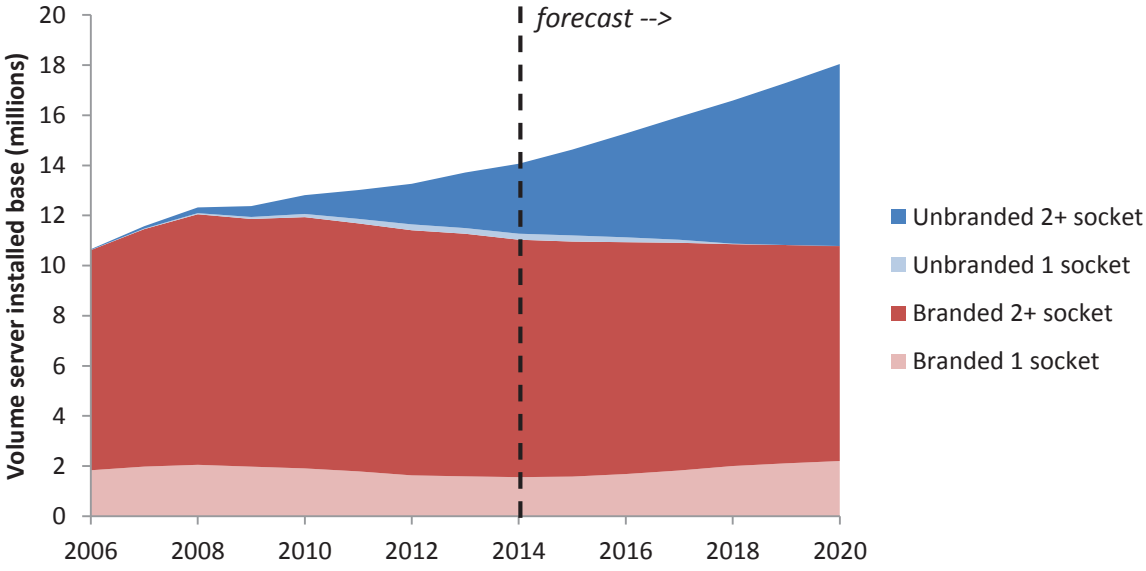


Figure 6. Volume Server Installed Base 2000-2020

Server Power Draw

Average power use of volume servers was calculated for each year using assumptions for: (1) maximum power consumption (2) average server utilization and (3) average ability for servers to scale power use with utilization. The maximum power represents the wattage of the server when being used at 100% utilization. Average server utilization represents the percent of computing ability used, on average, over the entire year. Average server scaling ability is the extent that servers, across the entire installed base, are able to use less-than-maximum power at non-maximum utilizations.

Maximum power in 2013 for 1S and 2S+ volume servers was estimated from the SERT database to be 118 W and 365 W respectively.[12] These values result in an overall volume server average maximum wattage of ~330 watts, which is the same assumption used in the later years of the 2007 Report. Maximum wattage for 2000-2007 was calculated for 1S and 2S+ servers by assuming that the estimates used in the 2007 Report represented a weighted average of 1S and 2S+ servers and that the ratio between the maximum power of the two types was the same as the 2013 ratio. Maximum power was held constant from 2007-2020 due to two observations: (1) the calculated 2007 values for 1S and 2S+ servers were very close to the SERT (2013) values, and (2) information in the SPEC database[15] shows that maximum server power has remained approximately constant from 2007-2015. While the wattages reported in the SPEC database were not used directly due to the assumed self-selection bias towards high efficiency servers in the database, the general temporal trends are assumed to be representative of all servers. The assumption that the average maximum power remains constant after 2005 is consistent with assumptions made by Heddgren et al.[16] (power draw based on 50% utilization) and the lower bound assumption by Koomey.[3] No difference in maximum power is assumed between branded and unbranded servers. Power consumption for mid-range and high-end servers is estimated at the overall average level, with utilization and scaling assumptions incorporated. These average wattage values for 2000-2007 were taken from the 2007 Report and extended to 2020 using the 2000-2007 CAGR of approximately 7%, which is consistent with projections through 2020 provided during industry review. Results are shown in Figure 7. These wattages assume underlying growth in both utilization levels and power scaling ability.

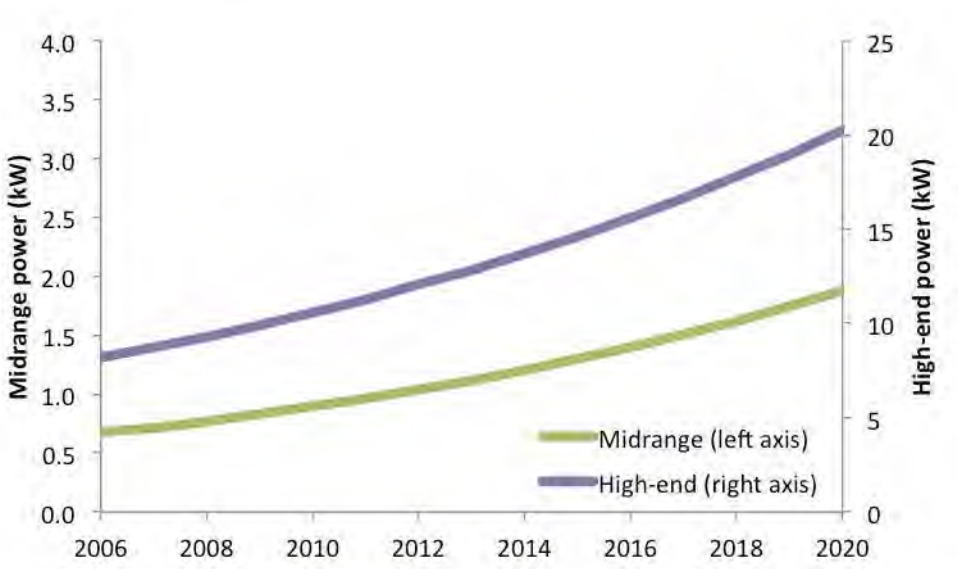


Figure 7. Average Power Draw Assumptions for Mid-Range and High-End Servers

Average utilization for volume servers is assumed to vary by space type, as shown in Table 1, and is assumed to be constant from 2000-2010. A steady increase from 2010 to 2020 is assumed, to account the prevalence of virtualization opportunities in data centers. Service provider data centers are assumed to run at higher utilizations than internal data centers, as the servers in service provider data centers are often configured for more specialized and predictable operations. Hyperscale data centers are assumed to run at higher utilizations than other service provider and internal data centers based on server utilization estimates in cloud and non-cloud data centers.[1] [17] [18] The values shown in Table 1 represent the average of active servers, and therefore the inclusion of inactive servers (assumed to be 10% of internal and 5% of service provider and hyperscale data centers) slightly lowers the overall averages. (See discussion in Section 4.2 for more information on inactive servers.)

Table 1. Average Active Volume Server Utilization Assumptions

Space Type	2000-2010	2020
Internal	10%	15%
Service Provider	20%	25%
Hyperscale	45%	50%

The amount of power consumed at average utilization is dependent on how closely servers come to achieving power-proportionality, where power consumption scales directly with utilization. In other words, perfect power-proportionality would mean that a server would only use 10% of maximum power when run at 10% utilization. One metric used to quantify this behavior is the dynamic range (DR), which is the ratio between the lowest power level (idle power) and the maximum power. Minimal documentation exists on the average DR of the U.S. data center servers stock. The DR varies among different server types and is influenced by hardware properties, power management software, and settings for server-specific operations,

all of which continue to change. This study estimates the DR of the installed base by first bounding possible values by a “Maximum DR” trend, which represents the lowest-performing servers (i.e. those that use a large amount of power at idle) and “Minimum DR” trend, which represents the highest-performing servers. The assumed Maximum DR is 0.67 in 2007 (the assumption used in the 2007 Report) and slopes linearly to 0.44 in 2020, as shown in Figure 8. The SERT database and recent publications[15] [18] show servers performing with an average dynamic range of ~0.44, and therefore this study assumes that, at a minimum, *all* volume servers will achieve a DR of 0.44 by 2020. The Minimum DR trend is derived from the SPEC database values from 2007-2015, which are shown in Figure 9, as this database is generally understood to represent well-performing servers due to self-selection bias in the server entries. The SPEC dynamic range trend is modeled as an exponential equation that asymptotically approaches a DR of 0.1, resulting in the Minimum DR trend shown in Figure 8.

The Maximum and Minimum dynamic range trends provide reasonable bounds of volume server DR, but an assumption must be made as to where the average DR lies between these bounds. This study estimates the annual installed base average as a 90/10 mix between the Maximum and Minimum trends for the Current Trends scenario, resulting in the effective average scaling trend shown in Figure 8. The DR is assumed to be constant across vendor types (branded and unbranded) and processor counts (1S and 2S+).

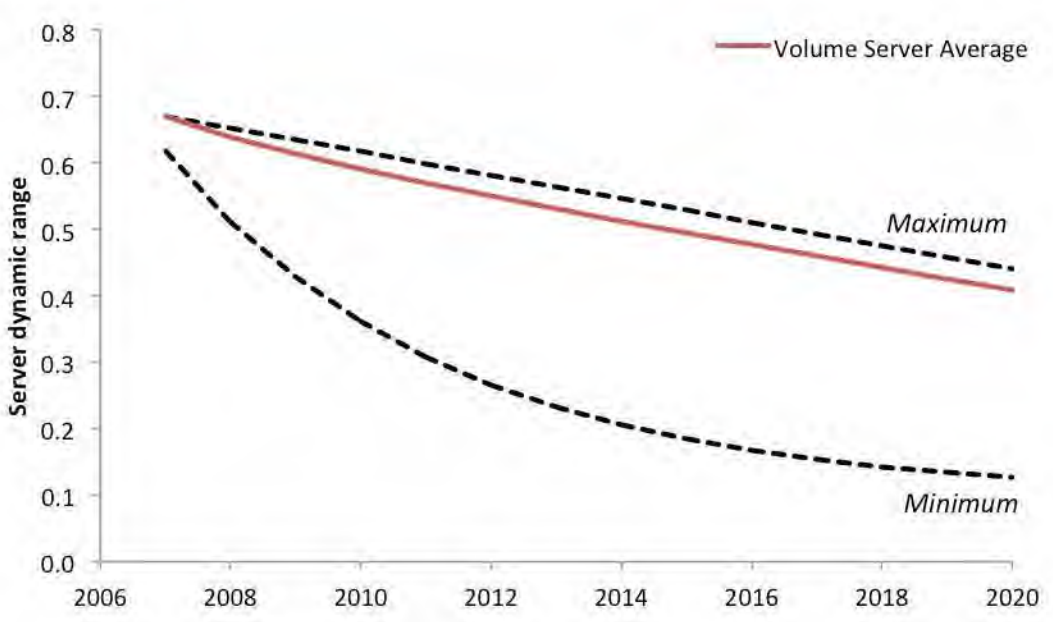


Figure 8. Assumed Dynamic Range of Volume Servers

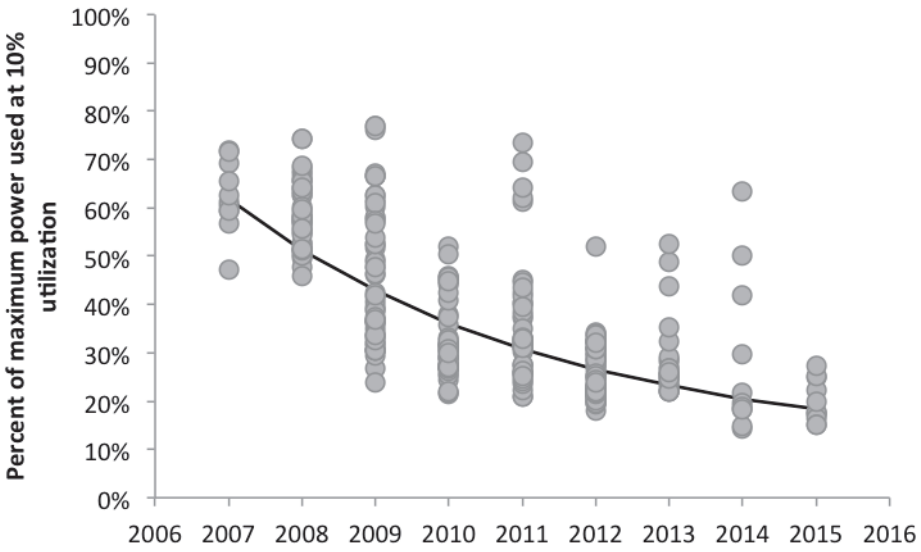


Figure 9. Dynamic Range of 1- and 2-Socket Servers in SPEC Database

Dynamic range and maximum wattage values are used to calculate the slope of the utilization versus power consumption curve for volume servers in each year, as shown in Equation 2. This slope is then used with utilization assumptions to calculate the average wattage of volume servers in each space type in each year. This calculation is shown in Equation 3, and results are shown in Figure 10. These average wattage values, along with installed base estimates, provide the total annual server energy consumption estimates shown in Figure 11.

Equation 2

$$m = \mathrm{P}_{\max} * (1 - DR)$$

Where m = slope of utilization vs. power line
P_{max} = maximum server wattage
DR = dynamic range of server (fraction of max power used at idle)

Equation 3

$$P_{avg} = P_{max} - m * (1 - u_{avg})$$

Where P_{avg} = average server wattage
m = slope of utilization vs. power line
u_{avg} = average server utilization

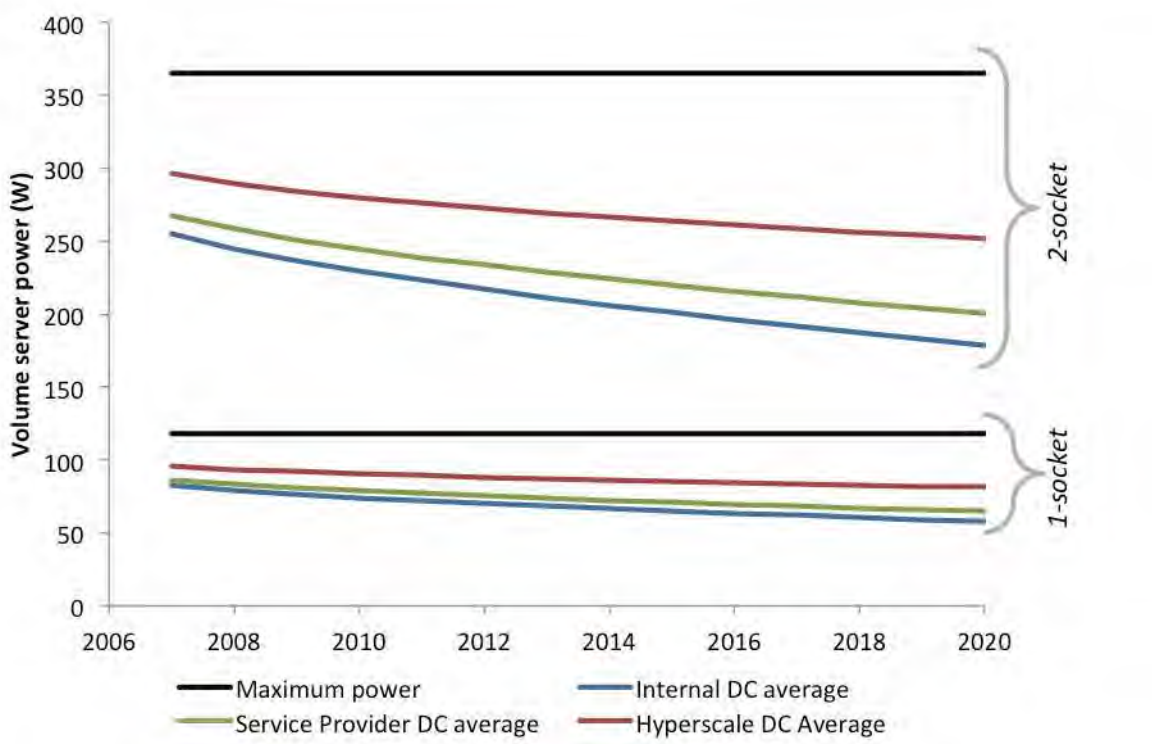


Figure 10. Maximum and Effective Average Power Estimates for Volume Servers
The solid black line represents maximum power of each server size. Servers in hyperscale data centers use more power than those in internal or service provider due to higher utilizations.

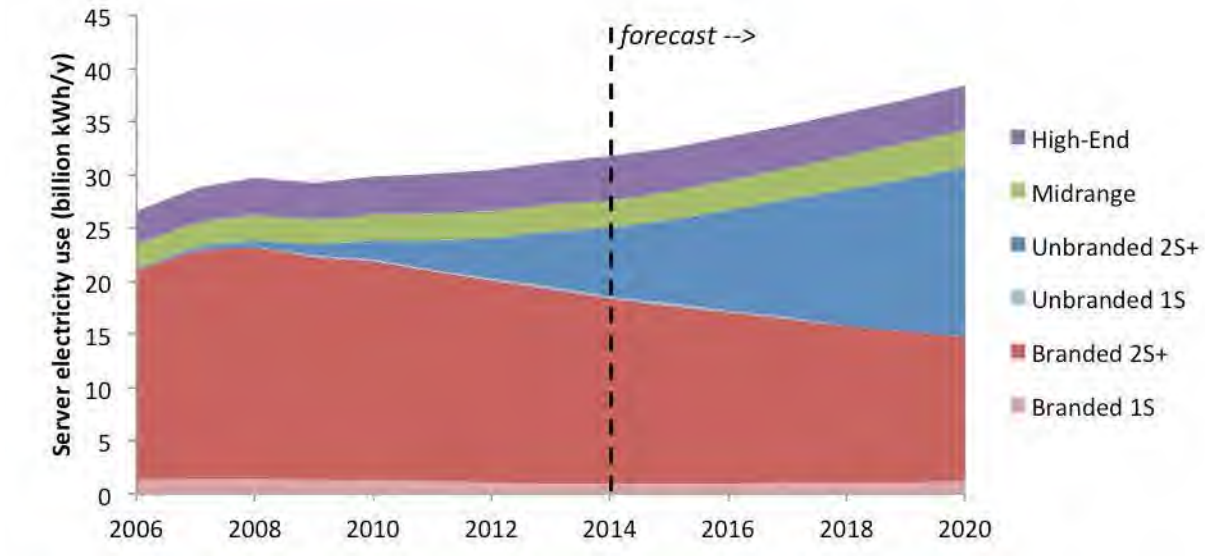


Figure 11. Total U.S. Annual Direct Server Electricity Consumption by Server Class

2.3.2 Storage Energy Use

The installed base of data storage equipment was calculated in terabyte (TB) units using IDC historical (2010-2014) and forecast (2015-2019) shipment data. This data includes external storage units from both branded and unbranded vendors as well as internal storage on servers with more than two storage drives. This study estimates the energy consumed by these supplemental storage types collectively, and refers to all types included in the IDC tracking data as either "Data Center Storage" or "External Storage". The provided shipment data is extended back to 2000 and forward to 2020 using the compound annual growth rate (CAGR) from 2010-2019. Then, installed base is calculated assuming an average storage life of 4.4 years, equal to the estimated lifetime of servers (see Section 2.2.1).[14] This installed base is then disaggregated into hard disk drive (HDD) and solid-state drive (SSD) storage categories using a 2015 ASHRAE report that estimated that in SSD accounted for 8% of non-tape storage in 2012, and would grow to 22% by 2017.[20] The final installed base estimate in TB is shown in Figure 12.

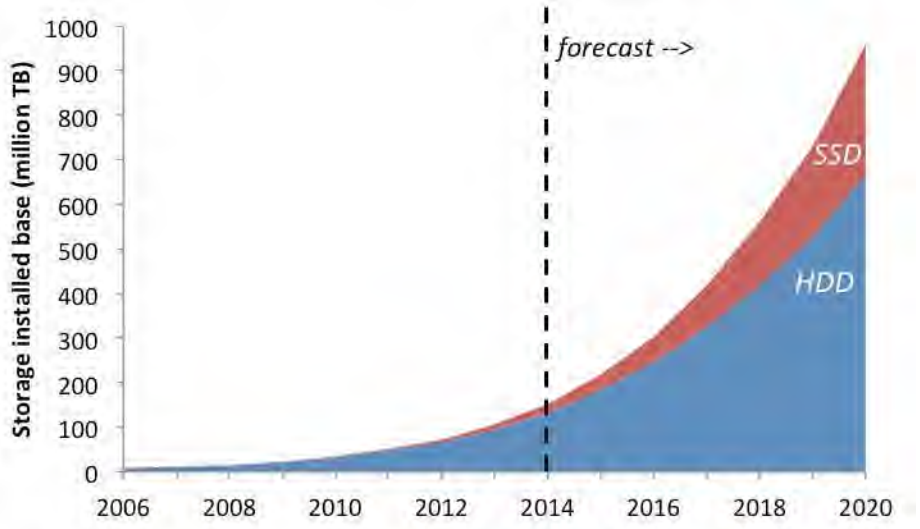


Figure 12. Total U.S. Data Center Storage Installed Base in Capacity (TB)

Power consumption of HDDs is relatively fixed on a per-disk level, and is generally not dependent on the capacity of the disk.[3 19] For SSD units, power consumption is more closely related to capacity (more specifically, to read/write frequency), but is still often reported on a per-disk level. Therefore, it is useful to convert installed base estimates of both HDD and SSD storage from capacity (TB) to number of drive units. To do so, the trend of TB/drive over time for each storage type is first estimated. For 2000-2007, the TB/drive metric for HDD is calculated from (1) this study's installed base estimate in TB, for external branded drives only, and (2) the 2007 Report's disk installed base data, which was provided by storage manufacturers at the time. In 2020, HDDs are assumed to provide an average capacity of 10 TB/disk from drive capacity improvements and capacity optimization methods, based on industry feedback. Data between the 2007 and 2020 estimates are populated using an exponential trend, resulting in the trend shown in Figure 13. For SSD, an average capacity of 5 TB/drive is assumed to be

reached by 2020 based on industry feedback, and the same annual growth rate seen in HDD TB/disk (approximately 27%) is assumed for SSD for all years prior, as shown in Figure 13.

Annual TB/drive estimates are multiplied by the TB installed base estimate (Figure 12) to get the estimated storage installed base in number of drives. This estimate is shown in Figure 14, which shows growth in number of installed drives through 2018, after which point HDD count begins to decrease (SSD count continues to grow). Note that this is the *number* of installed hard disk drives, and does not indicate slowing storage demand. Decreasing drive count is due to HDD capacity per disk (TB/disk, Figure 13) growing at a faster rate than projected HDD capacity demand (TB, Figure 12). SSDs make up 47% of the installed drive base in 2020, which is within the 40-50% range estimated by industry.

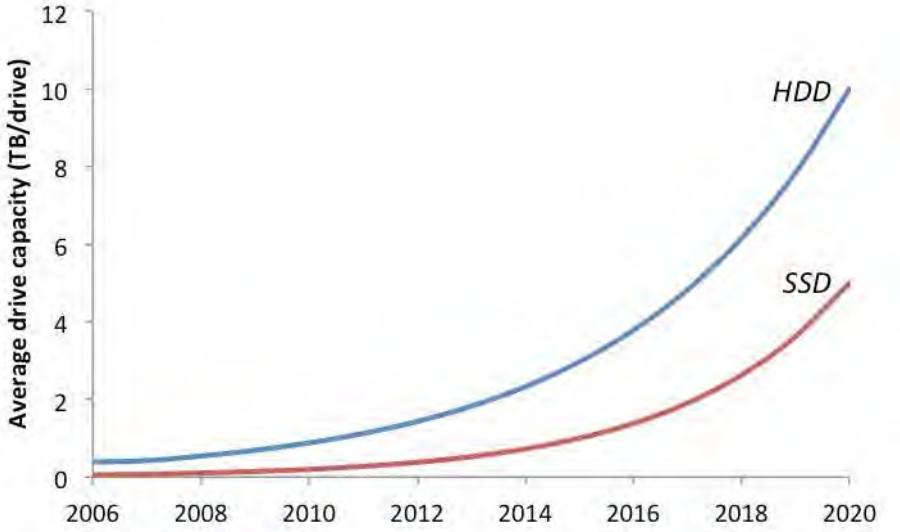


Figure 13. Estimated Average Capacity of U.S. Data Center Storage Drives

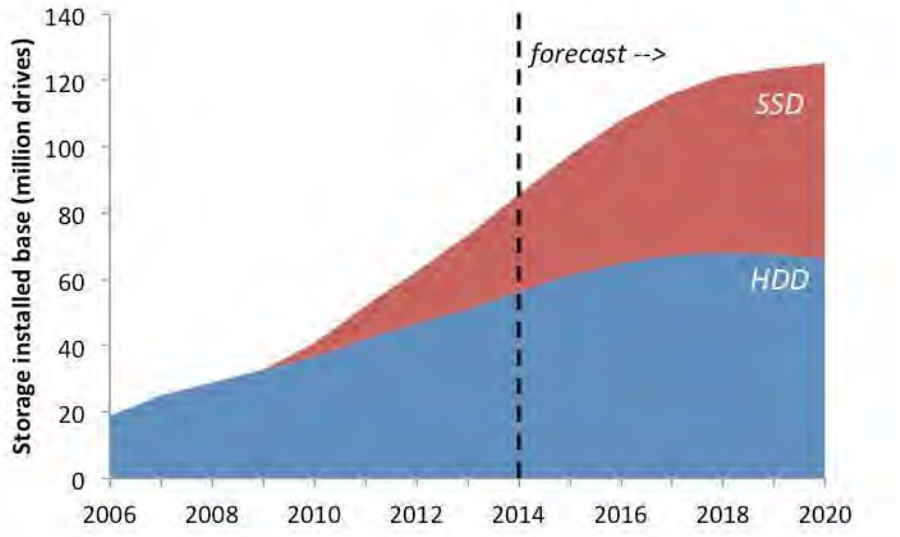


Figure 14. Total U.S. Data Center Storage Installed Base in Drive Count

Power consumption for HDDs was assumed to be 14 W/disk from 2000-2006 as estimated by Seagate for the 2007 Report. A 2015 ASHRAE report[20] stated minimum, average, and maximum power usage for various speeds and sizes of HDDs, while a NYSERDA report[21] estimated the breakdown of these various drive types in the installed base. Using these two reports, the average wattage of HDDs is estimated to be 8.6 W/disk in 2015. This represents a 5% annual decrease in disk wattage from 2006-2015, which is assumed to continue through 2020, resulting in 6.5 W/disk as shown in Figure 15. This improvement in disk efficiency represents more efficient disk drive components, lower power use in idle states, and use of capacity optimization methods.

SSD wattage is assumed to be constant at 6 W/drive, as shown in Figure 15, based on both IDC[22] and ASHRAE[20] reports. Constant drive wattage paired with our TB/drive estimates aligns with industry expectations that SSD capacity per watt will increase three to four-fold by 2020.

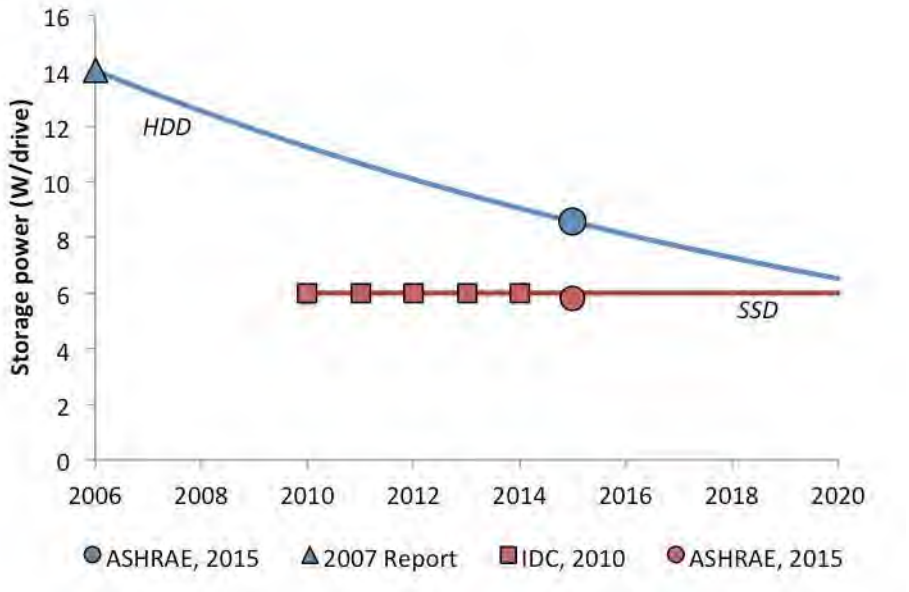


Figure 15. Average Wattage of Storage Drives in U.S. Data Centers

Electricity consumption for all data center storage is calculated as the product of the estimated installed base of drives and the assumed power consumption per drive. Additional operational consumption was then added to account for the controller and associated components required to operate external storage systems. This operational energy is assumed to equal 25% of the storage energy, based on industry comment, and only applies to storage that is external to servers. Resulting total storage energy consumption is calculated according to Equation 4 and results are shown in Figure 16.

Equation 4

$$E_y = \sum_{t=HDD,SSD} (I_{t,y} * P_{t,y}) * h_y * \left(1 + O * \frac{C_{external}}{C_{total}}\right)$$

Where E_y = Storage electricity consumption in year y
$I_{t,y}$ = Installed base of storage type t in year y
$P_{t,y}$ = Per-unit power consumption of storage type t in year y
h_y = Number of hours in year y
O = Operational energy as a fraction of storage energy
$C_{external}$ = Capacity of the external storage installed base
C_{total} = Capacity of the total storage installed base

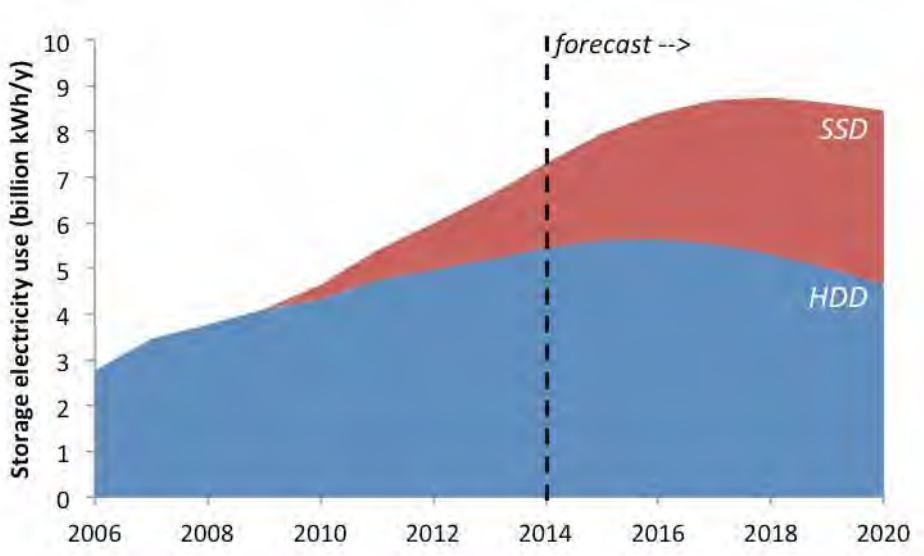


Figure 16. Total U.S. Data Center Storage Electricity Consumption

2.3.3 Network Energy Use

Previous reports estimated network energy use either as a percentage of server energy use[1] [16] or as a product of number of servers, ports per server, and watts per port.[2] This study expands upon these previous efforts by using port installed base estimates disaggregated by port speed along with port wattage estimates for each speed, as described below.

Network equipment data from IDC includes historical (2008-2014) and forecasted (2015-2019) shipments of network ports disaggregated into four port speed categories: 100 MB, 1000 MB, 10 GB, and 40 GB. Similar to storage installed base calculations, this shipment data is extrapolated to estimate number of shipments for 2000-2007 and 2020, then used to calculate the installed base of ports by assuming an average network equipment life of 4.4 years, as estimated from server data (see Section 2.2.1).[14] Resulting port installed base estimates are shown in Figure 17.

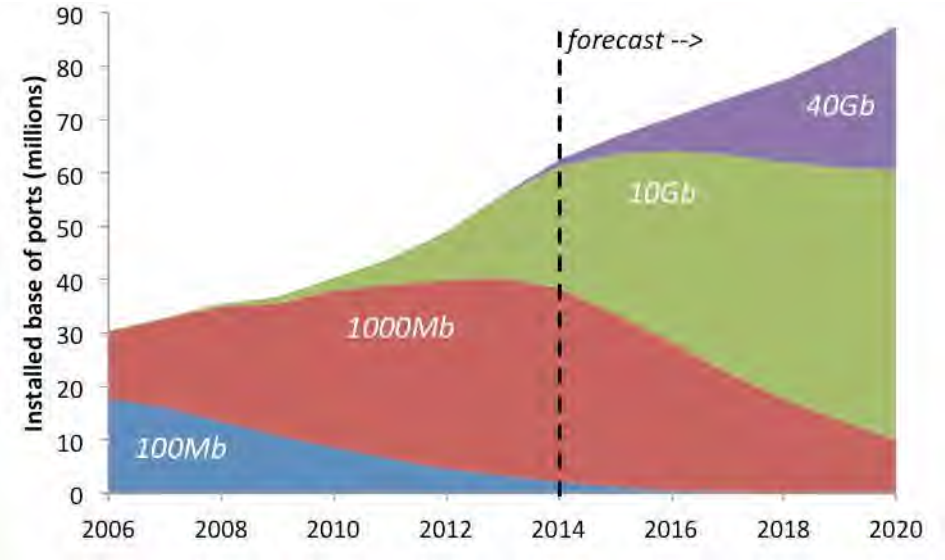


Figure 17. Total U.S. Data Center Installed Base of Network Ports

The power draw of network equipment was estimated on a per-port basis using different values for each port speed. Per-port wattage trends were estimated based on: the 2007 Report, which estimated an average of 8 watts (W) across the installed base; a 2012 empirical study on network energy in small to medium sized data centers,[23] which reported estimates of 1.4, 2.3, and 3.6 W for 100 MB, 1000 MB, and 10 GB ports, respectively; a survey conducted as part of this study of 51 technical specification sheets from network manufacturers, which indicated that 40 GB ports use approximately 1.7 times the power of 10 GB ports; and industry comment, which suggested 1 W/port for 1000 MB ports in 2020. These values were used to create the estimated trends shown in Figure 18. The approximate range of W/port values for various port speeds applied in this study is consistent with power estimates in previous network studies.[24] [25]

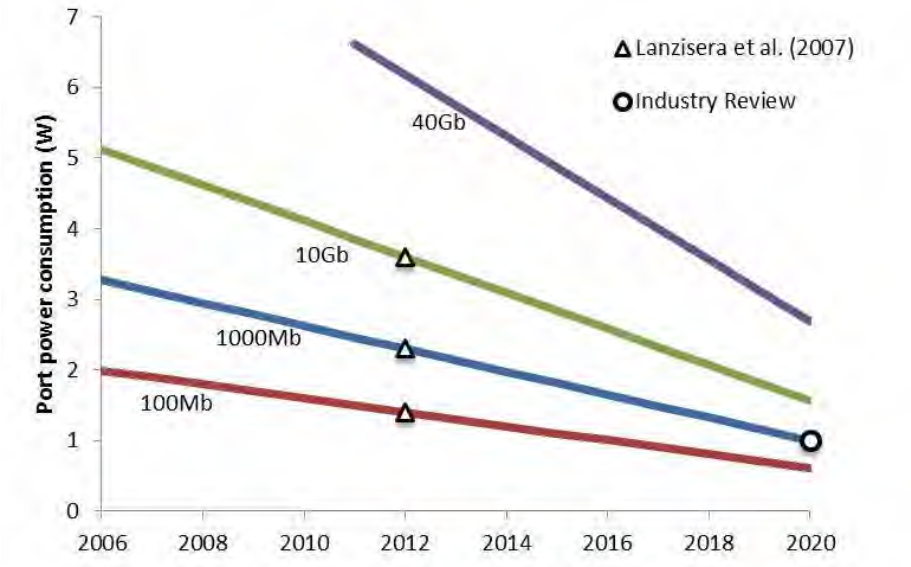


Figure 18. Assumed Network Power for Four Port Speeds

Total estimates of network energy consumption were calculated as the product of the number of ports in the installed base and the assumed per-port power draw for each port speed, as shown in Equation 5. Results are shown in Figure 19. While other types of network equipment besides Level 2/Level 3 network ports exist in data centers, detailed shipment and power consumption data are not available for these devices, and this equipment is assumed to contribute minimally to overall data center power consumption.

Equation 5

$$E_y = \sum_{s \in S} N_{s,y} * P_{s,y} * h_y$$

Where E_y = Network electricity consumption in year y
S = set of port speeds: 100 MB, 1000 MB, 10 GB, 40 GB
$N_{s,y}$ = Number of installed ports of speed s in year y
$P_{s,y}$ = Power consumption of ports of speed s in year y
h_y = number of hours in year y

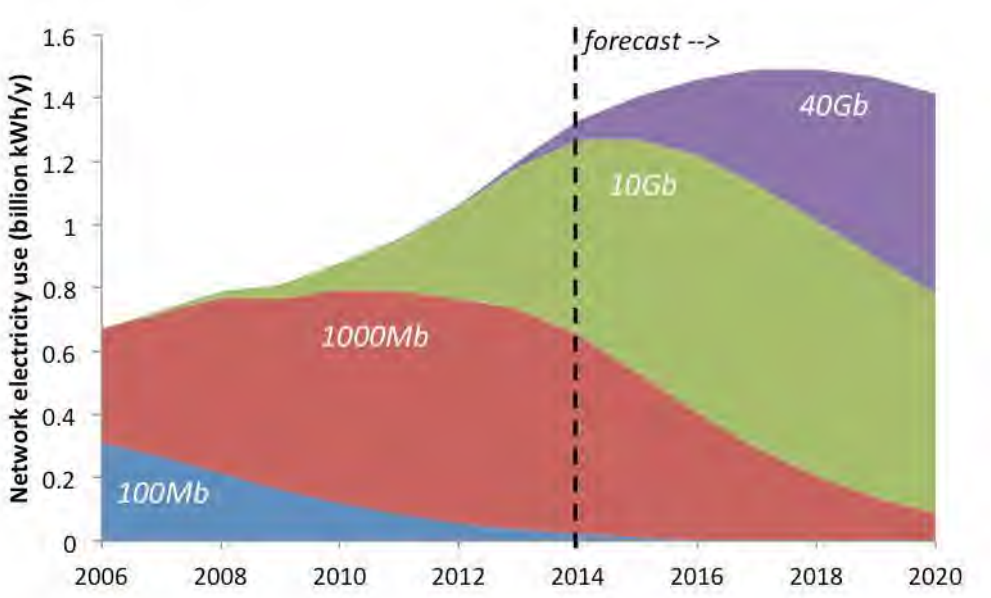


Figure 19. Total U.S. Data Center Network Equipment Electricity Consumption

2.3.4 Data Center Space Type Classifications

Installed base estimates of servers, storage, and network equipment were disaggregated into 11 different data center building space types: five internal data center types that include server closets, server rooms, localized data centers, mid-tier data centers, and high-end data centers, as well as six service provider data center types that include server closets, server rooms, localized data centers, mid-tier data centers, high-end data centers, and hyperscale data centers. Internal data centers represent facilities operated by an organization for internal

activities, including email and productivity software, and are typically associated with finance, education, and other institutions not directly involved with providing IT services. Large internal data centers are often referred to as enterprise or corporate data centers. Service provider data centers (also called production data centers, and inclusive of colocation facilities) contain IT equipment used to provide communication services often associated with the core product of a business, such as the services provided by Google, Amazon, Facebook, and other telecommunication and social media companies. Service provider data centers include the same five size categories as internal data centers, as well hyperscale sized data centers, which are sometimes referred to as "mega" or "warehouse scale" data centers and are often associated with cloud data centers. These types of spaces are defined by IDC as shown in Table 2.

Space disaggregation is necessary to estimate energy use, as half of U.S. servers are located in server closets and server rooms[26] that can have significantly different IT equipment and infrastructure characteristics than larger data centers, and because service provider data centers associated with cloud platforms, mobile devices, social media, and big data have grown significantly in recent years.[27] In the context of this study, "infrastructure" consists of the data center equipment that is not used solely for the purpose of performing computations or the storage or transmission of data. This includes cooling systems, lighting, power supplies, security, and so on. Determining the distribution of different servers across space types allows for more accurate characterization of the total energy use associated with different server environments. It also allows for better characterization of electricity costs because most server closets, server rooms, and localized data centers are expected to be subject to commercial electricity rates, whereas larger mid-tier and enterprise-class data centers are expected to be subject to industrial electricity rates. Disaggregation into the eleven space types is a significant expansion on the 2007 study's five space types. An overview of the methods used to allocate IT equipment to the various data center types are shown in Table 3, with detailed descriptions provided below.

The number of data centers in each space category in the U.S. for 2005 was derived from a 2006 IDC report,[26] while 2012-2018 estimates were taken directly from a 2014 IDC report.[27] The 2005 numbers only included five space categories, and therefore were split into internal and service provider categories (based on the 2012 ratios). No hyperscale data centers were assumed to exist in 2005. These 2005 numbers were then assumed to grow linearly to 2012 values. The number of data centers for 2000-2004 and 2019-2020 were estimated using the 2005-2009 (as reported by Bailey[26]) and 2012-2018 CAGRs, respectively, for each of the eleven room types.

Bailey[26] also reported average number of servers per data center for five space categories in 2005. Servers per data center for each of the five space sizes were assumed to be applicable to both internal and service provider data centers in that category. These numbers were then adjusted for each year so that, when multiplied by the number of data centers, the total number of servers was consistent with this study's estimates of total server installed base (excluding servers assigned to hyperscale data centers). The resulting total number of servers in each space category are shown in Figure 20.

Table 2. Typical IT Equipment and Site Infrastructure System Characteristics by Space Type

Space type	Typical size	Typical infrastructure system characteristics
Internal server closet	< 100 ft^2	Often outside of central IT control (often at a remote location) that has little to no dedicated cooling.
Internal server room	100-999 ft^2	Usually under IT control, may have some dedicated power and cooling capabilities.
Localized internal datacenter	500-1,999 ft^2	Has some power and cooling redundancy to ensure constant temperature and humidity settings.
Midtier internal datacenter	2,000-19,999 ft^2	Superior cooling systems that are probably redundant.
High-end internal datacenter	> 20,000 ft^2	Has advanced cooling systems and redundant power.
Point-of-presence server closet	< 100 ft^2	At local points of presence for OSS and BSS services. Typically leverages POP power and cooling. Space is often a premium.
Point-of-presence server room	100-999 ft^2	Secondary computer point of presence for OSS and BSS services. Typically leverages POP power and cooling.
Localized service provider datacenter Including subsegment: containerized datacenter	500-1,999 ft^2	Has some power or cooling redundancy to ensure constant temperature and humidity settings. These are typically facilities set up by VARs to provide managed services for clients.
Midtier service provider datacenter Including subsegment: prefabricated datacenter	2,000-19,999 ft^2	Location for small or midsize collocation/hosting provider. Also includes regional facilities for multinational communications service providers. Has superior cooling systems that are probably redundant.
High-end service provider datacenter	> 20,000 ft^2	Primary server location for a service provider. May be subdivided into modules for greater flexibility in expansion/refresh. Has advanced cooling systems and redundant power.
Hyperscale datacenter	Up to over 400,000 ft^2	Primary server location for large collocation and cloud service providers. Based on modular designs, with individual modules of 50,000 sq ft on average in up to 8 modules. Employs advanced cooling systems and redundant power.

While IDC shipment estimates include servers destined for hyperscale data centers, the percentage of servers that are located in hyperscale data centers was not available. Therefore, this study uses a simple estimation that the percent of servers housed in hyperscale data centers will grow linearly from 0% in 2005 to 40% in 2020. This assumption is a conservative

estimate of future unbranded server installed base as calculated by shipment forecasts, and aligns with other industry projections of the unbranded server market[28] and expectations that at least 40% of the data in 2020 is expected to be "touched" by the cloud at least once.[29] This estimate also aligns with current IDC estimates of the global average of servers per data center for high-end and hyperscale data centers.[30]

Table 3. Allocation of Data Center Equipment Across Space Types

Step	Equipment	Allocation Method
1	Total Servers	• Set percentage (varies annually) to Hyperscale • Remaining based on estimated data center counts and 2005 servers per data center estimate
2	Midrange Servers	• 5% Server Rooms 30% Localized and Mid-tier Data Centers 65% Enterprise Data Centers
3	High-End Servers	• 30% Localized and Mid-tier Data Centers 70% Enterprise Data Centers
4	Unbranded 1S and 2S+ Volume Servers	• 100% Hyperscale Data Centers
5	Branded 2S+ Volume Servers	• Fill remaining spots in Hyperscale
6	Branded 1S and 2S+ Volume Servers	• Fill remaining spots in all other data centers, keeping 1S and 2S+ in equal proportion
7	Storage	• None in Server Closets or Rooms • Allocated to all other spaces based on total server count
8	Network Ports	• Total allocated based on total server count, with higher speeds trending towards larger data centers

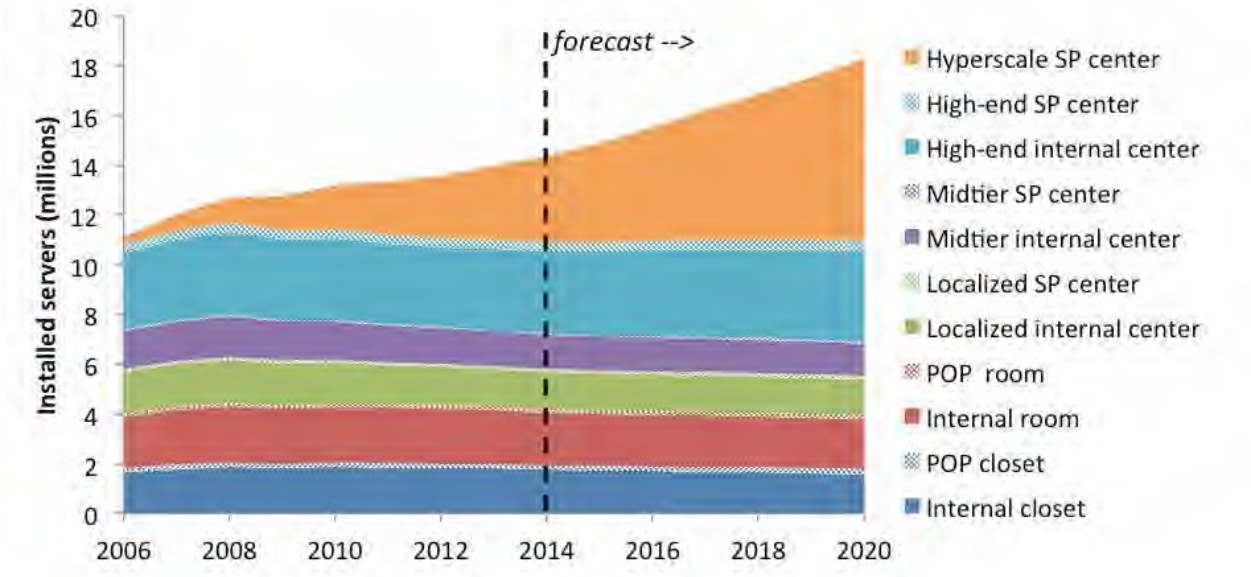


Figure 20. Total Server Installed Base by Data Center Space Category

Once total server installed base is allocated to various room types, the prevalence of each of the six server classifications in this study (volume branded 1S and 2S+, volume unbranded 1S and 2S+, mid-range, and high-end) is allocated to the various space categories. Mid-range and high-end servers were allocated based on a set of assumptions used in the 2007 Report: (1) no mid-range or high-end servers are in server closets (2) 5% of mid-range are in server rooms and (3) 65% and 75% of mid-range and high-end servers, respectively, are in high-end data centers. The remainder of mid-range and high-end servers were split evenly between localized and mid-tier data centers. Within a space type, servers were split between internal and service provider space categories based on the total number of data centers in each category. All volume unbranded servers were assumed to be in hyperscale data centers. Lastly, branded volume servers were assumed as the difference between the total number of servers assigned to a given space category, and the number of mid-range, high-end, and unbranded servers assigned in that category.

External storage is assumed to be present in all data center space types except server closets and server rooms, and is allocated based on the number of servers in each space type in the given year. Network ports are also distributed among space types in direct proportion to the number of servers in the given space type. While total number of ports per server is constant across space categories (in a given year), the speed of the ports installed varies between space categories. Space categories were grouped into “fast” (hyperscale and high-end), “medium” (mid-tier and localized), and “slow” (rooms and closets), and the installed base of ports was distributed accordingly.

Infrastructure energy consumption (cooling equipment, uninterrupted power supplies, lighting, etc.) is calculated using the power usage effectiveness (PUE) metric.[31] This metric represents the total energy required by the data center in relation to the energy needed for the IT equipment. A data center with PUE of 1 would use no electricity other than the IT equipment. At the time of the 2007 Report, the average PUE was estimated to be 2.0, indicating that non-IT energy use was about equal to the IT energy use in a data center. Other studies at that time showed many data centers with PUE values greater than 3.0.[32] [33] [34] More recent studies show that while a wide range of PUE values is still observed, the average PUE has only modestly improved to about 1.8-1.9.[35] [36] The slower rate of efficiency improvement in PUE relative to IT equipment is partially due to the slower turnover rate of a data center’s infrastructure relative to the IT equipment. The opportunities to improve data center PUE increase with larger data centers that have the ability to develop better airflow management and employ more efficient cooling equipment or advanced cooling technologies such as liquid cooling. Consequently, smaller data centers are still being measured with PUE values greater than 2.0[37] while large hyperscale cloud data centers are beginning to record PUE value of 1.1 or less.[38] [39] [40] Table 4 presents the characteristic infrastructure equipment and corresponding average PUE values assumed for each data center size for 2014. PUE values for each data center size are based on previously published values, expert elicitation, and energy modeling results for different data center infrastructure configurations.[41] For the current trends scenario, average PUE values for each size data center are assumed to be the same for internal and service provider data centers and, given the very modest improvements observed in published data for average PUE values, to improve by 1% per year through 2020, except for closets. The PUE for closets is held

constant at 2.0 throughout the analysis period, given that the lack of dedicated cooling and electrical equipment in this space type limits opportunity for improvement. Applying the PUE values in Table 4 to IT energy use in each data center type provides the total energy consumption by data center component (Figure 21) and by space type (Figure 22).

Table 4. 2014 PUE by Space Type

Space Type	IT	Transformer	UPS	Cooling	Lighting	Total PUE
Closet	1	0.05	-	0.93	0.02	2.0
Room	1	0.05	0.2	1.23	0.02	2.5
Localized	1	0.05	0.2	0.73	0.02	2.0
Midtier	1	0.05	0.2	0.63	0.02	1.9
High-end	1	0.03	0.1	0.55	0.02	1.7
Hyperscale	1	0.02	-	0.16	0.02	1.2

2.3.5 Total Data Center Energy Consumption

As shown in Figure 21, electricity consumption of data centers has been relatively flat in recent years, which is attributable to many factors. The growth rate of server shipments has diminished over the past 15 years. From 2000-2005, server shipments increased by 15% each year resulting in a near doubling of servers operating in data centers. From 2005-2010, the annual shipment increase fell to 5%, most likely driven by the economic recession as well as the emergence of server virtualization during that period. The annual growth in server shipments further dropped after 2010 to 3% and that growth rate is now expected to continue through 2020. This 3% annual growth rate coincides with the rise in hyperscale data centers and an increased popularity of moving previously localized data center activity to colocation or cloud facilities. In fact, nearly all server shipment growth since 2010 occurred in servers destined for hyperscale data centers, where servers are often configured for maximum productivity and operated at higher utilization rates, resulting in fewer servers needed than would be required to provide the same services in traditional, smaller, data centers.

Along with total server count, the power demand for each server has also changed. While server power requirements were observed to be increasing from 2000-2005, power demand appears to have stayed fairly constant since 2005. Additionally, servers are improving in their power scaling abilities, thus reducing power draw during idle periods or when at low utilization. Efficiency improvements in storage, network and infrastructure also influence the electricity estimates in this report. Storage devices are becoming more efficient on a per-drive basis, with the growth in drive storage capacity projected to outpace increases in data storage demand by 2020, ultimately reducing the number of physical drives needed throughout data centers. Recent estimates of network port power consumption are now much lower than estimates from the past decade. Increased awareness in data center infrastructure operations (e.g. cooling) has resulted in improved efficiency across data center types, though the most significantly in large cloud data centers that are innovatively designed to maximum infrastructure efficiency.

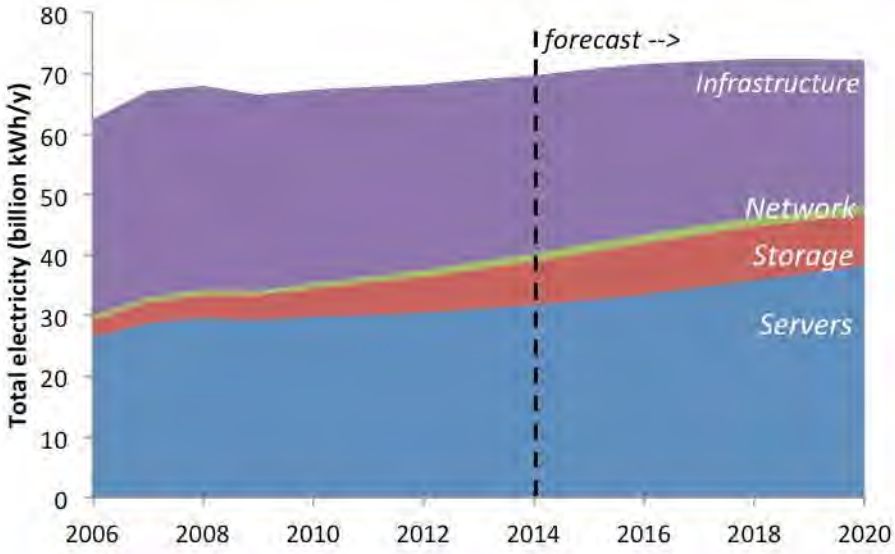


Figure 21. Total Electricity Consumption by Technology Type

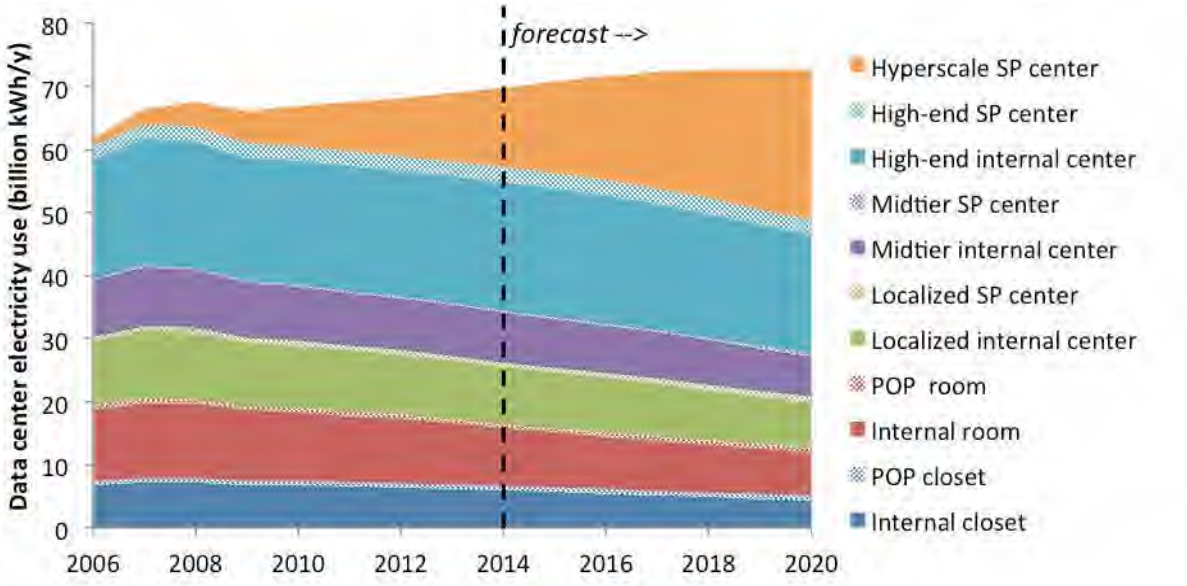


Figure 22. Total Electricity Consumption by Space Type

Results from this study for 2000-2014 are shown in Figure 23 alongside results from three previous studies: the 2007 Report; Masanet et al. (2011), which built upon the 2007 Report to estimate consumption in 2008; and Koomey (2011), which estimated 2010 consumption using updated server shipment data after the 2009 financial crisis. While data center operations since 2008 likely benefited from some adoption of energy efficiency measures, such as increased server consolidation and improved IT power management, the distinct reduction in electricity use observed in the later studies immediately after 2008 was likely also due to a lower installed server base associated with the economic recession and the related efficiency improvements driven by pressure to cut energy and equipment costs.

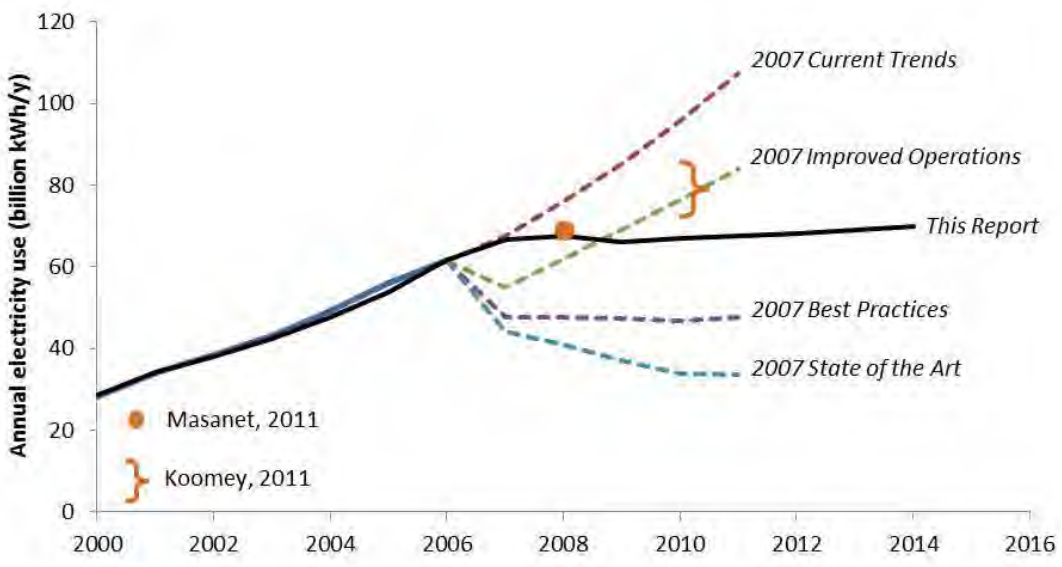


Figure 23. Historical Data Center Total Electricity Use

Growth in data center energy consumption has slowed drastically since the previous decade. However, demand for computations and the amount of productivity performed by data centers continues to rise at substantial rates.[42] Technology advancements have made IT equipment more efficient by being able to perform more work on a given device, while other design and management efforts have made the industry more energy efficient. A counterfactual scenario was created for this study that estimates what data center energy consumption would have been if industry energy-savings efforts were halted in 2010. The metrics frozen in 2010 include:

- Industry-wide average server utilization remains at 14%
- Dynamic range of server remains at 0.59 (i.e., servers use 59% of their maximum power at idle) (see Figure 8)
- Wattage per HDD remains at about 11.3 watts (see Figure 15)
- Wattage of network ports remains at 1.6, 2.6, 4.1, and 7.1 for 100Mb, 1000Mb, 10Gb, and 40 Gb, respectively (see Figure 18)
- Industry-wide weighted average PUE remains at 1.89

This scenario does not halt the technological advancements of the computing industry in terms computational performance (i.e., computations/second per servers) and the electrical efficiency of computations (i.e., computations per kWh). Computational performance and the electrical efficiency of computations are assumed to continue to improve in parallel and at similar rates[43] (thereby cancelling each other out), since the main trend driving both advancements are smaller transistors.[42] Additionally, wattage per HDD and per network port are held at 2010 levels but storage capacity (i.e., TB per drive) and a shift towards fasters ports are assumed to progress as normal.

The results of this scenario are shown in Figure 24, with 2014 energy use that is 60% higher than currently estimated, and projected 2020 use 170% higher than the Current Trends scenario. Energy savings of the industry are therefore estimated to be 100 billion kWh from 2010-2014, and an additional 520 billion kWh from 2015-2020. The overwhelming majority of these savings come from the servers and infrastructure. Server savings are driven by the increase in industry-wide average utilization that results from consolidation efforts and the growth data centers that operate at higher utilization levels (i.e., hyperscale and other service provider data centers). Infrastructure savings result from the reduced amount of IT equipment that require cooling and electrical services as well as the decrease in industry-wide average PUE, brought down by the growth in data centers with very low PUE values (i.e., hyperscale data centers).

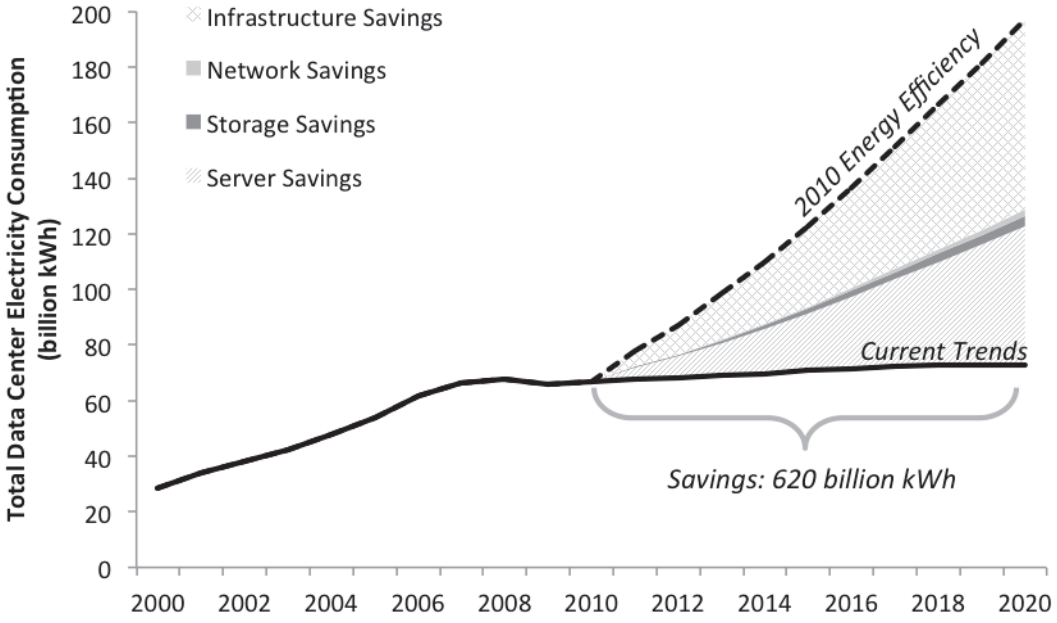


Figure 24. Data Center Electricity Consumption in Current Trends and 2010 Energy Efficiency Scenarios

The 2010 Energy Efficiency scenario assumes that data center energy-related design and operational efforts do not continue past 2010, which indicates that current trend energy efficiency practices will have saved 620 billion kWh of electricity over the period 2010-2020.

2.3.6 Data Center Water Consumption

Along with electricity demand, data centers require significant water consumption during operation. Water is consumed at two key points during data center operation.[44] First, water is required during the generation of electricity from primary energy that is eventually transmitted for use at the data center site. A national average of 7.6 liters (2.0 gallons) of water are consumed for each kWh when weighting the water losses at both thermoelectric and hydroelectric plants in the U.S.[45] Second, in medium to larger size data centers that employ cooling tower based chillers to improve energy efficiency, water is consumed at the data center

site itself. Cooling towers use water evaporation to reject heat from the data center causing losses approximately equal to the latent heat of vaporization for water, along with some additional losses for drift and blowdown. In larger data centers this on site water consumption can be significant, with data centers that have 15 MW of IT capacity consuming between 80-130 million gallons annually.[46] [47] In this study, on-site water consumption is estimated at 1.8 liters (0.46 gallons) per kWh of total data center site energy use for all data centers except for closet and room data centers, which are assumed to use direct expansion (air-cooled chillers). With these assumptions, approximately 626 billion liters of water was estimated to be consumed in 2014 for data centers, with that number reaching 660 billion liters in 2020. Data center water consumption is shown in Figure 25 and Figure 26. Note that water consumption associated with the generation of electricity varies significantly by primary energy type and power plant efficiency, such that the actual water consumption attributable to any individual data center will depend on its specific location and electricity provider.

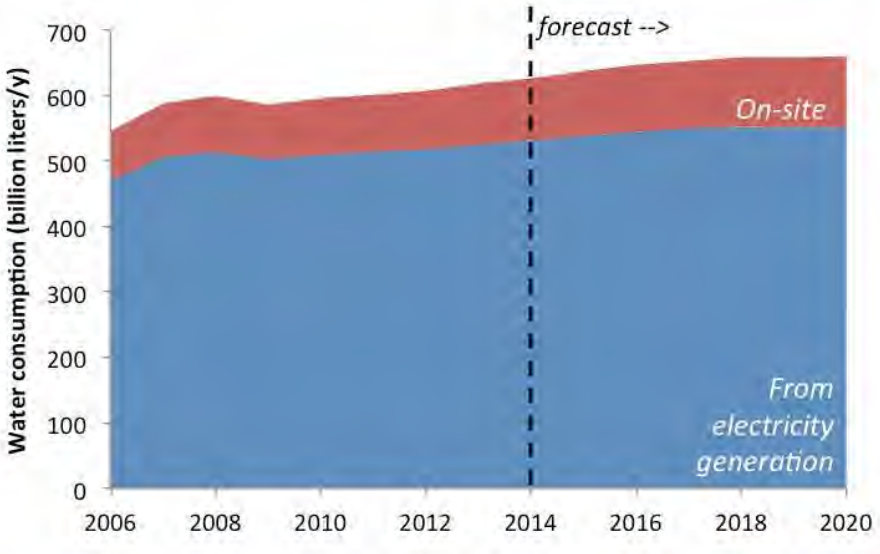


Figure 25. Direct vs. Indirect U.S. Data Center Water Consumption

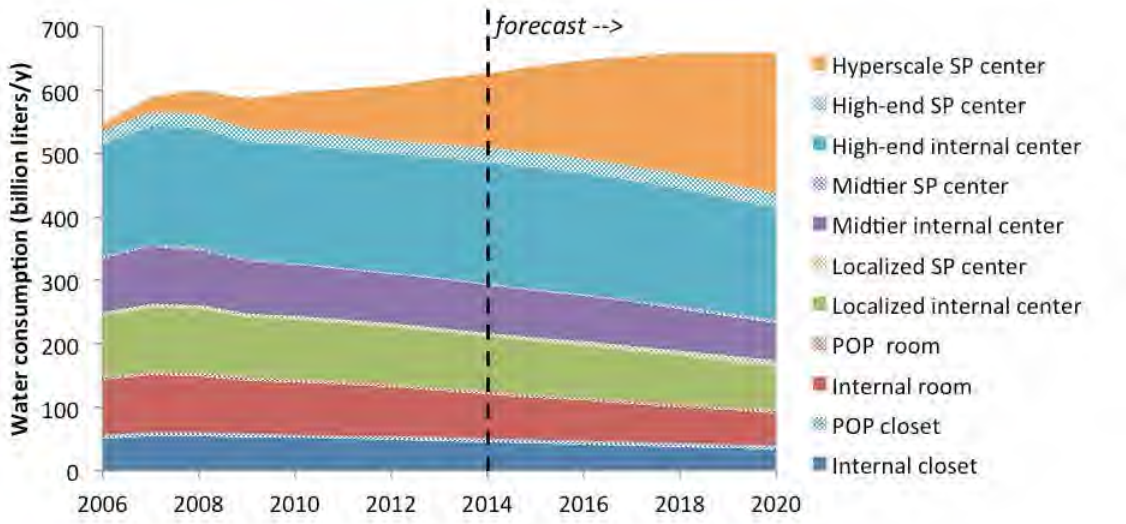


Figure 26. Total U.S. Data Center Water Consumption by Space Type

3 Energy Use Associated with Federal Government Servers and Data Centers

The Federal Data Center Consolidation Initiative (FDCCI), established in 2010 to reverse the historic growth of Federal data centers, has been conducting surveys on federally operated data centers to verify existing records and expand inventory data for these facilities (e.g. address, operational status and cost, square footage, server count, etc.).[48] For this study, server count estimates were provided by the Office of Management and Budget (OMB) for 2012-2014, corresponding to approximately 1-2% of nationwide server installed base estimates, as shown in Table 5.

Table 5. Servers in Federal Data centers Tracked by OMB

	2012	2013	2014
Total Server Count	238,709	295,316	118,851
Percent of National Installed Base	1.8%	2.1%	0.8%

Estimates provided in Table 5 do not capture shipments of servers to facilities that were managed by contractors for the federal government and adequate information to estimate the percent of federal server use that occurs in these facilities is not available. Therefore, these numbers provide only a portion and not a complete representation of the impact of the federal government associated with data center operation.

This estimate from OMB is a sharp decrease from the 2007 Report where federal servers and data centers were estimated to be about 10% of the U.S. total. At that time, no data could be found in the public domain on the number of servers or data centers operated by (or for) the

federal government and therefore the server estimate was based on interviews conducted with major U.S. manufacturers. These interviews led to the conclusion that server shipments to the federal government represented about 5-10% of annual U.S. server shipments and the higher end of this range was used in an attempt to account for servers shipped to government contractors that were not counted as federal shipments.

FDCCI efforts have resulted in the closing of approximately 1.7 million square feet of data center space since 2010.[49] According to current estimates of server density in various space types this correlates to the removal of approximately 60,000 servers from the federal inventory or about half of the 2014 estimate. However, even without these consolidation efforts the 2014 server count would correspond to only 1.2% of the national installed base. This large discrepancy compared to the 2007 Report estimate implies OMB's server accounting may not be capturing a significant portion of federal servers in the U.S. data center stock.

No data on federal server shipments by server class (i.e., volume, mid-range, and high-end) are available. It is possible that the federal government accounts for a significant fraction of high-end server electricity use, given that about one third of the 100 largest supercomputers in the world are housed in U.S. government-owned facilities, including four out of the top ten in the world.[50] This larger representation of high-end servers would potentially put federal energy consumption at a higher percentage of the national installed base than the percentage represented in Table 5.

4 Expected Energy Savings Opportunities

4.1 Energy Efficiency Trends

A number of energy efficiency trends have been shaping server operations over the past decade, including virtualization and consolidation, which are expected to continue to generate energy savings and reduce server footprint. Physical parts of the server such as the microprocessor, cooling fan, and power supply are also improving in energy efficiency (or being eliminated, such as the fan in servers with liquid cooling), thus further reducing server power consumption per unit of computing output. More efficient storage devices such as SSDs are coming down in cost and their increasing prevalence will continue to drive efficiency. Furthermore, the growing trend of cloud computing has resulted in significantly larger data centers that are more efficient, both in terms of server utilization and infrastructure PUE, compared to traditional enterprise data centers. Along with the current trend previously described in this report, three additional scenarios and two combinations of scenarios were modeled to estimate near-term energy efficiency opportunities in U.S. data centers.

4.2 Improved Management Scenario

The Improved Management (IM) scenario consists of two components: improved PUE and removal of inactive servers. Improved PUE represents an effort for smaller data centers to reduce their infrastructure (e.g. cooling, lighting) energy demand through improved airflow and thermal management, such hot/cold isle isolation and reducing set point temperatures. PUE

values trend linearly after 2014 to the improved numbers shown in Table 6. Inactive servers (also referred to as comatose or "zombie" servers) represent obsolete or unused servers that consume electricity but provide no useful information services. Previous studies have estimated that inactive servers represent 10-30% of servers in U.S. data centers.[51] [52] [53] [54] Inactive server removal represents an impact of raised awareness on part of data center operators as to what equipment is being utilized in the data center. In order to model this impact, servers are first assigned to each space type as described in Section 2.2.4, then the number of volume servers in internal data centers is decreased by 10%, and in service provider data centers by 5%, for each year after 2014. The percent decrease in service provider data centers is assumed to be smaller because these data centers tend to have a lower rate of inactive servers due to better management practices that avoid the institutional problems of dispersed responsibility between IT and facility departments which often plagues internal data centers.[55]

The IM scenario results in total energy savings in 2020 relative to the Current Trends scenario of 10% which is composed of: 2.5% from server energy savings due to the removal of inactive servers; no savings in storage or network energy; and 7.5% from savings in infrastructure energy due to the reduced server energy along with improved PUE.

Table 6. PUE and Redundancy Values for Efficiency Scenarios

Space Type	2014 PUE	2020 PUE			Redundancy
		Current Trends	Improved Management	Best Practices	
Closet	2.0	2.00	2.00	2.00	N+0.5N
Room	2.5	2.35	1.70	1.50	N+1
Localized	2.0	1.88	1.70	1.50	N+1
Midtier	1.9	1.79	1.70	1.40	N+0.2N
High-end	1.7	1.60	1.51	1.30	N+0.5N
Hyperscale	1.2	1.13	1.13	1.10	N

4.3 Best Practices Scenario

The Best Practices (BP) scenario builds upon the improvements in the IM scenario. These best practices include further improved PUE values (Table 6) from using more efficient infrastructure components and employing economizer or liquid cooling when applicable, as well as improved dynamic range (power scaling ability) of servers, server and network consolidation efforts, and reduced storage disk and network port power consumption.

In all scenarios, average dynamic range is calculated by determining what mix of servers follow a minimum versus a maximum dynamic range trend (Figure 8). For the CT scenario, the average dynamic range of volume servers is assumed to be represented by 90/10 mix of the maximum and minimum dynamic range trends. The BP scenario has a more aggressive penetration of servers that follow the maximum dynamic range trend and assumes that this ratio reaches 50/50 by 2020. This results in the dynamic range trend shown in Figure 27, where volume servers reach a dynamic range of 0.28 in 2020. While these number are possible, it should be noted that getting below 20-25% of maximum power at idle can require powering

down specific functionality that may increase idle-to-active wake-up latency and result in delayed response times. Attempts to improve the idle power savings versus latency include establishing different levels of inactive modes with varying degrees of power savings and response times.[56] [57] As discussed in Section 2.2.1, these numbers are used to calculate the slope of the utilization versus power line (Equation 2) and therefore the power consumption at average utilization levels (Equation 3).

Server consolidation entails replacing multiple servers running at low utilization with a single server running at a higher utilization. Eighty percent of the volume server installed base is assumed to be consolidated onto servers that operate at the utilization levels presented in Table 7. These parameters are chosen based on the assumption that servers in internal and service provider data centers could be consolidated through methods such as virtualization and containerization to the current high end of utilization observed in servers in small and medium size data centers[17] [18] and servers in hyperscale data centers could be consolidated to 75% utilization through improved CPU bandwidth provision techniques, which have been shown to achieve average data center server utilizations as high as 90%.[58] There is a small additional benefit to consolidation by reduction in redundant servers required, which is calculated according to the data center size-specific redundancy frameworks presented in Masanet (2013),[59] shown in Table 6. The formulas in the "Redundancy" column represent the total number of servers needed for a data center containing N functional servers. For example, redundancy of "N+1" means that there is one redundant server present in each data center, while redundancy of "N+0.1N" means that there is one redundant server for every 10 functional servers. For data centers where the number of redundant servers scales with server count (i.e. closets, mid-tier, and high-end enterprise), consolidation of servers reduces the number of redundant servers required.

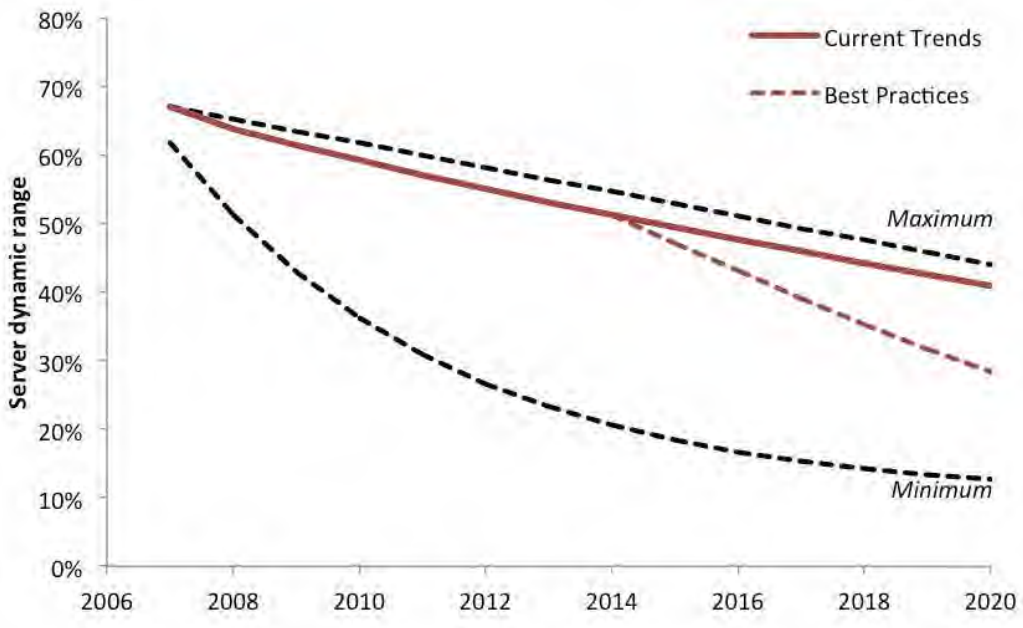


Figure 27. Average Volume Server Dynamic Range for Current Trends and Best Practices Scenarios

Table 7. Best Practices Scenario Consolidation Parameters

Space Type	Percent of installed base consolidated by 2020	Utilization		Consolidation utilization overhead
		Pre-consolidation	Post-consolidation	
Internal	80%	10-15%	45%	5%
Service Provider	80%	20-25%	55%	5%
Hyperscale	80%	45-50%	75%	5%

Equation 6 describes the number of servers that are consolidated each year from 2015-2020. Equation 7 describes the number of pre-consolidation servers that can be replaced by each post-consolidated server, based on pre- and post- consolidation utilization, utilization "overhead", and redundancy considerations. Utilization overhead is estimated as 5% per post-consolidation server and accounts for the applications that must be run on the server to balance multiple workloads. In essence, this means that consolidation of two servers running at 10% utilization would result in one server running at 25% utilization. Because the scenario's post-consolidation utilizations are defined, Equation 7 is used to calculate the number of pre-consolidation servers that are replaced by each post-consolidation server. The number of servers consolidated each year (Equation 6) is then divided by this metric to determine how many servers (out of those that are consolidated) remain in the installed base, as shown in Equation 8. Finally, the new post-consolidation installed base is calculated as shown in Equation 9. Consolidation impacts on server installed base are shown in Figure 28.

Equation 6

$$S_{con,y} = C_{y_f} * \frac{y - y_i}{y_f - y_i} * IB_y$$

Where $S_{con,y}$ = number of servers to be consolidated in year y
C_{yf} = Percent of installed base consolidated in final year
y_i = year consolidation begins
y_f = year consolidation ends
IB_y = baseline installed base in year y

Equation 7

$$N_{con} = \frac{u_{post} - u_o}{u_{pre}} * \frac{1}{r_{pre}}$$

Where N_{con} = number of servers that can be consolidated into one
u_{post} = post-consolidation server utilization
u_o = consolidation utilization overhead
u_{pre} = pre-consolidation server utilization
r = fraction of pre-consolidation servers that are non-redundant

Equation 8

$$S_{res,y} = \frac{S_{con,y}}{N_{con}}$$

Where $S_{res,y}$ = number of consolidated servers resulting in year y
$S_{con,y}$ = number of servers consolidated in year y
N_{con} = number of servers that can be consolidated into one

Equation 9

$$IB_{y,post} = IB_y - S_{con,y} + S_{res,y}$$

Where $IB_{y,post}$ = installed base in year y post-consolidation
IB_y = baseline installed base in year y
$S_{con,y}$ = number of servers to be consolidated in year y
$S_{res,y}$ = number of consolidated servers resulting in year y

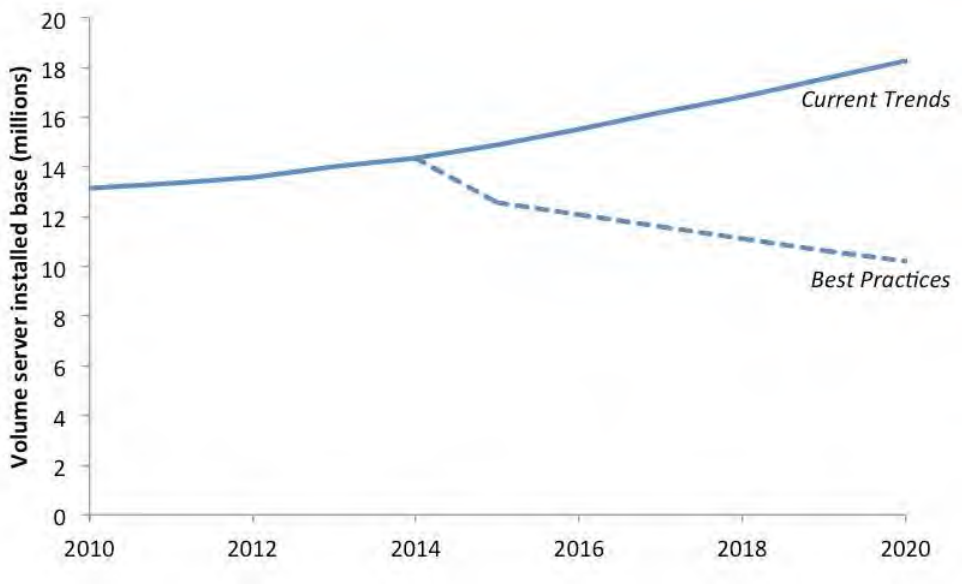


Figure 28. Volume Server Installed Base for Current Trends and Best Practices Scenarios

Network port consolidation is similar to server consolidation. Eighty percent of the installed base of 10 GB ports are assumed to be consolidated into 40 GB ports, which can transmit 4 times the data at only 1.7 times the power. In addition, the BP scenario assumes that ports installed in high-end enterprise and hyperscale data centers will become 25%[60] more efficient by 2020. This reduction in port wattage is based on network improvements in network topology, dynamic link rate adaptation, and link and switch sleep modes.[25] BP scenario impacts on port installed base are shown in Figure 29.

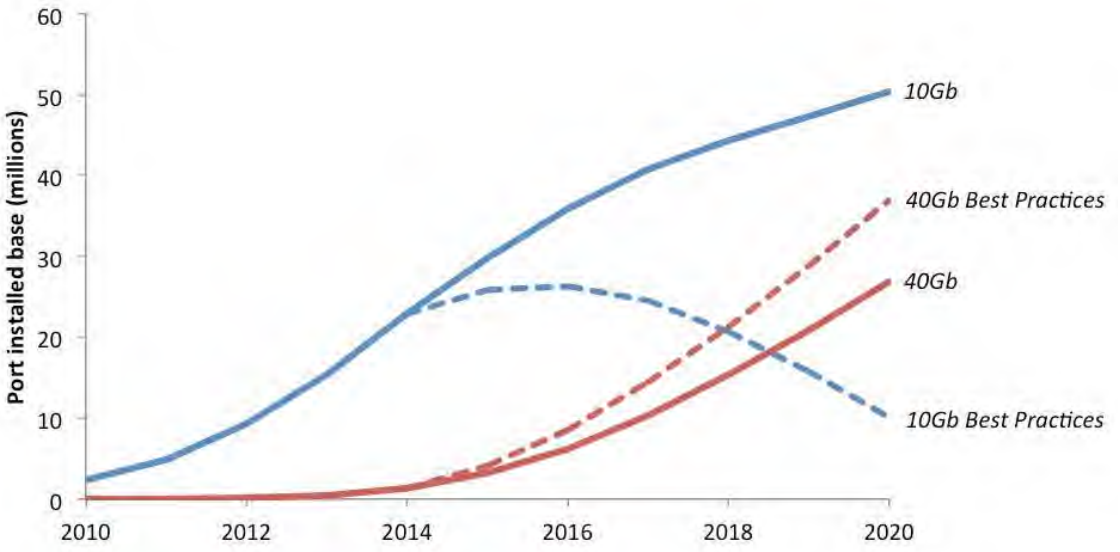


Figure 29. Network Installed Base for 10 GB and 40 GB Ports in Current Trends and Best Practices Scenarios

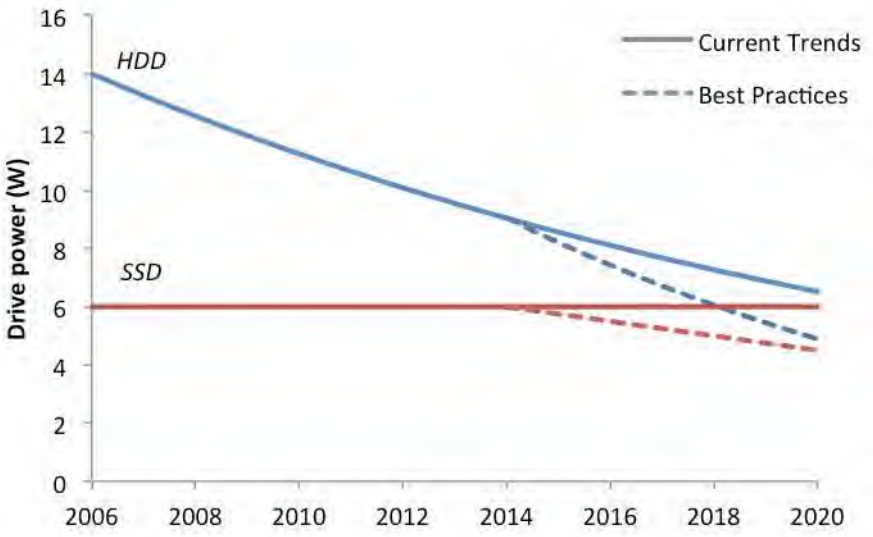


Figure 30. Storage Disk Power Consumption for Current Trends and Best Practices Scenarios

The BP scenario also includes a provision to improve the efficiency of storage disks by 25% in 2020. This improvement increases linearly, and is based upon a scenario where future storage disks have reduced energy usage in their idle state. The resulting disk power consumption is shown in Figure 30.

The BP scenario results in total energy savings in 2020 relative to the Current Trends scenario of 40% which is composed of: 15% from server energy savings due to the removal of inactive servers, the improvement in server scaling, and consolidation of servers; 3% from savings in storage energy due to improved disk efficiency, 1% from savings in network energy due to port consolidation; and 22% from savings in infrastructure energy due to the reduced IT energy along with improved PUE.

4.4 Hyperscale Shift Scenario

The Hyperscale Shift (HS) scenario involves the consolidation of 80% of the servers in non-hyperscale data centers into hyperscale data centers, excluding servers in Service Provider Rooms and Closets, which are defined to include local point-of-presence facilities that would still be needed to support management functions for hyperscale data centers.[27] The 80% shift is in addition to the shift already accounted for in the Current Trends scenario. Hyperscale data centers operate servers at higher utilizations in infrastructure-efficient (low-PUE) spaces, and include cloud-based platforms that remove the need for dedicated redundancy servers, so that consolidating IT services from many small disparate data centers into hyperscale data center can yield significant energy savings. HS scenario impacts on volume server installed base are shown in Figure 31. As shown, the installed base in non-hyperscale data centers decreases to approximately one quarter of the CT scenario value by 2020. The impact on the installed base in hyperscale data centers is smaller since, on average, one server in a hyperscale data center can replace 3.75 servers in non-hyperscale data centers. This is because servers in hyperscale data centers are assumed to run at roughly 3 times the utilization of non-hyperscale data centers and have no redundancy requirements.[61]

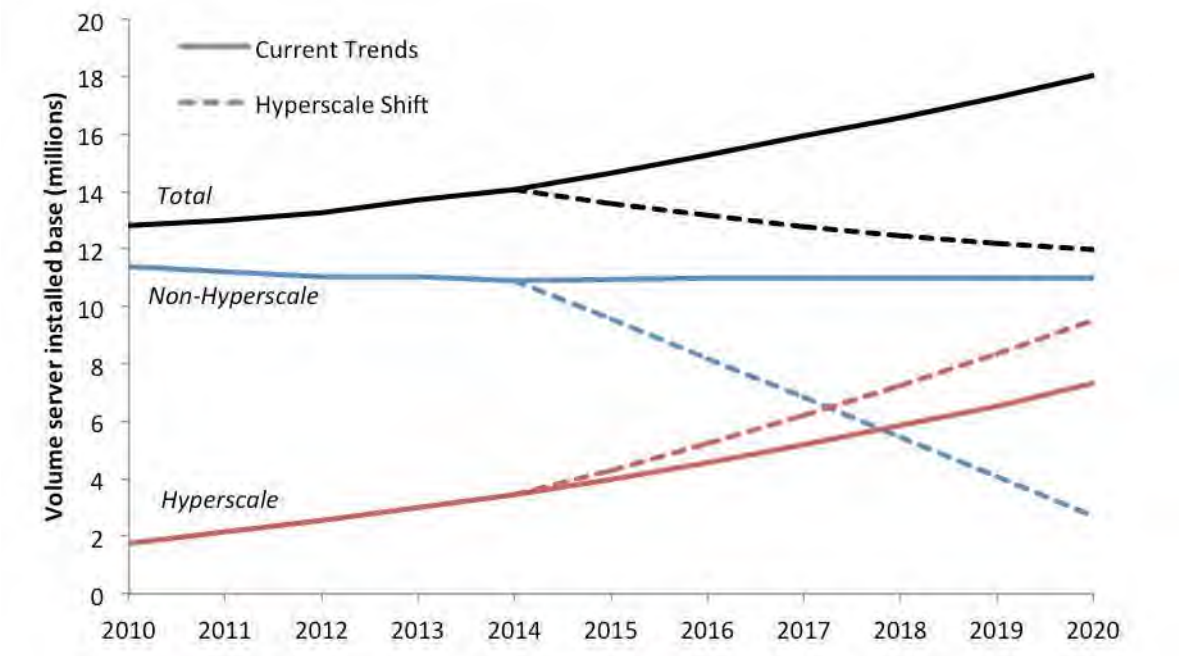


Figure 31. Volume Server Installed Base in Current Trends and Hyperscale Shift Scenarios

The HS scenario results in total energy savings in 2020 relative to the Current Trends scenario of 25% which is composed of: 10% from server energy savings, due to the consolidation; no savings in storage or network energy; and 15% from savings in infrastructure energy due to the reduced server energy along with the relocation of servers into data centers with lower PUE values.

4.5 Scenario Results

Server energy use is affected in all scenarios. Relative to the CT scenario, IM, BP, and HS measures reduce server energy consumption by 4%, 18%, and 28% respectively. When HS measures are applied to the IM and BP scenarios, server energy consumption is reduced an additional 16% and 3% of the CT value, respectively. These results are shown in Figure 32.

Storage energy use is only affected in the BP scenario where disks are assumed to be 25% more efficient in 2020 than in the CT scenario. Therefore, storage energy is 25% less in the BP and BP+HS scenarios relative to CT. Network energy is also only affected in the BP scenario due to both port consolidation and port efficiency improvements. The result is a 38% reduction in network energy consumption in BP and 40% in BP+HS scenarios relative to CT. This is shown in Figure 33.

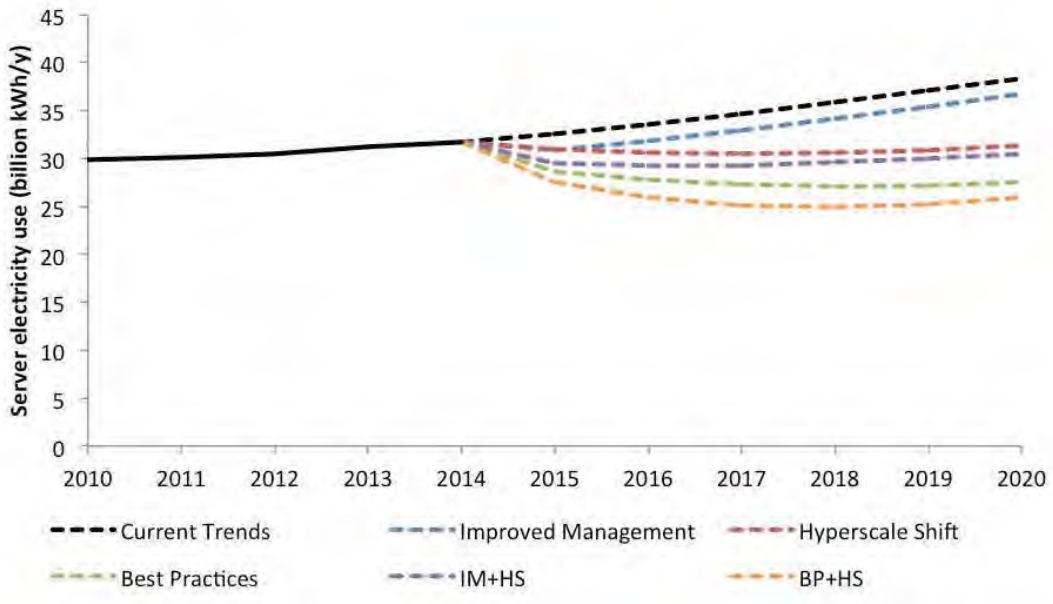


Figure 32. Server Electricity Use for All Scenarios

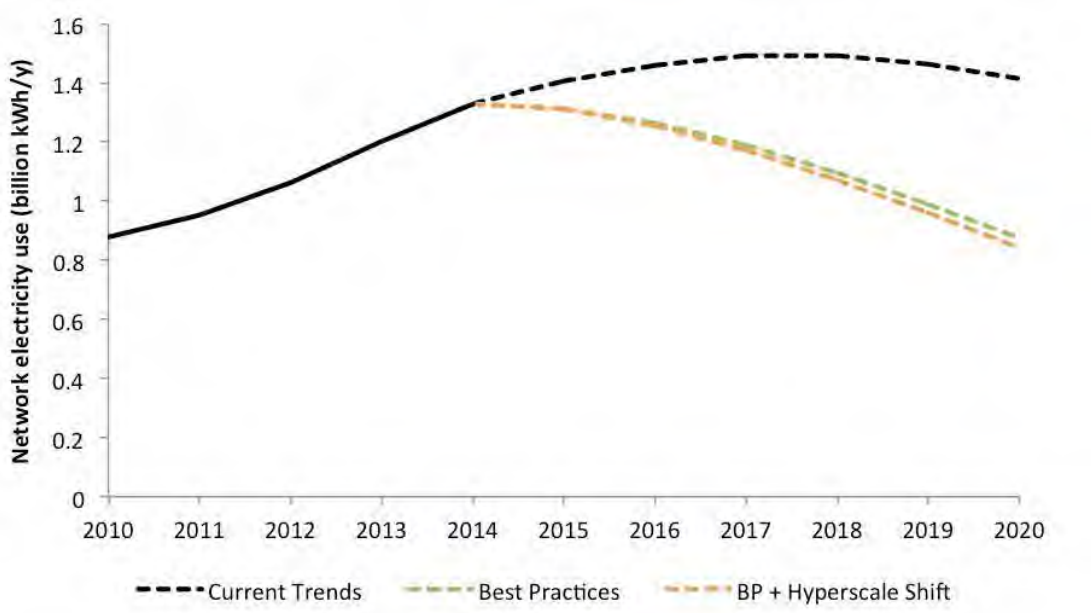


Figure 33. Network Electricity Use for Current Trends and Best Practices Scenarios.
Improved Operation, Hyperscale Shift, and IO+HS scenarios are identical to Current Trends. BP+HS network electricity is slightly lower than BP alone due to the higher prevalence of network ports in hyperscale data centers where the 25% wattage reduction is assumed to occur.

Infrastructure energy is affected in all scenarios, as shown in Figure 34. Infrastructure energy is the product of the space type PUE and the space IT energy consumption, so reductions in both of these areas compound for very large energy savings relative to the CT scenario. The HS scenario has infrastructure energy savings of 46% relative to the current trends scenario. This is due both to the reduction in server energy as well as the shift of this energy into hyperscale data centers, which have a lower PUE than other space types. The IM scenario saves 22% of infrastructure energy relative to CT due to both the reduction in IT energy and improvement in PUE across smaller space types. IM and HS in conjunction save 54% of infrastructure energy. Lastly, the BP and BP+HS scenarios have infrastructure energy savings of 64% and 75% respectively due to the large decrease in server energy, additional decrease in storage and network energy, and strong improvement in PUE across all space types.

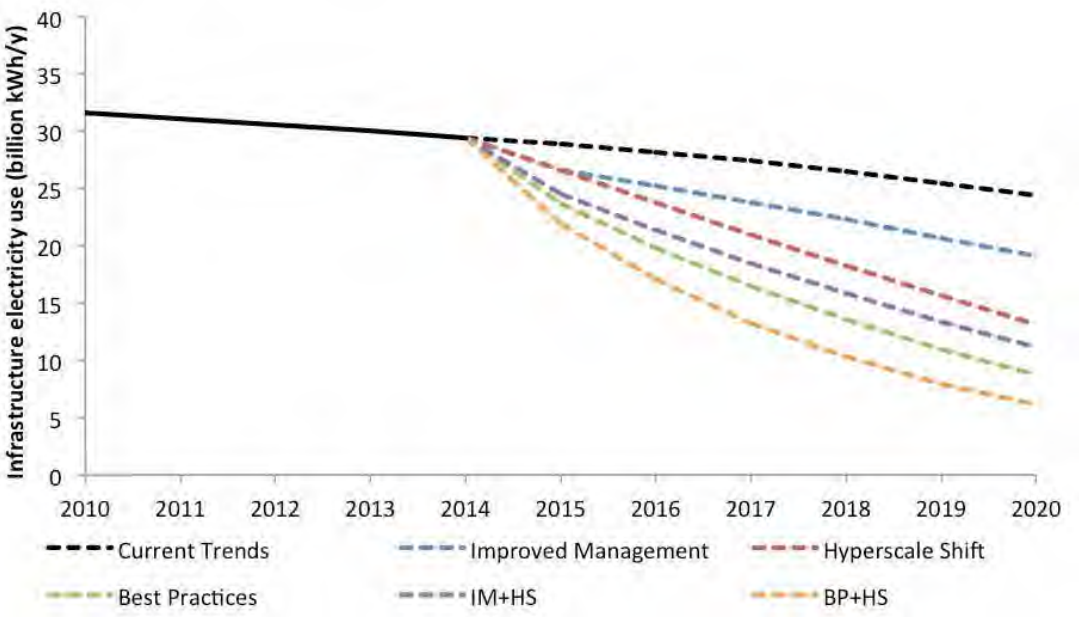


Figure 34. Infrastructure Electricity Use for All Scenarios

Total data center energy consumption for all scenarios is shown in Figure 35. Total electricity savings in 2020 for the IM, BP, and HS scenarios are 10%, 40%, and 25% respectively, relative to the CT scenario. When HS measures are applied to the IM and BP scenarios an additional 20% and 6% of CT total energy is saved. Water savings (Figure 36) are very similar with scenario 2020 savings as follows: IM, 9%; BP: 39%; HS: 24%; IM+HS, 28% (18% more than IM alone); and BP+HS, 45% (5% more than BP alone).

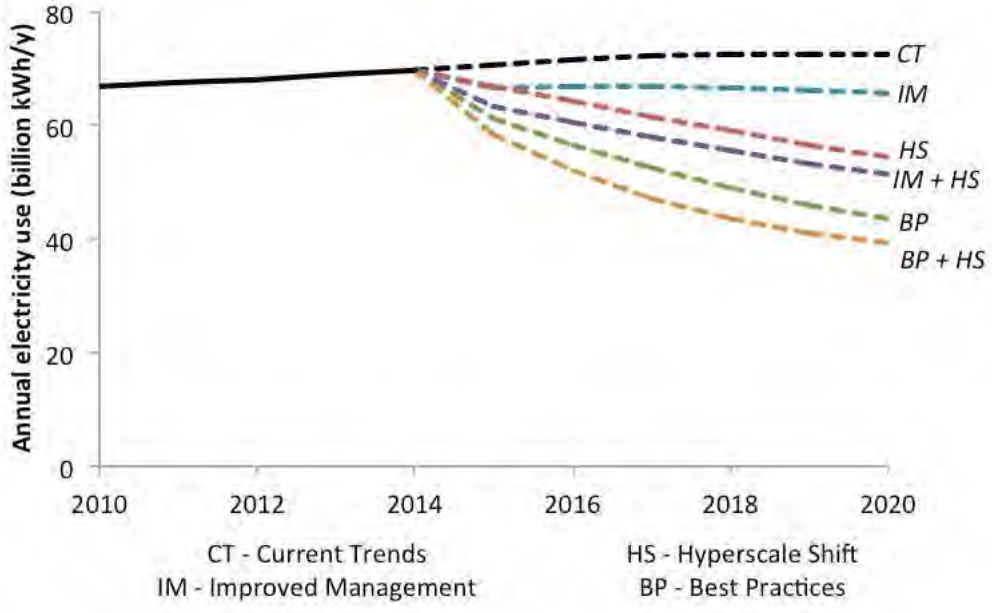


Figure 35. Total Electricity Consumption for All Scenarios

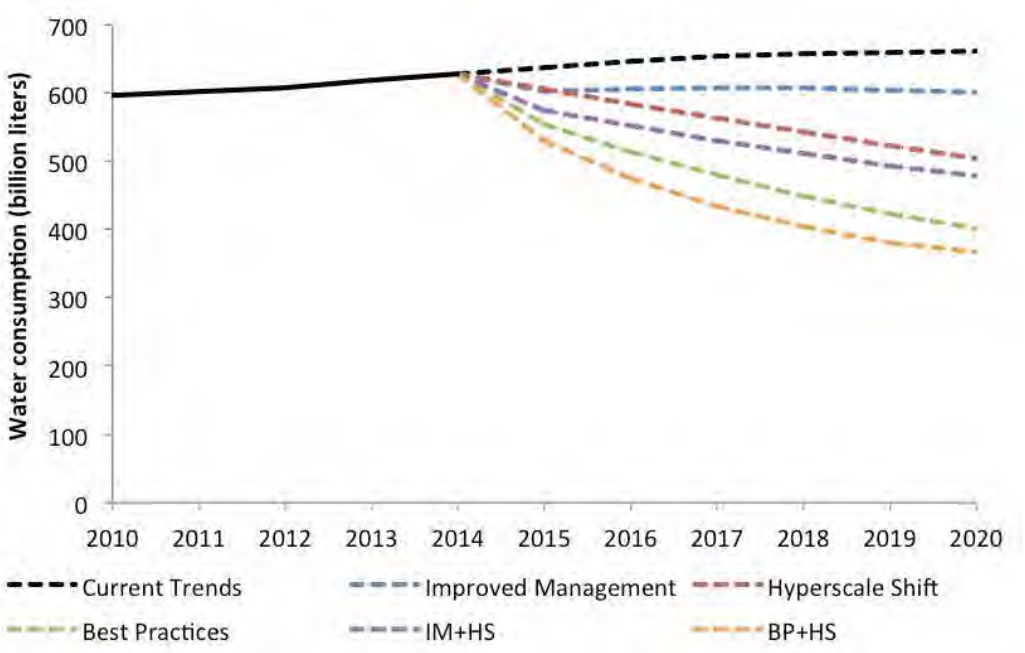


Figure 36. Water Consumption for All Scenarios

5 Indirect Energy Impacts

Data centers constitute a foundational component of the information and communication technology (ICT) that provides the services—such as streaming media, email, internet content, and electronic recordkeeping—now ubiquitous throughout much of the world.[a] Today, our computers, mobile devices, sensors, and networks are more likely than ever to utilize centralized information stored on a data center in the cloud. While the primary focus of this report is to estimate the electricity directly consumed in data centers, it is important to take a broader perspective and note that the services provided by data centers can profoundly affect how—and how much—energy[b] is used elsewhere by society. For example, ICT can enable existing products and services to become more efficient or create “e-substitutes” for physical products. Other, higher-order effects occur when the introduction of ICT causes a change in consumption or production elsewhere in the economy.

These implications for broader energy use are known as *indirect energy impacts*, and they might either reduce or increase overall energy use (Figure 37). From an energy savings standpoint, if the indirect energy impacts offset the direct consumption by data centers and other ICT equipment, then the synergy between ICT and societal energy savings is positive; if,

[a] The term information technology (IT) has been used in this report to refer to the servers, network, and storage equipment in the data center. In this chapter, *ICT* is used as a broader term encompassing data center IT components, other network infrastructure, and a wide variety of end-use devices.

[b] Resource usage and GHG emissions are, of course, concomitants of ICT energy consumption; while this report focuses on energy, much of the literature includes these associated impacts.

instead, the introduction of ICT causes an amplifying effect in which overall energy consumption increases, the synergy is negative. Characterizing this "net" impact of ICT deployment on societal energy consumption has been of great interest, as evidenced by the emergence of an ICT for Sustainability research community,[62] two special issues in the *Journal of Industrial Ecology*[63] [64] an OECD effort to link statistical indicators between the ICT and environment research fields,[65] work in "green computing" from the computer science field,[66] and a variety of other reports.[67] [68] This report chapter provides brief summary of the literature review and interpretation found in Horner et al.[69] on the indirect impacts of ICT.

There is, in fact, no consensus on the magnitude or even the sign of ICT's indirect energy impact. Generally in the positive synergy camp are Romm et al.[70] and a series of reports published by the American Council for an Energy Efficient Economy,[71] [72] who anticipate ICT-enabled energy efficiency gains across broad sectors of the economy, and work commissioned by the industry-sponsored Global e-Sustainability Initiative,[73] which estimates a greenhouse gas (GHG) abatement potential of 20% by 2030 due to ICT deployment. More cautionary is Rattle,[74] who posits that higher-order effects are likely to swamp these sorts of energy savings projections. Berkhout and Hertin[75] argue for moving "beyond the dichotomy between pessimism and optimism" to recognize that the relationship between ICT and energy impacts is "complex, interdependent, deeply uncertain and scale-dependent." Other literature reviews point to an ambiguous net impact or acknowledge that this complexity and uncertainty confound attempts to verify a general belief that the net energy savings of ICT should be positive. [76] [77] [78] [79]

5.1 Energy Impact Taxonomy

Direct energy consumption, which in addition to the operational energy use estimated in this report also includes the energy required to manufacture and dispose of ICT equipment, is likely the simplest and ultimately the least important ICT energy effect[80] although it is by no means small. One particular issue is that embodied energy can dominate operational consumption for some types of ICT equipment, such as mobile devices.[78] However, the *indirect* energy effects are likely to be of much greater magnitude,[78] owing to the breadth of the various mechanisms by which ICT services alter energy use. Table 8 breaks out individual effects, organizes them into a taxonomy of increasing scope, and maps them to other terms used in the literature, while Figure 37 shows this taxonomy graphically.

Working from narrow to broad scope, ICT adoption first leads to *efficiency* in and *substitution* for conventional products and services. Efficiency occurs when, for example, smart building technology reduces air conditioning energy consumption by tailoring climate-control to the real-time needs of building occupants. An example of substitution is the replacement of air travel with teleconferencing. There is no guarantee, however, that the substituted ICT service will be less energy intense than the conventional service it replaces, and even evaluation of simple cases is not always straightforward.

Any energy reduction achieved through efficiency or substitution can be plagued by *rebound effects*, in which expected gains are offset by induced additional consumption. Azevedo[81], Gillingham et al.[82], and Borenstein[83] provide comprehensive introductions to rebound effect types. Rebound is typically broken into direct rebound, indirect rebound, and economy-wide

effects. *Direct rebound* effects are own-price-elasticity effects: as prices fall (due to improvements in efficiency or productivity), substitution and income effects increase consumption. For an ICT example, if an e-book is less costly than a conventional book, then consumers might purchase more books. Alternatively, these savings could be spent on other goods and services, which are *indirect rebound* effects. Indirect rebound effects result from cross-price elasticity of demand for other products and services due to increased real consumer income.

Table 8. Taxonomy of ICT Energy Effects from Horner et al.[69]

Scope of effect increases from top to bottom. The third column provides and example of each effect type related to the deployment of Global Positioning System (GPS) Technology. Taxonomy expands on the general taxonomy of rebound effects from Azevedo.[81]

Taxonomy summarized in this report			Alternate taxonomies			
Effect	**Scope**	**GPS System Example**	**Hilty[84]**	**Berkhout & Hertin[75]**	**Williams[91]**	**Rattle[74]**
Embodied energy	Direct	Energy to produce a GPS system	1st-order	Direct effects	ICT infrastructure and devices	
Operational energy		Energy to operate a GPS system				
Disposal energy		Energy to dispose of a GPS system at end-of-life				
Efficiency	Indirect: Single-service	More efficient traffic flow due to GPS-enhanced routing	2nd-order	Indirect effects	Applications	Optimization
Substitution		Replacement of paper maps				Substitution
Direct rebound		More travel due to lower cost of traffic congestion	3rd-order	Structural & behavioral effects	Effects on economic growth and consumption patterns	Induction
Indirect rebound	Indirect: Complementary services	Energy consumed during time saved by more efficient travel				Supplementation
Economy-wide rebound (Structural change)	Indirect: Economy-wide	GPS enables autonomous vehicles, causes growth of intelligent transportation system manufacturing				Creation
Systemic Transformation	Indirect: Society-wide	Autonomous vehicles alter patterns in where people choose to live and work			Systemic effects on technology convergence & society	

Economy-wide effects occur when the ICT introduction causes macroeconomic adjustments across economic sectors. That is, the ICT industry can promote or inhibit growth in other sectors of the economy, inducing structural changes that have energy use implications of their own. For example, e-commerce is having broad effects on the logistics industry,[85] including growth in

urban freight vehicle sales and changing patterns in distribution center floor space,[86] increased trucking and adoption of new pricing strategies by freight carriers[87] and use of more specialized packaging and a broader range of box sizes.[88]

Finally, *transformational effects* refer to the altering of human preferences and economic and social institutions caused in part by the development of ICT.[89] [90] Historical examples include the advent of the telephone and automobile, which heavily altered where and how people lived and worked. We might conceive of a similar transformation (one of many possible ICT-enhanced futures) in which the fundamental constraints on where people live and work continue to loosen: e-commerce and home delivery make proximity to traditional retail outlets less important, seamless telework results in less commuting, and driverless vehicles allow for more productive use of the commuting time.

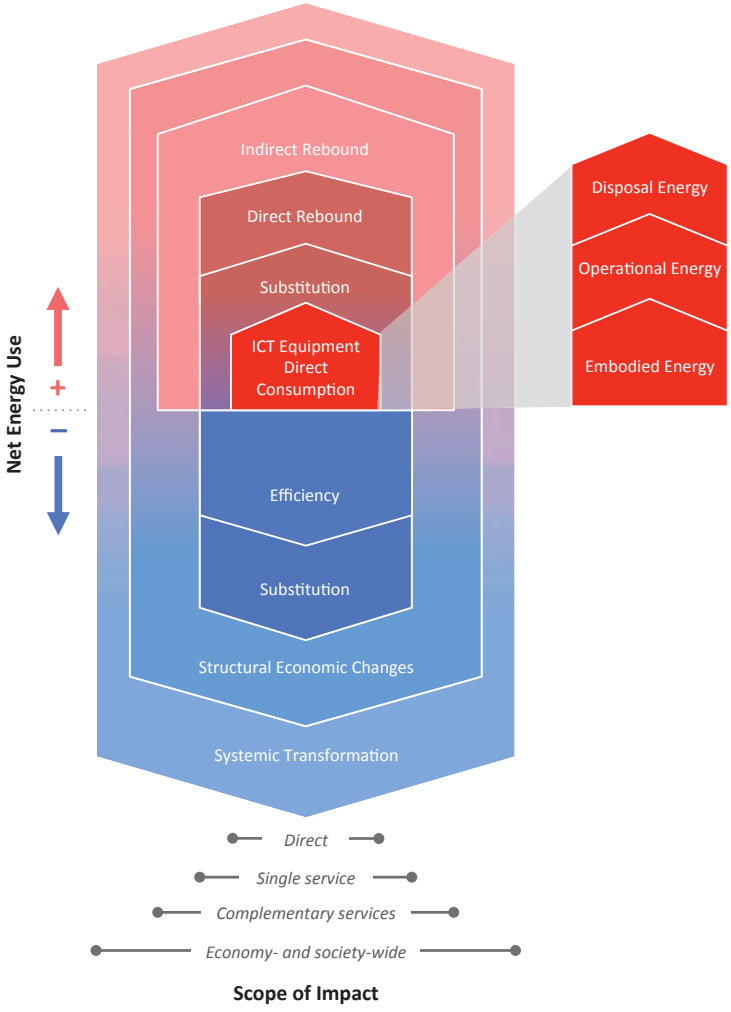


Figure 37. Taxonomy of Energy Effects from Adoption of ICT, from Horner et al.[69]
Red effects increase energy use, blue effects decrease energy use, and shading intensity decreases as effect scope increases.

As noted by Börjesson Rivera et al.,[76] the existing literature uses several different sets of terms for this hierarchy of effects, collected in the right half of Table 8. ICT energy effects are frequently grouped into first-order impacts due to direct consumption, second-order effects resulting from process changes, such as efficiency, and third-order effects due behavioral and economic changes.[75,84] Williams[91] adds a fourth level, essentially breaking third-order effects into rebound effects and broader systemic change.

5.2 Energy Impact Estimation

The literature on characterizing these indirect impacts can generally be divided into two broad types. One body of literature typically assesses the impact of a single service, such as e-commerce, telecommuting, or smart buildings. Such analyses often use lifecycle assessment (LCA),[92 93] modeling & simulation,[94] or case studies[95 96] and generally address only direct consumption, efficiency, substitution, and occasionally direct rebound. A separate body of literature focuses on the higher-order indirect energy impacts brought about by ICT-induced changes to complementary services, the broader economy, and societal systems. These studies typically rely on econometric analysis of macroeconomic indicators,[97] scenario analysis,[98 99] or anecdotal evidence.[100]

Importantly, neither type of study uniformly finds a positive or negative effect: results from both are highly dependent on modeling choices and assumptions used in scoping the study. For example, the energy savings reported in LCA studies of e-commerce for book retail range from negative 500% (i.e., a 5x increase in energy use in the e-commerce case) to nearly 50% (a reduction in energy use by half).[69] This variation results from differences in the system boundary and from sensitivity to assumptions, including population density, freight mode, product return rate, proportion of multipurpose trips, and packaging type. Case studies often show energy savings in specific deployment scenarios and provide valuable lessons on how to deploy ICT in such a way that energy savings are attained; however, scalability and higher-order effects remain uncertain in such work. Macroeconomic studies also show highly variable results.[67]

Thus, while both conceptual discussion and analytical modeling of ICT energy and environmental impacts have been occurring for at least two decades, the jury is still out on the net effects of ICT adoption for several reasons. First, the complexity and variability of ICT deployment schemes makes it difficult to isolate a standard implementation to analyze and to compare study results. Second, the lack of empirical data on how human users interact with ICT systems hinders the ability to assess actual, instead of potential, energy effects. Third, the difficulties in disentangling the causes of interconnected effects lead to a tendency to fall back on theory—and on modeling exercises that conform to these theories. Finally, as the impact scope increases up the effect taxonomy (Table 8), the potential effect's magnitude and uncertainty increase dramatically.

The current state of understanding can be summarized with three related statements: the technical potential of ICT net energy savings is likely positive; the sign and magnitude of realized net energy savings are highly sensitive to the parameters that characterize the ICT deployment and are not guaranteed; and, finally, the actual net energy effect is unclear and difficult to assess, especially when higher-order impacts are considered.

5.3 Pathway Forward

Just as implementation of best practices in data center design and operation has the potential to drastically reduce direct energy consumption (Figure 35), optimizing the manner in which we integrate ICT into our lives can have a large impact on overall energy consumption. During the first decade of the century, data center energy consumption grew rapidly (Figure 23). IT managers focused on service provisioning, with the power bill being a much lesser concern. However, the industry is now converging on a paradigm of virtualization and centralization that has both business and energy co-benefits, and such reductions in direct energy use should continue to be pursued.

The broader evolution of ICT is perhaps on a similar path: new systems and services are being developed rapidly without much consideration of energy impacts, and as a result it seems likely that ICT services are often deployed in a way that does not achieve their full potential to achieve energy savings. However, it also seems likely that more optimal deployment plans—those that create energy savings while maintaining the value of the service—exist, and more focus on characterizing these "system optima" is warranted. [101]

The danger in waiting to identify these deployment plans is that society-wide systems, structures, and habits that become entrenched can be much more difficult to alter. A server has a typical lifetime less than five years; the economic and social infrastructures built out through new ICT services can last much longer. Thus, the important role of analysis in this area is to identify the important drivers of ICT indirect energy impacts and gather data on actual, rather than potential, energy savings, so that these results can inform both public policy and private decision making on the implementation and use of ICT. For this reason, the field would benefit from more focus on empirical case studies and on understanding the behavioral aspects of how various stakeholders use ICT services in practice. Additional work on characterizing uncertainty in energy effect estimates would also benefit discussions in this area.

6 Future Work

Estimating U.S. data center energy use requires developing inputs and assumptions for an industry with rapidly evolving technologies and limited publically available energy use data, which ultimately limits the potential scope of analysis. Through the challenges of developing data center energy use estimates for this report, additional areas of research were identified that could improve future growth estimates in data center energy consumption and the potential impacts for specific efficiency efforts. Below are key areas identified that warrant future research.

6.1 Server Utilization and Power Proportionality

Due to the limited data on utilization rates for servers in U.S. data centers, this study generalizes server utilization using a single average (per space type), with no information about the actual distribution of utilization over the average year. This generalization prevents distinguishing between a server that is run at 40% utilization constantly and one that is run at

80% utilization half of the time and idled the other half of the time. Additionally, while this study assumes a linear relationship between utilization and power consumption (i.e., the "scaling curve") of servers, the actual relationship is generally nonlinear[18] and therefore there is a loss of accuracy in modeling server energy use at the average utilization level. Without the ability to model nonlinear scaling curves, it then becomes difficult to understand the impacts of certain efficiency measures, such as the targeted lowering of idle state power consumption (e.g. Emerson Network Power's proposed 10 Minus standard[102]) or powering down servers during idle times. As consolidation efforts like virtualization are increasing server utilization levels across the industry, it is even more important to understand how future energy savings opportunities associated with increasing dynamic ranges and low-power idle states are going to be affected.

6.2 Workload Variation

In addition to understanding server utilization over time, further efforts should be made to understand the distribution of various types of server workloads and their associated hardware requirements. This will help to quantify opportunities for energy savings associated with optimizing hardware for specific workloads as opposed to using a "one-size-fits-all" approach prevalent across large data centers today. This could include using single-socket designs and workload-optimized processors (RISC, FPGA, GPUs, etc.). Understanding workload variations among different servers within data centers would also assist in identifying strategies to further increase overall data center utilization loads and increase cooling efficiency by creating the opportunity to provide server-specific cooling demand.

6.3 Barriers to Hyperscale Shift

While there has been significant growth in hyperscale data centers, this report shows that a significant portion of servers are still expected to reside in small room or closet data centers. Better understanding the different barriers, including technical, legal, and security barriers, that are preventing movement to colocation or to the cloud can help drive solutions that increase the shift to large data centers and tailor energy efficiency strategies for the small data centers that remain.

6.4 Beyond PUE

There is a need in the data center industry for performance metrics that better capture the efficiency of a given data center. The limitations of PUE, the most commonly discussed metric of efficiency, are generally understood,[103] but a key issue it that PUE only measures the efficiency of the building infrastructure supporting a given data center and indicates nothing about the efficiency of the IT equipment itself. Metrics that capture the functionality of the data center (e.g. amount of computations it performs) and relate that to energy use can help industry better understand where progress has been made and where there are opportunities to reduce energy use. Initial efforts to accomplish this include The Green Grid's Data Center Productivity (DCP) and Data Center energy Productivity (DCeP),[104] the Uptime Institute and McKinsey's Corporate Average Data center Efficiency (CADE),[105] and JouleX's Performance per Watt (PPW),[106] but PUE is still the dominant metric broadly observed in the data center industry.

6.5 Beyond 2020

The significant energy efficiency improvements in the design and operation of data centers over the past decade have allowed U.S. data center energy use to remain nearly constant while simultaneously meeting a drastic increase in demand for data center services. However, the data available at the time of this study limited the scope of future projection to 2020. The key efficiency strategies identified in this report, improved PUE, increased server utilization rates, and better power proportionality all have theoretical and practical limits and the current rate of improvement indicates that these limits may be reached in the not too distant future. The potential for data center services, especially from a global prospective, are still in a fairly nascent stage and future demand could continue to increase after our current strategies to improve energy efficiency have been maximized. Understanding if, and when, this transition may occur, and the ways in which data centers can minimize their costs and environmental impacts under such a scenario, is an important direction for future research. This report highlights the success of the data center industry to stabilize electricity demand, but further investigation and technological breakthroughs in energy efficiency across the ICT equipment spectrum will be needed to insure that success is not simply a plateau before an increase in electricity demand resumes at a rate proportional to future growth of data center services.

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The environmental footprint of data centers in the United States

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Abstract

Much of the world's data are stored, managed, and distributed by data centers. Data centers require a tremendous amount of energy to operate, accounting for around 1.8% of electricity use in the United States. Large amounts of water are also required to operate data centers, both directly for liquid cooling and indirectly to produce electricity. For the first time, we calculate spatially-detailed carbon and water footprints of data centers operating within the United States, which is home to around one-quarter of all data center servers globally. Our bottom-up approach reveals one-fifth of data center servers direct water footprint comes from moderately to highly water stressed watersheds, while nearly half of servers are fully or partially powered by power plants located within water stressed regions. Approximately 0.5% of total US greenhouse gas emissions are attributed to data centers. We investigate tradeoffs and synergies between data center's water and energy utilization by strategically locating data centers in areas of the country that will minimize one or more environmental footprints. Our study quantifies the environmental implications behind our data creation and storage and shows a path to decrease the environmental footprint of

our increasing digital footprint.

1. Introduction

Data centers underpin our digital lives. Though relatively obscure just a couple of decades prior, data centers are now critical to nearly every business, university, and government, as well as those that rely on these organizations. Data centers support servers, digital storage equipment, and network infrastructure for the purpose of large-scale data processing and data storage [1]. Increasing demand for data creation, processing, and storage from existing and emerging technologies, such as online platforms/social media, video streaming, smart and connected infrastructure, autonomous vehicles, and artificial intelligence, has led to exponential growth in data center workloads and compute instances [2].

The global electricity demand of data centers was 205 TWh in 2018, which represents about 1% of total global electricity demand [3]. The United States houses nearly 30% of data center servers, more than any other country [3–5]. In 2014, 1.8% of US electricity consumption was attributable to data centers, roughly equivalent to the electricity consumption of New Jersey [1]. Previous studies found power densities per floor area of traditional data centers almost 15 - 100 times as large as those of typical commercial buildings [6], and data center power density has increased with the proliferation of compute-intensive workloads [7]. Though the amount of data center computing workloads has increased nearly 550% between 2010 and 2018, data center electricity consumption has only risen by 6% due to dramatic improvements in energy efficiency and storage-drive density across the industry [1, 3]. However, it is unclear whether energy efficiency

improvements can continue to offset the energy demand of data centers as the industry is expected to continue its rapid expansion over the next decade [8].

The growing energy demand of data centers has attracted the attention of researchers and policymakers not only due to scale of the industry's energy use but because the implications the industry's energy consumption has on greenhouse gas (GHG) emissions and water use. Data centers directly and indirectly consume water and emit GHG in their operation. Most data centers' energy demands are supplied by the electricity grid, which distributes electricity from connected power plants. Electricity generation is the second largest water consumer [9] and the second largest emitter of GHGs in the US [10]. These environmental externalities can be attributed to the place of energy demand using several existing approaches [11, 12].

In addition to the electricity consumed directly by data centers, electricity is used to supply treated water to data centers and treat the wastewater discharged by data centers. Like data centers, water and wastewater facilities are major electricity consumers, responsible for almost 1.8% of total electricity consumption in the US in 2013 [13]. The electricity required in the provisioning and treatment of water and treatment of discharged wastewater also emits GHGs that can be attributed to data centers. Likewise, water used to generate the electricity used by water and wastewater utilities in their service of data centers contributes to the water footprint of these data centers. Water is also used directly within a data center to dissipate the immense amount of heat that is produced during its operation.

The geographic location [14, 15] and the local electricity mix [16] are strong determinants of a data center's carbon footprint, though these spatial details are often excluded in data center stud-

ies. A preliminary water footprint assessment of data centers by Ristic et al. [17] provided a range of water footprints associated with data center operation. Although Ristic et al. provided general estimates based on global average water intensity factors, their study highlights the importance of considering both direct and indirect water consumption associated with data center operation. Moreover, Ristic et al. highlights the importance of considering the type of power plants supplying electricity to a data center and the type/size of a data center, as each of these factors can significantly impact energy use and indirect water footprint estimates.

In this study we utilize spatially-detailed records of data center operations to provide the first sub-national estimates of data center water and carbon footprints. Here, water footprint is defined as the consumptive blue water use (i.e. surface water and groundwater). The carbon footprint of a data center, expressed as equivalent CO_2, is used to represent its global warming potential. Our assessment focuses on the operational environmental footprint of data centers (Figure 1), which includes the power plant(s), water supplier, and wastewater treatment plant servicing the data center, since the environmental footprint of the non-operational stages of a data center's life cycle (e.g. manufacturing of servers) is negligible [18]. The spatial detail afforded by our approach enables more accurate estimates of water consumption and GHG emissions associated with data centers than previous studies. Moreover, we evaluate the impact of data center operation on the local water balance and identify data centers located in, or indirectly reliant upon, already water stressed watersheds. We investigate the following questions: (i) What is the direct and indirect operational water footprint of US data centers? (ii) Which watersheds support each data center's water demand and what portion of these watersheds are water stressed? (iii) How much GHG emissions are associated with the operation of data centers? (iv) To what degree can strategic placement of future

data centers within the US reduce the industry's operational water and carbon footprints?

2. Methods

We utilize spatially detailed records on data centers, electricity generation, GHG emissions, and water consumption to determine the carbon footprint and water footprint of data centers in the US. Our approach connects specific power plants, water utilities, and wastewater treatment plants to each data center within the US. All data used in this study are for the year 2018, the most recent year where all data are publicly available. A visual summary of our methods is shown in Supplementary Figure S1.

2.1 Data center location and energy use

Information availability on data center location and size varies depending on its type and owner. Ganeshalingam et al. [4] reports likely locations of in-house small and midsize data centers, which house approximately 40% of US servers. Detailed information on colocation and hyperscale data centers is derived from commercial compilations [19–21] that get direct support and input from data center service providers.

We classified data centers based on the International Data Corporation (IDC) classification system (summarized in Table 1 and S1) and estimated the electricity use based on data center floor space. We used IT load intensity values (IT_s in watt/ft^2) for different data center types (s) from Shehabi et al. [22] to estimate the total energy requirements (DC_E_{total}; in MWh) of colocation

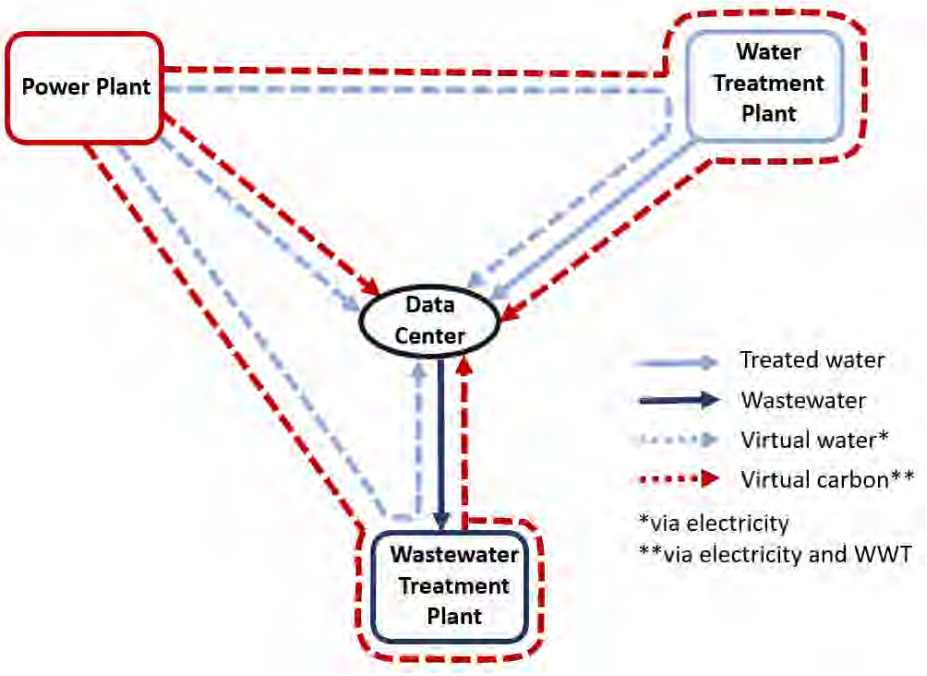


Figure 1: The system boundaries and interlinkages defining the operational water and carbon footprints of data centers. Specific power plants, water utilities, and wastewater treatment (WWT) utilities are connected to each data center through their provisioning of electricity and water. Power plants emit GHGs and consume water in the production of electricity. These environmental impacts are attributed to data centers in proportion to how much electricity the data center uses (red and blue dashed lines connecting facilities). The GHG emissions and water consumption associated with the provisioning of treated water and disposal of wastewater, including the GHGs and water consumed in the generation of the electricity supplied to these facilities, are also attributed to data centers in proportion to their use of these utilities. Data centers do not directly emit GHGs but they do directly consume water to dissipate heat. All these facilities work together to keep data centers operational and contribute to the water and carbon footprint of data centers.

and hyperscale data centers as follows:

$$DC_E_{total} = IT_s \times PUE_s \times A \tag{1}$$

where PUE_s is the power usage effectiveness of space type s, and A is the floor area of data center in ft^2. We account for potential overstatement of data center capacity [4], a lack of distinction between gross and raised floor area, and unfilled rack capacity by scaling our server counts to match the 2018 estimate of servers by data center type [3]. Scaled server estimates are then spatially distributed in proportion to the current spatial distribution of installed server bases. The number of servers by state is shown in Figure S2.

Power usage effectiveness (PUE) is a key metric of data center energy efficiency [23]. A value of 1.0 is ideal as it indicates all energy consumed by a data center is used to power computing devices. Energy used for non-computing components, such as lighting and cooling, increases the PUE above 1.0 (see Equation 2). Generally, a data center's PUE is inversely proportionate to its size since larger data centers are better able to optimize their energy usage. Average PUE values and energy use by data center type were taken from Masanet et al. [3] and shown in Table 1 and Table S1.

$$PUE = \frac{Total\ power\ supplied\ to\ the\ data\ center}{Power\ consumed\ by\ the\ IT\ equipment} \tag{2}$$

2.2 Electricity generation, water consumption, and GHG emissions

Power plant-specific electricity generation and water consumption data come from the US Energy Information Administration (EIA) [24]. Of the approximately 9,000 US power plants, the EIA requires nearly all power plants report electricity generation. However, only power plants with generation capacity greater than 100 MW (representing three-fourths of total generation) must report water consumption. We assigned national average values of water consumption per unit of electricity generation by fuel type (i.e., water intensity; m^3/MWh) to all power plants with unspecified water consumption. Operational water footprints of solar and wind power were taken from Macknick et al. [25]. Following Grubert [26], we assign all reservoir evaporation to the dam's primary purpose (e.g., hydropower). We connected hydroelectric dams with their respective power plants using data from Grubert [27]. Reservoir specific evaporation comes from Reitz et al. [28].

The U.S. Environmental Protection Agency's eGRID database [29] provided GHG emissions associated with each power plant. GHG emissions are converted to an equivalent amount of carbon dioxide ($CO_2 - eq$) with the same global warming potential so to derive a single carbon footprint metric [30]. Direct GHG emission during the operation of data centers are negligible [18] and therefore not considered in this study.

Data centers, water suppliers, and wastewater treatment plants typically utilize electricity generated from a mix of power plants connected to the electrical grid. Within the electrical grid, electricity supply matches electricity demand by balancing electricity generation within and transferred into/out of a power control area (PCA). Though it is infeasible to trace an electron generated

by a particular power plant to the final electricity consumer, there are several approaches to relate electricity generation to electricity consumption (Siddik et al. [31] summarizes the most common approaches).

Here, we primarily rely on the approach used by Colett et al. [32] and Chini et al. [33] to identify the generative source of electricity supplied to any given data center. This approach assesses electricity generation and distribution at the PCA level where it is primarily managed. PCA boundaries are derived from the Homeland Infrastructure Foundation level data (HIFLD) [34] and crosschecked against Form EIA-861 [35], which identifies the PCAs operating in each state. Annual inter-PCA electricity transfers reported by the Federal Energy Regulatory Commission [36] are also represented within this approach. A data center (as well as water and wastewater utilities) draws on electricity produced within its PCA, unless the total demand of all energy consumers within the PCA exceeds local generation, in which case electricity imports from other PCAs are utilized. If a PCA's electricity production equals or exceeds the PCA's electricity demand, it is assumed all electricity imports pass through the PCA and are re-exported for utilization in other PCAs. Siddik et al. [31] notes that water and carbon footprints are sensitive to the attribution method used to connect power plants to energy consumers. Therefore, we conduct a sensitivity analysis (see the Supporting Information for additional details) to test the degree to which our electricity attribution method affects our results. Additionally, we also test different assumptions regarding the water footprint of hydropower generation, as this too is a key source of uncertainty.

We focus on the annual temporal resolution and assume an average electricity mix proportional to the relative annual generation of each contributing power plant. Though the electricity mix

within a PCA can fluctuate hourly depending on balancing measures, these intra-annual variations will not significantly impact our annual-level results. While it is infeasible to determine the precise amount of electricity each power plant provides to each data center, water utility, and wastewater treatment plant, our approach will enable us to estimate where each facility is most likely to draw its electricity. The dependency of a data center on local and imported electricity from other PCAs was calculated using equation 3 and 4.

$$DC_E_{p,l} = DC_E_p \times (1 - \sum_i r_i) \tag{3}$$

$$DC_E_{p,im} = DC_E_p \times \sum_i r_i \tag{4}$$

where $DC_E_{p,l}$ and $DC_E_{p,i}$ are the local (l) and imported (im) electricity (MWh) to a data center from PCA p, respectively. DC_E_p is the total electricity consumption of the data center, whereas r_i represents the electricity contribution of each PCA i to PCA p as follows:

$$r_i = \begin{cases} \frac{Import_{con}}{Generation_p + \sum Import_p - \sum Export_p}, & \text{if PCA } p \text{ is net importer} \\ 0, & \text{if PCA } p \text{ is net exporter} \end{cases}$$

where $Import_{con}$ is defined as the electricity from a linked PCA i that was consumed within PCA p. Any imported electricity not consumed with PCA p is re-exported.

Adjusted electricity consumption from the PCAs were assigned to the power plants using

equation 5.

$$DC_E_{p,k} = DC_E_{p,adj} \times \frac{PP_k}{\sum_{k=1}^{n} PP_k} \tag{5}$$

Where $DC_E_{p,k}$ is the total energy directly consumed [MWh/y] by data centers from power plant k that is attributed to PCA p, $DC_E_{p,adj}$ is the total electricity consumption of the data center from PCA p after adjusting for the inter-PCA electricity transfers, PP_k is the net generation by a specific power plant in MWh/y, and n is the number of power plants within PCA p. A similar approach was taken to connect power plants to water and wastewater utilities, with their electricity usage (and associated environmental footprints) then linked to the data center they service. Boiler feed pumps require an insignificant amount of electricity to provide water to power plants. Therefore, we truncate our analysis at this point.

2.3 Water consumption and GHG emissions associated with data centers

The indirect water and carbon footprint of each data center consists of water consumption or GHG emissions associated with the generation of i) electricity utilized during data center operation, ii) electricity used by water treatment plants for treatment and supply of cooling water to data centers, and iii) electricity used by wastewater treatment plants to treat the wastewater generated by a data center. The GHG emissions or water consumption of a power plant supplying electricity to a data center is attributed to the data center as follows:

$$DC_IF_k = DC_E_k \times F_k \tag{6}$$

Where DC_IF_k is the indirect footprint (water or carbon) associated with electricity used during the operation of a data center from power plant k and DC_E_k is the total energy used [MWh/y] by a data center from power plant k (from equation 5). When calculating the indirect water footprint, F_k is the water consumption per unit of electricity generated by power plant k in m^3/MWh. When calculating the indirect carbon footprint, F_k is the GHG emitted per unit of generated electricity by power plant k (tons $CO_2 - eq$ /MWh).

Although the IPCC does not consider water treatment a notable emitter of GHGs [37], wastewater treatment plants are a major source of GHG emission [38, 39]. In 2017, total GHG gas emission from wastewater treatment plants was estimated to be 20 million metric tons, with a direct emission rate of 0.3 kg $CO_2 - eq/y$ per m^3 of wastewater treated [38, 39]. In absence of facility specific emission data, we have used the average emission rate for treating wastewater for all wastewater generated from data center operation [39]. No direct GHG emissions are assumed to be associated with data center operation at the facility [18].

The EPA Safe Drinking Water Information System contains information on the location, system type, and source of water for each public water and wastewater utility [40, 41]. We assumed the nearest non-transient water treatment plant and wastewater treatment plant services a data center's water demand and wastewater management, respectively. After calculating the water supply requirement of a data center (discussed later in this section), the electricity needed for treatment and distribution of cooling water can be calculated using the data from Pabi et al. [13] (see Table

S2). Water and wastewater treatment plants were linked to power plants (as described previously) to estimate the indirect water footprint associated with electricity required to distribute and treat water and wastewater used by a data center. We then sum the water consumed by each power plant to directly or indirectly service a data center to determine the total indirect water footprint of that data center. The indirect water footprint associated with each power plant was also aggregated within watershed boundaries to determine which water sources each data center was reliant upon.

Direct water consumption of a data center can be estimated from the heat generation capacity of a data center [42], which is related to the amount of electricity used [43]. Estimates of data center specific electricity demand were multiplied by the typical water cooling requirement [1] – 1.8 m^3/MWh – to estimate the direct water footprint of each data center. The direct water consumption is assigned to the watershed where the water utility supplying the data center withdraws its water.

Data center wastewater is largely comprised of blowdown; that is, the portion of cooling water removed from circulation and replaced with freshwater to prevent excessive concentration of undesirable components [44]. We assume all data centers utilize potable water supplies and cycle this water until the concentration of dissolved solids is roughly five times the supplied water [44]. We calculate blowdown from data center cooling towers using the following commonly employed approach [45]:

$$R_{Blowdown} = \frac{1}{C-1} \times R_{Evaporation} \tag{7}$$

Where $R_{Blowdown}$ is the blowdown rate required for a cooling tower (m^3/MWh), C is the

cycle of concentration for dissolved solids (assumed here as 5), and $R_{Evaporation}$ is the rate of evaporation (m^3/MWh).

2.4 Water scarcity footprint

The water scarcity footprint (WSF; as defined by ISO 14046 and Boulay et al. [46]) indicates the pressure exerted by consumptive water use on available freshwater within a river basin and determines the potential to deprive other societal and environmental water users from meeting their water demands. We quantified the WSF of data centers using the AWARE method set forth by Boulay et al. [46] (see the Supportive Information for more details). Other societal and environmental water use data, as well as data on natural water availability within each US watershed, come from ref [47–49].

3. Results

3.1 The water footprint of data centers

The total annual operational water footprint of US data centers in 2018 is estimated at 5.13 x 10^8 m^3. Data center water consumption is comprised of three components: i) water consumed directly by the data center for cooling and other purposes (Figure 2A), ii) water consumed indirectly through electricity generation (Figure 2B), and iii) water consumed indirectly via the water embedded with the electricity consumption of water and wastewater utilities servicing the data center (Figure 2C). The data center industry directly or indirectly draws water from 90% of US

watersheds, as shown in Figure 3A.

Roughly three-fourths of US data centers' operational water footprint is from indirect water dependencies. The indirect water footprint of data centers in 2018 due to their electricity demands is 3.83 x 10^8 m^3, while the indirect water footprint attributed to water and wastewater utilities serving data centers is several orders of magnitude smaller (4.50 x 10^5 m^3). Nationally, we estimate that 1 MWh of energy consumption by a data center requires 7.1 m^3 of water. However, this national average masks the large spatial variation (range 1.8 - 105.9 m^3) in water demand associated with a data center's energy consumption. Data centers are indirectly dependent on water from every state in the contiguous US, much of which is sourced from power plants drawing water from subbasins in the eastern and western coastal states. Less than one-fifth of the industry's total electricity demand is from data centers in the West and Southwest US (regions as defined by NOAA [50]; see outlined areas in Figures 2-5, and Figure S4 for region identification), yet nearly one-third of the industry's indirect water footprint is attributed to data centers in these regions. Indirect water consumption associated with energy production in Southwest subbasins is particularly high, despite relatively low electricity supplied from this region, due to the disproportionate amount of electricity from water-intensive hydroelectricity facilities and the high evaporative potential in this arid region. Conversely, the Southeastern region consumes one-quarter of the electricity used by the industry but only one-fifth of the indirect water since data centers in this region source their electricity from less water-intensive sources.

On-site, direct water consumption of US data centers in 2018 is estimated at 1.30 x 10^8 m^3. Collectively, data centers are among the top-ten water consuming industrial or commercial

industries in the US [47]. Approximately 1.70 x 10^7 m^3 of water directly consumed by data centers are sourced from a different subbasin than the location of the installed servers. Large direct water consumption in the Northeast, Southeast, and Southwest regions indicate clustering of servers in these regions. Combined direct and indirect water and carbon intensities are broken down by data center type in Table 1.

Table 1: Combined direct and indirect water consumption and greenhouse gas emissions (carbon equivalence) by data center type. Water intensity and carbon intensity are reported per MWh of electricity used and per computing workload. Estimates of public and private cloud workloads are from ref [2, 3]. Better energy utilization, more efficient cooling systems, and increased workloads per deployed server has increased the water efficiency of larger data centers. Computing workloads in hyperscale data centers are almost 6 times more water efficient compared to internal data centers

Category	**Energy Use (million MWh)**	**Computing workloads (million)**	**Water intensity (m^3/MWh)**	**Carbon intensity (ton/MWh)**	**Water intensity (m^3/workload)**	**Carbon intensity (ton/workload)**
Internal	26.90	16	7.20	0.45	12.15	0.75
Colocation	22.40	41	7.00	0.42	3.85	0.25
Hyperscale	22.85	76	7.00	0.44	2.10	0.15

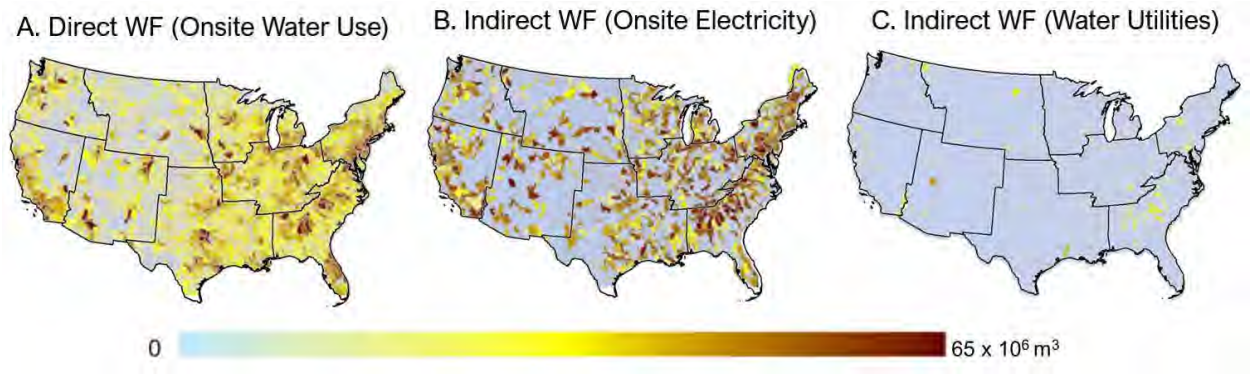


Figure 2: The blue water footprint (m^3) of US data centers in 2018, resolved to each subbasin (8-digit Hydrologic Unit Code). (A) Direct water footprint of data centers, (B) indirect water footprints associated with electricity utilization by data center equipment, and (C) indirect water footprints associated with treatment of supplied cooling water and treatment of generated wastewater.

3.2 Reliance of data centers on scarce water supplies

The water scarcity footprint of data centers in 2018 is 1.29 x 10^9 m^3 of US equivalent water consumption, which is more than twice that of the volumetric water footprint reported in the previous section. The water scarcity footprint (including both direct and indirect water requirements) per unit of energy consumption is 17.9 m^3 US-eq water/MWh, more than double the nationally averaged water intensity (7.1 m^3/MWh) that does not account for water scarcity. Water scarcity footprints that are larger than volumetric water footprints suggest that data centers disproportionately utilize water resources from watersheds experiencing greater water scarcity than average.

Only one-fourth of the volumetric water footprint of data centers resulted from onsite water use. Yet, more than 40% of the water scarcity footprint is attributed to direct water consumption.

This indicates that direct water consumption of data centers, which occurs close to where the data center is located, is skewed towards water stressed subbasins compared to its indirect water consumption, which is distributed more broadly geographically. We find that most of the watersheds that data centers draw from, particularly those in the Eastern US, face little to no water stress on average. In contrast, many of the watersheds in the Western US exhibit high levels of water stress, which is exacerbated by data centers direct and indirect water demands. Combined, the West and Southwestern watersheds supply only 20% of direct water and and 30% indirect water to data centers, while hosting approximately 20% of the nation's servers. Yet, 70% of the overall water scarcity footprint occurs in these two regions (Figure 3B), which indicates a disproportionate dependency on scarce waters in the western US.

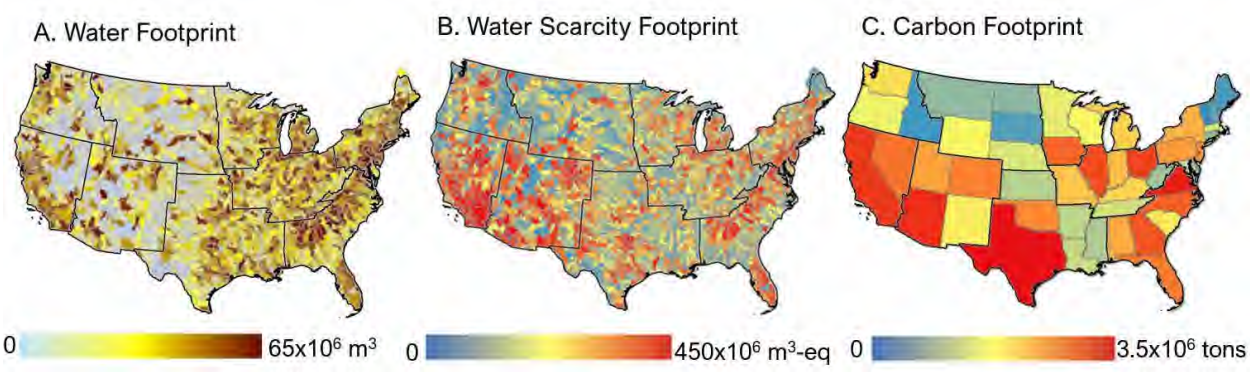


Figure 3: The subbasin or state of direct and indirect environmental impact associated with data center operation. (A) water footprint (m^3). (B) water scarcity footprint (m^3 US-eq water). (C) carbon footprint (tons $CO_2 - eq/y$).

3.3 GHG emissions attributed to data centers

Total GHG emissions attributed to data centers in 2018 was 3.15 x 10^7 tons $CO_2 - eq$, which is almost 0.5% of total GHG emissions in the US [10]. A little over half (52%) of the total emissions of data center operations are attributed to the Northeast, Southeast, and Central US, which have a high concentration of thermoelectric power plants, along with large number of data centers (Figure 3C). Almost 30% of the data center industry's emissions occur within the Central US, which relies heavily on coal and natural gas to meet its electricity demand. Yet, only 10% the industry's energy demand comes from the Central US, and just 9% of the water consumption associated with data centers operation occurs in this region. Moreover, the Central region is a net exporter of electricity to other regions, providing electricity for data centers located in the Northeast and Southeast regions, which houses almost one-third of servers. Yet, the generation of less carbon intensive electricity in the Northeast (hydroelectricity) and Southeast (wind/solar) regions means that while their electricity consumption comprises 34% of data centers' national electricity demand, these regions only constitute 23% of the industry's GHG emissions. The GHG emissions from treating the wastewater generated from data centers is around 550 tons/y (0.002% of total GHG emissions associated with data centers).

3.4 Where to locate data centers to minimize water and carbon footprints

Our results indicate significant variability of environmental impacts depending on where a data center is located. Here we explore how the geographic placement of a data center can lead to improved environmental outcomes. We find that the total water intensity of a data center can range

from 1.8 - 106 m^3/MWh, the water scarcity intensity from 0.5 to 305 m^3 US-eq/MWh, and the carbon intensity from 0.02-1 ton $CO_2 - eq$/MWh depending on where the data center is placed (Figure 4). Data center placement decisions are complicated by the electricity grid, which displaces environmental impacts from the physical location of a data center.

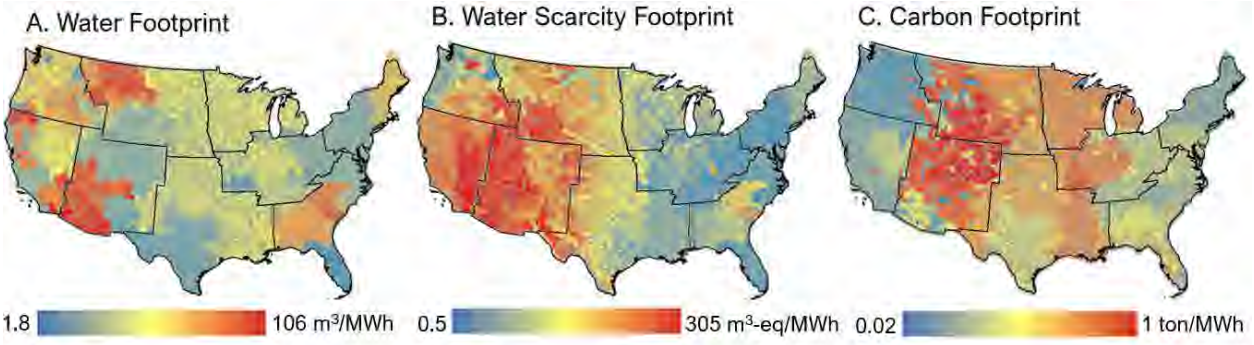


Figure 4: A data center's environmental footprint is highly contingent on where it is located. The (A) water intensity (m^3/MWh), (B) water scarcity intensity (m^3 US-eq/MWh), and (C) GHG emissions intensity (tons $CO_2 - eq$/MWh) of a hypothetical 1 MW data center placed in each of the 2110 subbasins of the continental United States.

Figure 5 depicts subbasins in the top quartile of environmental performance as it relates to water footprint (5A), water scarcity footprint (5B), and carbon footprint (5C) per MWh of electricity used by a hypothetical data center located within each subbasin. Less than 5% of subbasins are in the top quartile of environmental performance for both water scarcity footprint and carbon footprint (hatched areas in Figure 5B and 5C), meaning that 40% of subbasins will require making a trade-off between reducing water scarcity footprints and carbon footprints. The remaining 55% of subbasins (white areas shared by Figure5B and 5C) are not among the best locations to place a data center for either water or GHG reduction. Though the water footprint and water scarcity footprint are related concepts, we show that nearly one-fifth of subbasins that were in the top quartile

with respect to the water footprint are in the bottom quartile for water scarcity footprint. In other words, a data center placed in these basins would use less water than 75% of potential sites, but it would draw that water from subbasins facing higher levels of water scarcity. In general, locating a data center within the Northeast, Northwest, and Southwest will reduce the facilities carbon footprint, while locating a data center in the Midwest and portions of the Southeast, Northeast, and Northwest will reduce its water scarcity footprint.

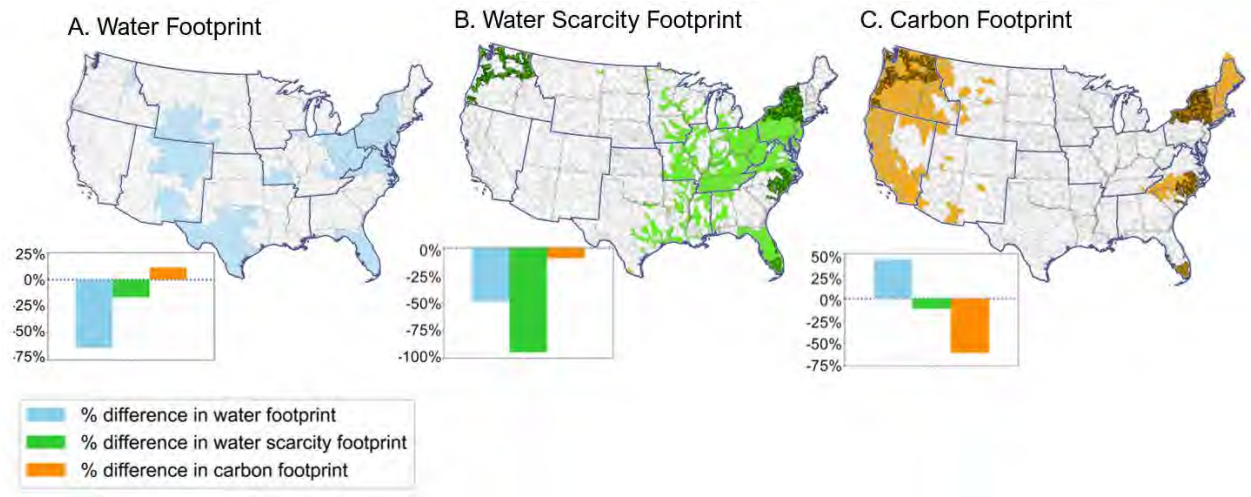


Figure 5: The (A) water footprint, (B) water scarcity footprint, and (C) carbon footprint of data centers can be reduced by placing them in subbasins with the smallest footprint (top quartile of all subbasins), as denoted by the shaded subbasins in each panel. The bar graphs represent the percent reduction/increase of each environmental footprint within the shaded subbains compared to the national average data center environmental footprint. Hatched areas indicate subbasin that are among the most (top quartile) environmentally favorable locations for both water scarcity and GHG emissions.

In the coming years, cloud and hyperscale data centers will replace many smaller data centers [3]. This shift will lower the environmental footprint in some instances but introduce new environ-

mental stress in other areas. Assuming added servers employ similar technology as existing servers and are placed in cloud and hyperscale data centers in proportion to the current spatial distribution of data centers (i.e., business-as-usual scenario), these new data center servers will have a collective water footprint of 77.77 x 10^6 m^3 (15% of the current industry total), water scarcity footprint of 170.56 x 10^6 m^3 US-eq (9%), and 4.36 x 10^6 tons $CO_2 - eq$ (14%). However, if these new servers are strategically placed in areas identified to have a lower environmental footprint, their water and carbon burden could be significantly reduced.

The water scarcity footprint and carbon footprint of new data centers can be reduced by 153.00 x 10^6 m^3 US-eq (90% less than business-as-usual expansion) and 2.34 x 10^6 tons $CO_2 - eq$ (55%), respectively (Figure 6A) if they are placed in areas with the lowest carbon and water scarcity footprints (hatched areas in Figure 5). However, placing all new data centers within a small area may strain local energy and water infrastructure due to their collective water and energy demands. Data centers can be dispersed more broadly in areas that are favorable with respect to water footprint (Figure 5A), water scarcity footprint (Figure 5B), or carbon footprint (Figure 5C). However, only considering one environmental characteristic can lead to environmental trade-offs (Figure 6).

4. Discussion and conclusion

The amount of data created and stored globally is expected to reach 175 Zettabytes by 2025, representing nearly a six-fold increase from 2018 [51]. The role of data centers in storing, managing, and distributing data has remained largely out of view of those dependent on their services. Simi-

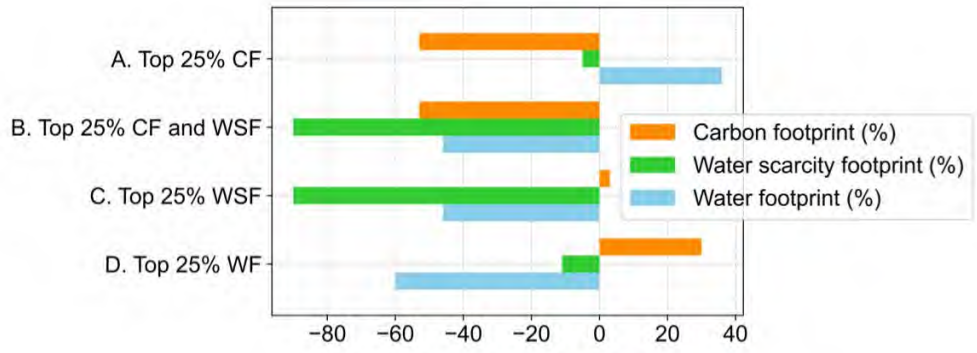


Figure 6: Percent change in environmental footprints associated with new data center servers compared to the 'business-as-usual' scenario. While the business-as-usual scenario assumes new servers will be placed in proportion to historical server locations, alternative scenarios explicitly consider the environmental implications of data center placement. Scenario A places data center servers in subbasins within the top quartile of all subbasins in environmental performance for both carbon (CF) and water scarcity(WSF) footprints. Scenario B represents server placement within subbasins in the top quartile for carbon footprints, while scenario C and D represent the best (top 25%) subbasins to place data center servers with respect to minimizing water scarcity footprints and water footprints (WF), respectively.

larly, the environmental implications of data centers have been obscured from public view. Here, for the first time, we estimate the water and carbon footprints of the US data center industry using infrastructure and facility-level data. Data centers heavy reliance on water scarce basins to supply their direct and indirect water requirements not only highlight the industry's role in local water scarcity, but also exposes potential risk since water stress is expected to increase in many watersheds due to increases in water demands and more intense, prolonged droughts due to climate change [52–54]. For these reasons, environmental considerations may warrant consideration

alongside typical infrastructure, regulatory, workforce, customer/client proximity, economic, and tax considerations when locating new data centers.

The data center industry can take several measures to reduce its environmental footprint, as well as minimize its water scarcity risks. First, the industry can continue its energy efficiency improvements. The ongoing shift to more efficient hyperscale and co-location data centers will lower the energy requirements per compute instance. Software and hardware advances, as well as further PUE improvements, can continue to reduce energy requirements, and thus environmental externalities. For instance, quarterly PUE of as low as 1.07 has been reported by Google for some of their data centers [55]. Liquid immersion cooling technologies show promise of further reductions in PUE, with one study reporting a PUE below 1.04 [56]. The prospect of recovering low-grade heat (i.e., low temperature or unstable source of heat) from data centers for space or water heating is limited; however, approaches such as absorption cooling and organic Rankine cycle are promising technologies for generating electricity from waste heat [57].

Second, the data center industry can make investments in solar and wind energy. Directly connecting data center facilities to wind and solar energy sources ensures that water and carbon footprints are minimized. Purchasing renewable energy certificates from electricity providers does not necessarily reduce the water or carbon footprints of a data center. However, these investments gradually shift the electrical grid towards renewable energy sources, thus lowering the overall environmental impact of all energy users. Data center workloads can be migrated between data centers to align with the portion of the grid where renewable electricity supplies exceed instantaneous demand [58].

Third, as we show in this study, strategically locating new data centers can significantly reduce their environmental footprint. Climatic factors can make some areas more favorable due to lower ambient temperatures, thereby reducing cooling requirements. Lower cooling requirements reduces both direct and indirect water consumption, as well as GHG emissions, associated with data center operation. Since most data centers meet their electricity demands from the grid, the composition of power plants supplying electricity to a data center plays a significant role in a data center's environmental footprint. For an industry that is centered on technological innovation, we show that real estate decisions may play a similar role as technological advances in reducing the environmental footprint of data centers.

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Data availability Data center locations come from ref [4, 19–21]. Power plant electricity generation, water consumption, and GHG emission data come from ref [35, 59, 60]. Location of public water utility and wastewater treatment data comes from ref [40, 41]. Data produced through this research can be found in the Supporting Information, as well as at [DOI to be inserted upon acceptance]. The DOI contains relevant shapefiles, tabular data, and scripts to help replicate and extend our work.

Author contributions L.M. conceived and designed the study. M.A.B.S. conducted the analysis. A.S. provided data and fundamental concepts regarding the analysis. All authors contributed to the writing of the manuscript.

Competing interests The authors declare that they have no competing financial interests.

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DATA CENTER WATER USAGE

Mary Zhang, December 2022

Data centers are significant consumers of natural resources, and while carbon emissions and electricity consumption are at the forefront of people's minds, water usage is gaining increased recognition. Water is used in data center cooling systems, which ensure that the heat produced by these massive facilities is controlled, such that their internal servers can run uninterrupted 24 hours a day, 7 days a week.

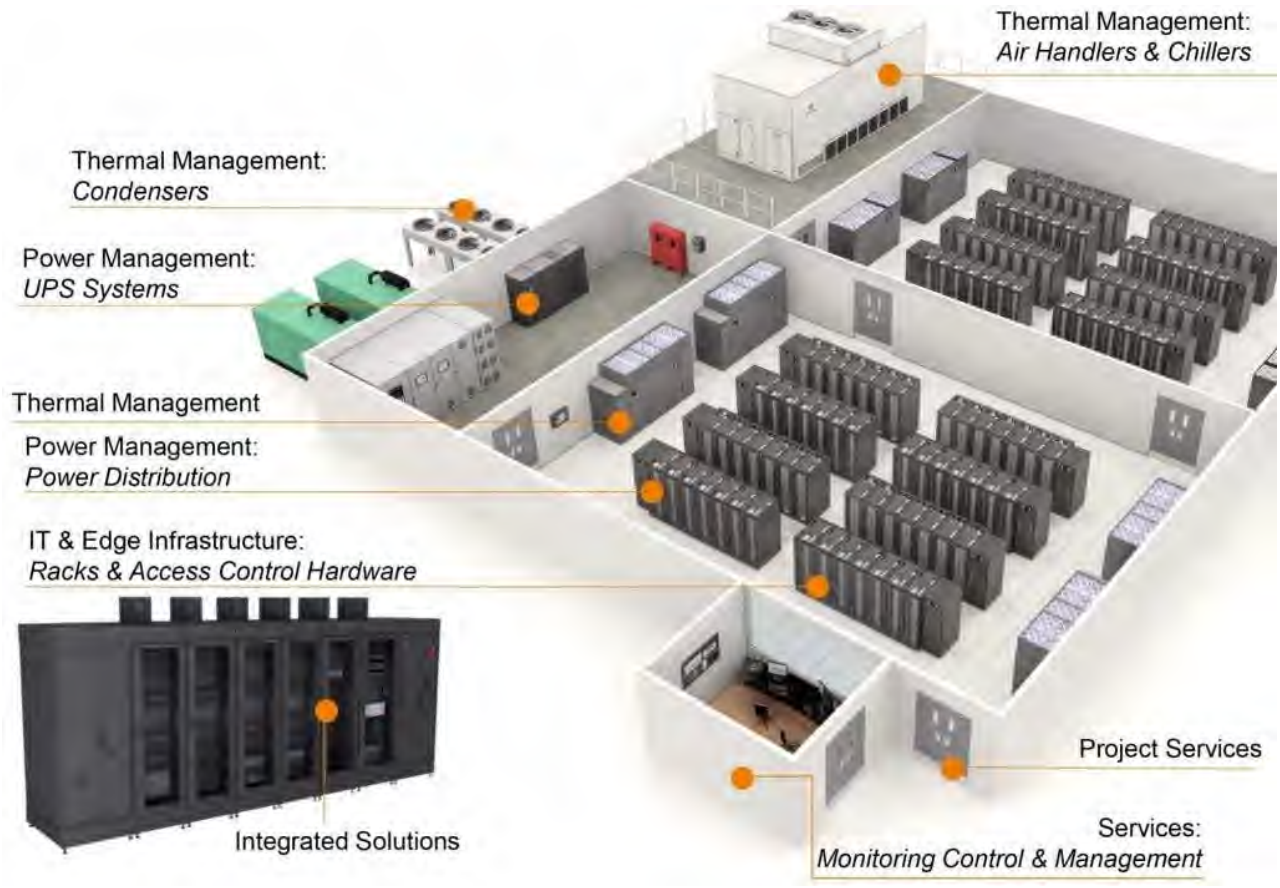
Data centers use large amounts of water for their cooling system, which includes cooling towers, chillers, pumps, piping, heat exchangers / condensers, and computer room air conditioner (CRAC) units. Additionally, data centers need water for their humidification systems and facility maintenance.

Globally, data centers are located in all different types of countries and climates, including many facilities in water-stressed regions of the world, which are prone to droughts. According to the United Nations, by 2025, 50% of the world's population is projected to live in water-stressed areas, making data center water usage a key environmental area to prioritize change.

Dgtl Infra provides an in-depth overview of data center water usage, explaining how data centers use water and how much water they consume on an annual basis. Additionally, we track key water metrics and sustainability initiatives from some of the world's largest data center operators, such as Amazon Web Services (AWS), Microsoft, Google, Facebook (Meta Platforms), and Apple.

Why do Data Centers Use Water?

Data centers use significant amounts of water on-site *primarily* for their cooling system, which is comprised of cooling towers, chillers, pumps, piping, heat exchangers / condensers, and computer room air conditioner (CRAC) or computer room air handler (CRAH) units. Below is an illustration of a typical data center layout showing some of these cooling system components:



Source: Vertiv.

To a lesser degree, data centers also need water for their **humidification systems** and facility maintenance.

Notably, data centers indirectly consume large amounts of water off-site – *at a power generation plant* – in order to supply the data center with electricity. For the purposes of this analysis, only water used on-site, for the operation of a data center's cooling and humidification systems will be considered.

Cooling System

Traditionally, data center air conditioning equipment is either water-cooled or air-cooled, with water-based cooling via evaporative cooling systems more common, particularly for large data centers. These cooling systems remove and release all of the heat produced inside a data center – *from servers, IT equipment, and mechanical infrastructure* – into the outside environment, through a cooling tower that uses a water evaporation process.

In a water-cooled system, water-cooled chillers and cooling towers produce chilled water, which is supplied to computer room air conditioner (CRAC) units for cooling both inside and outside of the data center room.

Humidification System

Data centers use water in the operation of humidification systems, which help maintain humidity levels in the facility's server rooms. Specifically, humidifiers use electricity to vaporize water, creating steam in the air.

How Much Water Does a Data Center Use?

Data center water consumption varies depending on several factors, including the size of the facility, cooling system used, and outdoor temperature and humidity. Typically, data centers use less water during the winter months and more during the summer months. To this end, higher outdoor air temperatures mean that more energy – *and thus more water* – is required for a data center's cooling system, to lower the facility's internal air temperature back down to appropriate levels.

Below are two examples of data center water consumption for varying facility sizes: i) hyperscale data centers and ii) wholesale and retail data centers. In both instances, a single data center consumes several million gallons / liters of water annually.

Water Consumption	Hyperscale	Wholesale and Retail*
per day	450k gallons (1.7m liters)	18k gallons (68k liters)
per year	164m gallons (622m liters)	6.57m gallons (24.9m liters)

**Average daily water consumption of a single data center building.*

Hyperscale Data Centers – Water Usage

Hyperscale data centers are very large, often single-tenant facilities for cloud service providers (CSPs) and large internet companies. These data centers

individually comprise tens of megawatts of power capacity and can reach millions of square feet in size, meaning their corresponding water consumption is very high.

Google operates hyperscale data centers to support its cloud regions and the company's core products and platforms, such as Gmail, Google Drive, Google Maps, Google Photos, Google Play, Search, and YouTube. In 2021, the average Google data center consumed 450,000 gallons (1.7 million liters) of water per day, equivalent to 164 million gallons (622 million liters) of water annually.

Wholesale and Retail Data Centers – Water Usage

In late 2021, Prince William County, which is part of the Northern Virginia data center market, studied water consumption for its 25 operational data centers. These facilities were much smaller, typically ranging from 100,000 to 250,000 square feet, meaning their corresponding water consumption was meaningfully lower, as compared to Google's hyperscale data centers.

Based on the county's findings, the average daily water consumption of a single data center building was about 18,000 gallons (68,100 liters) per day, equivalent to 6.57 million gallons (24.9 million liters) of water annually. While the maximum daily water consumption of a single data center building was about 88,000 gallons (333,100 liters) per day, equivalent to 32.1 million gallons (121.6 million liters) of water annually.

Where do Data Centers Get their Water?

Data centers get their water primarily from a municipal or regional water utility company, which provides water supply for the data center's cooling and humidification systems.

For cooling purposes, data centers typically draw potable water, meaning drinking water, from the water utility and, to a lesser extent, they source non-potable / greywater and recycled water, which is treated sewage. For example, Google utilizes *some* reclaimed or non-potable water at more than 25% of its data center campuses.

On average, less than 5% of a data center's total water supply comes from alternative sources such as on-site groundwater, surface water, seawater,

produced water (byproduct of oil & gas extraction), and rainwater capture systems.

What Happens to Water Used to Cool Data Centers?

Water used to cool data centers is either consumed, meaning it evaporates into the atmosphere via the data center's cooling towers or discharged, as industrial wastewater, usually to a local wastewater treatment plant.

Effective water treatment, either on-site or off-site through a wastewater treatment plant, means that the water can be reused in the cooling system multiple times, if the water quality (e.g., hardness) is acceptable.

Do Data Centers Reuse Water?

Data centers reuse water by recirculating the same water through their cooling systems multiple times. According to Google, this practice saves up to 50% of water when compared with "once-through" cooling systems.

However, eventually this reused water needs to be replaced with new water, due to the risk of scale formation or once the conductivity of the water is too high.

The need for new water results from the build-up of scale-forming minerals in the reused water – *such as calcium, magnesium, and silica*, which become concentrated over multiple evaporative cooling cycles.

Ultimately, the spent data center cooling water can be treated and reused (or recycled) for other purposes such as irrigation or toilet flushing.

Water Usage Effectiveness (WUE)

Data center water usage efficiency employs a metric known as water usage effectiveness (WUE), which measures the water a data center uses to cool its equipment. Specifically, water usage effectiveness (WUE) is the ratio of the annual water usage for data center operations *in liters*, divided by the energy consumption of the IT computing equipment *in kilowatt hours (kWh)*. Therefore, WUE is signified using the units of liters per kilowatt-hour (L/kWh).

Data Center Water Usage by Hyperscaler

Cloud service providers (CSPs) and large internet companies, collectively known as hyperscalers**,** have disclosed metrics on their data center water usage. Moreover, hyperscalers including Amazon Web Services (AWS), Microsoft, Google, and Facebook (Meta Platforms) have all committed to be water positive by 2030**.**

Amazon Web Services (AWS) – Data Center Water Usage

Amazon Web Services (AWS) has committed to be water positive by 2030, returning more water to communities and the environment than it uses in its direct operations. Specifically, AWS' water positive commitment applies to AWS leased, owned, and colocation data centers**,** as well as AWS offices. The company's data center commitments form the basis of its water use strategy for each operational AWS Region.

Presently, AWS uses recycled water for cooling in 20 data centers around the world, including those shown in the map below, namely Virginia (United States), California (United States), Oregon (United States), United Kingdom, Brazil, South Africa, India, Indonesia, and Singapore.

Water Positive Calculation

AWS calculates its progress toward its water positive goal as follows:

$$\text{AWS Water Positive \%} = \frac{\text{Reused Water + Water from Replenishment}}{\text{Total Water Withdrawal – Water from Sustainable Sources}}$$

Water efficiency improvements by AWS will be reflected in a declining volume of incoming water. If the percentage is under 100%, that means AWS has not met its water positive goal. Whereas if the percentage is over 100%, that means AWS is returning more water to the community than it is using – *meaning AWS is water positive*.

AWS' four key strategies to become water positive are:

1. Improving water use efficiency across its operations

2. Using sustainable water sources (e.g., recycled water)
3. Returning water for community reuse
4. Supporting water replenishment projects for communities and the environment

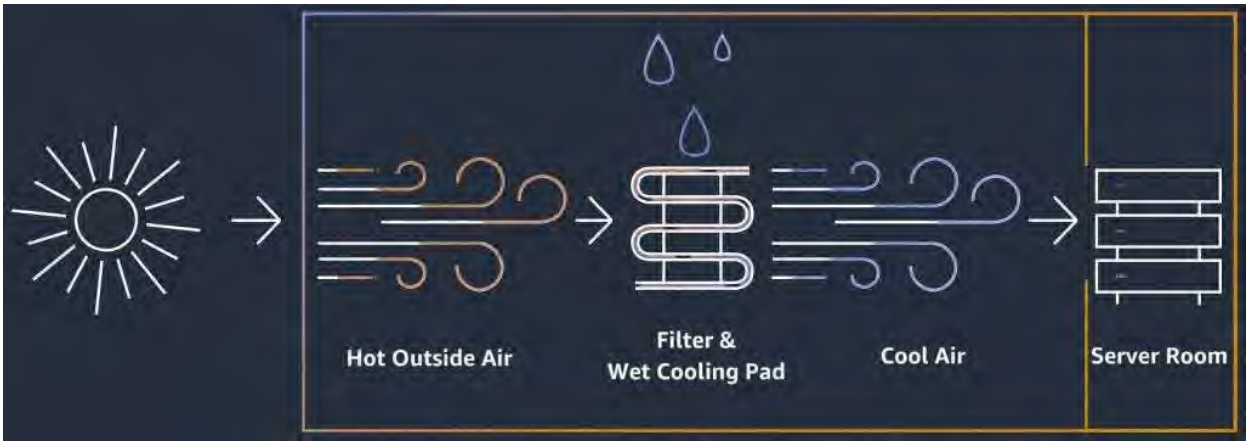
Water Usage Effectiveness (WUE)

In 2021, AWS' global water usage effectiveness (WUE) metric was 0.25 liters of water per kilowatt-hour (L/kWh) of electricity used on average across AWS data centers worldwide. On an annual basis, AWS will report on its WUE metric, new water reuse and recycling efforts, new activities to reduce water consumption in its facilities, and replenishment projects.

Cooling System Strategies

AWS' preferred cooling strategy for its data centers is known as direct evaporative cooling. In this system, hot air is pulled from outside and pushed through water-soaked cooling pads. The water evaporates, reducing the air's temperature, and the cool air is then sent into the server rooms.

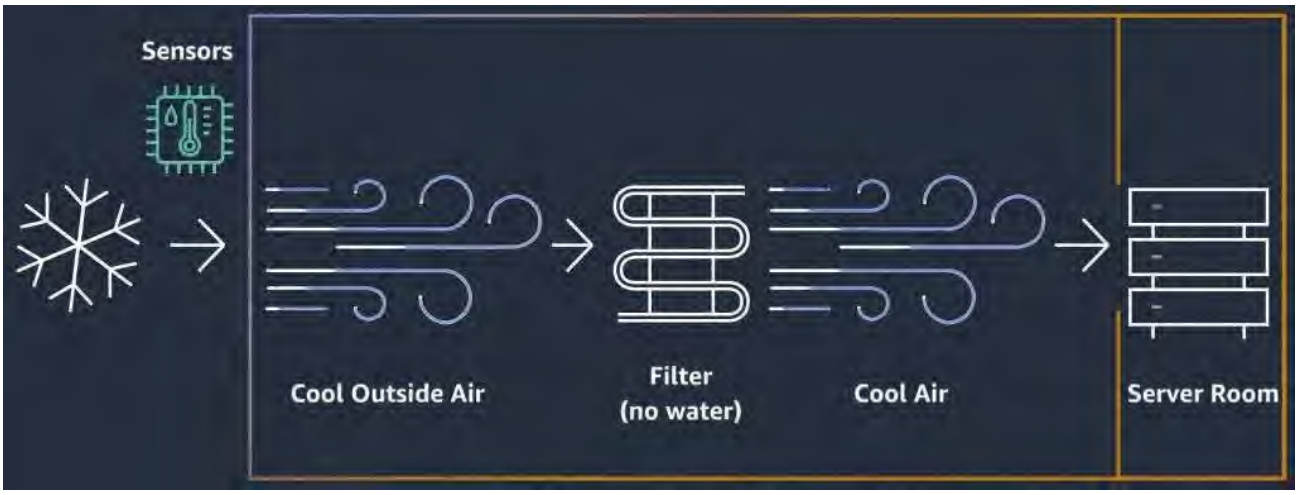
Direct Evaporative Cooling



Source: Amazon Web Services (AWS).

To reduce the water use of its cooling systems, AWS also employs a free-air cooling system. At its data centers, AWS installs sensors that track weather parameters like temperature and humidity. As soon as the conditions drop to a safe operating range, the evaporative cooling system shuts off, and cool air from outside is pulled into the server rooms.

Free-Air Cooling



Source: Amazon Web Services (AWS).

Microsoft – Data Center Water Usage

Microsoft has committed to be water positive for its direct operations by 2030, which means that Microsoft will replenish more water than it consumes on a global basis. Particularly, Microsoft's water consumption strategy has two main pillars:

- Reducing Water Use Intensity**:** the water Microsoft uses per megawatt of energy used for its operations
- Replenishing Water**:** in the water-stressed regions where Microsoft operates

Focusing on data centers, Microsoft has committed to reduce the water used in its evaporative cooled data centers globally by 95% by 2024. This reduction represents an estimated 1.5 billion gallons (5.7 billion liters) of water annually.

As an example, Microsoft is leveraging a method called adiabatic cooling, which uses outside air instead of water for cooling when temperatures are below 85 degrees Fahrenheit (29.4 degrees Celsius).

Google – Data Center Water Usage

Google has committed to replenish more water than it consumes by 2030 and support water security in communities where it operates. Specifically, Google will invest in community projects that replenish 120% of the water it consumes, on average, across all its offices and data centers.

To achieve its water commitments, Google is focusing on three areas:

1. Responsible Water Use**:** enhance management of water resources across Google office campuses and data centers
2. Watersheds and Communities**:** replenish Google's water use and improve watershed health, while supporting ecosystems in water-stressed communities
3. Water Security with Technology**:** share technology and tools that enable everyone to predict, prevent, and recover from water stress

Google uses water to cool the data centers that support its cloud regions and the company's core products and platforms, such as Gmail, Google Drive, Google Maps, Google Photos, Google Play, Search, and YouTube. Water is also used in Google's supply chain, in the manufacturing of its data center equipment.

During 2021, Google's global data center portfolio consumed 4.34 billion gallons (16.4 billion liters) of water, equivalent to the water needed to irrigate and maintain 29 golf courses in the southwest U.S. each year.

Of this global total, Google consumed 3.37 billion gallons (12.7 billion liters) of water (78% of total) across its 15 U.S. data centers and 971 million gallons (3.68 billion liters) of water (22% of total) through additional global data center locations.

Google Data Centers – Annual Water Metrics for 2021

Data Center	Withdrawal	Discharge	Consumption
Berkeley County, South Carolina	541.3m gallons	65.9m gallons	475.3m gallons
Council Bluffs, Iowa	1,111m gallons	265.2m gallons	845.8m gallons
The Dalles, Oregon	358.3m gallons	83.8m gallons	274.5m gallons
Douglas County, Georgia	421.8m gallons	61.7m gallons	360.1m gallons
Henderson, Nevada	68.9m gallons	28.4m gallons	40.5m gallons

Jackson County, Alabama	92.3m gallons	22.1m gallons	70.2m gallons
Leesburg, Virginia	59.6m gallons	15.0m gallons	44.7m gallons
Lenoir, North Carolina	352.2m gallons	21.5m gallons	330.7m gallons
Mayes County, Oklahoma	863.1m gallons	192.0m gallons	671.2m gallons
Midlothian, Texas	51.3m gallons	11.4m gallons	39.9m gallons
Montgomery County, Tennessee	166.5m gallons	27.3m gallons	139.2m gallons
New Albany, Ohio	27.0m gallons	11.1m gallons	15.9m gallons
Papillion, Nebraska	34.2m gallons	16.7m gallons	17.5m gallons
Sterling, Virginia	51.3m gallons	9.3m gallons	41.9m gallons
Storey County, Nevada	0.6m gallons	0.6m gallons	0.1m gallons
Subtotal – U.S. Locations	***4.20bn gallons***	***832.0m gallons***	***3.37bn gallons***
Additional Global Locations	1.33bn gallons	361.2m gallons	971.0m gallons
Total Locations	**5.53bn gallons**	***1.19bn gallons***	***4.34bn gallons***

Google defines its water **"**Consumption**"** as **"**Withdrawal**"** less "Discharge". Therefore, in 2021, Google's global data center portfolio consumption of 4.34 billion gallons (16.4 billion liters) of water is comprised of withdrawal of 5.53 billion gallons (20.9 billion liters) of water, less discharge of 1.19 billion gallons (4.5 billion liters) of water.

Notably, in 2021, the average Google data center consumed 450,000 gallons (1.7 million liters) of water per day, equivalent to 164 million gallons (622 million liters) of water annually.

Facebook (Meta Platforms) – Data Center Water Usage

Facebook, part of Meta Platforms, has committed to be water positive by 2030, meaning the company will restore more water to the environment than it consumes (i.e., evaporates) for its global operations. To achieve this goal, Meta will restore 200% of the water it consumes in high water stress areas, and 100% of the water it consumes in medium water stress areas.

Facebook (Meta Platforms) follows a water usage strategy that focuses on:

1. Sourcing water responsibly
2. Driving water efficiency across its facilities and operations

3. Investing in critical water restoration projects in the same watersheds where its facilities are located

Facebook (Meta Platforms) uses water at its data centers to cool servers and maintain optimal humidity. During 2021, Meta's total data center portfolio consumption was 636 million gallons (2.41 billion liters) of water, comprised of withdrawal of 903 million gallons (3.42 billion liters) of water, less discharge of 267 million gallons (1.01 billion liters) of water.

Facebook (Meta Platforms) – Data Center Water Metrics for 2021

Water Data	Gallons	Liters
Consumption	636 million	2.41 billion
Withdrawal	903 million	3.42 billion
Discharge	267 million	1.01 billion

Below is a further breakdown of the water withdrawal of Facebook (Meta Platforms), by each of its data centers:

Data Center	Gallons	Liters
Altoona, Iowa	37.0 million	140 million
Clonee, Ireland	245.2 million	928 million
Eagle Mountain, Utah	15.3 million	58 million
Forest City, North Carolina	16.9 million	64 million
Fort Worth, Texas	67.1 million	254 million
Henrico, Virginia	21.1 million	80 million
Huntsville, Alabama	10.3 million	39 million
Los Lunas, New Mexico	40.4 million	153 million
Luleå, Sweden	10.3 million	39 million
New Albany, Ohio	32.0 million	121 million
Newton County, Georgia	27.7 million	105 million
Odense, Denmark	98.5 million	373 million
Papillion, Nebraska	28.0 million	106 million
Prineville, Oregon	93.5 million	354 million
East Coast Leased Data Centers	147.4 million	558 million

Data Center-Related Facilities	11.9 million	45 million
Total Locations	**903 million**	**3.42 billion**

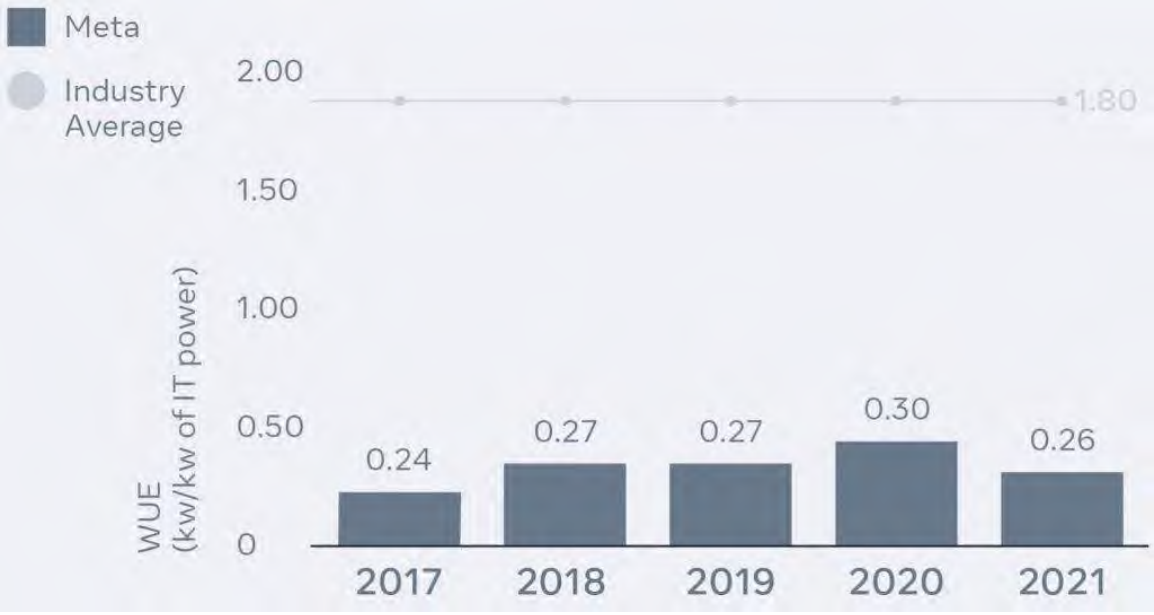
Over 99% of the company's total water withdrawal was sourced from third-party water, such as a municipal water supply.

Additionally, in 2021, Meta's restoration was 617 million gallons (2.34 billion liters) of water throughout its operations. Looking forward, Meta has contracted 1 billion gallons (3.79 billion liters) of water per year for restoration.

Water Usage Effectiveness (WUE)

Data center buildings which Facebook (Meta Platforms) completed in 2021 exhibit a water usage effectiveness (WUE) metric of 0.26 liters of water per kilowatt-hour (L/kWh) of electricity used. Historically, the company's annual data center water usage effectiveness (WUE) metrics have trended as follows:

Facebook (Meta Platforms) – Data Center Water Usage Effectiveness (WUE)



Source: Meta Platforms.

According to Facebook (Meta Platforms), the company's innovative server cooling process enabled its data centers operating in 2021 to be at least 80% more water efficient than the average data center.

Apple – Data Center Water Usage

Apple is committed to reduce water impacts in the manufacturing of its products, use of its services, and operation of its facilities (offices, data centers, and stores). Specifically, Apple's efforts to address the water footprint of its corporate sites and of its suppliers' sites focus on the following key efforts:

- Using water efficiently
- Minimizing freshwater use by expanding the use of alternative water sources, including on-site reuse
- Improving the quality of water it discharges
- Protecting shared water resources and keeping watersheds healthy for all who rely on them

During Fiscal Year 2021 (12-months ended September 25, 2021), Apple's worldwide corporate facilities consumption was 636 million gallons (2.41 billion liters) of water, comprised of withdrawal of 1.407 billion gallons (5.3 billion liters) of water, less discharge of 771 million gallons (2.9 billion liters) of water.

Article by: Mary Zhang

Mary Zhang covers Data Centers for Dgtl Infra, including Equinix (NASDAQ: EQIX), Digital Realty (NYSE: DLR), CyrusOne, CoreSite Realty, QTS Realty, Switch Inc, Iron Mountain (NYSE: IRM), Cyxtera (NASDAQ: CYXT), and many more. Within Data Centers, Mary focuses on the sub-sectors of hyperscale, enterprise / colocation, cloud service providers, and edge computing. Mary has over 5 years of experience in research and writing for Data Centers.

Caroline County Rappahannock River Water Supply Project
JPA No. 20-0514
January 16, 2024

APPENDIX C

PUBLIC MEETING PRESS RELEASE

Caroline County Public Utilities Office

NOTICE
RAPPAHANNOCK RIVER INTAKE TOWN HALL PUBLIC MEETING

For immediate release
December 28, 2023
Contact:
Joseph C. Schiebel, Director of Public Works/Utilities
(804) 633-4390
jschiebel@co.caroline.va.us

The Caroline County Department of Public Utilities will hold a town hall style meeting on January 22, 2024 to present an overview of the Rappahannock River Draft Intake Permit Application/Project to the public. The Board of Supervisors and County staff have been working on obtaining a permit to withdraw water from the Rappahannock River for over ten years to meet Caroline County's long-term water supply requirements.

The details of the meeting are as follows:

RAPPAHANNOCK RIVER INTAKE TOWN HALL
January 22, 2024 - 6:00 pm – 8:00 pm
Caroline County Community Services Center
17202 Richmond Turnpike
Milford, Virginia 22514

The meeting will include an overview of the proposed project, its history, permitting milestones, design considerations and the studies that have been performed to date. Citizens will hear from the Caroline County Director of Public Utilities, engineers from the County's water supply consultants (Hazen) and the Virginia Department of Environmental Quality.

A question and answer session will follow the presentations.

Questions regarding the town hall meeting should be directed to the Caroline County Department of Public Utilities at (804) 633-4390.

Hazen

Summary of Water Demand Projections

Caroline County Rappahannock River Water Supply Project

December 2024

Caroline County (along with all other cities, counties, and towns in Virginia) is required to conduct water supply planning over a planning horizon of at least 30 years. The Virginia State Water Resources Plan (DEQ, 2022) indicates that Caroline County is among the localities with the highest anticipated population increases between 2020 and 2040 due to its proximity to northern Virginia and Washington, DC. Additionally, the County's existing water supply is limited due the Eastern Virginia Groundwater Management Area (EVGMA). As a result, the County has identified a need for additional water supply to meet the projected needs of the community.

Water demand projections were developed based on the County's Water Master Plan (2016). This document summarizes the water demand projections for residential and commercial consumers in Caroline County and the Town of Bowling Green over a planning horizon of 15 years. Water demand projections associated with industrial cooling are not included. Additional details on the County's historical water demands and the demand projection methodology are presented in the Joint Permit Application (2020) and the prior *Summary of Water Demand Projections* (September 2023).

Table 1 summarizes the projected average day and maximum day demands for Caroline County and the Town of Port Royal, including residential and commercial demands. Demands associated with industrial cooling water were removed from the total demand projections. The standard peaking factors provided by DEQ and VDH were used to estimate maximum day demands.

Table 1: Caroline County and Port Royal Projected Average and Maximum Day Demands

Demand Category	Source	10-Year Planning Horizon (mgd)	15-Year Planning Horizon (mgd)
Current Demands (2022)	Historical Data	0.58	0.58
Residential	Master Plan	1.76	2.47
Commercial/Business	Master Plan	1.01	1.34
Total average day demand (without industrial cooling)	----	3.35	4.39
Total maximum day demand (without industrial cooling)	-----	5.89	7.73

[1] Residential water demand adapted from the Water Master Plan based on a midpoint between Transit-Oriented Development (TOD) and non-TOD scenarios.

Hazen

Table 2 summarizes the combined demand projections for the Rappahannock River Water Supply Project for Caroline County (including the Town of Port Royal) and the Town of Bowling Green. The water withdrawal projections were calculated assuming a 5 percent increase from maximum day demand to account for water treatment plant (WTP) process water.

Table 2: Summary of Water Withdrawals for Caroline County and the Town of Bowling Green

Category	10-Year Planning Horizon (mgd)	15-Year Planning Horizon (mgd)
Caroline County: [1]		
Caroline County total average day water demand	3.4	4.4
Caroline County total average day withdrawal	3.5	4.6
Caroline County total max day withdrawal	6.2	8.1
Town of Bowling Green: [2]		
Town of Bowling Green average day water demand	0.4	0.5
Town of Bowling Green average day withdrawal	0.5	0.5
Town of Bowling Green max day withdrawal	0.8	0.9
Total Withdrawals:		
Total average day withdrawal	4.0	5.1
Total maximum day withdrawal	7.0	9.0

[1] *Caroline County water demand projections include the Town of Port Royal.*
[2] *Water withdrawals include a 5% increase to account for water treatment plant process water.*

The combined demand projections for Caroline County and the Town of Bowling Green were used as the basis for the proposed average river withdrawal rates. **Table 3** summarizes the proposed withdrawal rates for a 15-year planning horizon for residential and commercial consumers.

Table 3: Summary of Proposed Withdrawal Rates for a 15-Year Planning Horizon

Permitted Withdrawal Condition	Withdrawal Rate
Average Daily	5.1 mgd
Maximum Monthly	237 mg
Maximum Daily	9.0 mgd
Maximum Instantaneous	9.0 mgd
Maximum Annual	1,862 mg

Commonwealth of Virginia

VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

www.deq.virginia.gov

Travis A. Voyles
Secretary of Natural and Historic Resources

Michael S. Rolband, PE, PWD, PWS Emeritus
Director
(804) 698-4020

Subject:	Disposition of Public Hearing Request, Caroline County VWP No. 20-0514
To:	James Golden, Director of Operations
Through:	Alex Samms, Chief Deputy
	Scott Morris, Director, Water Division
	Meghan Mayfield, Director, Water Permitting
From:	Eric Seavey, Water Withdrawal Permitting Manager
Date:	July 17, 2024

Proposed Permit Action: Surface Water Withdrawal Permit issuance, Caroline County VWP No. 20-0514

Permittee: Caroline County Public Utilities (CPU)

Background:
The areas in Caroline County proposed to be supplied by the Rappahannock River include:

- Caroline County;
- The Town of Bowling Green; and,
- The Town of Port Royal.

The project consists of the construction of a raw water pump station and associated infrastructure, an intake structure located on the south bank of the tidal portion of Rappahannock River, the installation of approximately 35 miles of water line for the transfer of raw water from the intake to the proposed water treatment plant (WTP) located in the vicinity of Carmel Church, VA, which will connect to a new distribution system as well as to parts of the existing distribution system. Operations associated with the two (2) outfalls will be addressed through the existing Virginia Pollutant Discharge Elimination System (VPDES) permits. Operation of the planned water treatment plant is not part of this application and will be addressed through permitting by the Virginia Department of Health (VDH).

Pursuant to 9VAC25-210-330 the DEQ, or Department, coordinated this application review for a surface water withdrawals that also required a Virginia Marine Resources Commission (VMRC)

permit under Chapter 12 (§ 28.2-1200 et seq.) of Title 28.2 of the Code of Virginia with the VMRC in accordance with § 62.1-44.15:5.01 of the Code of Virginia.

For the construction of the permanent raw water intake, three (3) 42" stainless steel wedge wire t-screens will be installed. The intake wedge wire screens will have a slot size of 1 mm and an intake velocity of no more than 0.25 fps, in accordance with applicable standards. In addition, air burst cleaning lines will be installed, each intake screen will be attached to three 6" submerged pipes to convey raw water to the junction box, and a 30" pipe will be installed to convey raw water to the pumping station. The proposed withdrawal limits, as outlined in the draft permit, are as follows:

The Permittee's authorized water withdrawal shall not exceed:

2,884 million gallons per year,
337 million gallons per month,
13.90 million gallons per day

Preparation of Draft Permit: The purpose of this permit action is the issuance of the Surface Water Withdrawal Permit VWP #20-0514 to Caroline County for the Caroline County Public Water Supply Project located on the south bank of the Rappahannock River, approximately six (6) miles east of the Town of Farmville in Prince Edward County, Virginia (hereafter referred to as the draft permit or permit action).

Public Notice Publication: The public notice was published jointly with DEQ and the Virginia Marine Resource Commission (VMRC) in *The Free Lance-Star* and *The Richmond Times-Dispatch* on May 18, 2024. The public comment period began May 18, 2024, and ended on June 18, 2024. The public notice and draft permit were posted on the DEQ website and the VMRC website for the duration of the public comment period.

Summary of Comments and Public Hearing Requests: During the 30-day public comment period, DEQ received and individually reviewed correspondence from 264 separate commenters, 163 of which requested a public hearing. In addition, DEQ reviewed the comments posted to the VMRC website of which 31 were directly related to the DEQ Draft Permit. Comments on the VMRC website were consistent regarding concerns as those received by DEQ. The correspondence from all commenters consisted of comments in compliance with the information requirements outlined in § 62.1-263.1 of the Code of Virginia. Below, the summary of comments and accompanying requests for a public hearing are provided with background provided by DEQ staff. The comment category is provided in parenthesis beside the summary of comments provided.

1. **Summary of Comment Category No. 1 – Interbasin Transfer between the Rappahannock River and the Mattaponi River:**

   Multiple commenters were concerned about the interbasin transfer between the Rappahannock River and the Mattaponi River. A summary of the concerns are as follows:

   a. Rappahannock River specific concerns:
      i. Potential impacts caused by a decrease in water level and velocity;

ii. The potential impacts caused by a change in salinity and potentially altering the biochemical regime of the two rivers as well as their associated freshwater marshes, wetlands.

iii. Comments were raised in regard to the impacts to water availability and use for downstream communities. Specifically, the impacts to farmers who withdrawal from the Rappahannock for irrigation purposes, impacts to recreational activities such as fishing, boating, and swimming, and potential infringement of the water rights of the federally recognized tribal nations.

b. Mattaponi River and Polecat Creek

i. Commenters are concerned that there will be an increase in the water level and velocity as a result of the additional discharge. As a result of the assumed increase, commenters believe this will cause the erosion and sedimentation along the banks of the water way. In addition, comments and questions were raised about the potential for an increase in flooding as a result.

ii. Many individuals questioned why the water would not be returned to the Rappahannock and disapprove of the decision to discharge into Polecat Creek and the Mattaponi River from the existing WWTP located in the Town of Bowling Green and in Caroline County respectively.

Background Provided by DEQ Staff Related to Comment

Pursuant to 9VAC25-210-340 B 5, "the applicant shall provide "information on flow dependent beneficial uses along the affected stream reach. For projects that propose a transfer of water resources from a major river basin to another major river basin, this analysis should include both the source and receiving basins."

The requirements of 9VAC25-210-340 B 5 are addressed and are summarized in background for Comment Category No. 2 – Water Quality, No. 4 - Endangered and Threatened Species/Wildlife and Habitat Impacts, and No. 5 – Environmental Justice.

2. Summary of Comment Category No. 2 – Water Quality:

Many comments were received regarding water quality impacts as a result of the proposed withdrawal from the Rappahannock, erosion and sedimentation caused during construction, as well as impacts at the points of discharge into the Mattaponi and its tributaries. The impact parameters and concerns are identified below:

a. Rappahannock River specific concerns:

i. Salinity in Rappahannock:

ii. Reduced water volume/flow in the Rappahannock

b. Mattaponi River and Polecat Creek specific concerns:

Many individuals are concerned and raised questions as to why a Salinity Model was not done for the Mattaponi River and Polecat Creek. Many requests were made to do a more detailed analysis on the impacts a change in salinity and water quality would have on the biochemical regime of the Mattaponi as a result of the discharge. Increased water temperatures and volume at the point of discharge were additionally a concern.

c. Runoff during the construction of the new water supply system.

Background Provided by DEQ Staff Related to Comment

a. The Rappahannock River:

i. Salinity: Per the Department of Wildlife Management's (DWR) pre-application comments, Caroline County coordinated with consultants Draper Aden Associates and the Virgina Marine Institute of Science to conduct an analysis of potential changes to the hydrology and salinity in the Rappahannock River as a result of the proposed withdrawal[1]. It is important to recognize that natural annual variability in river flows result in significant changes in the salinity regime from year to year. Given the special concern regarding potential project impacts to anadromous fish species, particularly American shad, at issue is whether water withdrawals and discharges would alter salinity regimes in summer and fall, when the tidal freshwater portions of the Rappahannock River and Mattaponi River serve as nursery grounds for those species. The modeling results indicate that the minimum instream flows (MIF) parameters proposed in the draft VWP Water Withdrawal Permit often preclude and consistently restrict the magnitude of water withdrawal during most summer and fall periods, when river flows are low. Per the Salinity Modeling Report, the fall and summer periods are when salinity regimes are most likely to be affected by withdrawal of the limited freshwater available. The modeling results also indicated that changes would be so small as to be immeasurable, given natural variability and measurement error. Given that no significant changes in salinity regimes are predicted no long-term consequences to fish are anticipated.

The salinity analysis concluded the following:

- Freshwater inflows are reliable and sufficient to supply the anticipated withdrawals for Caroline County.
- Salinity in the vicinity of the proposed intake would be in the range of fresh water, even during typical low flow conditions.
- Salinity levels downstream of the proposed intake would not change appreciably at the proposed withdrawals rates for Caroline County.
- Salinity impacts are not expected to occur for freshwater wetlands or aquatic species downstream of the proposed intake.

[1] Refer to Appendix B – Rappahannock River Hydrologic and Salinity Analysis, dated March 27, 2020.

ii. Reduced Water Volume/Flow: Because the County intake would be located in the tidal portion of the river, withdrawals will not affect flow depths in the river in the same manner as in a non-tidal stream. Per the Salinity Model in Appendix B of the Draft Permit, the data indicates that freshwater flows have minimal influence over the tidal range until flow exceeds approximately 5,000 cfs. Therefore, withdrawals on the order of approximately 10 to 20 cfs are expected to have no measurable impact on the river water surface elevations.[2] The proposed withdrawal represents around 0.7% of the average freshwater inflow at the proposed intake location. Therefore, a flow-by requirement is not included in the permit.

b. Receiving Basin - Mattaponi River and Polecat Creek

Water withdrawal from the Rappahannock River will be conveyed and distributed to consumers in Caroline County before flowing to the Mattaponi River basin. The majority of existing and anticipated water demands to be supplied by this project are primarily located in the western portion of the County and in the Town of Bowling Green. Non-consumptive water use in this area will be transferred to the Mattaponi River basin via wastewater treatment plants (WWTPs) owned and operated by Caroline County and the Town of Bowling Green. The Caroline County Regional Wastewater Treatment Plant (WWTP) is located in the southwestern portion of the County and discharges to Polecat Creek, which flows into the Mattaponi River approximately 5 miles east of the WWTP. The Town of Bowling Green WWTP discharges to an unnamed tributary of the Mattaponi River, eventually flowing into the Mattaponi River approximately 1 mile west of the Caroline County WWTP. The estimated maximum day transferred flow to the Mattaponi River Basin is approximately 9.06 mgd. The expected average transferred flow to the Mattaponi River Basin, considering future consumptive uses, is approximately 5.6 mgd. Approximately 5.12 mgd is expected to flow through the Caroline County Regional WWTP and 0.475 mgd through the Town of Bowling Green WWTP. Historical flow data over the past 10 years indicates the average flow rate of Mattaponi River is approximately 567 cfs. A combined flow through the Caroline County Regional WWTP and Town of Bowling Green WWTP of 5.6 mgd or 10.41 cfs to the Mattaponi River would be an increase from 567 cfs to approximately 577.41 cfs, an average daily flow increase of about 2%. During peak flow events, transferred flows would increase river flows by about 0.1%. These transferred flows would not exacerbate natural high flow events in the river and would support river flows during periods of low streamflow. Caroline County will expand on this analysis of impact to the receiving basin with respect to salinity and submit the findings to DEQ in advance of a permit decision. If a public hearing is granted, a summary of this information will be provided at the public hearing.

The VPDES Permit Regulation at 9VAC25-31-210 requires monitoring and 9VAC25-31-220 D requires all discharges to protect water quality. The VPDES Permit Regulation at 9VAC25-31-730 through 900, and the Federal Pretreatment Regulation at 40 CFR Part 403 requires Publicly Owned Treatment Works (POTW) with a design flow of >5.0 MGD

[2] Refer page 6 of Appendix B – Rappahannock River Hydrology and Salinity Analysis, dated March 27, 2020.

and receiving from Industrial Users (IUs) pollutants which pass through or interfere with the operation of the POTW or are otherwise subject to pretreatment standards to develop a pretreatment program.

VPDES Permit No. VA0073504: The Caroline County WWTP is a POTW with a current design capacity of 1.5 MGD with an expansion to 3.0 MGD. The pretreatment program for this permittee was approved on January 22, 2001. Currently there is only one IU connected to the treatment plant; Blue Beacon Truck Wash, representing approximately 12% of the average daily flow for this facility. The pretreatment program conditions in the proposed permit reissuance will require implementation of the approved pretreatment program that complies with the Clean Water Act, State Water Control Law, state regulations, and the approved program.

VPDES Permit No. VA0020737: Town of Bowling Green WWTP: The Bowling Green WWTP is a POTW with a current design capacity of 0.25 MGD. Since this facility's discharge is greater than 0.040 MGD, the facility is subject to the following requirement in accordance with Pretreatment Program Guidance Manual, Section 5.2, Criteria Used by DEQ to Evaluate the Necessity of Program Development states, "Note: It is recommended that POTWs with design flows greater than or equal to 40,000 GPD conduct an IU survey and be evaluated for Pretreatment programs. The 40,000 GPD flow figure has been a standard in Agency practice and is consistent with the increased operator oversight and testing requirements provided by VDH at this flow, as established in the Virginia Sewerage Regulations."

Therefore, the VPDES permit includes the requirement for the facility owner to conduct an Industrial User survey. The VPDES permit also includes pretreatment program requirements if there are any Significant Industrial Users or Categorical Users found during the survey.

Potential water quality impacts to aquatic life as a result of the discharge from the WWTPs will be addressed by the DEQ VPDES permitting program. Effluent limits are calculated and incorporated into VPDES permits to be protective of water quality standards.

3. Summary of Comment Category No. 3 – Water Withdrawal Purpose, Use, and Demand Projections

a. Comments were received in regard to the projected water demand and use for industrial and commercial development being significantly disproportionate to that of the demand for residential use.

   i. Commenters stated that the municipal water supply should not be utilized for the purpose of cooling data centers or any other potential private industrial user.

   ii. Commenters stated that the residential water use is an inflated representation of Caroline County's, and its partners, population growths due the applicants projected growth incorporating the Transit-Oriented Development (TOD) project.

b. Comments were received regarding the projected population projections calculated differ from the projections done by the Weldon Cooper Center.

DEQ Staff Provided Background Related to Comment

Pursuant to 9VAC25-210-360, the applicant shall demonstrate to the satisfaction of the Department that the project meets an established need for water to serve the project purpose. The applicant has provided all information requested and the Department is satisfied with the applicant's responses[3]. The project purpose is to establish a surface water withdrawal system to serve as a regional public water supply to meet long-term needs and economic development proposed in Caroline County, and surrounding localities included in the draft permit. Domestic public water supplies are an established offstream beneficial use for state waters as defined in §62.1-44.3 of the Code of Virginia.

The Department evaluated Caroline County's requested water withdrawal demands by comparing the historical water use data reported to the Department for the existing water systems service areas, through the review of the applicant's projected demands for residential, commercial, and industrial water use provided in the Joint Permit Application (JPA), and through the review of the Weldon Cooper Center – VA Population Projections.

Water consumption at each data center varies depending on the design of the cooling system, the size of the facility, the energy consumption for servers, and the local ambient outdoor temperature and humidity. Due to these variables, cooling system design and estimates of maximum water demands are often based on proprietary analysis and design by data center operators. To update industrial water needs, the County developed industrial water use estimation through the combination of the analysis of industry literature and published research on water use at data centers, coordination between the County's Economic Development Department and prospective industrial users, and the review of reported water use rates for existing data centers of comparable size.[4] The Department reviewed the supporting documents and found the water purpose, use, and need justification to be sufficient.

Caroline County's 2010 Comprehensive Plan as well as Caroline County's 2016 Water Master Plan was used by the applicant to estimate the projected residential water demands for the proposed service area. Total residential water demand was calculated using the size of each growth area, a percentage of developable land within the area, a density of units based on anticipated zoning, a population growth rate of 2.61 per unit[5], and a daily water demand of 100 gallons per capita based on the VDH Capacity Development Strategy guidance. The combined residential demand for the proposed service area is estimated to be an average of 2.63 MGD within the 15-year permit term.

The applicant provided a Capital Improvement Plan (CIP) that demonstrates the County's financial commitment in preparation of the TOD Project implementation and has designated

[3] Refer to the 6th Additional Information Response – Appendix B, dated January 16, 2024.
[4] Refer to the 6th Additional Information Response – Appendix B, dated January 16, 2024.
[5] Refer to Caroline County's 2010 Comprehensive Plan – Chapter 8, Table 8.2.

the area as an Urban Development Area (UDA). The CIP and UDA were found to be sufficient justification for the commercial water purpose and need for the TOD Project and as justification for a potential increase in population as a result of the completion of the TOD Project.

4. Summary of Comment Category No. 4 – Endangered and Threatened Species/Wildlife and Habitat Impacts:

a. Comments were received in regard to the discharge from Caroline County's WWTP. The commenters had concern regarding changes in water quality from discharges into the Mattaponi River and Polecat Creek. Commenters state that there are risks to vegetation, aquatic species, and human health. It could also harm endangered Atlantic Sturgeon, and critical species such as shad and striped bass, which inhabit the Mattaponi River.

b. Comments and questions were raised in regard to the need for Time of Year Restrictions (TOYR). Some believe that the TOYR proposed in the draft permit are not stringent enough.

c. Comments were received concerning the impingement and entrainment of fish larvae and eggs due to the new intake and water withdrawal in the Rappahannock.

<u>DEQ Staff Provided Background Related to Comment</u>

a. Potential water quality impacts to aquatic life as a result of the discharge from the WWTPs will be addressed by the DEQ VPDES permitting program. The existing VPDES permits require monitoring for E-coli, Biochemical Oxygen Demand, Dissolved Oxygen, Total Suspended Solids, Total Kjeldahl Nitrogen, pH, Ammonia Nitrogen, and Flow Volume. In addition, the DEQ VPDES permitting program will assess the potential changes in temperature and all other required monitoring parameters to account for any additional potential impacts to water quality as a result of water being processed from the new public water system's users.

b. The Department of Wildlife Resources (DWR) provided recommendations and comments that were incorporated into Part I Special Condition C 1 a-c. These conditions included TOYR for instream work to install the intake and infrastructure in the Rappahannock River from February 15th through June 30th and August 1st through November 15th for the protection of Atlantic Sturgeon and other Anadromous Fish Species. Additional TOYR from April 15th through June 15th and August 15th through September 15th were included due to the presence of freshwater mussels. DWR also recommends that prior to any instream work, a mussel survey be performed from 100 meters upstream through 400 meters downstream of impact areas. The survey should be performed by a qualified, permitted biologist, preferably no more than six months prior to the start of construction. If mussel relocations are necessary, they should be coordinated with DWR and no federally listed species should be relocated without first coordinating with the United States Fish and Wildlife Service

(USFWS). Coordination with United States Fish and Wildlife Services (USFWS) if required regarding potential impacts upon federally endangered long-eared bats associated with tree removal.

c. The VMRC pre-application comments recommended the applicant coordinate with the Virginia Marine Institute (VIMS) to conduct a Particle Tracking Model[6]. To provide sound scientific-based information for the environmental assessment, a numerical modeling approach was used to simulate ichthyoplankton dispersion and changes in mortality caused by the intake. As stated in the Draft Permit Decision Rational (PDR), VIMS employed a three-dimensional hydrodynamic model with particle tracking to simulate egg and larval mortality in response to the withdrawal.

Based on the report submitted by VIMS and the review of other data relevant to the proposed withdrawal, staff have determined the proposed project complies with applicable standards identified in 9VAC25-210-110 and that conditions in the draft permit were developed with full consideration of the criteria identified in 9VAC25-210-370.B.

In addition, Special Condition Part I D.3 was incorporated into the permit per DWR's recommendation to install intake screens with openings no larger than 1 millimeter in width and height for mesh screens or a slot size of 1 millimeter in width for wedgewire screens. The permittee shall ensure that the maximum through-slot velocity does not exceed 0.25 feet per second.

5. Summary of Comment Category No. 5 – Environmental Justice:

a. Comments were made in relation to the lack of public involvement. Commenters stated that information was not publicly represented at the Town Hall meetings demonstrating a lack of transparency to Caroline's constituents who will be financially contributing to the interbasin project through tax revenue.

b. Tribal Nations Environmental Justice Comments:

i. The following Tribal Nations commented that there was a lack of meaningful consultation from Caroline County:

- Upper Mattaponi Tribe
- Mattaponi Tribe
- Rappahannock Tribe

ii. The Upper Mattaponi Tribe stated in their comments that the Commonwealth of Virginia must honor the 1677 Treaty of Middle Plantation (Treaty) and its obligations to the Tribe through meaningfully and comprehensively addressing its

[6] Refer to Draft Permit, Appendix A – Final Particle Tracking Model Report, dated February 3, 2023.

impacts to fish, shellfish, aquatic species and their habitats, and the water temperature, flow rate, and salinity changes that contribute to these impacts.

iii. The Rappahannock Tribe expressed concern for the potential impacts the project would have with respect to natural historical heritage, tradition, and cultural practices along the Rappahannock River. The Tribe also states that native fish, bird and plant species along the river are also of cultural significance to the tribe.

iv. The Tribal Nations additional comments were like those of other public comments which are captured by each of the additional Comment Summary Categories identified in this document.

c. Comments were received with respect to the County's method of and acquisition of land through eminent domain.

d. Comments were received regarding the potential impacts to water users downstream and are summarized below:

i. Many individuals stressed the importance to the legacy and well-being of the agricultural community located along the Rappahannock River and Mattaponi River. The comments and concerns are addressed and are summarized in memo response No. 2 – Water Quality, No. 4 – Endangered and Threatened Species/Wildlife and Habitat Impacts, and No. 5 – Environmental Justice.

ii. Comments in regard to the potentially negative impact of eco-tourism, such as boating, fishing, swimming, and intrinsic value that the project may have on the economy as a result of reduced recreational travel and community participation.

iii. In addition, homeowners along the Rappahannock River and Mattaponi River commented that they were concerned that the water supply project would reduce their property value.

iv. The Virginia Department of Conservation and Recreation (DCR) commented on June 9, 2020, that there were no natural heritage resources within a 100 buffer of Water Treatment Plants project boundary.

DEQ Staff Provided Background Related to Comment

a. Public Involvement:

Per 9VAC25-210-140 and 9VAC25-210-330, the DEQ and the VMRC jointly published a public notice in *The Free Lance-Star* and *The Richmond Times-Dispatch* on May 18, 2024. The public comment period began May 18, 2024 and ended on June 18, 2024. The public notice and draft permit were posted on the DEQ website and the VMRC website for the duration of the public comment period. The public notice provided the public an

opportunity to provide comments on the permit decision. This document serves as a response to all comments received.

The DEQ issued Notification of Application Letters to all relevant local governments and property owners as required by Chapter 3.1 Section 62.1-44.15:4.D of the Code of Virginia.

b. Tribal Nation Environmental Justice:

The DEQ recognizes and respects the importance of inclusion and consultation with the Tribal Nations to ensure protection of the tradition and cultural practices along the Rappahannock River and the Mattaponi River and its tributaries. DEQ does not have oversight over the County's public involvement process, however, below is a summary of the DEQ's coordination history with the Tribal Nations during the review of the application and draft issuance:

Each of the seven federally recognized Tribal Nations were coordinated with on April 27, 2020 as part of the application review and comment process. Comments were received on April 4, 2020 from the Monacan Tribal Nation and on June 8, 2020 from the Rappahannock Tribal Nation. Comments were not received from the following Tribal Nations:

- Chickahominy
- Chickahominy Easten Division
- Nansemond
- Pamunkey
- Upper Mattaponi

Comments were received and reviewed during the Public Comment Period aforementioned above, by the following Tribal Nations:

- Upper Mattaponi
- Mattaponi
- Rappahannock
- Pamunkey

Comments were not received from the following Tribal Nations:

- Chickahominy
- Chickahominy Easten Division
- Nansemond

In addition, the DEQ participated in the following requested meetings:

The Rappahannock Tribe

- June 16, 2023
- August 18, 2023

The Upper Mattaponi Tribe

- June 17, 2024

Impacts to Water Quality, Endangered and Threatened Species/Wildlife, and Habitat Impacts were addressed in Summary Comments Nos. 2 (two) and 4 (four).

Draper and Aden Associates completed a Phase IA cultural resource reconnaissance study of a series of locations for a potential water line and potential associated facilities and Phase IB Historical and Archaeological Evaluation in September of 2019 for the Caroline County Water Supply Project for Caroline County.

Caroline County sent a letter to the Department of Historical (DHR) in response to DHR's January 14, 2022, letter confirming the receipt of DHR's letter concerning the proposed Caroline County Water Intake Project, including the comments requesting additional clarity on actions taken to avoid impacts to sites 44CE0914 and 44CE0915. In response, Caroline County has adjusted the location of the proposed raw water intake facility at site 44CE0914. The revised location avoids impacts and remains within the area that was initially surveyed. To further minimize the potential for impacts to sites 44CE0914 and 44CE0915 during construction, fencing will be placed around the proposed project site. In addition, during construction the contractor is prohibited from stockpiling soil or using the site for construction staging activities.

The Phase IA Survey of archaeological and architectural resources identified three architectural resources within a 500-foot buffer of the intake parcel that are eligible or potentially eligible for listing with the National Register of Historic Places (NRHP). However, the intake is proposed to be constructed at the center of the 24-acre parcel along the river, which increases the buffer distance by 500 to 1,000 feet from these resources. The Phase IA survey found no archaeological resources in the project area; however, a Phase IB survey was recommended. The results of the Phase IB survey identified one archaeological site consisting of a scatter of lithic debitage dating to an unknown prehistoric period. As a result of the site's low artifact density and disturbance of the deposits by plowing, the site was determined to be not eligible for inclusion in the NRHP. The project is not expected to adversely affect architectural or archaeological resources in the vicinity of the Rappahannock River.

c. The DEQ does not have oversight over an applicant's method of land acquisition.

d. Impacts to all downstream users including agricultural users, recreational users, and homeowners are addressed and are summarized in memo response No. 2 – Water Quality and No. 4 – Endangered and Threatened Species/Wildlife and Habitat Impacts.

6. **Summary of Comment Category No. 6 – Stormwater Management, Erosion and Sediment Control, and VPDES, EIS:**

Comments were received regarding stormwater management, erosion and sediment control, and point source discharges. Additional comments were also received regarding the discharge from Caroline County's WWTPs. In summary, the commenters believe there will be an increase in the velocity of flow in the Mattaponi River and Polecat Creek that will cause increased erosion and sedimentation.

DEQ Staff Provided Background Related to Comment

Stormwater management, erosion and sediment control, and point source discharges will be handled through separate permits issued by DEQ. All permitting must be completed prior to initiation of construction activities of the intake structure, water transmission lines, water treatment plant, and distribution lines.

In a letter dated and sent via email July 10, 2020, Caroline County responded to the DCR's comments. The County states they will adhere to applicable state and location erosion and sediment control/storm water management laws and regulations, including, as practicable, replanting riparian buffer areas as disturbed as part of this Project with native plant species and maintaining natural stream flow.

In addition, the County stated they will undertake efforts to retain natural corridors that allow movement between fragments including implementing landscape design with native plant species that prioritizes natural cover over lawn to soften and reduce the length of edge, where practicable.

The applicant provided a copy of the Federal Railroad Administration May 2019 Final Environment Impact Statement (EIS) and a Record of Decision in September 2019 for the Transit Oriented Development May 2019. All relevant impacts related to the water withdrawal for the Caroline County Water Supply Project were addressed and evaluated pursuant the the Virginia Water Protection regulation and statute during the JPA review process and Draft Permit issuance.

7. **Summary of Comment Category No. 7 – Alternatives**

Comments were received in regard to the withdrawal from the Rappahannock and discharge into the Mattaponi River as the least environmentally damaging alternatives. Preferred alternatives recommended in a number of comments include the following:

a. Receiving water from existing municipalities/existing public water supplies from the surrounding area.

b. Continued use of groundwater wells.

c. Questions were raised about why an alternative, such as constructing a new Wastewater Treatment Plant, to return water back to the Rappahannock was not considered.

DEQ Response Related to Comment Category No. 7

Caroline County satisfied the regulatory requirements in their provided alternatives analysis pursuant to 9VAC25-210-360.3. Alternatives were identified in County and Regional Water Supply Plans (Caroline County and the Town of Bowling Green Regional Water Supply Plan) used by applicant for the Caroline County Public Water Supply Project.

a. As summarized in the Draft PDR *Alternatives Evaluated to Meet the Water Need (Least Environmentally Damaging Practicable Alternative)*, the applicant conducted a detailed evaluation of purchasing finished water from the 5 (five) surrounding localities and determined that the alternative was not feasible.

b. The current source of groundwater is not a sustainable option into the future to meet the long-term water use and needs for Caroline County and the surrounding service areas. Based on the location of modeled critical cells[7] located in the region, continued use of the aquifer to meet projected water demands could lead to damage to the confined aquifer system and would likely fail the Technical Evaluation criteria for reissuance of groundwater withdrawal permits within the County.

c. The DEQ will add a condition in the Permit to have Caroline County provide a study to determine the feasibility for construction of a WWTP that discharges directly to the Rappahannock River.

[7] Critical Cells are modeled cells where water level has been simulated below 80% of the distance from the land surface to the top of the confined aquifer.

Public Hearing Criteria and Analysis of Public Notice Responses:

According to 9VAC25-210-165 C, upon completion of the public comment period on a permit action, the director shall review all timely requests for public hearing filed during the comment period on the permit action and, within 30 calendar days following the expiration of the time period for the submission of requests, shall grant a public hearing, unless the permittee or applicant agrees to a later dates, if the director finds the following:

1. That there is significant public interest in the issuance, denial, modification, or revocation of the permit in question as evidenced by receipt of a minimum of 25 individual requests for a public hearing;

2. That the requesters raise substantial, disputed issues relevant to the issuance, denial, modification, or revocation of the permit in question; and

3. That the action requested by the interested party is not on its face inconsistent with or in violation of the basic laws of the State Water Control Board for a water permit action, a federal law, or any regulation promulgated thereunder.

Regarding the first criterion, DEQ received 163 requests from individuals for a public hearing. The first criterion of 9VAC25-210-165 C has been met.

Regarding the second criterion, the commenters raised substantial, disputed issues relevant to the issuance of the permit. Therefore, the second criterion of 9VAC25-210-165 C is met.

Regarding the third criterion, the commenters requested action by the interested party is not on its face inconsistent with or in violation of the basic laws of the State Water Control Board for a water permit action, a federal law, or any regulation promulgated thereunder. Therefore, the third criterion of 9VAC25-210-165 C is met.

Recommendation: Based on staff analysis, the commenters met the regulatory threshold for convening a public hearing for this draft Surface Water Withdrawal permit action. Based on the significant interested raised by the community, staff recommends that the commenters' request for a hearing be approved.

Approved:

_____

James J. Golden
Director of Operations

Commonwealth of Virginia

VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

www.deq.virginia.gov

Travis A. Voyles
Secretary of Natural and Historic Resources

Michael S. Rolband, PE, PWD, PWS Emeritus
Director

November 1, 2024

Dear Commentor,

Thank you for your comments provided to the Virginia Department of Environmental Quality (DEQ or Department) either submitted during the second comment period from August 25, 2024 to October 11, 2024 or provided at the public hearing on September 25, 2024, regarding the Caroline County Surface Water Withdrawal Permit Application, Virginia Water Protection (VWP) Permit No. 20-0514.

In order to respond to the comments received, the Department has requested additional information and modeling from the Applicant. The Department issued the Applicant an *Additional Information Request Letter* dated October 25, 2024 (Copy Attached). Submission of the additional information and additional modeling were requested to be submitted within 60 days from the date of the letter (December 24, 2024). In the interim, all actions for this permit will be suspended by the Department until the additional information and modeling is received. This includes suspending the scheduling of the next public hearing for the Draft Permit, which has not been scheduled as of the date of this letter. Upon review of the information submitted by the Applicant, the Department will determine if any changes to the Draft Permit are required and then recommence action to approve or deny the draft permit.

If you have any questions or additional concerns, please contact me at (804) 698-4087 or by email at allison.major@deq.virginia.gov.

Sincerely,

Allison Major
Water Withdrawal Permit Writer
Virginia Department of Environmental Quality
1111 East Main Street, Suite 1400
Richmond, Virginia 23219

Attachment: Additional Information Request Letter, dated October 25, 2024.

CC: Scott Morris, DEQ Water Division Director

Meghan Mayfield, DEQ Director, Water Permitting
Eric Seavey, DEQ Office of Water Withdrawal Permitting Manager
Trevor Lawson, DEQ Team Lead - VWP Water Withdrawal Permitting

Time of Year Restrictions and Other Recommendations

Wildlife Information and Environmental Services

September 29, 2023

This document provides general guidance for the protection of selected wildlife resources, focusing on times of year during which certain species may be most sensitive to human activities such as construction and land clearing. It does not constitute a list of best management practices to protect imperiled or sensitive wildlife species or their habitats; nor is adherence to these restrictions essential for every project. These recommendations, however, should be considered as guidance for project planning and scheduling of construction activities that may impact the identified wildlife species. Environmental documents and permit applications are reviewed individually, and modification or waiver of these time of year standards will be considered on a case-by-case basis.

Furthermore, any project with a federal nexus (e.g., the project entails any federal funding, permits, or federal agency action) must comport with consultation requirements pursuant to Section 7 of the Endangered Species Act. To ensure such compliance, the project applicant or proponent should access the USFWS Virginia Field Office Project Review (IPaC) website at: https://www.fws.gov/office/virginia-ecological-services/virginia-field-office-online-review-process. Since listing of Atlantic Sturgeon, all hydraulic hopper dredging activities in the Chesapeake Bay, Atlantic Ocean, and major tributaries, regardless of time of year must be coordinated with NOAA Fisheries Service.

Designated Waters	TOYR (no instream work to occur)
Wild Trout Streams and tributaries	
Brook and Brown Trout waters	October 1 through March 31
Rainbow Trout waters	March 15 through May 15
Stocked/Stockable Trout Streams and tributaries	No TOYR; contact Aquatic Regional Area Manager for guidance
Anadromous Fish Use Areas and tributaries*	February 15 through June 30 (*see exceptions below*)
Exceptions in James River:*	
• Below Rt. 17 crossing	No TOYR necessary unless project spans width of river, significantly impeding fish passage
• Bosher's Dam upstream, including Rivanna River and tribs	March 15 through June 30
Exception in Rappahannock River:	
• Rappahannock River and tribs below Rt. 360 crossing	February 15 through June 15
Exception in York River:	
• York River and tribs below Rt 33 crossing	February 15 through June 15
Exception in Elizabeth River:	
• Elizabeth River and tribs	No TOYR necessary unless project spans width of river, significantly impeding fish passage
Exception in Nansemond River:	
• Nansemond River and tribs	February 15 through June 15
Threatened and Endangered Species Waters and tributaries	TOYR dependent upon species known to inhabit the stream/river, see species information below.
** we understand that federal navigation channel dredging may require modification from the standard TOYR recommended for protection of anadromous fishes in the James River due to funding and project scheduling timeframes.*	

Fishes	TOYR (no instream work to occur)
General Warm Water Species spawning	April 15 through July 15
General Cold Water Species spawning	March 1 through June 30
Landlocked white bass/striped bass/sunfish (Lake Anna, Dan River)	March 15 through June 30
Smith Mountain Lake Fish Assemblage	February 15 through June 15

Atlantic Sturgeon (FESE)	TOYR and/or other protective recommendations are applicable for work in the segments of designated Threatened and Endangered Species Waters (TE Waters) indicated below. However, in addition to these waters, Atlantic Sturgeon are known from tributaries to designated TE Waters, the Chesapeake Bay, Chesapeake Bay embayments, small tributaries to the Chesapeake Bay (including on the eastern Shore), and the Piankatank River. Impacts upon Atlantic sturgeon may be considered for projects impacting such waters, on a case-by-case basis.
Spring spawning/migration	March 15 through June 15
• James River from Wilcox Wharf downstream to the Rt. 17 crossing	
Fall spawning/migration	August 1 through November 15
• James River from upper extent of designated water (Bosher's Dam) downstream to the Rt. 17 crossing	
• Appomattox River from Lake Chesdin Dam downstream to confluence with James River	
• Chickahominy River from Walker's Dam downstream to confluence with James River	
• Pamunkey River from upper extent of designated water (Ashland Mill Dam) downstream to White House Landing/Pamunkey Indian Reservation	
• Mattaponi River from upper extent of designated waters (Matta & Po rivers at I95) downstream to King and Queen Courthouse Landing	
• Rappahannock River from the fall line downstream to the Rt. 360 bridge	
Larval and Juvenile life stages	Upon review by DWR biologist
• Within designated TE Waters year-round in shallow habitats, often near-shore	
Congregation areas	Upon review by DWR biologist
• Rappahannock River from Rt 360 crossing downstream to Rt 3 bridge at White Stone	
• James River from Hog Point (Hog Island WMA) downstream to the Rt 17crossing	
Blackbanded Sunfish (SE)	May 1 through June 30
Blackside Dace (FTST)	April 1 through July 31; not in Clinch Drainage, where the species was introduced
Bridle Shiner (Tier Ia)	May 15 through July 31
Candy Darter (FECC)	March 15 through June 30
Carolina Darter (ST)	March 15 through June 30
Clinch Dace (Tier Ia)	April 1 through July 31
Duskytail Darter (FESE)	April 1 through July 15
Golden Darter (ST)	May 1 through August 31
Greenfin Darter (ST)	May 1 through June 30
Orangefin Madtom (ST)	March 15 through May 31; not in James River drainage, where the species was introduced
Roanoke Bass (Tier Ia)	March 15 through July 15

Roanoke Hogsucker (Tier IVc)	March 15 through July 15
Roanoke Logperch (FESE)	March 15 through June 30
Roughead Shiner (Tier Ib)	March 15 through June 30
Sharphead Darter (SE)	June 15 through August 31
Sickle Darter (ST)	February 1 through April 30
Slender Chub (FTST)	April 1 through May 31
Spotfin Chub (FTST)	May 1 through August 31
Steelcolor Shiner (ST)	May 1 through August 31
Tennessee Dace (SE)	April 1 through July 31
Variegate Darter (SE)	March 15 through July 31
Western Sand Darter (ST)	April 1 through June 30
Whitemouth Shiner (ST)	March 15 through June 30
Yellowfin Madtom (FTST)	April 1 through August 31
Crayfish	**TOYR (no instream work to occur)**
Big Sandy Crayfish (FTST)	July 1 through October 31 (females brooding young)
Freshwater Mollusks	**TOYR (no instream work to occur)**
Long-term brooders (see list at end of document)	April 15 through June 15 (glochidia release); and August 15 through September 30 (spawning)
Short-term brooders (see list at end of document)	May 15 through July 31
Exceptions:	
• Dwarf Wedgemussel (FESE)	March 15 through May 31; and August 15 through October 15
• Tennessee Bean (FESE; previously Purple Bean, Cumberland Bean)	February 15 through June 15; and August 15 through September 30
• Spiny Riversnail (ST)	April 1 through June 15
• Spider Elimia (SE)	April 1 through June 15
Birds	**TOYR (certain activities not to occur)**
Bachman's Sparrow (ST)	April 1 through August 15
Bald Eagle nest sites	December 15 through July 15
Bald Eagle concentration areas and roost sites (BECAR)	Summer:May 15 through August 31; Winter: December 15 through March 15
Bewick's Wren (SE)	April 1 through June 30
Black Skimmer (Tier IIa)	April 1 through August 31; TOYR ends when last brood fledges as determined during most recent monitoring activity
Black Rail (SE)	April 1 through August 31
Common Tern (Tier IIa)	April 1 through August 31; TOYR ends when last brood fledges through determined during most recent monitoring activity
Henslow's Sparrow (ST)	April 1 through August 31
Least Tern (Tier IIIa)	April 1 through August 31; TOYR ends when last brood fledges as determined during most recent monitoring activity
Loggerhead Shrike(ST)	April 1 through July 31
Peregrine Falcon (ST)	February 15 through July 15 for activities w/in 600 ft of nest/box
Piping Plover (FTST)	March 15 through August 31; TOYR ends when last brood fledges as determined during most recent monitoring activity
Wilson's Plover (SE)	March 15 through August 31; TOYR ends when last brood fledges as determined during most recent monitoring activity

Red-cockaded Woodpecker (FESE)	A. Time of Year Restriction: April 1 - July 31 of any year for activities* within 1,000 ft of an active cavity tree cluster; Time of Day Restriction from 2 hours before to 2 hours after sunrise and from 2 hours before to 2 hours after sunset for activities* within 1,000 ft of an active cavity tree cluster. *Activities to which these are applied: • Use of motorized or unmotorized vehicles should occur only on existing road • Tree removal, tree trimming, hardwood midstory control • Military training activities, unless approved by USFWS and/or DWR • Construction activities, use of mechanized machinery B. Activities Prohibited at any time: • Impacts (construction, development, tree removal) upon an active or inactive (but still suitable) cavity tree cluster should be avoided, unless performed to enhance RCW habitat and in coordination with USFWS and/or DWR. • Specifically, the following activities are prohibited unless a permit is obtained from the USFWS. a) Removing any red-cockaded woodpecker cavity tree, through cutting, bulldozing, or any other activity. b) Damaging an active cavity tree which results in the death of that tree. Damage includes, but is not limited to, injury to the bole or root system (generally due to heavy equipment use), exposure to herbicides, and fire scorch to the crown due to inadequate protective measures during prescribed burning. c) Using insecticides on any standing pine tree. Prevention and control of disease and insect infestations is encouraged through silvicultural BMPs. d) Constructing roads and utility rights-of-way within a cluster. e) Construction of facilities including, but not limited to, buildings, campgrounds, recreational developments, residential dwellings, and industrial or business complexes f) Planting of shrubs and/or ornamental plants that will exceed 2.1 m (7 ft) in height within 15.24 m (50 ft) of active and inactive cavity trees. Construction equipment and construction material cannot be stored within 61 m (200 ft) of cavity trees. Landscaping within clusters should be accomplished with hand tools or lightweight power equipment rather than tractor mounted equipment
General beach-nesting birds	March 15 through August 31; TOYR ends when last brood fledges as determined during most recent monitoring activity
General migratory and resident songbirds	March 15 through August 15
Colonial Waterbird Colonies	**TOYR (certain activities not to occur)**
Great Egret, Green Heron (Tier IVb), Yellow-Crowned Night Heron, etc	April 1 through August 15 for activities w/in 0.25 mile of rookery (site with more than one nesting pair); maintain undisturbed naturally vegetated buffer of at least 500 ft around rookery.

Great Blue Heron	February 15 through July 31 for activities w/in 0.25 mile of rookery or high intensity activity w/in 0.5 mile of rookery; maintain undisturbed naturally vegetated buffer of at least 500 ft around rookery.
Mammals	**TOYR (certain activities not to occur)**
Bat data layers: Unless otherwise indicated, all hibernacula locations are randomly offset, and then circumscribed by 2 buffers; a 0.5 mile radius buffer (small), and a 5.5 mile radius buffer (large). These two buffers were developed to assist in compliance with established bat protection measures. Other species records including summer roosts, maternity colonies, and bachelor colonies, and acoustic captures are not offset, but may be circumscribed by buffers to facilitate state or federal guidelines during project reviews. Physical captures are offset prior to buffering. Typically, acoustic and physical captures are circumscribed by a 3.0 mile buffer and roost trees are buffered by 1.5 miles, including a 150 ft no tree clearing buffer.	
Cave-hibernating bats:	
Gray Bat (FESE) *Currently, SppObs records for Gray Bats that are located within karst/cave habitat indicate the presence of a hibernaculum. Spp Obs may also indicate an occupied roost on bridges or large culverts within the Tennessee River drainage, to which the recommendations to the right also apply.*	For projects located within buffers around documented hibernacula or bachelor and maternity roosts: NO disturbance of bats and/or physical modification of the cave/roost entrance/structure.
Indiana Bat (FESE) *Currently, SppObs records for Indiana Bats that are located within karst/cave habitat indicate the presence of a hibernaculum.*	For projects located within buffers around documented hibernacula, roosts and maternity colonies and for projects located outside of these buffers, but within suitable habitat: TOYR for tree removal, tree timbering, and/or prescribed burns from April 1 – November 14.
Little Brown Bat (SE) and/or Tri-Colored Bat (SE) *Hibernacula records are offset and circumscribed as described above. In addition, the online application depicts a 150-foot-radius circle around documented roost trees (there are no known roosts as of this date).*	1) Regarding removal (exclusion) of individual animals from human habited structures to reduce human health risk: Provided the "Required Conservation Measures" described in 4VAC15-20 are implemented, we do not anticipate take of this species, and any incidental take is not prohibited. We refer interested parties to the Department's "Best management practices for conservation of little brown bats and tri-colored bats" for additional guidance. 2) Regarding tree removal, prescribed fire, or other land management actions proposed to enhance public safety or to reduce risk of property damage: Provided the "Required Conservation Measures" described in 4VAC15-20 are implemented, we do not anticipate take of this species, and any incidental take is not prohibited. We refer interested parties to the Department's "Best management practices for conservation of little brown bats and tri-colored bats" for additional guidance. 3) Regarding any other tree removal or harvest, prescribed fire, or other land management actions: If the activity would occur within 0.25 miles of a "major" hibernaculum (i.e., a hibernaculum documented to support at least 50 individual little brown bats and/or Tri-Colored bats in any year since December 31, 1994) or within 150 feet of a known roost tree, the applicant should refer to the Department's "Best management practices for conservation of little brown bats

	and tri-colored bats" for additional guidance regarding development of a Conservation Plan for these species, if authorization of incidental take is desired. Lacking such plan approval by the Department, the applicant may proceed with the proposed activities at their own discretion, but is not provided any authorization of purposeful or incidental take of these species. To initiate review of such a project, and consultation with DWR regarding development of a project-specific Conservation Plan, the project proponent should access the Department's online application for these species at: http://www.DWR.virginia.gov/wildlife/bats/little-brown-bat-tri-colored-bat-winte-habitat-roosts-application/ to determine whether the project footprint intersects with the application-specific buffers. If the 0.5 mile radius inner buffer and the project footprint overlap, the project proponent should contact Mr. Rick Reynolds at Rick.Reynolds@DWR.virginia.gov, or at 540-248-9360, for further guidance.
Northern Long-Eared Bat (FTST) *Hibernacula, roost tree, and capture records are offset and circumscribed as described above.*	Coordinate with the USFWS Virginia Field Office Project Review (IPaC) website at: https://www.fws.gov/office/virginia-ecological-services/virginia-field-office-online-review-process.
Virginia Big-Eared Bats (FTST) *Currently, SppObs records for Virginia Big-eared Bats that are located within karst/cave habitat indicate the presence of a hibernaculum.*	For projects located within buffers around documented hibernacula or bachelor and maternity roosts: NO disturbance of bats and/or physical modification of the cave/roost entrance. Coordinate with the USFWS for all projects that may affect Virginia Big-eared Bats.
Tree-hibernating bats:	
Rafinesque's Eastern Big-Eared Bat (SE) *One should rely upon SppObs to indicate presence or potential presence.*	Perform habitat assessment if the site: (1) is forested and proposed for timbering and/or tree removal; and/or (2) includes abandoned structures (e.g., barns, houses), bridges, and/or culverts which are proposed for impacts. DWR recommendations will be based on results of the habitat suitability assessment and anticipated project impacts.
Amphibians	**Protective Recommendations**
Mabee's Salamander (ST)	Avoid impacts upon suitable/occupied habitat. To preserve a natural breeding pond and adjacent upland habitat used by this species, we recommend preservation of a 900-foot-wide naturally forested buffer around the breeding pond: to protect more opportunistic or temporary breeding sites, or where such a wide buffer is infeasible, the buffer width/location may be modified upon review and approval by DWR.
Eastern Tiger Salamander (SE)	Avoid impacts upon suitable/occupied habitat. To preserve a natural breeding pond and adjacent upland habitat used by this species, we recommend preservation of a 900-foot-wide naturally forested buffer around the breeding pond: to protect more opportunistic or temporary breeding sites, or where such a wide buffer is infeasible, the buffer width/location may be modified upon review and approval by DWR.

Reptiles	TOYR (certain activities may not occur)
Bog Turtle (FESE)	Avoid impacts upon suitable or occupied habitat. If impacts are unavoidable, consult with DWR.
Wood Turtle (ST)	Instream work: October 1 through March 31; Work within 900 ft of stream: April 1 through September 30. Maintain undisturbed naturally vegetated buffer of at least 300 ft (preferably larger) on stream.
sea turtles (federal and state-listed)	For activities on beaches: May 1 through November 15. Nest searches are conducted from May 1 through August 31. TOYR ends when last nest hatches as determined during most recent monitoring activity. For dredging: April 1 through November 30 for hydraulic hopper dredging in the Bay, ocean and major tributaries. Efforts to waive the TOYR must be coordinated through NOAA Fisheries Service.

Additional Information

Freshwater Mollusks: long-term brooders TOYR: April 15 through June 15 (glochidia release); and August 15 through September 30 (spawning)	**Freshwater Mollusks: short-term brooders** TOYR: May 15 through July 31
Birdwing Pearlymussel (FESE)	Appalachian Monkeyface (FESE)
Black Sandshell (ST)	Atlantic Pigtoe (FPST)
Brook Floater (SE)	Cracking Pearlymussel (FESE)
Cumberlandian Combshell (FESE)	Cumberland Monkeyface (FESE)
Dromedary Pearlymussel (FESE)	Fine-rayed Pigtoe (FESE)
Elktoe (Tier IIc)	James Spinymussel (FESE)
Fluted Kidneyshell (FESE)	Pistolgrip (ST)
Fragile Papershell (ST)	Pyramid Pigtoe (SE)
Green Floater (ST)	Rough Pigtoe (FESE)
Green Blossom (FESE)	Rough Rabbitsfoot (FESE)
Littlewing Pearlymussel (FESE)	Sheepnose Mussel (FESE)
Oyster Mussel (FESE)	Shiny Pigtoe (FESE)
Pink Mucket (FESE)	Slabside Pearlymussel (FESE)
Purple Lilliput (SE)	Tennessee Clubshell (Tier IIa)
Rayed Bean (FESE)	Yellow Lance (FT)
Slippershell Mussel (SE)	
Snuffbox (FESE)	
Spectaclecase (FESE)	
Tan Riffleshell (FESE)	
Tennessee Heelsplitter (SE)	
Yellow Lampmussel (Tier IIa)	
Status Definitions	
FE = federal endangered	SE = state endangered
FT = federal threatened	ST = state threatened
Tier/Rank = Virginia Wildlife Action Plan Species of Greatest Conservation Need; see www.bewildvirginia.org	

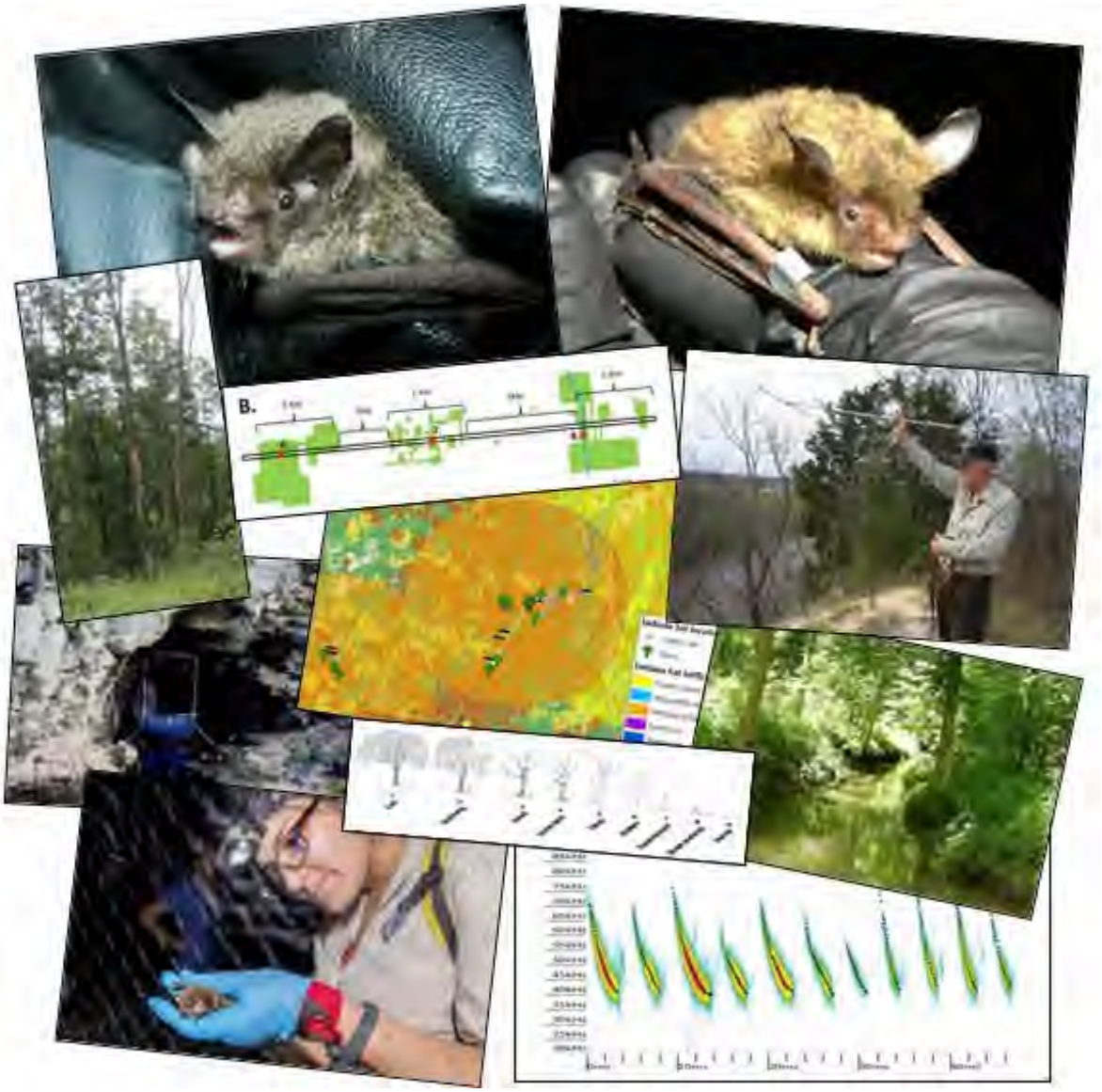
Avian Species Nesting Dates (for informational purposes only)	
Raptors (including hawks, owls, falcons)	January 1 through May 31
Woodpeckers	April 1 through July 31
Resident passerines and non-passerines	March 1 through July 31

Migrant passerines and non-passerines	May 1 through July 31
American goldfinch	July 15 through September 15
Examples: *resident passerines and non-passerines* - Mourning Dove, Carolina Chickadee, White-breasted Nuthatch, Carolina Wren, American Robin, Northern Mockingbird, Common Grackle, Northern Cardinal, Song Sparrow	
Examples: *migrant passerines and non-passerines* - cuckoos, nightjars, swifts, hummingbirds, swallow, warblers, vireos, tanagers	

Additional resources available through the Environmental Services page on DWR's website at:
https://dwr.virginia.gov/wies/

U.S. Fish and Wildlife Service

RANGE-WIDE INDIANA BAT & NORTHERN LONG-EARED BAT SURVEY GUIDELINES



March 2024

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RANGE-WIDE INDIANA BAT & NORTHERN LONG-EARED BAT SURVEY GUIDELINES

(modifications from the previous guidelines are in **blue**)

INTRODUCTION

The Indiana bat (IBAT) (*Myotis sodalis*) was originally listed as being in danger of extinction under the Endangered Species Preservation Act of 1966 (32 FR 4001, March 11, 1967), and is currently listed as endangered under the Endangered Species Act (ESA) of 1973, as amended. The northern long-eared bat (NLEB) (*Myotis septentrionalis*) was listed as threatened under the ESA on April 2, 2015, and reclassified to endangered on March 31, 2023. This survey protocol provides the U.S. Fish and Wildlife Service's (USFWS) recommended guidance on survey methods and outlines additional reporting requirements for surveyors. These guidelines provide recommendations to project proponents completing habitat assessments and presence/probable absence surveys for IBAT and NLEB. Following these recommendations streamlines project coordination with USFWS[1]. The USFWS does not require surveys for federally listed species to meet ESA compliance within Section 7 or 10 contexts. Therefore, use of these guidelines remains optional, and project proponents may discuss other options with the local USFWS Field Office (FO).

The following guidance is designed to determine whether IBAT or NLEB are present[2] or probably absent (P/A)[3] at a given site during the summer/active season (see Appendices B, C, I, or J), within bridges and culverts (see Appendix K), or during the winter (see Appendix H) (also refer to Table 1). The phased-approach includes coordination with the USFWS, habitat assessments, acoustic, mist-net, and an assortment of survey guidance appendices, and supersedes all prior survey guidance for these two species. Future changes to this document may occur and will be posted on the USFWS IBAT and NLEB survey guidance website by March 31st of each year. Before conducting surveys, please check this website to ensure use of the most current version of this document. All USFWS survey guidance documents can be found at https://www.fws.gov/library/collections/range-wide-indiana-bat-and-northern-long- eared-bat-survey-guidelines.

These protocols may be different from those designed for general bat monitoring as part of the North American Bat Monitoring Program (NABat)[4]. NABat surveys may be thought of as similar to breeding bird surveys and are not project-specific surveys in most cases. Information from NABat surveys can be considered as part of "best available" information when assessing whether there is already some existing information on presence of IBAT or NLEB in the vicinity of a given project.

NOTE: These protocols may also be used for tricolored bat (*Perimyotis subflavus*; TCB) presence/probable absence surveys using the NLEB level of effort (LOE) for the 2024 field season. We collected preliminary data from these datasets to complete an initial evaluation of LOE for TCB to ensure that deferring to the NLEB LOE for 2024 was acceptable. The unique factors and differences from NLEB protocols include:

- The definition of suitable summer habitat for tricolored bats (Appendix A);

[1] Coordinate with the appropriate state natural resource agencies and any involved federal agency(ies) whenever "USFWS" coordination is listed. USFWS FO(s) may direct project sponsors to state agencies for existing occurrence information. Coordinate with your local USFWS FO(s) to understand the process for their area of jurisdiction.
[2] The guidance is not intended to be rigorous enough to provide sufficient data to fully determine population size or structure.
[3] Recognizing protocols are not 100% likely to detect IBAT and NLEB when present and identification errors may occur.
[4] Loeb et al. 2015 available at https://www.nabatmonitoring.org

- Acoustic or combination acoustic and mist-netting surveys are required for TCB when it is the only species (IPaC species list includes TCB but not IBAT or NLEB) being surveyed for P/A (Appendix C or I);

- Manual vetting is necessary for linear projects when using an approved version of Kaleidoscope Pro if the MLE is > 0.05 for all site-nights and 10 or more passes are auto-classified as potentially belonging to TCB at any site-night. If you choose not to manually vet calls meeting these criteria, then you should assume presence of TCB for the project (Appendix C or I);

- Radio-tracking of TCB should prioritize identification of the immediate roosting area (if the exact roosting locations cannot be determined) of the transmittered bat given the frequent difficulty in locating the bats' exact roosting location (Appendix D);

- Emergence surveys of potentially suitable (versus known) roost trees for TCB is not always a viable option given the variability in roosting locations (Appendix E); and

- Internal surveys of potentially suitable hibernacula may be completed for TCB (Appendix H).

OBJECTIVES

The objectives of IBAT and NLEB survey guidelines are to: (1) standardize range-wide survey procedures; (2) maximize the potential for detection/capture of IBAT and NLEB at a minimum acceptable level of effort (LOE); (3) make accurate presence/probable absence determinations; and (4) aid in conservation efforts for the species' by identifying areas where they are present.

BACKGROUND

In 2011, the USFWS developed a multi-agency team to determine whether improvements could be made to the 2007 IBAT Mist-Net Protocols (USFWS 2007). The USFWS implemented the revised guidance in 2014. Since then, a USFWS team with support from USGS has made any necessary revisions to the guidelines each year (e.g., formally incorporated NLEB in 2022). The USGS conducted initial independent testing of automated acoustic software programs during the winter of 2014-15 and continues to provide support to USFWS testing new versions of available software using software- testing procedures updated in January 2019[5].

We considered the best available information for all aspects of the guidance. For example, see our white paper[6] and 2018 addendum outlining the methods used to determine the minimum IBAT LOE. Our 2022 addendum provided the rationale for the NLEB minimum LOE for acoustic and mist-net surveys (previously we deferred to LOE used for IBAT) as well as updating the IBAT acoustic LOE. The 2023 addendum utilized new data to provide updated mist-netting LOE recommendations for IBAT and NLEB and year-round active LOE recommendations for NLEB. As we receive additional information, we may incorporate additional survey recommendations for the IBAT, NLEB, and/or other bat species. The USFWS continues to partner with local, State, and Federal biologists; scientific and academic institutions; commercial organizations; and other interested parties to collect additional data on the distribution, ecology, and biology of the IBAT and NLEB, as well as other at- risk bat species, and looks forward to receiving any additional pertinent information from partners.

[5] Revised USFWS Software Testing Procedures are available on the USFWS website provided in the intro.
[6] The white paper, 2018, 2022 and 2023 addenda are available on the USFWS website provided in the intro.

GENERAL PROCESS

IBAT and NLEB surveys for some proposed projects will require modification (or clarification) of this guidance through coordination with the USFWS Ecological Services Field Office(s) (FOs) responsible for the state(s) in which the project occurs[7]. Before coordinating with the USFWS FO(s) on survey plan development, project proponents should submit their project through the Information for Planning and Consultation (IPaC) website (https://ipac.ecosphere.fws.gov/). If not already required by federal permit, federal action agencies and surveyors should develop a proposed survey study plan in coordination with the USFWS FO(s) so that all parties fully understand which methods will be deployed, what assumptions will be made, and what the various outcomes would be based on the results of each step. Although optional, we encourage the use of the fillable USFWS Study Plan Form for Bat Surveys and Monitoring as it will ensure all the information necessary is provided to the USFWS FO and expedite review and approval. Project proponents are encouraged to coordinate with the USFWS FO(s) regarding when they may cease survey work once an assumption or documentation of their targeted species presence occurs. Pre-survey coordination typically will preclude the need for subsequent reviews of intermediate steps by USFWS FO(s) during the busy field season. An online directory of USFWS FO(s) is available on the USFWS website (https://www.fws.gov/our-facilities). Unless otherwise agreed to by the USFWS, negative P/A survey results obtained using this guidance are valid for a minimum of five years[8] from their completion unless new information (e.g., other nearby surveys) suggest otherwise. If negative survey results are older than 5 years, coordinate with the USFWS FO(s) to discuss if additional surveys are needed. If not already required by federal permit, submit all results (negative or positive) from any phase to the USFWS FO(s) you have been in coordination with. We strongly encourage this coordination as it improves the USFWS' understanding of (1) the level of survey effort underway and (2) the distribution of the species. A single report can be submitted at the end of all phases conducted for a given project. Results of acoustic survey data collected as part of P/A surveys must also be submitted annually in Section 10 reporting spreadsheets to the USFWS.

USFWS FO-level coordination is also important during the survey planning process. USFWS Section 10 permits require FO approval for each individual survey study plan in order to be in compliance. Field Offices have the authority to deny a proposed survey if it is determined that the study plan is insufficient for Section 7 consultation requirements of the ESA. For example, radio-tracking of captured IBAT and/or NLEB may be required by individual FOs and should be discussed as part of the study plan and pre-survey coordination. The guidelines that are described in this document are designed to be implemented during acceptable survey windows (see Table 1) and in typical habitats that are conducive to the standard survey techniques described herein. However, the USFWS recognizes that occasionally there may be some site-specific conditions in summer habitats or at potential hibernacula sites that do not lend themselves to being surveyed using the standard survey options (e.g., mist nets, acoustic detectors, or harp traps) even though a site may otherwise meet the definition of suitable IBAT and/or NLEB habitat. Therefore, we strongly encourage coordination with the FO(s) prior to using methods that may not be appropriate for site-specific habitat conditions. The bat activity timeframes (see Appendix L) are intended to provide consistency across the species' ranges and aid conversations between project proponents and USFWS FOs regarding Section 7 consultations (e.g., avoidance and minimization). Similarly to other components of the guidelines, these timeframes are subject to change based on use of the best science available.

[7] For example, project sponsors for large acreage and/or landscape-scale projects that do not result in permanent habitat loss and would not pose an ongoing threat of lethal take, especially those proposed by land management agencies, may work with local USFWS FOs to apply different scales of surveys (broad vs. project-level) or different types of surveys, such as long-term monitoring results (e.g., forest-wide acoustic data) and/or targeted survey efforts (e.g., sub- sampling of large project areas), to address P/A concerns.

[8] The timeframe may be reduced if significant habitat changes have occurred in the area or increased based on local information.

Because surveys that result in the capture of IBAT and/or NLEB result in take, such surveys should only be conducted by a qualified biologist[9]. Generally, a recovery permit for the IBAT and NLEB authorizes the capture of bats for identification, and handling of bats for measurements, photography, banding, and radio transmitter attachment; some (but not all) may also authorize entry into potential hibernacula to conduct internal surveys and other study-specific collection. Following this survey guidance will meet standard USFWS Section 10 recovery permit requirements; however, surveyors also need to ensure they meet all applicable state permitting and reporting requirements. Failure to follow the survey guidance, as written, and/or failure to follow a study plan which has received concurrence from the local USFWS FO(s), may result in a USFWS FO requesting additional survey effort.

The following provides a step-by-step outline of how IBAT and/or NLEB summer surveys and/or potential hibernacula surveys should be conducted. Some of these steps can occur concurrently.

NOTE: If surveys are specifically targeting both the IBAT and NLEB, **make sure to use the higher minimum LOE for chosen survey methods (e.g., NLEB range-wide acoustic or mist-netting LOE, also see 2022 and 2023 Addendum)** to ensure it meets the needs for both species.

PHASE 1 – INITIAL PROJECT SCREENING

Step 1. Determine if your project is within the range of IBAT and/or NLEB through the U.S. Fish and Wildlife Service's Information for Planning and Consultation website (https://ipac.ecosphere.fws.gov/). Once completed, coordinate with the U.S. Fish and Wildlife Service Field Office(s)[10] regarding existing IBAT and/or NLEB summer and/or winter occurrence information. [*Projects located within known IBAT and/or NLEB summer habitat and/or known hibernacula/spring-staging/fall swarming zones will not proceed to Phase 2 of this process unless the project meets the definition of an "outer-tier project" outlined in Appendix G. "Outer-tier" guidance only applies to summer captures/detections (not hibernacula)*].

a) If a project (located within or outside of a known maternity colony home range or spring-staging/fall-swarming zone of a known hibernaculum) is already covered under an existing Endangered Species Act (ESA) incidental take authorization (e.g., HCP, BO), then no further summer and/or potential hibernacula surveys are needed, follow the procedures previously authorized by the USFWS FO(s).

b) If there are known IBAT or NLEB occurrences (e.g., known roost trees, capture locations, foraging locations or hibernacula) within the project action area[11];

OR

if there are no known IBAT or NLEB summer or spring/fall/winter occurrences within the proposed project area itself, but the project area is located within a known maternity colony

[9] A qualified biologist is an individual who holds a USFWS Recovery Permit (Federal Fish and Wildlife Permit) for IBAT and/or NLEB in the state/region in which they are surveying and/or has been authorized by the appropriate state agency to net and handle IBAT and/or NLEB. Several USFWS offices maintain lists of qualified bat surveyors, and if working in one of those states with authorizations in lieu of a Recovery Permits, the individual will either need to be on that list or submit qualifications to receive USFWS approval prior to conducting any field work.

[10] Coordinate with the appropriate state natural resource agencies and any involved Federal Action agencies whenever "USFWS" coordination is listed. USFWS FO(s) may direct project sponsors to state agencies for existing occurrence information. Coordinate with your local USFWS FO(s) to understand the process for their area of jurisdiction.

[11] The "action area" is defined as all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action. [50 CFR Section 402.02]

home range and/or the spring-staging and fall-swarming zone of a known hibernaculum[12];

OR

if the project is located outside a known maternity colony home range and/or spring- staging and fall-swarming zone of a hibernaculum but is within the range of the IBAT and/or NLEB (note this can change over time), then proceed to Step 2.

Step 2. Conduct Habitat Assessment (Desktop or Field-based; see Appendix A, H, and K).

a) If suitable summer habitat, a potential hibernaculum(a), and/or a potential bridge/culvert roost is present within the action area, then proceed to Step 3.

b) If suitable summer and winter habitat (i.e., potential hibernaculum) and potential bridge/culvert roosts are absent within the action area, then no further P/A surveys are recommended; however, additional coordination with the USFWS FO(s) may be recommended if IBAT and/or NLEB may be present in an action area during other seasons (e.g., spring and fall migration) and may be affected by the proposed project.

Step 3. Assess potential for adverse effects to IBAT and/or NLEBs

a) If the project is not anticipated to result in adverse effects to IBAT and/or NLEB (as proposed), then no further summer, bridge/culvert roost, and/or potential hibernacula surveys are recommended, coordinate with the USFWS FO(s).

b) If the project may result in adverse effects to IBAT and/or NLEB, but impacts can be adequately assessed and conservation measures can be designed to minimize those effects without additional P/A information (this includes **all** proposed projects within known summer maternity colony home ranges and /or at known hibernacula and their surrounding spring-staging and fall-swarming zones, but may include other areas as well), then no further surveys are recommended. Coordinate with the USFWS FO(s) regarding an assessment of the project's potential effects, development of conservation measures, determination of the need for any ESA incidental take authorization, and discussion of value of additional surveys.

c) If the project does not meet the conditions of 3a or 3b, then proceed to **Phase 2, 5, and/or 6**.

PHASE 2 – SUMMER/ACTIVE SEASON P/A SURVEYS (NETTING AND/OR ACOUSTIC)[13]

Presence/probable absence (P/A) of IBAT and/or NLEB may be determined by conducting either Step 4 (mist-netting; see Appendix B or Appendix J) or Step 5 (acoustics; see Appendix C or Appendix J) as outlined below. If the project area contains habitat that is appropriate to conduct either survey method, it is the project proponent's choice as to which option to use, for each survey area unit (i.e., ≤123-acre area or 1-km section of linear project). A combined mist-netting and acoustic approach is also acceptable (see "pilot" Appendix I). Under no scenario can a project proponent use either mist-netting or acoustic Phase 2 surveys to challenge the other methods results. The USFWS accepts the results of either option and has no preference for methods. The USFWS FO(s) can discuss pros and cons of different approaches depending on project sponsor needs and project- specific habitat conditions. For example, a project area may not have suitable conditions for a mist- net survey and an acoustic survey may be the only

[12] See USFWS IBAT Section 7 and Section 10 Guidance for Wind Energy Projects (Questions 4 & 5) on the USFWS website provided in the introduction.

[13] NOTE: acoustic and/or mist-net surveys should be conducted in the best suitable habitat possible for each survey type to increase the likelihood of detecting/capturing IBAT and/or NLEB. In some cases, the most suitable habitat for effectively conducting surveys may occur outside a project site boundary and may be sampled if landowner permission is granted.

appropriate method for establishing P/A. It is up to the surveyor's professional judgment to determine whether the habitat on-site has the appropriate structure for the survey method chosen prior to the survey and to coordinate with the FO(s) if issues arise with the method chosen and need to be reconsidered.

Acoustics at the Phase 2 level of effort (LOE) (or otherwise agreed to with the USFWS FO) may be used as a coarse screening tool for conducting subsequent mist-netting at the Phase 2 LOE. For example, if NO high frequency (HF) calls (≥35 kHz) are detected, then no netting is required within that 123-acre (non-linear) or 1-km (linear) survey area due to IBAT and/or NLEB probable absence. If ANY HF calls are detected, then mist-net at the Phase 2 LOE. Any project study plan that includes use of both acoustics and netting needs to be written clearly to avoid potential misunderstandings between the project proponent and the USFWS FO.

Also, Phase 2 acoustic results should be used to inform whether, when, and where to conduct any optional Phase 3 mist-netting. In this case, acoustics is the P/A method and if presence is detected (HF screen, automated/MLE and/or manual vetting), then IBAT and/or NLEB presence is established. Negative results from follow-up mist-netting (at any LOE) does not refute a previously established positive acoustic result. The goal of Phase 3 netting is simply to verify where IBAT and/or NLEB(s) are active and to capture and track individuals to document roost trees and population size to further inform consultation or coordination under the ESA.

The summer survey season for IBAT and the hibernating[14] NLEB range is from 15 May through 15 August, unless the survey is being conducted within the year-round active portion of the NLEB range where the survey season is from 1 March through 15 October (see Appendix J). All P/A surveys should be completed by the end of the designated survey season unless otherwise indicated by USFWS FO[15]. The minimum prescribed survey level of effort for any given survey area unit (i.e., ≤123-acre area or 1-km section of linear project) **cannot** be completed in a single calendar night regardless of which survey method (netting or acoustic) is used (i.e., minimum survey effort must be spread over at least 2 calendar nights with suitable weather conditions). If netting is chosen as the preferred P/A method and an IBAT and/or NLEB is captured, then surveyors may immediately begin Phase 4/radio- tracking. Project proponents must decide whether they will proceed to Phase 4 in coordination with the USFWS FO before any mist-netting occurs. Submit Phase 2 study plans to USFWS FO prior to conducting surveys for their review and site-specific authorization.

Step 4. Conduct Mist-Netting Surveys following IBAT and/or NLEB Protocols[16] (See Figure 1, Table 2, and Appendix B, I, or J)

OR

Step 5. Conduct Acoustic Surveys[17] (see Figure 1, Table 2, and Appendix C, I, or J)

[14] The hibernating NLEB range includes the portion of the range where the species hibernates in the winter, stages and swarms outside of hibernacula in the spring and fall, and migrates to summer home ranges.
[15] With prior USFWS FO approval, a survey may be completed after the end of the designated survey season if it was initiated in time to be completed by August 15 or October 15 (year-round active portion of the NLEB range) and extenuating weather circumstances resulted in delaying completion. Delays as a result of not meeting the acceptable weather requirements are the ONLY valid justification for surveying after August 15. If tracking is proposed, surveys should be scheduled so that tracking is concluded prior to August 15 or October 15.
[16] We have no recommendations for reducing the mist-netting minimum level of effort to demonstrate probable absence for projects <123 acres in size. Level of effort is based on detection probabilities and occupancy estimates that were derived from past survey efforts that used the same acreage threshold. Level of effort for mist-netting is designed to reach 90% confidence in negative survey results (see Niver et al. 2014; Armstrong et al. 2023).
[17] Acoustic surveys are available as a P/A option throughout the ranges of both species. We have no recommendations for reducing the minimum level of effort required to demonstrate probable absence for projects <123 acres in size. Level

PHASE 3. CONDUCT MIST-NETTING SURVEYS TO CAPTURE INDIANA and/or NORTHERN LONG-EARED BATS.

If mist-netting was not conducted as the P/A method, then mist-netting may be conducted in Phase 3 to capture and characterize (e.g., sex, age, reproductive condition) the IBAT and/or NLEB that are present in an area and to facilitate Phase 4 efforts. We encourage working with the FOs to develop Phase 3 netting plans based on best available information (e.g., positive acoustic locations). There are no minimum requirements for this phase as this is not a P/A phase.

a) If no IBAT and/or NLEB are captured, then coordinate with the USFWS FO.

b) If IBAT and/or NLEB are captured, then proceed to **Phase 4**.

PHASE 4. CONDUCT RADIO-TRACKING AND EMERGENCE SURVEYS (See Appendices D and E)

PHASE 5. CONDUCT POTENTIAL HIBERNACULA SURVEYS (See Appendix H)

PHASE 6. CONDUCT BRIDGE AND CULVERT ROOST SURVEYS (See Appendix K)

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TABLE 1. Standard survey seasons for conducting P/A surveys for IBAT and/or NLEB.

IBAT & NLEB SURVEY SEASONS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
IBat Internal Winter Hibernacula Surveys[1,2]												
Acceptable survey window (1 Jan. - 28 Feb.)												
Traditional survey window of known sites (15 Jan. - 15 Feb.)												
IBat & NLEB Spring & Fall Surveys at Entrances of Potential Hibernacula [3,4]												
Acceptable survey window (1 - 21 Apr. & 15 Sep. - 31 Oct.)												
IBat & NLEB Summer Surveys of Suitable Summer Habitat [5]												
Acceptable survey window (15 May - 15 Aug.)												
Optimal survey window (1 Jun. - 31 Jul.) [6]												
NLEB Surveys of Suitable Habitat in Year-round Active Range												
Acceptable survey window - (1 Mar. - 15 Oct.)												
Optimal survey window (1 May - 30 Sep.) [6]												
IBat & NLEB Bridge and Culvert Surveys [7]												
Acceptable survey window (Year-round)												

[1] visual and photographic surveys conducted within known and/or potential hibernacula (if deemed safe to enter).

[2] internal winter hibernacula surveys are seldom appropriate for NLEB as they typically fail to reliably detect and accurately enumerate the species when present.

[3] conducted using harp traps or mist nets at cave/mine entrances.

[4] if State/USFWS FO approve, spring and fall survey windows can "drift" a bit earliler or later to better accommodate prevailing weather patterns and/or climate conditions in the location of the proposed survey. For example, the fall survey window in nothern portions of the IBAT or NLEB range may begin on or after 1 Sep. and end prior to 31 Oct. pending local State and FO approval. Likewise, if agencies approve, spring surveys of potential hibernacula may be pushed back/extended a few days or longer due to an extended period of unseasonably cold spring weather.

[5] conducted using mist nets or acoustic detectors deployed within suitable flight corridors and foraging areas.

[6] the middle of the maternity season is considered by many to the best or "optimal" time to capture resident bats.

[7] coordinate with your local USFWS FO to determine best time to conduct bridge or culvert surveys for your project.

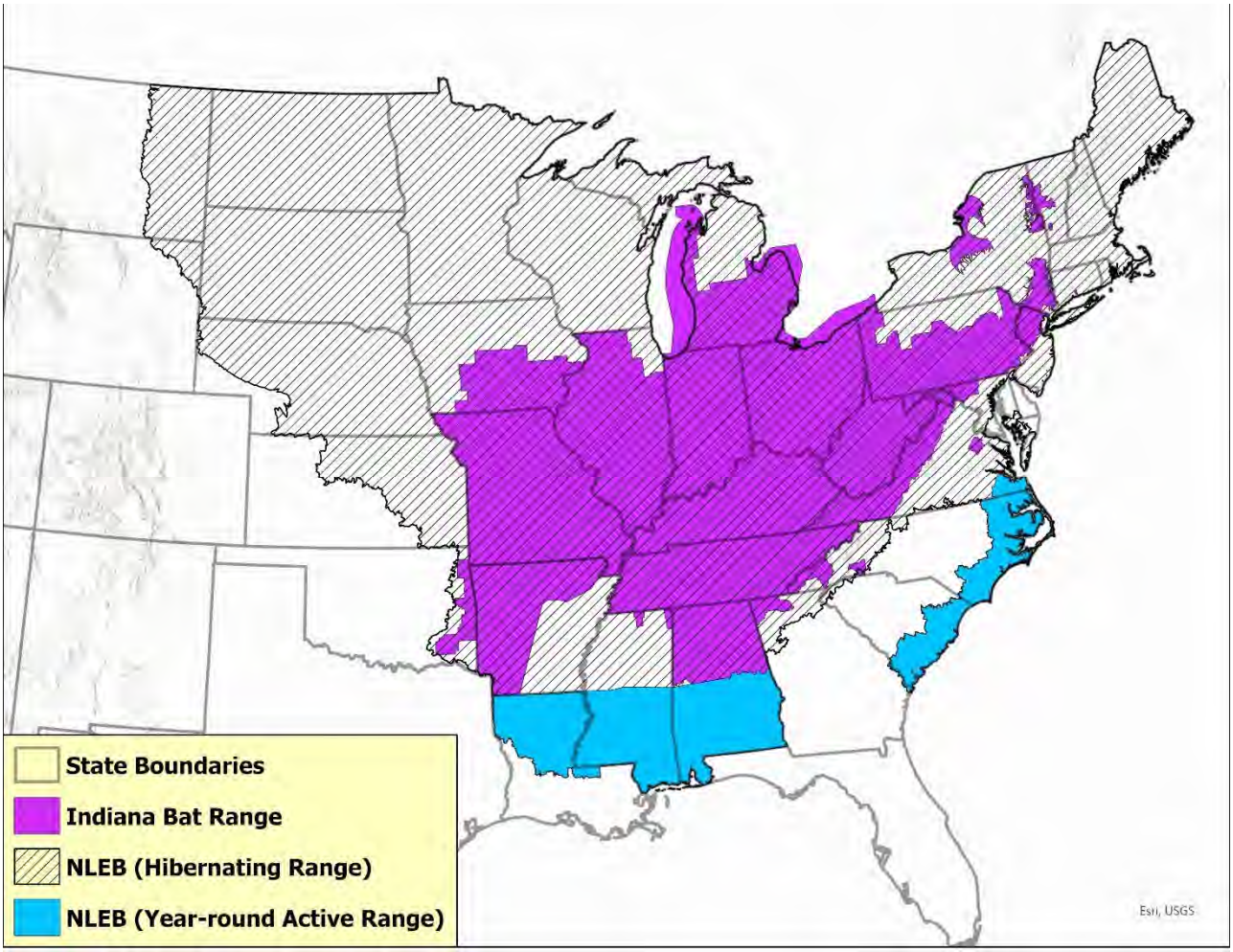


FIGURE 1. IBAT and NLEB ranges as defined for use in presence/ probable absence surveys (also see Table 2).

TABLE 2. Summary of current survey LOEs for IBAT and NLEB.

		MIST-NETTING (net nights)		ACOUSTICS (detector nights)	
Species	Region	Linear (per km)	Non-Linear (per 123 ac.)	Linear (per km)	Non-Linear (per 123 ac.)
IBAT	[illegible]	2	6	4	10
NLEB	Hibernating Range (non-coastal areas)	4	10	4	14
	Year-round Active Range (coastal areas)	2	6		

APPENDIX A: PHASE 1 HABITAT ASSESSMENTS

Summer habitat and potential hibernacula assessments are Step 2 of Phase 1- Initial Project Screening. The information below is provided to assist applicants, consultants, and/or project proponents (hereinafter termed the "applicant") in establishing whether surveys for IBAT and/or NLEB should be conducted. As a reminder, the first steps for determining presence of IBAT and/or NLEB at a given site is to 1) use the USFWS's Information for Planning and Consultation (IPaC) website (https://ipac.ecosphere.fws.gov/), and 2) determine whether there is any existing occurrence data available for the vicinity of the project from the local USFWS FO. This step can be conducted remotely via a desktop analysis (e.g., use of aerial photography to assess the potential presence of suitable summer habitat); however, on-site field assessment is always preferred. The applicant is responsible for developing and providing sufficient information as to whether suitable summer habitat and/or potential hibernacula exist within a proposed project area. If suitable habitat is present, the applicant should calculate the amount and submit this to the USFWS FO(s) and determine the need for any P/A surveys (Phase 2).

NOTE: If IBAT and/or NLEB are present or assumed to be present during any phase, more detailed habitat information may be necessary to adequately assess the potential for impacts (see attached example Bat Habitat Assessment Datasheet). If no suitable habitat is present or it is determined through discussions with USFWS FO(s) that no adverse effects are anticipated from the proposed project, no surveys are recommended to assess risk. Habitat assessments for IBAT and/or NLEB can be completed any time of year and applicants are encouraged to submit results and proposed Phase 2 study plans well in advance of survey seasons.

PERSONNEL

Habitat assessments should be completed by individuals with a natural resource degree or equivalent work experience demonstrating skills and knowledge in area-specific ecoregions, landscapes, habitats, and ecosystems.

DEFINITION FOR SUITABLE INDIANA BAT SUMMER HABITAT

Suitable summer habitat for IBAT consists of a wide variety of forested/wooded habitats where they roost, forage, and travel and may also include some adjacent and interspersed non-forested habitats[18] such as emergent wetlands and adjacent edges of agricultural fields, old fields and pastures. This includes forests and woodlots containing potential roosts (i.e., live trees and/or snags ≥5 inches dbh[19] (12.7 centimeter) that have exfoliating bark, cracks, crevices, and/or hollows), as well as linear features such as fencerows, riparian forests, and other wooded corridors. These wooded areas may be dense or loose aggregates of trees with variable amounts of canopy closure. Individual trees may be considered suitable

[18] Non-forested habitats typically should be excluded from acreages used to establish a minimum level of survey effort for Phase 2 surveys.

[19] While trees <5 inches (<12.7 cm) dbh that have exfoliating bark, cracks, crevices, and/or hollows may have some potential to be male IBAT summer roosting habitat, the USFWS does not consider early successional, even-aged stands of trees <5 inches dbh to be suitable roosting habitat for the purposes of this guidance. Suitable roosting habitat is defined as forest patches with trees of 5-inch (12.7 cm) dbh or larger. However, early successional habitat with small diameter trees may be used as foraging habitat by IBATs. Therefore, a project that would remove or otherwise adversely affect ≥20 acres of early successional habitat containing trees between 3 and 5 inches (7.6-12.7 cm) dbh would require coordination/consultation with the USFWS FO to ensure that associated impacts would not rise to the level of take. The USFWS may request P/A surveys if >20 acres of early successional habitat were proposed for removal.

habitat when they exhibit the characteristics of a potential roost tree and are located within 1,000 feet (305 meters) of other forested/wooded habitat.

Indiana bats have also been observed roosting in human-made structures, such as bridges and bat houses (artificial roost structures); therefore, these structures should also be considered potential summer habitat[20]. We recommend that project proponents or their representatives coordinate with the appropriate USFWS Field Office (FO) to define suitable habitat more clearly for their region as some differences in state/regional suitability criteria may be warranted (e.g., high-elevation areas may be excluded as suitable habitat in some states).

Examples of unsuitable habitat:

- Individual trees that are greater than 1,000 feet from forested/wooded areas;
- Trees found in highly developed urban areas (e.g., street trees, downtown areas); and
- A pure stand of less than 3-inch dbh[21] trees that are not mixed with larger trees.

DEFINITION FOR SUITABLE NORTHERN LONG-EARED BAT SUMMER HABITAT

Suitable summer habitat for the NLEB consists of a wide variety of forested/wooded habitats where they roost, forage, and travel. Although they may also traverse habitat adjacent and interspersed with forest habitat, such as emergent wetlands and field edges, they are predominately found in forest/wooded habitat. This includes forests and woodlots containing potential roosts (i.e., live trees and/or snags ≥3 inches dbh that have exfoliating bark, cracks, crevices, and/or cavities), as well as linear features such as fencerows, riparian forests, and other wooded corridors. These wooded areas may be dense or loose aggregates of trees with variable amounts of canopy closure. NLEBs are nocturnal foragers and use hawking (catching insects in flight) and gleaning (picking insects from surfaces) behaviors in conjunction with passive acoustic cues (Nagorsen and Brigham 1993, p. 88; Ratcliffe and Dawson 2003, p. 851). NLEB often prefer intact mixed-type forests with small gaps (i.e., forest trails, small roads, or forest-covered creeks) in forest with sparse or medium vegetation for foraging and commuting rather than fragmented habitat or areas that have been clear cut (USFWS 2015, p.17992). Individual trees may be considered suitable habitat when they exhibit characteristics of suitable roost trees and are within 1,000 feet of other forested/wooded habitat[22]. The NLEB has also been observed roosting (although to a lesser degree than forested habitat) in human-made structures, such as buildings, barns, bridges, and bat houses; therefore, these structures should also be considered potential summer habitat[23].

NLEBs typically occupy their summer habitat from mid-May through mid-August each year[24] and the

[20] If human-made structures are present within your project area and are proposed to be removed or modified, see Appendix E (Emergence Surveys) and then coordinate with the local USFWS FO(s) regarding how to determine P/A.
[21] Suitable roosting habitat is defined as forest patches with trees of 5-inch (12.7 cm) dbh or larger. However, early successional habitat with small diameter trees may be used as foraging habitat by IBAT. Therefore, a project that would remove or otherwise adversely affect ≥20 acres of early successional habitat containing trees between 3 and 5 inches (7.6- 12.7 cm) dbh would require coordination/consultation with the USFWS FO to ensure that associated impacts would not rise to the level of take. The USFWS may request P/A surveys if >20 acres of early successional habitat were proposed for removal.
[22] This number is based on observations of bat behavior indicating that such an isolated tree (i.e., ≥1000 feet) would be extremely unlikely to be used as a roost. This distance has also been evaluated and vetted for use for the NLEB. See the "Indiana bat Section 7 and Section 10 Guidance for wind Energy Projects," question 33, found on the USFWS website provided in the intro.
[23] Trees found in highly-developed urban areas (e.g., street trees, downtown areas) are extremely unlikely to be suitable habitat.
[24] Exact dates vary by location., with NLEBs typically being found earlier in spring at lower latitudes. Also, NLEBs in

species may arrive or leave some time before or after this period. In most areas, roosting habitat is considered suitable summer habitat because NLEBs are only present in forested habitat during the summer active months. In some areas of the southern U.S., NLEBs are present in potential roosting habitat year-round. In these areas (see Figure 1 and Figure 3 in Appendix J), habits and habitat use differ significantly from the rest of the species' range.

Examples of unsuitable habitat:

- Individual trees that are greater than 1,000 feet from forested/wooded areas;
- Trees found in highly developed urban areas (e.g., street trees, downtown areas); and
- A pure stand of less than 3-inch dbh trees that are not mixed with larger trees.

DEFINITION FOR SUITABLE TRICOLORED BAT SUMMER HABITAT

Suitable TCB summer habitat consists of a wide variety of forested/wooded habitats where they roost, forage, and travel and include some adjacent and interspersed non-forested habitats such as emergent wetlands, shrublands, grasslands, and forested edges of agricultural fields, old fields, and pastures. Roosting habitat includes forests, woodlots, and linear features (e.g., fencerows and riparian corridors) containing trees with potential roost substrate (e.g., live and dead leaf clusters of live and recently dead deciduous trees, Spanish moss [*Tillandsia usneoides*], and beard lichen [*Usnea trichodea*]).[25] TCBs will roost in a variety of tree species, especially oaks (*Quercus spp.*), and often select roosts in tall, large-diameter trees, but will roost in smaller diameter trees when potential roost substrate is present (e.g., 4-inch [10-centimeter]; Leput 2004). TCBs commonly roost in the mid to upper canopy of trees although males will occasionally roost in dead leaves at lower heights (e.g., < 16 feet [5 meters] from the ground; Perry and Thill 2007) and females will occasionally roost in Spanish moss of understory trees (Menzel et al. 1999). TCBs seem to prefer foraging along forested edges of larger forest openings, along edges of riparian areas, and over water and avoid foraging in dense, unbroken forests, and narrow road cuts through forests (Davis and Mumford 1962; Kurta 1995; Lacki and Hutchinson 1999; Ford et al. 2005; Menzel et al. 2005; White et al. 2006; Thames 2020; Hantulla and Valdez 2021).

TCBs also roost in human-made structures, such as bridges and culverts, and occasionally in barns or the underside of open-sided shelters (e.g., porches, pavilions); therefore, these structures should also be considered potential summer habitat. TCBs occupy similar forest habitats in the spring, summer, and fall (i.e., non-hibernating seasons) but in the southern portion of the range, where TCBs exhibit shorter torpor bouts and remain active and feed year-round, they may roost in culverts, bridges, cavities in live trees, live and dead leaf clusters, and/or Spanish moss during the winter (Sandel et al. 2001; Newman et al. 2021). TCBs may roost and forage in forested areas near anthropogenic structures and buildings (e.g., suburban neighborhoods, parks, etc.) (Helms 2010; Shute et al. 2021). However, highly developed urbanized areas generally devoid of native vegetation (including isolated trees surrounded by expansive anthropogenic development) are considered unsuitable habitat (e.g., parking lots, industrial buildings, shopping centers).

SUBMISSION OF PHASE 1 HABITAT ASSESSMENT & PHASE 2, PHASE 5, AND/OR PHASE 6 STUDY PLAN (IF NEEDED)

the year-round active portion of the range are an exception as they utilize the same habitat in summer as they do in winter.

[25] Occasional summer roosts also include clusters of dead pine needles of large live pines (Pinus echinata), live branches of Norway spruce (Picea abies), eastern red cedar (Juniperus virginiana), abandoned gray squirrel (Sciurus carolinensis) nests, and under exfoliating birch (Betula spp.) bark (Veilleux et al. 2003; Perry and Thill 2007; WDNR 2016; WDNR 2017a; WDNR 2017b; WDNR 2018; Thames 2020; Hammesfahr et al. 2022).

If a proposed project may affect (positively or negatively) IBAT and/or NLEB and the conditions outlined in Step 3 a or b are not met, a habitat assessment report should be submitted to the appropriate USFWS FO(s) (and/or to the lead Federal Action Agency as appropriate) along with a draft study plan for the Phase 2 (acoustic or netting), Phase 5 (potential hibernaculum), and/or Phase 6 (bridge/culvert potential roost) survey(s) (if suitable habitat(s) is present). Although optional, we encourage the use of the new fillable USFWS Study Plan Form for Bat Surveys and Monitoring as it will ensure all the information necessary is provided to the USFWS FO and expedite review and approval of your study plan. If you choose not to submit the study plan form, ensure all information requested on the form applicable to your survey are included with your study plan request submittal to your local USFWS FO(s). Complete Phase 1 reports will include the following:

1. Full names and relevant titles/qualifications of individuals (e.g., John E. Smith, Biologist II, State University, B.S. Wildlife Science 2007) completing the habitat assessment and when the assessment was conducted
2. A map and latitude/longitude or UTM clearly identifying the project location (or approximate center point) and boundaries
3. A detailed project description (if available)
4. Documentation of any known/occupied spring staging, summer, fall swarming, winter habitat, and/or bridge/culvert roosts for IBAT and/or NLEB within or near the project area
5. A description of methods used during the habitat assessment
6. A summary of the assessment findings and a completed Bat Summer Habitat Assessment Datasheet (see example below; use of this datasheet is optional)
7. Other information that may have a bearing on use of the project area (e.g., presence of fall or winter habitat [caves, crevices, fissures, or sinkholes, or abandoned mines of any kind], bridges/culverts and other non-tree potential summer roosts.)
8. A Phase 1 Habitat Assessment on all potential hibernacula that could be affected by the proposed project (see Appendix H for additional instructions for completing this assessment and sample datasheet), if necessary
9. A Step 1 Initial Assessment of Suitability and Safety on all bridges and culverts that could be affected by the proposed project (see Appendix K for additional instructions for completing this assessment and sample datasheet), if necessary
10. Any other information requested by the local USFWS FO(s) related to the project

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BAT HABITAT ASSESSMENT DATASHEET

Project Name:_____ Date:_____

Township/Range/Section:_____

Lat Long/UTM/ Zone:_____ Surveyor:_____

Brief Project Description

Project Area

	Total Acres	Forest Acres	Open Acres
Project			

	Completely cleared	Partially cleared (will leave trees)	Preserve acres- no clearing
Proposed Tree Removal (ac)			

Vegetation Cover Types

Pre-Project	Post-Project

Landscape within 5 mile radius

Flight corridors to other forested areas?
Describe Adjacent Properties (e.g. forested, grassland, commercial or residencial development, water sources)

Proximity to Public Land

What is the distance (mi.) from the project area to forested public lands (e.g., national or state forests, national or state parks, conservation areas, wildlife management areas)?

Use additional sheets to assess discrete habitat types at multiple sites in a project area

Include a map depicting locations of sample sites if assessing discrete habitats at multiple sites in a project area

A single sheet can be used for multiple sample sites if habitat is the same

Sample Site Description
Sample Site No.(s): _____

Water Resources at Sample Site				
Stream Type (# and length)	Ephemeral	Intermittent	Perennial	Describe existing condition of water sources:
Pools/Ponds (# and size)		Open and accessible to bats?		
Wetlands (approx. ac.)	Permanent	Seasonal		

Forest Resources at Sample Site				
Closure/Density	Canopy (> 50')	Midstory (20-50')	Understory (<20')	1=1-10%, 2=11-20%, 3=21-40%, 4=41-60%, 5=61-80%, 6=81-100%
Dominant Species of Mature Trees				
% Trees w/ Exfoliating Bark				
Size Composition of Live Trees (%)	Small (3-8 in)	Med (9-15 in)	Large (>15 in)	
No. of Suitable Snags				

Standing dead trees with exfoliating bark, cracks, crevices, or hollows. Snags without these characteristics are not considered suitable.

IS THE HABITAT SUITABLE FOR INDIANA BATS? _____

IS THE HABITAT SUITABLE FOR NORTHERN LONG-EARED BATS? _____

Additional Comments:

Attach aerial photo of project site with all forested areas labeled and a general description of the habitat

Photographic Documentation: habitat shots at edge and interior from multiple locations; understory/midstory/canopy; examples of potential suitable snags and live trees; water sources

APPENDIX B: PHASE 2 OR PHASE 3 MIST–NETTING

Mist-netting can be used as a P/A method (Phase 2 surveys) or it can be conducted for the purpose of attempting to capture IBAT and/or NLEB after detection during acoustic P/A surveys (Phase 3 surveys). The same recommendations (e.g., season, personnel, equipment, net placement, checking nets) apply for either use of mist-netting surveys. NOTE: Appendix B is intended for use within the IBAT range and/or NLEB hibernating range (see Figure 1); also refer to Appendix J for additional guidance on conducting mist-netting in the year-round active range of the NLEB.

SUMMER MIST-NETTING SEASON: May 15 – August 15[26]

Capture of reproductive adult females (i.e., pregnant, lactating, or post-lactating) and/or young of the year during May 15 – August 15 confirms the presence of a maternity colony in the area. Since adult males and non-reproductive females have commonly been found summering with maternity colonies, radio-tracking results will be relied upon to help determine the presence or probable absence of a maternity colony or large concentrations of bats in the area when only males and/or non-reproductive females are captured.

PERSONNEL

A qualified biologist(s)[27] must (1) select/approve mist-net sets in areas that are most suitable for capturing IBAT and/or NLEB, (2) be physically present at each mist-net site[28] throughout the survey period, and (3) confirm all bat species identifications. This biologist may oversee other biological technicians and manage mist-net sets in close proximity to one another if the net-check timing (i.e., every 10 minutes) can be maintained while **walking** between net-sets[29]. A minimum of two (2) biologists (e.g., one qualified and one technician) must be on-site for every four (4) net-sets being operated. Exceptions to on-site minimum staffing levels may be allowed under extenuating circumstances, provided written justification is included in the proposed survey study plan and subsequently approved by the local USFWS FO(s).

NOTE: The mist-netting survey protocol may also be used for determining P/A of TCBs using the NLEB LOE for the 2024 field season when the survey is also being conducted for IBAT and/or NLEB; however, an acoustic or combined acoustic/mist-net survey must be completed in portions of the range where TCBs are the only species identified by IPaC and the project proponent chooses to conduct a P/A survey.

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[26] With prior USFWS FO approval, a survey may be completed after August 15 if it was initiated in time to be completed by August 15 and extenuating weather circumstances resulted in delaying completion. Delays as a result of not meeting the acceptable weather requirements are the ONLY valid justification for surveying after August 15. If tracking is proposed, surveys should be scheduled so that tracking is concluded prior to August 15.

[27] A qualified biologist is an individual who holds a USFWS Recovery Permit (Federal Fish and Wildlife Permit) for IBAT and NLEB in the state/region in which they are surveying and/or has been authorized by the appropriate state agency to net and handle IBAT and/or NLEB. Several USFWS offices maintain lists of qualified bat surveyors, and if working in one of those states with authorizations in lieu of a Recovery Permits, the individual will either need to be on that list or submit qualifications to receive USFWS approval prior to conducting any field work.

[28] A Net Site is defined as one or more net sets that can be efficiently walked to and checked by a survey team (typically 2 people) within a 10-minute window from a central bat-processing location. For example, a single net "site" is often composed of 4 individual net sets (separated by at least 30 m apart) that are checked every 10 minutes by a 2-person team (each person checks 2 nets for each net check).

[29] A Net-Set is defined as one mist-net deployment consisting of two poles and typically from 1-3 affixed mist-nets stacked onto one another. A typical net set is at least 5 m to 9 m high consisting of two or more nets stacked on top of one another (without gaps) and from 6 m to 18 m wide.

COORDINATION WITH USFWS FIELD OFFICES (FOs)

If not already required by federal permit, we recommend that applicants submit a draft study plan for all survey phases to the USFWS FO(s) for review and approval (See Appendix A for guidance on submitting a draft study plan).

EQUIPMENT

Use the finest, lowest visibility mesh mist-nets commercially available, as practicable. Currently, the finest net on the market is 75 denier, 2 ply, denoted 75/2 (Arndt and Schaetz 2009); however, the 50 denier nets are still acceptable for use currently. The finest mesh size available is approximately 1½ inches (38 millimeters). No specific hardware is required. There are many suitable systems of ropes and/or poles to hold nets. The systems of Gardner et al. (1989) and Chenger's BCM triple high has been widely used. See NET PLACEMENT discussion below for minimum net heights, habitats, and other netting requirements that affect the choice of hardware.

To minimize potential for disease transmission, any equipment that comes in contact with bats should be kept clean and disinfected, following approved protocols; this is particularly a concern relative to white-nose syndrome (WNS). Disinfection of equipment to avoid disease transmission (e.g., WNS) is required; protocols are posted at http://www.whitenosesyndrome.org/. Federal and state permits may also have specific equipment restrictions and disinfection requirements.

MINIMUM P/A MIST-NETTING LEVEL OF EFFORT (PHASE 2)

The level of netting survey effort required for a non-linear project will be dependent upon the overall acreage of suitable habitat that may be impacted by the action (directly or indirectly). To determine the survey effort, quantify the amount of suitable summer habitat within the project area.

NOTE: for projects where other impacts than tree removal are likely (e.g., collision), ensure that P/A surveys are designed to cover all suitable habitat within the entire project area (where exposure to any kind of impacts may be anticipated) and NOT just the locations where tree removal is planned. Additional guidance for linear projects is in Appendix F.

Conduct Mist-Netting Surveys following IBAT and/or Hibernating NLEB Range Level-of-Effort Recommendations (See Figure 1 and Table 2)

Range-wide IBAT Mist-netting LOE:

Linear projects: a minimum of 2 net nights per km (0.6 miles) of suitable summer habitat (see Appendix F).

Non-linear projects: a minimum of 6 net nights per 123 acres[30] (0.5 km^2) of suitable summer habitat.

After 2 consecutive nights of netting at the same location without capturing target species, you must change net locations or wait at least 2 calendar nights before resuming netting at the same location.

[30] We have no recommendations for reducing the minimum level of effort required to demonstrate probable absence for projects <123 acres in size. Detection probabilities and occupancy estimates were derived from past survey efforts that used the same acreage threshold (see Niver et al. 2014).

a) If no capture of IBAT(s), then no further summer surveys are recommended[31].

b) If capture of IBAT(s), then stop or proceed to **Phase 4** as previously decided in coordination with the FO(s).

Hibernating NLEB Range Mist-netting LOE:

Linear projects: a minimum of 4 net nights per km (0.6 miles) of suitable summer habitat (see Appendix F).

Non-linear projects: a minimum of 10 net nights per 123 acres (0.5 km^2) of suitable summer habitat.

After 2 consecutive nights of netting at the same location without capturing target species, you must change net locations or wait at least 2 calendar nights before resuming netting at the same location.

a) If no capture of NLEB(s), then no further summer surveys are recommended.

b) If capture of NLEB(s), then stop or proceed to **Phase 4** as previously decided in coordination with the FO.

MIST-NETTING SURVEYS TO CAPTURE INDIANA AND/OR NORTHERN LONG- EARED BATS AFTER ACOUSTICS WERE USED AS P/A METHOD (PHASE 3)

If netting was not conducted as the P/A method, then netting may be conducted to capture and characterize (e.g., sex, age, reproductive condition) the IBAT and/or NLEB (documented through the Phase 2 acoustic P/A survey) present in an area and to facilitate radio-tracking (Phase 4) efforts. We encourage working with the FO(s) to develop Phase 3 netting plans based on best available information (e.g., positive acoustic locations). There are no minimum requirements for this phase as this is not a P/A phase.

a) If no IBAT and/or NLEB are captured, then coordinate with the USFWS FO.
b) If IBAT or NLEB are captured, then proceed to **Phase 4** as previously decided in coordination with the FO(s).

NET PLACEMENT

Indiana and Northern long-eared bats typically forage in habitats that do not completely overlap (see species-specific habitat definitions in Appendix A) therefore, net placement should reflect these differences when targeting both species. Net placement along potential travel corridors (e.g., streams, logging trails, roads) as well as other edge habitats (e.g., other water sources, field edges) have traditionally been the most common habitats sampled due to their ease of access. However, non-traditional net placement in interior forest habitats may also be productive, especially for NLEB and IBAT (Carroll et al. 2002). Because the best survey sites for capturing bats may fall outside of a project footprint, the surveyor and project proponent should coordinate with the appropriate USFWS FO(s) to establish a project-specific maximum net placement distance from the centerline or project boundary

[31] NOTE: For Phase 2 P/A Surveys, wherever the phrase "no further summer surveys are recommended" occurs within this document, the USFWS FO(s) is in affect assuming probable absence of IBAT and/or NLEB during the summer.

prior to initiating surveys.

When sampling traditional travel corridors with defined edges, place net-sets approximately perpendicular to the edge and, ideally within bends or curves in the corridor that reduces bat reaction time to avoid capture. Net-sets should fill the corridor from side to side, extending beyond the corridor boundaries and into the interior forest to prevent bats from flying along the edges of the corridor and avoiding the nets, and from water (or ground) level up to the overhanging canopy. Surveyed corridors must have overhanging branches, most often within 9 m of the ground, that force bats to fly downward and into the nets. Net-sets of varying widths and heights may be used as the situation dictates. A typical net-set is at least 5 m to 9 m high consisting of two or more nets stacked on top one another (without gaps) and from 6 m to 18 m wide. If netting over water, ensure there is enough space between the net and the water so that captured bats will not get wet. Justification for placing net-sets perpendicular to a forest edge, or any net-set, without overhanging vegetation (i.e., no funneling effect) should be specifically provided in the survey report or ideally discussed with the FO(s) prior to sampling.

Because a) NLEB is a clutter-adapted gleaning species (see definition of suitable summer habitat in Appendix A) or b) a project area may not have well-defined travel corridors, surveyors may sample more non-traditional habitat types (e.g., small forest openings, ponds, interior forest). The typical equipment and placement described in the section above may be inadequate when netting for IBAT and NLEB in these non-traditional locations, where a travel corridor is less obvious. This would require innovation on the part of the surveyor (see Humphrey et al. 1968). For example, net placement in interior forests should be a minimum of 50 m from edge habitats and should represent a variety of understory cover and canopy closure (Carroll et al. 2002). Ponds and large water-filled road ruts can be productive places to net when other water sources are limited. See Kiser and MacGregor (2005) for additional discussion about net placement.

Mist-net sets should be spaced a minimum of 30 m apart, surveyors should attempt to evenly distribute net-sets throughout suitable habitat and not over-sample individual habitat features (e.g., three or more mist-net sets on a single travel corridor or stream). Surveyors must provide written justification in their report if net-sets were not distributed throughout suitable habitat (i.e., why were they clumped?). Surveys conducted for northern long-eared bat should include both traditional and non-traditional (as described above) net placements within suitable habitat when present. Net-sets can be repeatedly sampled throughout the project, but no more than 2 nights at a single location is recommended. In addition, changing locations within a project area may improve capture success (see Robbins et al. 2008; Winhold and Kurta 2008). Photo-document placement of net-sets.

SURVEY PERIOD

The survey period for each net shall begin at sunset[32] and continue for at least 5 hours (longer survey periods may also improve success).

CHECKING NETS

Each net-set should be checked every 10 minutes (Gannon et al. 2007). If surveyors monitor nets continuously, take care to minimize noise, lights, and movement near the nets. Monitoring the net-sets continuously with a bat detector (ideally using earphones to avoid alerting bats) can be beneficial: (a) bats can be detected immediately when they are captured, (b) prompt removal from the net decreases stress on the bat and potential for the bat to escape (MacCarthy et al. 2006), and (c) monitoring with a bat detector also allows the biologist to assess the effectiveness of each net placement (i.e., if bats are active near the

[32] Surveys may need to start a little earlier or later than official sunset times (i.e., at "dusk") in some settings such as a deep/dark forested valleys or ridge tops to avoid missing early flying bats or capturing late-flying birds, respectively. Sunset tables for the location of survey can be found at: https://sunrise-sunset.org.

net set but avoiding capture), which may allow for adjustments that will increase netting success on subsequent nights. There should be no other disturbance near the nets, other than to check nets and remove bats. Biologists should be prepared to cut the net if a bat is severely entangled and cannot be safely extracted within 3 or 4 minutes (CCAC 2003; Kunz et al. 2009). Capture and handling are stressful for bats. Emphasis should be on minimizing handling and holding bats to as short a time as possible to achieve field study objectives. Indiana and/or northern long-eared bats should not be held for more than 30 minutes after capture, unless the individual is targeted for radio-tracking. Bats targeted for radio-tracking should be released as quickly as possible, but no longer than 30 minutes[33] after capture, or as allowed in federal and state permits. See Kunz and Kurta (1988) for general recommendations for holding bats.

WEATHER, LIGHTING, AND OTHER ENVIRONMENTAL CONDITIONS

Severe weather adversely affects capture of bats. Some IBAT and NLEBs may remain active despite inclement weather and may still be captured while others in the same area become inactive. Therefore, negative surveys combined with any of the following weather conditions throughout all or most of a sampling period are likely to require an additional night of mist-netting[34]: (a) temperatures that fall below 50°F (10°C)[35]; (b) precipitation, including rain and/or heavy fog, that exceeds 30 minutes or continues intermittently during the survey period; and (c) sustained wind speeds greater than 9 miles/hour (4 meters/seconds; 3 on Beaufort scale) for 30 or more minutes.

NOTE: Provided that nets are not dripping wet, surveyors can resume netting to meet the minimum 5-hour requirement after short periods of adverse weather. If nets are under good cover, light rain may not alter bat behavior. However, if no bats are being captured during marginal weather, coordinate with the USFWS FO(s).

It is typically best to place net sets under the canopy where they are out of moonlight, particularly when the moon is half-full or greater. Net sets illuminated by artificial light sources should also be avoided. The shining of lights, and noise should be kept to a minimum with no smoking around the survey sites. In addition, the use of radios, campfires, running vehicles, punk sticks, citronella candles and other disturbances will not be permitted within 300 feet of mist nets (or acoustic detectors) during surveys.

DOCUMENTATION OF INDIANA AND/OR NORTHERN LONG-EARED BAT CAPTURES

If an IBAT and/or NLEB is captured during mist-netting, protocols for radio-tracking and emergence survey requirements, as provided in Appendix D and E, respectively, should be followed. In addition, the appropriate USFWS FO(s) must be notified of the capture within 48 hours (or in accordance with permit conditions), and the sex and reproductive condition of the bat and GPS coordinates of the capture site should be provided. Ensure GPS coordinates are recorded for each individual net set on datasheets.

Several species of bats from the genus *Myotis* share common features which can make identification difficult; IBATs and little brown bats (*Myotis lucifugus)* can be particularly difficult to distinguish. Photo documentation of all bats captured and identified as IBAT and/or NLEB and the first 10 little brown bats

[33] Current standard federal Section 10 bat permit conditions require prior written approval from the Field Supervisor in the USFWS FO(s) if capture times may exceed 30 minutes.

[34] With prior USFWS FO approval, a survey may be completed after August 15 if it was initiated in time to be completed by August 15 and extenuating weather circumstances resulted in delaying completion. Delays because of not meeting the acceptable weather requirements are the ONLY valid justification for surveying after August 15. If tracking is proposed, surveys should be scheduled so that tracking is concluded prior to August 15.

[35] Overnight survey temperatures may be lower in northern portions of the NLEB range, coordinate with the local USFWS FO in the northern portions of the range for any variation in temperature requirements.

per project are requested to verify the identifications made in the field.

Photo documentation should include diagnostic characteristics:

- a ¾-view of face showing ear, tragus, and muzzle
- view of calcar showing presence/absence of keel
- a transverse view of toes showing extent of toe hairs

Consider taking short video clips of the bat and its diagnostic features, as videos may also be helpful to later confirm bat identification. If a bat from the genus *Myotis* is captured during mist-netting that cannot be readily identified to the species level, then species verification may be attempted through fecal DNA analysis. Collect one or more fecal pellets (i.e., guano) from the bat in question by placing it temporarily in a holding bag (15 minutes is usually sufficient, no more than 30 minutes is recommended). The pellet (or pellets) collected should be placed in a small vial (e.g., 1.5 ml) with silica gel desiccant; pellets from each individual bat should be stored in separate vials and out of direct light. Fees charged by independent laboratories for sequencing fecal DNA samples is generally inexpensive (approx. $50 per guano sample).

BAT BANDING

Bat banding (i.e. application of any type of band to the forearm of a bat) should be limited to well-designed projects with clear objectives addressing a research question of significant importance to the species' conservation and coordinated with the appropriate USFWS FO and state agency. Bat banding should be limited to efforts that are committed to returning to the capture site or a location where marked bats have a high likelihood of being recovered (e.g., hibernacula), thus enabling meaningful data collection from marked individuals. If approved to band bats, surveyors are required to demonstrate that banding is approved on their USFWS 10(a)1(A) Recovery Permit and adhere to any State permit conditions.

Banding pliers are required for applying bands to bat forearms; securing bands by pinching a band down with fingertips is not permitted. Banding pliers should be maintained at the correct calibration to ensure proper function. Surveyors must carry needle nose pliers that can be used to safely remove a band that was either improperly placed or is causing distress to a bat.

Bats must be banded with bands that are appropriate in size for the species. TCB should receive 2.4 mm aluminum metal-lipped bands and IBAT and NLEB should receive 2.9 mm bands. Males should be banded on the right forearm and females on their left. Proposals that deviate from these standards must include written justification in the site-specific Study Plan submitted to the USFWS FO for approval. All band information needs to be included in the mist net survey report and as part of the annual Section 10 reporting spreadsheet.

Any recovered bats with bands on their forearms should be assessed for injury and their condition noted on the mist net data form, and as part of the USFWS 10(a)1(A) Permit reporting spreadsheet in the comment section of the Capture Data Worksheet. Surveyor should note (1) type of injury and (2) whether band was left on or removed. Photos and/or videos of the site of injury should be included with the report. If known, duration from time the band was applied should also be noted. Bands should be cautiously removed when bats show signs of injury, except in situations where band removal may result in additional trauma or fatality.

SUBMISSION OF MIST-NETTING RESULTS

Provide results of netting surveys to the appropriate USFWS FO(s) in accordance with previously agreed

upon[36] timeframes and formats[37]. If IBAT and/or NLEB are captured, this report should also include the results of subsequent radio-tracking and emergence counts. Reports should include the following:

1. Copy of prior phase reports (if not previously provided).
2. Explanation of any modifications from original survey plan (e.g., altered net locations)[38]
3. Description of net locations (including site diagrams), net sets (include net heights), survey dates, duration of surveys, weather conditions, and a summary of findings.
4. Map identifying netting site locations and information regarding net sets, including lat/long or UTM, individual net placement, net spacing (i.e., include mist-netting equipment in photographs of net locations), and adequate justification if net sets are not evenly distributed across suitable habitat within the project area.
5. Full names of mist-netting personnel attending each mist-net site during an operation, including the federally permitted/qualified biologist present at each mist-net site. Indicate on the field data sheet the full name of person who identified bats each night at each site.
6. Legible copies of all original mist-netting datasheets (see example datasheet below) and a summary table with information on all bats captured during the survey including, but not limited to: capture site, date of capture, time of capture, sex, reproductive condition, age, weight, right forearm measurement, band number and type (if applicable), and Reichard's wing damage index score (Reichard and Kunz. 2009).
7. Photographs of all net sets, as well as **all** IBAT and NLEB and the first 10 little brown bats captured from each project, so that the placement of netting equipment and identification of species can be verified. Photographs of bats should include all diagnostic characteristics that resulted in the identification of the bat to the species level.
8. Any other information requested by the local USFWS FO(s) related to the project.

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[36] As discussed in the Introduction, we encourage coordination with USFWS FO(s) prior to implementation of any surveys to ensure that all parties agree upon the need for surveys, the methods proposed, and the decisions from various survey results.

[37] In 2016, the USFWS implemented a new standardized approach for reporting of bat survey data. In addition to a traditional written report, federal permit holders are now required to submit their survey data using the standardized permit reporting spreadsheets available on the USFWS website provided in the intro.

[38] If the USFWS previously agreed upon the study plan, we need to understand whether the revised work still accomplished the agreed upon methods.

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Sample Data Sheets for Bat Surveys

Site No.				Project/Firm:								Date:
Location:												
County:				State:	Quad:							Quadrant:
Lat/Long (DMS):	N			W		Zone:						Surveyors:

#	Time	Species	Age	Sex	Repro. Cond.*	RFA (mm)	Mass (g)	Net/ Ht	Guano/ Hair	Wing Score	Band # Type
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
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25											
26											
27											
28											
29											
30											

Moon Phase:		%
	Rise	Set
Moon:		
Sun:		

Time	Temp	Sky	Wind	# Bats
Avg				

Sky Code	
0	Clear
1	Few Clouds
2	Partly Cloudy
3	Cloudy or overcast
4	Smoke or fog
5	Drizzle or light rain
6	Thunderstorm

Beauford Wind Code	
0	Calm (0 mph)
1	Light wind (1-3 mph)
2	Light breeze (4-7 mph)
3	Gentle breeze (8-12 mph)
4	Moderate breeze (13-18 mph)

*Repro. Cond (Reproductive Condition): (P) pregnant; (L) lactating; (PL) post-lactating; (NR) non-reproductive, (TD) testes descended

Sample Data Sheets for Bat Surveys

Net Site Diagram	Dominant Vegetation
	1
	2
	3
	4
	5

Net Site(s) by Habitat				
Habitat	A	B	C	
River				
Stream				
Pond				
Road Rut				
Corridor				
Cave/mine				
Total				

No. of Poles X Net length				
A	=		X	
B	=		X	
C	=		X	
D	=		X	

Other Species:

Comments:

APPENDIX C: PHASE 2 ACOUSTIC SURVEYS

SUMMER ACOUSTIC SURVEY SEASON: May 15 – August 15[39]

PERSONNEL[40]

Overall: Acoustic surveyors should have either completed one or more of the available bat acoustic courses/workshops put forth by various entities (e.g., Bat Conservation & Management, Bat Survey Solutions, Titley/AnaBat, Wildlife Acoustics, USFWS, Vesper Bat Detection Services) or be able to show similar on-the-job or academic experience. NOTE: Appendix C is intended for use within the IBAT range and/or NLEB hibernating range (see Figure 1); also refer to Appendix J for additional guidance on conducting acoustic surveys in the year-round active range of the NLEB.

Detector Deployment: Acoustic surveyors should have a working knowledge of the acoustic equipment and IBAT and/or NLEB ecology. Surveyors should be able to identify appropriate detector placement sites and establish those sites in the areas that are most suitable for recording high-quality IBAT and/or NLEB calls. Thus, it is highly recommended that all potential acoustic surveyors attend appropriate training and have experience in the proper placement of their field equipment.

Acoustic Analysis: Acoustic surveyors should have a working knowledge of the approved acoustic analysis programs, and any candidate acoustic analysis programs used for surveys. Thus, it is highly recommended that all potential acoustic surveyors attend appropriate training and have experience in the analysis of acoustic recordings.

Qualitative Analysis: Individuals qualified to conduct qualitative analysis of acoustic bat calls typically have experience: (1) gathering known calls as this provides a valuable resource in understanding how bat calls change and the variation present in them; (2) identifying bat calls recorded in numerous habitat types; (3) familiarity with the species likely to be encountered within the project area; and (4) individuals must have multiple years of experience and must have stayed current with qualitative ID skills. A resume (or similar documentation) must be submitted along with final acoustic survey reports for anyone making final qualitative identifications.

NOTE: The acoustic survey protocol may also be used for determining P/A of TCBs using the NLEB LOE for the 2024 field season; however, at this time, qualitative analysis is necessary for linear projects when using an approved version of Kaleidoscope Pro if the MLE is > 0.05 for all site-nights and 10 or more passes are auto-classified as potentially belonging to TCB at any site-night to reduce risk of false negatives. If you choose not to manually vet calls meeting these criteria, then you should assume presence of TCB for the project.

COORDINATION WITH USFWS FIELD OFFICES (FOs)

If not already required by federal permit, we recommend that applicants submit a draft study plan for all survey phases to the USFWS FO(s) for review and approval. Study plans should include a map/aerial photo identifying the proposed project area boundaries, suitable bat habitats and acreages within the project area, the proposed number and tentative locations of acoustic monitoring sites, and the identification of the approved (or candidate[41]) acoustic software program(s) (and version #) used for

[39] With prior USFWS FO approval, a survey may be completed after August 15 if it was initiated in time to be completed by August 15 and extenuating weather circumstances resulted in delaying completion. Delays as a result of not meeting the acceptable weather requirements are the ONLY valid justification for surveying after August 15.
[40] Coordinate with your local FO regarding any state-specific requirements.
[41] At this time, all acoustic software programs are considered 'candidate' for locations identified in Figure 2.

analysis of calls for the specific project. If a single software program is used for analysis, surveyors will not be allowed to switch programs from what was originally identified in their final study plan.

DETECTOR AND MICROPHONE REQUIRED CHARACTERISTICS

Full-spectrum (FS) and/or zero-crossing (ZC) detectors are suitable for use in this survey protocol, however, FS is preferred given that FS call files capture more detail and can be converted to ZC for analysis if desired. Detectors used during surveys must be able to retain detailed information that is important for distinguishing between bat species with overlapping echolocation characteristics (e.g. high frequency component of the call). Multiple detectors capable of recording high-quality data are available for commercial use (e.g. Anabat Swift, Wildlife Acoustics SM4BatFS, Pettersson D500×). Until further refinements and testing of the AudioMoth detector (Open Acoustic Devices) take place, use of this detector for P/A surveys is not acceptable (Starbuck et al. 2022; Kunberger and Long 2023).

Directional, hemispherical, and omnidirectional microphones are acceptable for acoustic surveys. The use of external microphones on an extension cable is the preferred deployment as it further limits degradation of call quality. Recording without directional horns on hemispherical and omnidirectional microphones is preferred as the addition of these systems may result in some signal degradation and directional microphones are commercially available.

Use recommended manufacturer detector settings for conducting IBAT and/or NLEB P/A surveys unless otherwise noted on the Service's IBAT Summer Survey Guidance webpage. For ZC detectors (as well as when converting WAV files to ZC files), the data-division ratio must be set to 8.

ACOUSTIC SAMPLING PROTOCOL

Detector/Microphone Placement

IBAT and NLEB typically forage in habitats that do not completely overlap (see species-specific habitat definitions in Appendix A); therefore, acoustic sites should reflect these differences when targeting both species. When sampling for multiple species, surveyors are expected to understand which sites are more likely to detect each species of interest and avoid oversampling habitat that only one species is likely to use. Early coordination with the FOs is highly encouraged to ensure the sampling methods are suitable. For instance, NLEB is a clutter-adapted gleaning species (see definition of suitable summer habitat in Appendix A), and therefore acoustic sites should target interior forests and forested riparian streams representing a variety of understory cover and canopy closure (Carroll et al. 2002). Ponds and large water-filled road ruts can be productive places to deploy detectors when other water sources are limited. Detectors placed on forest edges are less likely to detect NLEB.

Detector/Microphone placement is critical to the successful isolation of high-quality bat call sequences for later analysis. The following locations are likely to be suitable sites for detectors/microphones to sample for IBAT and/or NLEB, including, but not limited to: (a) forest-canopy openings; (b) near water sources; (c) wooded fence lines that are adjacent to large openings or connect two larger blocks of suitable habitat; (d) blocks of recently logged forest where some potential roost trees remain; (e) road and/or stream corridors with open tree canopies or canopy height of more than 33 feet (10 meters); and (f) woodland edges (Britzke et al. 2010). Of equal importance to acoustic site selection is the surveyor's working knowledge of the sampling volume and area of highest sensitivity within the zone of detection around a given microphone, which helps to ensure that detector placement as well as microphone selection and orientation are best suited for a particular site to ensure the detection zone is free of clutter. Detection distance, placement (e.g., location, orientation, height of microphone), and specific features (e.g., vegetation, water, and other obstructions) at the sample site should dictate whether a directional,

hemispherical, or omnidirectional microphone is used. If detectors/microphones are placed in unsuitable locations, effective data analysis may be impossible, and the results of the sampling effort will likely be invalid.

Many features (e.g., vegetation, water, wind turbines, high-tensile powerlines, micro-wave towers) can obstruct and reflect call sequences recorded in the field and thereby reduce the surveyor's ability to record high-quality bat call sequences. The following recommendations are provided to aid surveyors in their selection of acoustic sites (also see Chenger and Tyburec 2014). If surveyors choose acoustic sites outside of these recommendations, then adequate justification for doing so should be provided with the acoustic survey report provided to the USFWS FO(s); otherwise, results from these sites will not be accepted. Surveyors should deploy microphones: (a) at least 10 feet (3 meters) in any direction from vegetation or other obstructions (Hayes 2000; Weller and Zabel 2002; Chenger and Tyburec 2014, Fraser et al. 2020); (b) in areas without, or with minimal[42], vegetation within 100 feet (30 meters) of highly directional microphones or 33 feet (10 meters) from other microphones; (c) parallel to woodland edges; and (d) at least 49 feet (15 meters) from known or suitable roosts[43] (e.g., trees/snags, buildings, bridges, bat houses, cave or mine portal entrances).

Elevating a detector greater than 3 meters above ground level (AGL) vegetation may dramatically improve recording quality. Microphones can be attached horizontally to a pole to listen out into flight space, rather than just listening up from the ground. This will serve to increase the volume of airspace sampled and avoid the distortion effect of recording near the ground. However, the relationship between the zone of detection and the vegetation/clutter, not the placement of the detector is the most important consideration during site selection. Because NLEBs are a clutter- adapted gleaning species (see definition of suitable summer habitat in Appendix A), placement of detectors should be as close to clutter as possible but not in clutter.

Surveyors should distribute acoustic sites throughout the project area or adjacent habitats. In most cases, acoustic sites should be at least 656 feet (200 meters) apart. If closer spacing is determined to be necessary or beneficial (e.g., multiple suitable habitats and acoustic sites immediately adjacent to each other), sufficient justification must be provided in the acoustic study plan and survey report submitted to USFWS FO(s).

Verification of Deployment Location

It is recommended to temporarily attach GPS units to each detector (according to manufacturer's instructions) to directly record accurate location coordinates for each acoustic site that is paired with the acoustic data files. Regardless of technique used, accurate GPS coordinates must be generated and reported for each acoustic detector location.

Verification of Proper Functioning

It is highly recommended that surveyors ensure acoustic detectors are functioning properly through a periodic verification of performance to factory specifications (a service currently offered or in development by several manufacturers). It may be possible that independent service bureaus would be willing to perform this service, providing that a standard test/adjustment procedure can be developed.

[42] If necessary, surveyors can remove small amounts of vegetation (e.g., small limbs, saplings) from the estimated detection zone at a site, much like what is done while setting up mist-nets. Deployment of detectors/microphones in closed-canopy locations that typically are good for mist-netting are acceptable as long as the area sampled below the canopy does not restrict the ability of the equipment's detection zone to record high-quality calls (i.e., vegetation is outside of the detection zone).

[43] If the surveyor discovers a potential roost and wishes to document bat use, refer to Appendix E for guidance on conducting emergence surveys and contact the USFWS FO(s).

It is also recommended to ensure equipment is working during set-up in the field. This can be done simply by producing ultrasound (e.g., finger rubs, calibrator, or follow the equipment manufacturer's testing recommendations) in front of the microphone at survey start and survey finish. These tests document that the equipment was working when deployed and when picked up (and by assumption throughout the entire period). Detector field settings (e.g., sensitivity, frequency, etc.) should follow the recommendations provided by the manufacturer. Surveyors should also save files produced by detectors (e.g., log files, status files, sensor files) as an excellent way to provide documentation when equipment was functioning within the survey period. Many types of detectors allow for setting timers that initiate and end recording sessions. This saves battery life as well as reducing the number of extraneous noise files recorded. However, if the units are visited when the timer is on (i.e., unit is in standby mode), the surveyor cannot verify that the unit is functioning properly. This is particularly important in areas where no bat activity is recorded for the entire night or during the last portion of the night. In these cases, if the surveyor cannot demonstrate that the detector was indeed functioning properly throughout the survey period, then the site will need to be re-sampled, unless adequate justification can be provided to the USFWS FO(s).

Selection of acoustic sites is similarly important. Suitable set-up of the equipment should result in high-quality call sequences that are adequate for species identification. Nights of sampling at individual sites that produce no bat calls may need to be re-sampled unless adequate justification (e.g., areas with significant bat population declines due to WNS) can be provided to the USFWS FO(s). Modifications of the equipment (e.g., changing the orientation and/or microphone type) at the same location on subsequent nights may improve quantity and quality of call sequences recorded, which can be determined through daily data downloads. If modifications of the equipment do not improve call identification, then the detectors will need to be moved to a new location.

Orientation

Detectors deployed with directional microphones should be aimed to sample the majority of the identified flight path/zone to maximize the number of call pulses recorded from individual bats. Omnidirectional microphones deployed on a pole in the center of the flight path/zone should be oriented horizontally. In some circumstances, it might be desirable to aim a directional microphone straight up in smaller forest openings. As always, the goal is to sample as large a volume of likely bat flight space as possible while minimizing clutter. Hemispherical microphones should be aimed vertically, creating a dome-like detection field. Hemispherical microphones are best suited for open areas where deploying at heights greater than 3 meters AGL is problematic because of the lack of structure to hide the microphone and prevent it from becoming a novel item of interest to bats. Vertical orientation, however, precludes the use of weatherproofing for protection of the microphone. Once acoustic sites are identified, photographs documenting the orientation, detection zone (i.e., "what the detector is sampling"), and relative position of the microphone should be taken for later submittal to the USFWS FO(s) as part of the acoustic survey report (See Submission of Acoustic Survey Results for additional description).

Weather Conditions

If any of the following weather conditions exist at a survey site during acoustic sampling, note the time and duration of such conditions, and repeat the acoustic sampling effort for that night[44]: (a) temperatures fall below 50°F (10°C)[45] during the first 5 hours of survey period; (b) precipitation, including rain and/or fog, that exceeds 30 minutes or continues intermittently during the first 5 hours of the survey period; and (c) sustained wind speeds greater than 9 miles/hour (4 meters/second; 3 on Beaufort scale) for 30 minutes or more during the first 5 hours of the survey period. At a minimum, nightly weather conditions for survey sites should be checked using the nearest NOAA National Weather Service station and

[44] With prior USFWS FO approval, a survey may be completed after August 15 if it was initiated in time to be completed by August 15 and extenuating weather circumstances resulted in delaying completion. Delays as a result of not meeting the acceptable weather requirements are the ONLY valid justification for surveying after August 15.

[45] Overnight survey temperatures may be lower in northern portion of the NLEB range, coordinate with the local USFWS FO in the northern portion of the range for any variation in temperature requirements.

summarized in the survey reports.

Weatherproofing

Depending on the brand and model, bat detectors may or may not be weatherproof when delivered from the factory or supplier. Recording without after-market weatherproofing is preferred as the addition of these systems may result in some signal degradation. The decision to weatherproof detectors or not should be determined nightly based on the likelihood of precipitation in the survey area. If necessary, detectors should be placed in after-market weatherproof containers and an external microphone, attached by an extension cable should be deployed greater than 3 meters AGL.

For directional microphones, the use of a polyvinyl chloride (PVC) tube[46], generally, in the form of a 45-degree elbow the same diameter as the microphone (Britzke et al. 2010) is acceptable, if the situation requires the use of after-market weatherproofing. The microphone should be placed facing the open end of the elbow and as close to the opening as is consistent with the aim of weatherproofing. The microphone should be pointing at an angle below horizontal so water will not collect in it. Corben & Livengood (2014) showed that the direction of greatest sensitivity of tubes like this varies greatly depending on details of the specific tube shape and the exact position of the microphone. Often the greatest sensitivity will be pointed up at a substantial angle (up to 45 degrees) above horizontal when the microphone itself is pointing 45 degrees below horizontal. Users should be aware of the characteristics of the setup they use so they can know what region is being sampled. Again, the preferred option for weatherproofing detectors is to detach the microphone from the detector so that the detector can be placed in a weatherproof container, but the microphone (tethered by a cable) remains unobstructed.

Other after-market weatherproofing systems may become available and approved by the USFWS provided they show that call quality and the number of calls recorded are comparable to those without weatherproofing.

MINIMUM LEVEL OF EFFORT

The level of acoustic survey effort required for a project will be dependent upon the overall acreage of suitable habitat that may be impacted by the action (directly or indirectly). To determine the acoustic survey effort, quantify the amount of suitable summer habitat within the project area.

NOTE: for projects where impacts other than tree removal are likely (e.g., collision), ensure that P/A surveys are designed to cover all suitable habitat within the entire project area and NOT just the locations where tree removal is planned.

IBAT Range-wide Acoustic LOE (See Figure 1 and Table 2)

Linear projects: a minimum of 4 detector nights per km (0.6 miles) of suitable summer habitat (See Appendix F).

At least 1 detector location for at least 2 calendar nights (can sample the same location or move within the km site).

Non-linear projects: a minimum of 10 detector nights per 123 acres (0.5 km^2) of suitable summer habitat.

At least 2 detector locations per 123-acre "site" shall be sampled over the course of at least 2 calendar nights (may be consecutive) until at least 10 detector nights has been completed.

[46] The PVC option has only been tested with AnaBat SD1/SD2 detectors and directional microphones. It may not perform as well with other detector microphone combinations.

NLEB Range-wide Acoustic LOE (See Figure 1 and Table 2)

Linear projects: a minimum of 4 detector nights per km (0.6 miles) of suitable summer habitat (see Appendix F).

At least 1 detector location for at least 2 calendar nights (can sample the same location or move within the km site).

Non-linear projects: a minimum of 14 detector nights per 123 acres (0.5 km^2) of suitable summer habitat.

At least 2 detector locations per 123-acre "site" shall be sampled over the course of at least 2 calendar nights (may be consecutive) until at least 14 detector nights has been completed.

The acoustic sampling period for each site must begin at sunset[47] and ends at sunrise each night of sampling.

ANALYSIS OF RECORDED ECHOLOCATION CALLS

Step 5. Optional coarse screening - for high frequency (HF) or myotid calls (depending on available H/L frequency filters) or Proceed to Step 6.

a) If no positive detection of HF calls[48] (≥35 kHz) or myotid calls, no further summer/active season surveys recommended.

b) If positive detection of HF or myotid calls, then
   i) proceed to Step 6 for further acoustic analysis; **OR**
   ii) assume presence of IBAT and/or NLEB and coordinate with the USFWS FO(s); **OR**
   iii) assume presence and proceed to **Phase 3**.

Step 6. Conduct Automated Acoustic Analyses for each site that had HF or Myotid calls from Step 5 or ALL sites and ALL calls if Step 5 was not conducted.

Use **one or more** of the currently available 'approved' acoustic bat ID programs[49] (use most current approved software versions available and manufacturer's recommended settings for IBAT and/or NLEB P/A surveys) as previously identified in your Phase 2 study plan.

'Candidate' programs are not yet approved by USFWS for stand-alone use for P/A surveys but may be used in conjunction with one or more of the approved programs. At this time, no acoustic bat ID programs are 'approved' for many western states (Figure 2). Two or more of the currently available 'candidate' programs must be used for surveys conducted in these locations (always use most recent versions of software programs).

Include your plans for which specific software program(s) you will use in your survey study plan and submit for USFWS FO(s) review prior to conducting surveys. Beginning with acoustic data

[47] Surveys may need to start a little earlier or later than official sunset times (i.e., at "dusk") in some settings such as a deep/dark forested valleys or ridge tops to avoid missing early flying bats or capturing late-flying birds, respectively. Sunset tables for the location of survey can be found at: https://sunrise-sunset.org

[48] HF calls are defined as individual call pulses whose minimum frequency is ≥35 kHz.

[49] Approved and candidate programs are listed on the USFWS website provided in the intro; note all programs are considered 'candidate' for areas identified in Figure 2.

from night one at each acoustic site, run each night's data for each site through your chosen ID program(s). Review results by site by night from each acoustic ID program used[50].

a) If IBAT and NLEB presence is considered unlikely by the approved and candidate program(s) used in analysis, then no further summer surveys recommended.

b) If IBAT and/or NLEB presence is considered likely at one or more sites on one or more nights by any approved or candidate program(s) used in analysis, then

i) proceed to Step 7 for qualitative ID; **OR**
ii) assume presence of IBAT and/or NLEB and coordinate with the USFWS FO(s); **OR**
iii) assume presence and proceed to **Phase 3**.

Step 7. Conduct Qualitative Analysis of Calls.

At a minimum, for each detector site-night a program identified IBAT and/or NLEB presence likely (i.e., P<0.05), review all HF (i.e., ≥35 kHz) call files (regardless of MLE value and including no ID files) from that site-night. Qualitative analysis (i.e., manual vetting) must also include and present within a written report a comparison of the results of each acoustic ID program by site and night (see Reporting Requirements below).

a) If no visual confirmation of IBAT and NLEB, then no further summer/active season surveys recommended[51].

b) If visual confirmation of IBAT and/or NLEB, then

i) assume presence of IBAT and/or NLEB and coordinate with the USFWS FO(s); **OR**
ii) assume presence and proceed to **Phase 3**.

SUBMISSION OF ACOUSTIC SURVEY RESULTS

NOTE: All originally recorded (ZC or FS) data MUST be maintained for a period of 7 years and be made available to the USFWS FO(s), if requested. Failure to do so may result in invalidation of survey results. Results of acoustic survey data collected as part of P/A surveys must also be submitted annually in Section 10 reporting spreadsheets to the USFWS.

Provide results of acoustic surveys to the appropriate USFWS FO(s) within 30 days of completing the survey unless otherwise agreed upon with the local USFWS FO(s)[52]. Each acoustic survey report should include the following[53] (also, see checklist at end of this appendix):

[50] The approved acoustic identification programs all have implemented a maximum likelihood estimator (MLE) at this time. If the analysis of collected calls at a given site on a given night results in the presence of IBAT and/or NLEB with high levels of certainty (P<0.05), then select one of the options available in Step 6b.
[51] If you identify any suspected mis-identifications from programs, the Service will share those results with the software manufacturer(s) and the USGS to assist with future improvements and testing of software.
[52] As discussed in the Introduction, we encourage coordination with USFWS FO(s) prior to implementation of any surveys to ensure that all parties agree upon the need for surveys, the methods proposed, and the decisions from various survey results.
[53] In 2016, the USFWS implemented a new standardized approach for reporting of bat survey data. In addition to a traditional written report, federal permit holders are now required to submit their survey data using the standardized permit reporting spreadsheets available on the IBAT Summer Survey Guidance webpage (http://www.fws.gov/midwest/Endangered/mammals/inba/inbasummersurveyguidance.html).

1. Copy of habitat assessment (if not previously provided)
2. Explanation of any modifications from original survey plan (e.g., altered site locations)[54]
3. Full names of all personnel conducting acoustic surveys, including those that selected acoustic sites and deployed detectors
4. Full name and resume of individual(s) conducting qualitative acoustic analyses (if applicable)
5. Description of acoustic monitoring sites, survey dates, duration of survey, weather conditions, and a summary of findings
6. Table with information on acoustic monitoring and resulting data, including but not limited to: detector GPS coordinates for each detector, survey dates, survey hours
7. Map identifying acoustic detector locations and a corresponding table including the GPS coordinates. Include arrow(s) showing direction(s) of microphone(s)
8. Photographs documenting the location of each detector, the orientation of the detector, and the intended sampling area. Include detector and something for scale (e.g., vehicle, person) in photographs of acoustic sites
9. Description of acoustic detector and microphone brand(s) and model(s) used, microphone type, use of weatherproofing, acoustic monitoring equipment settings (e.g., sensitivity, audio division ratios), deployment data (i.e., deployment site, habitat, date, time started, time stopped, orientation), and call analysis methods used
10. A description of how proper functioning of bat detectors was verified
11. Discussion of what software program(s) was/were used (including settings)
12. Acoustic detector log files renamed by site identifier
13. Acoustic analysis software program output/summary results by site by night (i.e., number of calls detected, species composition, MLE results, settings files)
14. Discussion for any site-nights with zero bat calls (were additional nights added? was detector functioning? was placement appropriate?)
15. If manual vetting was used, discussion of how this was done (e.g., what keys were used?)
16. If manual vetting was used, detailed analysis and results of any qualitative acoustic analysis conducted on those projects where a program(s) considered IBAT and/or NLEB presence likely, including justification for rejecting any program MLE results (if applicable). We recommend providing a table with each species ID from the program(s), suggested species ID from manual vetting, and rationale for any changes.
17. Any other information requested by the local USFWS FO(s) related to the project

[54] If the USFWS previously agreed upon the study plan, we need to understand whether the revised work still accomplished the agreed upon methods.

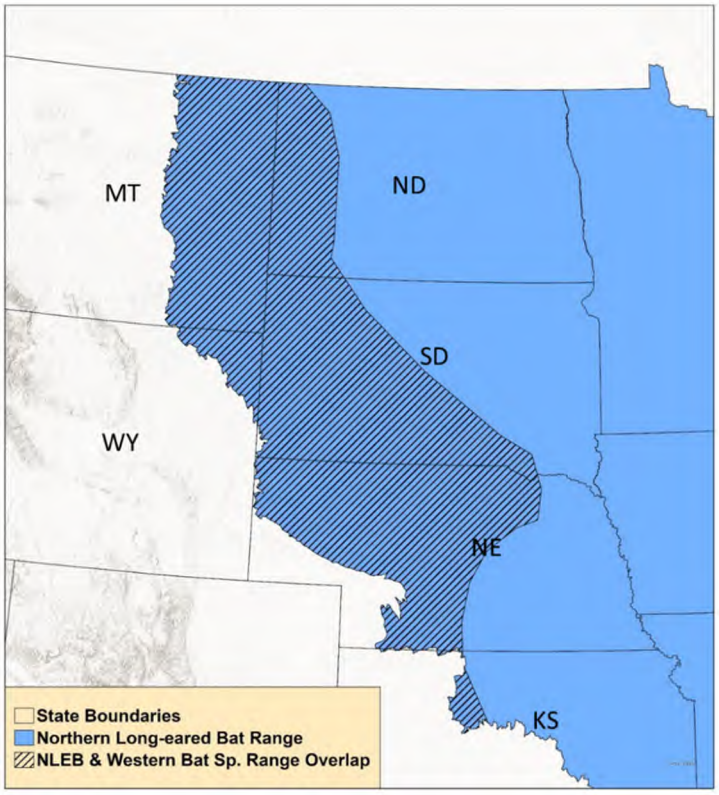


FIGURE 2. Portion of NLEB range overlapping with western bat species.

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General Checklist for Acoustic Surveys of Indiana and/or Northern Long-eared Bats

The following items should be documented and clearly presented within acoustic bat survey reports submitted to the Service

ACOUSTIC SURVEY INFO

- ☐ Project Name
- ☐ Site ID No./Name
- ☐ State and County
- ☐ Site Lat./Long. Coordinates (e.g., decimal degrees, NAD83)
- ☐ Approx. accuracy of Lat./Long. Coordinates
- ☐ Survey Date(s)
- ☐ Person who Selected Acoustic Site(s)
- ☐ Person who Deployed Detector(s)
- ☐ Detector Brand & Model
- ☐ Microphone Brand & Model
- ☐ Microphone Type: Directional/Hemispherical/Omnidirectional
- ☐ Type of Weatherproofing (if any)
- ☐ Microphone Height above Ground-level Vegetation(m)
- ☐ Distance from Nearest Vegetation or other Obstruction (m)(apart from veg. on ground)
- ☐ Horizontal Orientation of Microphone (1-360°)
- ☐ Vertical Orientation of Microphone (assuming 0° is parallel with horizon)
- ☐ Photographs of Detector Set-up at each Site
- ☐ Detector Settings and/or Log Files (all settings used for each brand/model of detector. For example, sensitivity, gain, data division, 16k high filter, sample rate, min/max duration, min trigger freq., trigger level, etc.)
- ☐ Survey Start Time (military)
- ☐ Survey End Time (military)
- ☐ Methods used to Field-test proper Functioning of Detector
- ☐ Were calls collected in Full Spectrum or Zero Crossing?
- ☐ Habitat Type and/or Feature Surveyed
- ☐ Weather Conditions during Survey Period

ACOUSTIC ANALYSIS INFO

- ☐ Program used to convert Full Spectrum to Zero Cross (if applicable)?
- ☐ Filter(s) used (if any) and parameters used (e.g., CFRead, noise, bug, etc.)
- ☐ Name of Service-approved Bat ID Software Program(s) and Version(s) used and Candidate program(s)(if used)
- ☐ Program Settings (if applicable):
  - Min. # of pulses for species ID
  - Min. # of pulses per group ID
  - Min. discrim. prob. for species ID
  - Other relevant settings affecting ID
  - Suite of species/groups included in program analysis
- ☐ Table summarizing Number of Calls ID'd for each Species/Site/Night/Program (including MLE p-values)
- ☐ If Qualitative Analysis was conducted, include Number of Calls Confirmed through Qualitative ID for each Species/Site/Night
- ☐ Full Name of Person(s) who conducted Qualitative Analysis
- ☐ Additional Survey Reporting Requirements
- ☐ Acoustic Report Appendices:
  - data sheets and maps,
  - photographs of detector set-ups,
  - computer screen captures of representative bat species identified during acoustic analyses, and
  - resume(s) highlighting relevant qualifications of person(s) who conducted qualitative analysis (e.g., experience visually identifying *Myotis*, certificates of training, publications etc.)

APPENDIX D: PHASE 4 RADIO-TRACKING

PERSONNEL

Transmitter Attachment: A qualified biologist[55] who is experienced in handling IBAT and/or NLEB and attaching radio transmitters must perform transmitter attachments, as further explained in the protocol below.

Tracking: Biological technicians and/or a qualified biologist who is experienced in tracking transmittered bats must be present and actively involved in all tracking activities for IBAT and/or NLEB as further explained in the protocol below.

NOTE: The radio-tracking protocol may also be used for captured TCBs; however, radio-tracking of TCB should prioritize identification of the immediate roosting area of the transmittered bat given the difficulty in locating the bats exact roosting location.

METHODS

If one or more IBAT and/or NLEB are captured, the following radio-tracking protocols will be applicable:

1. Biologists should coordinate in advance with USFWS FO(s) regarding radio-tracking recommendations (e.g., number and distribution of transmitters, including prioritization of sex/age and maximum number per site) and whether foraging data would be beneficial to collect. Also, professional judgment should be used to determine whether attachment of transmitters could compromise the health of a bat. Since the maximum holding times for IBAT and/or NLEB targeted for radio-tracking is 30 minutes[56], or as allowed in federal and state permits, surveyors should be prepared to place transmitters on bats immediately following their capture to minimize holding times.

2. The radio transmitter, adhesive, and any other markings (e.g., wing bands) should weigh less than 5% of pre-attachment body weight (Aldridge and Brigham 1988, American Society of Mammalogists 1998) and must comply with any USFWS and state permits. In all cases, the lightest transmitters capable of the required task should be used, particularly with pregnant females and volant juveniles. With pregnant bats, biologists should always use the lightest transmitter possible but no more than 5% of their expected non-pregnant weight.

3. Proper application methods are paramount to the successful retention of an applied transmitter. Qualified biologists should apply commonly accepted methods. Examples of available resources include:

    - https://tccarterlab.files.wordpress.com/2017/10/application-of-transmitters-in-small-insectivorous-bats1.pdf

[55] A qualified biologist is an individual who holds a USFWS Recovery Permit (Federal Fish and Wildlife Permit) for federally-listed bats in the state/region in which they are surveying and/or has been authorized by the appropriate state agency to mist-net for IBAT and/or NLEB. Several USFWS offices maintain lists of qualified bat surveyors, and if working in one of those states with authorizations in lieu of a Recovery Permits, the individual will either need to be on that list or submit qualifications to receive USFWS approval prior to conducting any field work.

[56] Current standard federal Section 10 bat permit conditions require prior written approval from the Field Supervisor in the USFWS FO(s) if capture times may exceed 30 minutes

- https://www.holohil.com/wp-content/uploads/2015/07/carter2009.pdf
- https://www.holohil.com/links/bat-attachment/#:~:text=Transmitters%20should%20be%20attached%20to,the%20fur%20is%20not%20clipped.

4. Adhesives (or "glues") used during radio-tracking and telemetry studies[57] to attach transmitters to bats must be included in the "Approved Adhesives for P/A Telemetry Studies" list (Table 3)[58]. The list includes commercially available latex and silicone-based cements that are known to adhere transmitters to bats for approximately 1 to 30 days. Latex-based rubber cements have a long history of use by researchers and to our knowledge have no adverse health effects to bats. Products that are likely to adhere transmitters to bats for more than 4 weeks or have been reported to have adverse reactions are not permitted (see Figure 3). For a list of examples of products that are currently not permitted, see Table 4.

TABLE 3. Approved Adhesives

Type	Active ingredients	Name	Manufacturer
Latex-based Surgical Cement[1]	Liquid latex, N-hexane, zinc oxide	Torbot	Torbot Group, Inc.
	Liquid latex, N-hexane, zinc oxide	Ostobond	Montreal Ostomy Products.
	Liquid latex, N-hexane, zinc oxide	Permatype	Perma-Type Company, Inc.
Silicone-based Surgical Adhesive[2]	Silicone solids, ethyl acetate	Uro-Bond III 5000	Urocare Products, Inc.
Butyl-cyanoacrylate Surgical Adhesives[3]	100% n-butyl cyanoacrylate	Vetbond	3M

[1] Liquid, malleable bonding cements that contain latex and take several minutes to cure. Bonds skin to skin.
[2] Liquid, malleable surgical adhesives that contain silicone and takes several minutes to cure. Bonds appliances to skin.
[3] Stiff, cyanoacrylate-based products react quickly with water to form a durable, waterproof bond.

TABLE 4. Examples of Prohibited Adhesives. (This list is not exhaustive)

Type	Active ingredients	Name	Manufacturer
Octyl-cyanoacrylate Surgical Adhesives[1]	100% 2-octyl cyanoacrylate	Dermabond	Zoetis Canada Inc
	100% 2-octyl cyanoacrylate	Surgi-Lock 2oc	Meridian Animal Health
	60% 2-octyl cyanoacrylate, 40% n-butyl cyanoacrylate	GluTure	Ethicon, Inc
	60% cyanoacrylate	Locktite 422	Henkel Adhesives

[1] Stiff, cyanoacrylate-based products react quickly with water to form a durable, waterproof bond.

[57] The Guidelines do not address recommendations for MOTUS based transmitter applications, wound closure for pit-tag studies, or other applications of adhesives. However, we strongly recommend researchers review SDS information for products prior to use to determine their safety for use on bats. Adhesives that are not recommended for use on human or animal skin should never be used to attach transmitters to bats or to close up pit tag wounds. Therefore, products such as (but not limited to) F2 Adhesive, Lash Grip, Shut Eye, and Locktite Superglues, whose Safety Data Sheets specifically state that the product is not intended for application to skin and may cause skin irritation, should be avoided.
[58] To request a specific product addition to the list of adhesives in Table 3, submit a request to FW4_Bat_Survey_Guidance@fws.gov. In the email, provide the product name, product Safety Data Sheet, manufacturer recommendations for product use, active ingredient list, whether the product was developed for human or veterinary purposes, if the product is designed for bonding appliances to skin (preferred) or for closing wounds and any other relevant information.

NOTE: Surveyors who recapture a bat after using any adhesive should observe the bat's skin for signs of irritation, infection, excessive fur loss, and take photos or a video of the area where transmitter was applied (for example, see Figure 3). Report information to the Guidelines Team (FW4_Bat_Survey_Guidance@fws.gov).



FIGURE 3. A photo of a back of an Indiana bat with significant fur loss three weeks after transmitter was attached using GluTure. In this example, the transmitter was applied using a small dab of GluTure between the scapulae.

5. Proposed radio telemetry equipment (e.g., receivers, antennas, and transmitters) and frequencies should be coordinated with the appropriate state natural resource agency and USFWS FO(s). Prior to purchasing transmitters, biologists should inquire with transmitter manufacturers about signal boosting to determine if this option would improve bat detectability in their planned work areas. Transmitters with modified signals must be built to last the duration of the telemetry study approved in the Site Study Plan (e.g., > 7 days).

   Surveyors should thoroughly test transmitter function prior to the Study. Transmitters should be new or no more than one year old at the time they are applied to a bat and should be stored as recommended by manufacturer prior to use. Transmitters more than 1 year old must be tested prior to the study to ensure function and no degradation in anticipated signal strength. To establish function, all transmitters should be temporarily activated for at least 24 hours. To determine signal strength, surveyors should temporarily activate transmitter and test receiver signal strength. Topography, ambient weather conditions, and location of the bat and direction of antenna are all examples of variables that will dictate the distance at which a signal is detectable, but in general, the signal should be consistently detectable from at least one mile away. Transmitters more than 2 years old should be refurbished before using for P/A surveys.

6. The qualified biologist or biological technician(s) should track all radio-tagged bats captured to diurnal roosts in accordance with permit requirements. We generally recommend tracking until the transmitter fails, fall off, or cannot be located for at least 7 days and should conduct a minimum of 2 evening emergence counts at each identified roost (See Appendix E for Emergence Survey Protocols). However, biologists are encouraged to continue radio-tracking efforts for the life of the transmitter. Biologists should contact the USFWS FO(s) immediately if they plan to cease tracking efforts before the 7-day tracking period ends. If landowner access is denied, approximate roost locations (i.e., coordinates) should be determined using triangulation.

7. Daily radio telemetry searches for roosts must be conducted during daylight hours and should be conducted until the bat(s) is located or for a minimum of 4 hours of ground or 1 hour of aerial-searching effort per tagged bat per day for 7 days. However, multiple bats captured at the same net location or nearby may be tracked simultaneously. Once a signal is detected, tracking should continue until the roost is located. At a minimum, biologists should document all ground and aerial-searching effort for all bats not recovered during radio- tracking for submittal with the survey report. For each roost identified during tracking, the biologist should complete a "USFWS

IBAT and/or NLEB Roost Datasheet".

8. To minimize potential for disease transmission, any equipment that comes in contact with bats should be kept clean and disinfected, following approved protocols; this is particularly a concern relative to WNS. Protocols are posted at http://www.whitenosesyndrome.org/. Federal and state permits may also have specific equipment restrictions and disinfection requirements.

SUBMISSION OF RADIO-TRACKING RESULTS

Phase 4 radio-tracking results should be included with the Phase 2 or 3 mist-netting report and submitted to the appropriate USFWS FO(s). Each report should include the following information related to radio-tracking efforts[59]:

1. Copy of prior phase reports (if not previously provided)
2. Explanation of any modifications from original survey plan (e.g., number of transmitters used, frequency of transmitters changed)[60]
3. Map and narrative detailing all ground and aerial search effort for all bats not recovered during radio-tracking and relative to the negotiated or agreed effort as determined by the appropriate USFWS FO(s)
4. Map summarizing IBAT and/or NLEB data collected from summer surveys for the proposed project (e.g., project area boundary and results from the site habitat assessment, acoustic survey, mist-net survey, radio-tracking, and emergence surveys)
5. Full names and permit numbers of personnel who attached transmitters to IBAT and/or NLEB and full names of all personnel conducting radio-tracking efforts
6. Photographs of all roosts identified during radio-tracking
7. Legible copies of all original USFWS IBAT and/or NLEB Roost Datasheets
8. Any other information requested by the local USFWS FO(s) where work was conducted

REFERENCES

Aldridge, H., and R.M. Brigham. 1988. Load carrying and maneuverability in an insectivorous bat: a test of the 5% "rule." Journal of Mammalogy 69:379-382.

American Society of Mammalogists. 1998. Guidelines for the capture, handling and care of mammals. Journal of Mammalogy 79:1416-1431.

[59] In 2016, the USFWS implemented a new standardized approach for reporting of bat survey data. In addition to a traditional written report, federal permit holders are now required to submit their survey data using standardized permit reporting spreadsheets available on the USFWS website provided in the intro.

[60] If the USFWS previously agreed upon the study plan, we need to understand whether the revised work still accomplished the agreed upon methods.

USFWS INDIANA AND/OR NORTHERN LONG-EARED BAT ROOST DATASHEET

Biologists (Full Name):_____ Date: _____

UTM: Zone_____ Easting _____ Northing_____ *OR*

LAT_____ LONG_____

Property Owner: _____ Phone#_____

State_____ County_____ Site #_____

Roost #_____ Roost Name: _____

Roost Tree Data

Species: _____ Live __ Snag __ Other _

(if other, explain) _____

DBH (in or cm) _____ Total Height (ft or m) _____

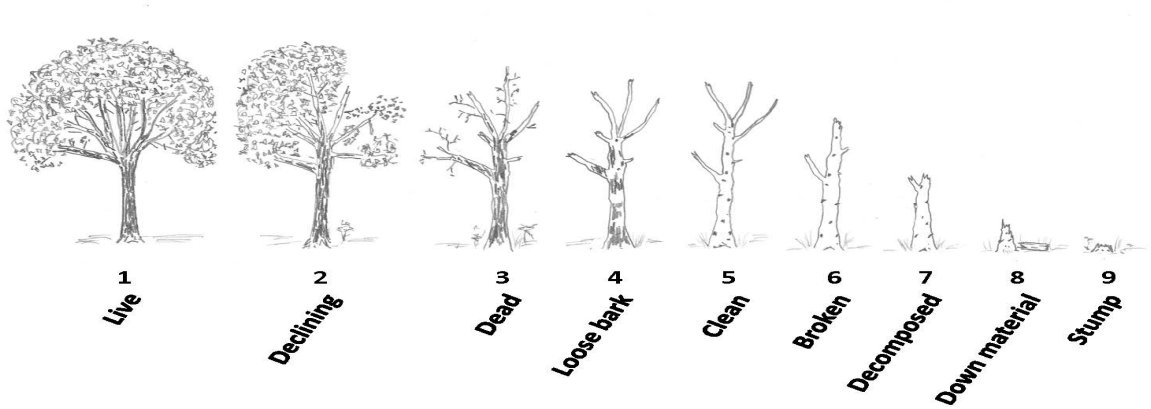
Height of roost area (if known) _____Dist. from capture site_____

Roost position aspect (deg) _____

Exfoliating bark on bole (%) _____ Describe: sloughing _ platy_ tight_

Cavities present? ____ If so, describe: _____

Roost Decay State: 1 2 3 4 5 6 7 8 9 Other



Roost tree or snag canopy position: Dominant __ Co-Dominant __ Suppressed _

Surrounding Habitat Condition

Canopy closure at roost (%) _____

Approximate woodlot size (ac or ha) _____ Distance to non-forest (ft or m) _____

Describe forest/woodlot current condition (mature, partially cut-over, burned, insect damage, etc.)

_____

_____

_____

_____

_____

_____

Additional Comments_____

_____

_____

_____

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APPENDIX E: PHASE 4 EMERGENCE SURVEYS

PERSONNEL

Qualified biologists[61], biological technicians, and any other individuals deemed qualified by a local USFWS FO may conduct emergence surveys for IBAT and/or NLEB by following the protocols below.

EMERGENCE SURVEYS FOR KNOWN IBAT AND/OR NLEB ROOSTS

The following protocols should begin as soon as feasible after identification of a diurnal roost (ideally that night):

NOTE: The emergence survey protocol should not be used for radio-tracked TCBs or emergence surveys of identified potential roosts given the variability in roosting locations typically used by the species (e.g., roosting in dead leaf clusters in the canopy of live trees) and difficulty observing bats emerging. An emergence count may be attempted on the rare occasion that the surveyor is able to discover the exact roosting location of a transmittered TCB and believes he/she can observe the bat(s) emerging.

1. Bat emergence surveys should begin one half hour before sunset[62] and continue until at least one hour after sunset or until it is otherwise too dark to see emerging bats. The surveyor(s) should be positioned so that emerging bats will be silhouetted against the sky as they exit the roost. Tallies of emerging bats should be recorded every few minutes or as natural breaks in bat activity allow. There should be at least one surveyor per roost. Surveyors must be close enough to the roost to observe all exiting bats but not close enough to influence emergence. That is, do not stand directly beneath the roost, do not make noise or carry on a conversation, and minimize use of lights (use a small flashlight to record data, if necessary). Do not shine a light on the roost as this may prevent or delay bats from emerging. Use of an infra-red, night vision, or thermal-imaging video camera or spotting scope is encouraged but not required. Likewise, use of an ultrasonic bat detector may aid in identifying the exact timing of bats emerging and may be used to help differentiate between low- and high-frequency bats species, and therefore, is strongly recommended. If multiple roosts are known within a colony, then simultaneous emergence surveys are encouraged to estimate population size. [NOTE: If a roost cannot be adequately silhouetted, then the local USFWS FO(s) should be contacted to discuss alternative survey methods].

2. Bat activity is affected by weather; therefore, emergence surveys should not be conducted when the following conditions exist: (a) temperatures that fall below 50□F (10□C); (b) precipitation, including rain and/or fog, that exceeds 30 minutes or continues intermittently during the survey period; and (c) sustained wind speeds greater than 9 miles/hour (4 meters/second; 3 on Beaufort scale).

3. Surveyors should use the attached (or similar) “Bat Emergence Survey Datasheet”.

[61] A qualified biologist is an individual who holds a USFWS Recovery Permit (Federal Fish and Wildlife Permit) for federally listed bats in the state/region in which they are surveying and/or has been authorized by the appropriate state agency to mist-net for IBAT and/or NLEB. Several USFWS offices maintain lists of qualified bat surveyors, and if working in one of those states with authorizations in lieu of a Recovery Permits, the individual will either need to be on that list or submit qualifications to receive USFWS approval prior to conducting any field work.

[62] Surveys may need to start a little earlier or later than one half hour before official sunset times (i.e., before “dusk”) in some settings such as deep/dark forested valleys or ridge tops, respectively. Sunset tables for the location of survey can be found at: https://sunrise-sunset.org

4. Surveyors should also complete an "IBAT and/or NLEB Roost Datasheet" for each roost known to be used by one or more IBAT and/or NLEB (see Appendix D for an example).

5. Completed datasheets should be included in reports prepared for the USFWS.

EMERGENCE SURVEYS FOR POTENTIAL IBAT AND/OR NLEB ROOSTS

In some limited cases (e.g., individual hazard tree removal during the active season[63]), surveyors may have the option of conducting emergence surveys for individual potential IBAT and/or NLEB roosts to determine use prior to removal. Evaluations whether potential roosts meet the criteria to conduct emergence surveys should be for each individual tree rather than groups of trees. The following protocol applies to these surveys:

1. Consult with the local USFWS FO(s) to determine whether a tree(s) that needs to be felled/ cleared may be potential roosting habitat for IBAT and/or NLEB and whether conducting an emergence survey is an appropriate means of avoiding take of IBAT and/or NLEB[64]. In general, the USFWS only approves of conducting emergence surveys as a means of avoiding direct take of bats for projects that only affect a very small number of potential roosts (e.g., less than or equal to 10)[65] in relatively small project areas. In addition, emergence surveys are only valid if all parts of the tree (limbs and trunk) can be observed by the surveyor. Therefore, trees within woodlands that are directly adjacent to other trees and whose canopy is blocked are not suitable for emergence surveys. An online directory of USFWS offices is available at: http://www.fws.gov/offices/.

2. If the USFWS FO(s) approves/concurs with Step 1, then follow the emergence guidelines for Emergence Surveys for Known IBAT and/or NLEB Roosts (above) to determine if any bats are roosting in the tree(s).

3. At the conclusion of the emergence survey:

    a. If **no** bats were observed emerging from the potential roost(s), then it maybe felled immediately. If safety concerns dictate that a tree cannot be felled immediately (i.e., in the dark), then the tree(s) should be felled as soon as possible after sunrise on the following day. If a tree is not felled during the daytime immediately following an emergence survey, then the survey must be repeated, because bats may switch roosts on a nightly basis. Immediately after the tree is felled, a visual inspection of the downed tree must be completed to ensure that no bats were present, injured, or killed. The USFWS FO should be contacted immediately if bats are discovered during this inspection.

    b. If **1 or more** bats (regardless of species, because species identification cannot reliably be made during visual emergence counts alone) are observed emerging from the roost, then it should **not** be felled, and the USFWS FO(s) should be contacted the next working day for further guidance.

[63] The active season periods for IBat and NLEBs are available in Appendix L.
[64] If a potential bat roost tree poses an imminent threat to human safety or property, then emergency consultation procedures should be followed as appropriate. (50 CFR §402.05). If a hazard tree does not pose an imminent threat, then the USFWS requests that it be felled during the bat's inactive season. When possible, felling of potential roost/hazard trees should be avoided during the primary maternity period to avoid potential adverse effects to non-volant pups (see Appendix L for specific inactive and pup season dates for your area).
[65] Areas containing >10 hazard trees will be assessed by the USFWS on a case-by-case basis with the project proponent.

SUBMISSION OF EMERGENCE SURVEY RESULTS

Emergence survey results should be included with the mist-netting survey report, unless the survey was completed as an evaluation of potential roosts and should be submitted to the appropriate USFWS FO(s) for review. Each survey report should include the following information related to emergence survey efforts[66]:

1. Copy of prior phase reports (if not previously provided)
2. Explanation of any modifications from the Phase 4 emergence count study plan (e.g., number of potential roosts surveyed), if applicable
3. Summary of roost emergence data
4. Map identifying location of roost(s) identified during radio-tracking and/or emergence surveys for IBAT and/or NLEB(s) including GPS coordinates
5. Full names of personnel present during emergence survey efforts and who conducted emergence surveys of roosts
6. Photographs of each identified roost
7. Copies of all "Emergence Survey" and "IBAT and/or NLEB Roost" datasheets
8. Any other information requested by the local USFWS FO(s) where work was conducted
9. Copy of the pre-approved site-specific written authorization from USFWS and/or state natural resource agency (if required)

[66] In 2016, the USFWS implemented a new standardized approach for reporting of bat survey data. In addition to a traditional written report, federal permit holders are now required to submit their survey data using standardized permit reporting spreadsheets available on the USFWS website provided in the intro.

USFWS BAT EMERGENCE SURVEY DATASHEET

Date: _____ Surveyor(s) Full Name: _____

State: _____ County: _____ Project Name: _____
Site Name/#: _____ Roost Name/# _____ Bat #:_____

Lat/Long or UTM of Roost: _____
Description of Roost/Habitat Feature Surveyed: _____

_____

Bat Species Known to be using this Roost/Feature (if not known, leave blank):

_____

Other Suspected Bat Species (explain): _____
Weather Conditions during Survey (temperature, precipitation, wind speed):

_____

Survey Start Time: _____ Time of Sunset: _____ Survey End Time: _____

NOTE: Emergence surveys should begin ½ hour before sunset and continue until at least one hour after sunset or until it is otherwise too dark to see emerging bats. The surveyor(s) should position him or herself so that emerging bats will be silhouetted against the sky as they exit the roost. Tallies of emerging bats should be recorded every few minutes or as natural breaks in bat activity allow. Ensure that surveyor(s) are close enough to the roost to observe all exiting/returning bats, but not close enough to influence emergence (i.e., do not stand directly beneath the roost and do not make unnecessary noise and/or conversation, and minimize use of lights other than a small flashlight to record data, if necessary). Do not shine a light on the roost tree crevice/cave/mine entrance itself as this may prevent or delay bats from emerging. If available, use of an infra-red, night vision, or thermal-imaging video camera or spotting scope and an ultrasonic bat detector are strongly recommended but not required.

Time	Number of Bats Leaving Roost*	Comments / Notes

APPENDIX E: PHASE 4 EMERGENCE SURVEYS

Site Name/#: _____ Roost Name/#: _____

Time	Number of Bats Leaving Roost*	Comments / Notes
Total Number of Bats Observed Emerging from the Roost/Feature During the Survey:		

* If any bats return to the roost during the survey, then they should be subtracted from the tally.

Describe Emergence: Did bats emerge simultaneously, fly off in the same direction, loiter, circle, disperse, etc. If a radio-tagged bat was roosting in the tree, at what time did it emerge?

APPENDIX F: LINEAR PROJECT GUIDANCE

For linear projects (e.g., pipelines and roadways) >1 km in length (shorter lengths should be considered as a non-linear project), surveyors have the option to use either mist nets or acoustic detectors in any given 1-km segment of suitable habitat. A survey site may also cover other associated linear project facilities (e.g., access roads) that are located within a pre-determined distance of each segment. When possible, surveyors should seek out the best available survey sites located within the footprint of the project alignment, and directly adjacent to, or near, the alignment if no suitable sites are available within the footprint. Because the best survey sites for capturing/detecting bats may fall outside of a project footprint, the surveyor and project proponent should coordinate with the appropriate USFWS FO(s) to establish a project-specific maximum distance from the centerline or project boundary prior to initiating surveys.

Tentative survey site locations along linear projects should be included in a proposed study plan to be reviewed and approved by the USFWS FO(s). Adequate survey effort should be conducted within each approximate 1-km segment that contains suitable forested habitat along the proposed workspace. It is not appropriate to cumulatively add up each habitat block crossed until 1km of habitat has been traversed. Segments along a linear project that do not contain suitable habitat should be skipped until the next patch of suitable habitat is encountered (Figure 4). Establishing exactly how many survey sites are needed for P/A surveys along a linear project often involves some give and take particularly in fragmented habitat areas (Figure 4, rows B and C). The final number of survey sites could be greater than the minimum number of sites prescribed in the protocol to adequately cover the areas of suitable habitat to be impacted. When available, habitat quality and quantity (e.g., size and location of suitable maternity roost trees) from on-the-ground habitat assessments can be used to fine tune and guide the placement of survey sites. In some marginal habitat areas, the quality and quantity of the existing habitat may be low enough to justify skipping some survey segments (e.g., Figure 4, Site 11). Likewise, some isolated woodlots, fence lines or individual trees may be considered too isolated and/or small to independently support bats and may be skipped if the USFWS FO(s) concurs. Habitat suitability in fragmented areas should be assessed on a site-specific basis and consider habitat configuration and connectivity to other suitable habitat patches. In general, we recommend surveying a few more sites for a project than the absolute minimum required.

In instances where a mist netting survey has been proposed, but no suitable mist net sites can be found or accessed within a particular segment, biologists should contact the USFWS FO(s) for further guidance or ideally agree in advance as to how such situations will be handled when encountered in the field (e.g., an acoustic survey may be substituted). Similarly, if an area of forest habitat that seemed suitable from aerial photography appears to be unsuitable or of particularly low quality upon field inspection, then you should coordinate with the USFWS FO(s) to determine if an area may be exempted from surveys. To avoid problems, any significant departures from previously agreed to survey plans should be justified and coordinated with the USFWS FO(s) prior to leaving the field.

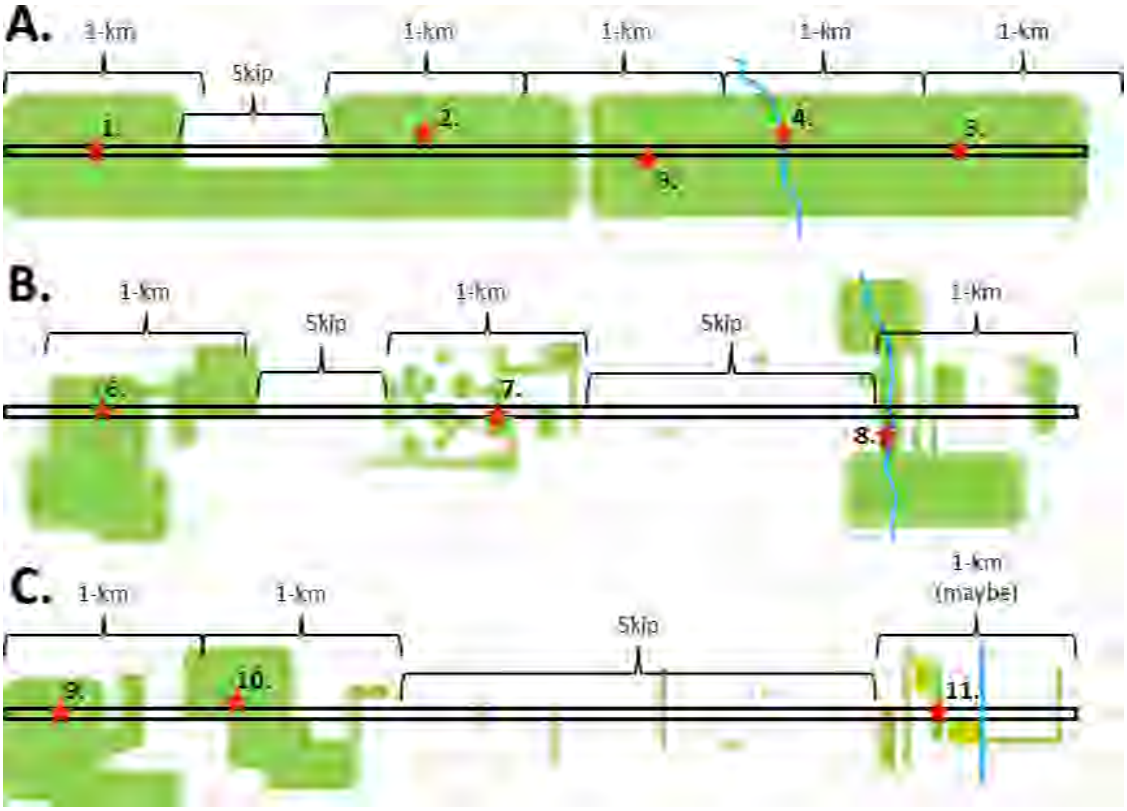


FIGURE 4. Conceptual linear project (black double lines) through relatively contiguous (A.) and fragmented (B. and C.) forested habitats (green patches) delineated into approximate 1-km survey sections. Numbered red stars represent suitable survey sites (1-11) on or near the project boundaries. Blue lines represent natural streams (A. and B.) and a ditch (C.). Yellow-green patches near Site 11 represent low-quality habitat.

APPENDIX G: THE OUTER–TIER GUIDANCE

Since early radio-tracking studies in Illinois, it has become standard practice for USFWS FOs to assume that an IBAT summer maternity colony will utilize suitable habitat within approximately 2.5 miles of its primary roost tree(s)/focal roosting area. However, if a reproductive adult female or juvenile IBAT is captured (or acoustically detected), but not radio-tracked to a roost site, then FOs typically assign its capture site a 5-mile conservation buffer and assume that its roost tree is located somewhere within 2.5 miles of the capture site. This approach is further detailed in the Service's IBAT Section 7 and Section 10 Guidance for Wind Energy Projects[67].

NOTE: The same principles used for the IBAT can be used for the NLEB using a 3-mile conservation buffer around capture/detections. Additionally, the outer-tier guidance may also be used for TCB presence/probable absence surveys using a 3-mile conservation buffer around capture/detections. "Outer-tier" guidance only applies to summer captures/detections (not hibernacula).

Because a 5-mile buffer encompasses four times more area than a 2.5-mile buffer (50,265 acres vs. 12,566 acres), it is reasonable to assume that only approximately 25% of a 5-mile buffered area is actually occupied by the documented IBAT summer maternity colony at any given time and that approximately 75% remains unoccupied or could be used by members of another yet undocumented colony(s). Therefore, if a subsequently proposed project is either ≤123 acres in size or affects ≤1% of existing suitable summer habitat within a 5-mile buffer (whichever is greater) but is situated ≥2.5 miles from the original capture/detection site, then it will have a relatively low probability of being within the true maternity colony home range (assuming suitable habitat is more or less evenly distributed in all directions from the capture site) (See Figures 5 & 6). Allowing project proponents of such "outer tier" projects to conduct a summer P/A survey for IBAT and/or NLEB using the standard survey level of effort (LOE) (as outlined in Appendix B and C) in such cases is reasonable and the additional survey data would 1) help refine the home range boundaries of the original colony, 2) confirm presence of additional colonies if present, 3) provide additional radio-tracking opportunities /roost tree locations, and 4) provide an option for project proponents to survey instead of always assuming presence.

Prior to emergence of WNS, NLEBs were widely distributed throughout much of the eastern U.S. and Canada. Although not nearly as common today, surveys show that the species continues to occur in pockets distributed throughout the WNS-impacted portion of its range. NLEB populations continue to remain stable in portions of the Southeast Coastal Plain (Virginia, North Carolina, and South Carolina) as well as in Alabama, Mississippi, and Louisiana where they are active year-round in forested or wooded habitats due to mild winter temperatures, and these populations, which are not dependent upon caves or mines for hibernation, may not be susceptible to WNS. Similarly, IBATs within the Northeast and Appalachian Recovery Units (RUs) have seen significant declines due to WNS; however, populations remain stable to increasing within the Midwest and Ozark-Central RUs (USFWS unpublished data 2023).

Due to the severity of the impact of WNS on populations across much of the hibernating NLEB and eastern IBAT RUs (i.e., Northeast and Appalachian) ranges, there is uncertainty where surviving NLEBs and IBATs are located in these portions of their ranges. To address this uncertainty, we recommend allowing project proponents whose project is either ≤123 acres in size or affects ≤1% of existing suitable summer habitat within a 5-mile (IBAT) or 3-mile (NLEB) buffer (whichever is greater) the opportunity to survey in both the inner-tier and outer-tier of known Hibernating Range NLEB buffers and IBAT buffers within the Northeast and Appalachian RUs when the buffered occurrence was prior to 2 years[68] after WNS was first confirmed in the state. We recommend coordinating with the local USFWS FO in the state where the proposed project survey is planned to determine whether inner-tier NLEB and/or IBAT

[67] Document is available on the USFWS website provided in the introduction.
[68] An alternative year may be used if the USFWS FO(s) has data to more precisely support when WNS affected abundance and distribution in their state.

buffers can be surveyed or not. Provided proponents use at least the prescribed minimum LOE for NLEBs and/or IBAT in these locations and the survey is approved by the Field Office, the USFWS would accept the results as evidence of presence/probable absence. For example, if WNS was confirmed in 2011, project proponents can survey both inner and outer tiers of a known buffer for presence/probable absence if the occurrence was in 2012 or earlier. For this example, presence/probable absence surveys could not be conducted in the inner tiers of occurrence buffers documented in 2013 and later.

NOTE: USFWS FO(s) may decide not to approve an outer-tier survey under the following circumstances: (1) If available forest habitat with a 5-mile (or 3-mile for NLEB) buffer is not more- or-less evenly distributed, but rather is highly clumped or restricted to a relatively narrow strip(s) (e.g., a riparian corridor); (2) <10% of a 5-mile (or 3-mile for NLEB) buffer contains suitable summer habitat; or (3) other site-specific reasons.

If a project proponent of an "outer-tier" project coordinates with the USFWS FO(s) upfront and conducts a valid summer mist-netting (Appendix B) or acoustic (Appendix C) survey using the appropriate LOE and does not capture/detect an IBAT and/or NLEB(s), then no IBAT or NLEB related restrictions will be required for that specific project area. However, all restrictions/ assumptions of IBAT and/or NLEB presence outside of a completed outer-tier project survey area shall remain intact indefinitely within the 5-mile (or 3-mile for NLEB) buffer zone or until additional negative survey data or discovery of roost trees indicate adjustments to a buffer are warranted by USFWS. Negative survey results from "outer-tier" projects are valid for 5 years for that project area. If an IBAT and/or NLEB(s) is captured/detected/radio-tracked during the survey, then the project area will be presumed to be occupied, restrictions will remain in place, and the USFWS FO(s) will reassess/adjust the original buffer(s) if warranted using the newly acquired bat location data.

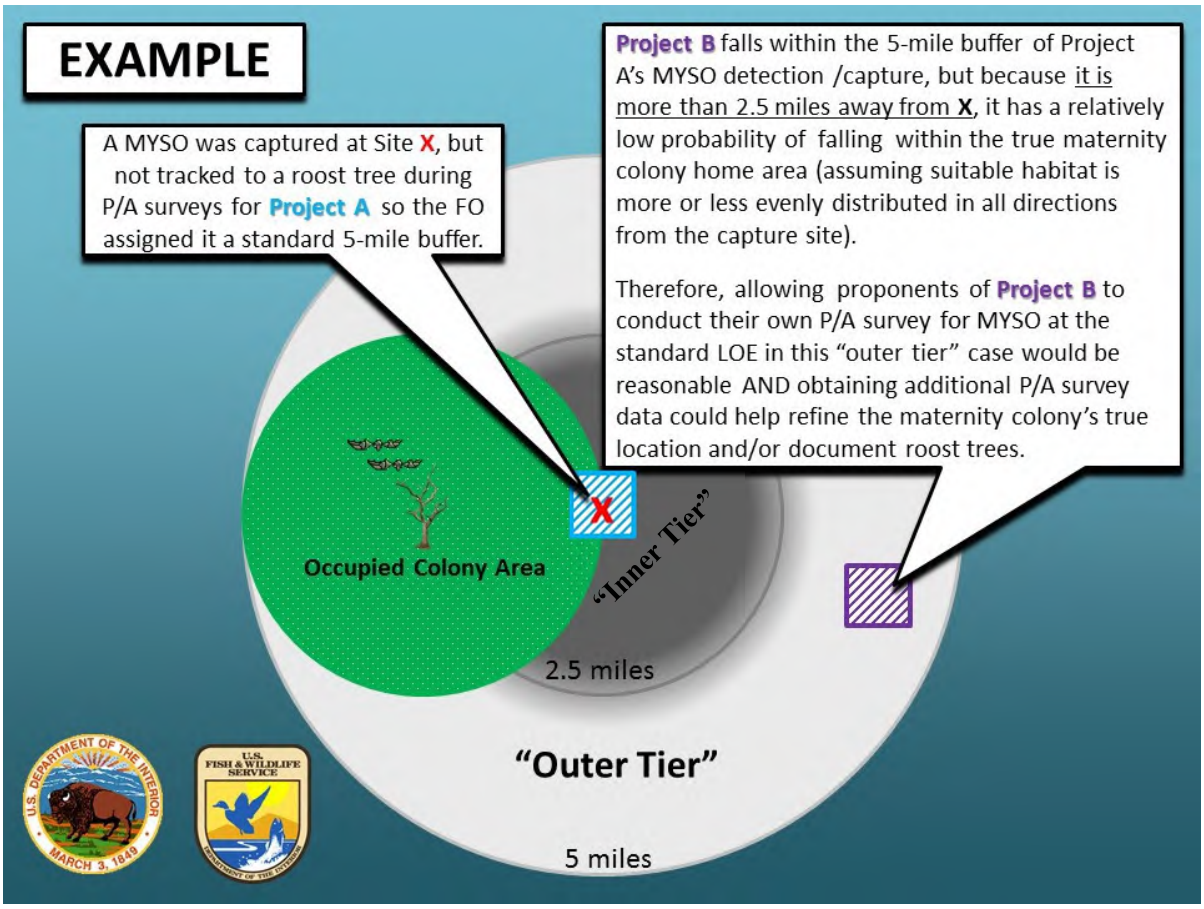


FIGURE 5. Graphical example depicting the proper application of the outer-tier guidance.

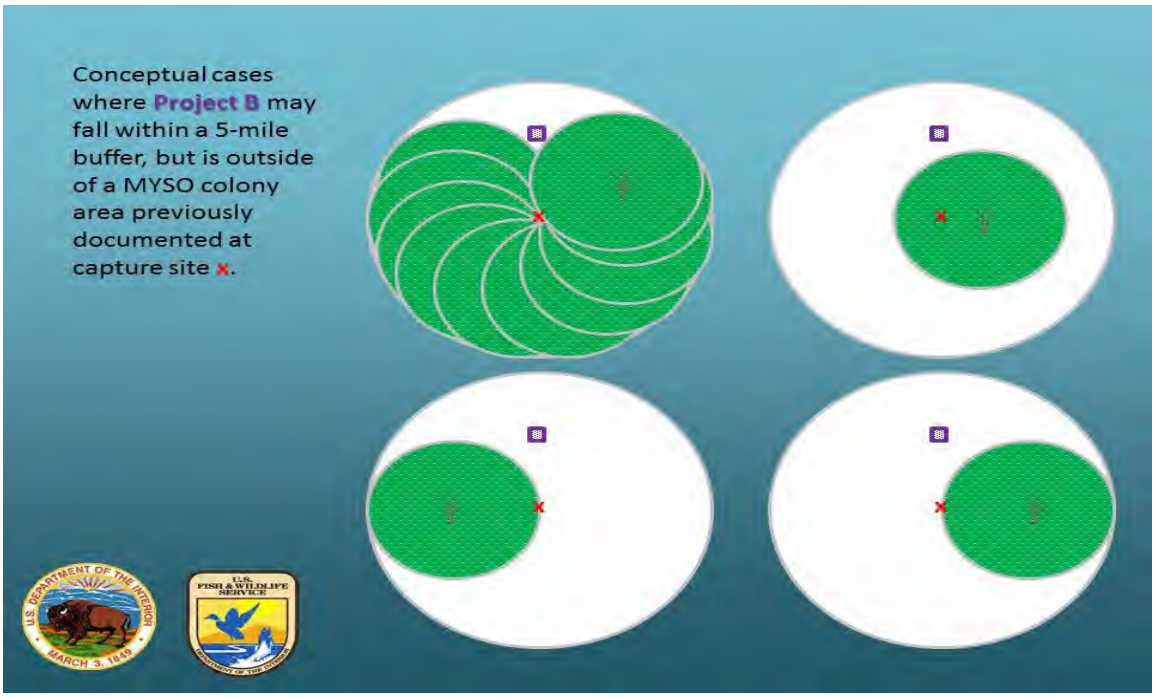


FIGURE 6. Hypothetical outer-tier scenarios where a proposed project area (depicted by a purple square) falls outside of the "true" IBAT maternity colony area(s) (depicted in green).

APPENDIX H: POTENTIAL HIBERNACULUM SURVEY GUIDANCE

Indiana and NLEBs have been documented using caves (and their associated sinkholes, fissures, and other karst features), as well as anthropogenic features such as mines and tunnels as winter hibernation habitat (i.e., hibernacula). Project proponents need to evaluate whether any potentially suitable IBAT and/or NLEB hibernacula exist within a proposed project area. This knowledge will be derived from a variety of sources. The following phased process should be followed to determine presence or probable absence of IBAT and/or NLEB in potential hibernacula:

NOTE: The potential hibernaculum survey guidance may also be used for TCB presence/probable absence surveys, including winter (internal) surveys, in portions of the TCB range that the species hibernates. TCBs use a wider variety and warmer hibernacula than what would often be considered as suitable for IBATs and NLEBs. Coordinate with the local USFWS FO(s) if you are proposing to use this guidance to survey for TCB.

PHASE 1 – INITIAL PROJECT SCREENING

Step 1. Coordinate with the USFWS FO(s) and appropriate state natural resource agencies regarding existing federally listed bat hibernaculum or other occurrence information.

Prior to initiating P/A surveys (Phase 2) of potential IBAT and/or NLEB hibernacula (as determined by the Phase 1 Habitat Assessment), the USFWS FO(s) and appropriate state natural resource agencies must be contacted to determine if any caves or other underground features have been previously documented as hibernacula or other habitat for federally listed bat species. Any proposed surveys of previously documented hibernacula must be coordinated directly with these agencies to ensure that adverse effects to listed species do not occur because of the survey.

Step 2. Desktop Analysis and Initial Field Reconnaissance.

After coordinating with the FO and appropriate state natural resource agency (when applicable), a desktop analysis and initial field reconnaissance should be completed by individuals with a natural resource degree or equivalent work experience and a solid understanding of karst topography and/or surface features associated with underground mines. These initial assessments can be completed at any time of year.

For all projects, a FO-approved field survey of all land within 0.5 miles of the edge of the project footprint (where access can be obtained) and documentation (e.g., a literature search, maps and information provided by local cave survey groups or grottos, review of aerial photography and topographical maps, previous mining records (if applicable), forest inventories, previous species survey reports, and the work of consultants or other designees) of all known caves and abandoned mines within 3 miles of the outside edge of the project footprint should be conducted. If caves or abandoned mines are found, further detail about the known or estimated underground extent of the cave/mine should be provided to the USFWS FO(s), including minimum and maximum depth of features and where those features are located on a map(s).

In general, underground openings can be deemed unsuitable as a hibernaculum and dismissed from further assessment and surveys if:

a) There is only one horizontal opening, and it is less than 6 inches (15.2 cm) in diameter;

b) Vertical shafts are < 1 foot (0.3 m) in diameter;

c) Passage continues < 50 feet (15.2 m) and terminates with no visible fissures that bats can access;

d) Openings are prone to flooding, collapsed shut and completely sealed, or otherwise are inaccessible to bats; and

e) Openings that have occurred recently (i.e., within the past 12 months) due to human activity or subsidence. (Include written documentation verifying this determination).

The results of initial field assessments should be submitted to the USFWS FO(s) and State regulatory partners (when applicable) for review and approval prior to proceeding to Step 3. FO- approved results from Step 2 will remain valid for a minimum of five years. **NOTE**: longer time frames may not be appropriate due to cave/mine dynamics.

Step 3. Conduct a Phase 1 Habitat Assessment of Potentially Suitable Hibernacula.

If underground openings are documented during field surveys in Step 2 and cannot be dismissed during initial project screening above, then a qualified biologist[69] will need to conduct a Phase 1 Habitat Assessment to determine whether bats using a potentially suitable hibernaculum within a project area could be adversely affected by the proposed project as described below (see Phase 1 Habitat Assessment Sample Data Sheet).

Habitat assessments should include all entrances or openings that will be directly or indirectly impacted by the proposed project. This would include those caves (and their associated sinkholes, fissures, and other karst features), as well as anthropogenic features such as mines and tunnels that are within the project site or that are otherwise connected (i.e., by physical passageway, airflow or hydrologically) to any underground feature that will be directly or indirectly impacted by the proposed project.

The results of a Phase 1 Habitat Assessment should be submitted to the USFWS FO(s) and State regulatory partners (when applicable) for review and approval prior to proceeding to Phase 2. FO-approved results from Step 3 will remain valid for a minimum of five years. **NOTE**: longer time frames may not be appropriate due to cave/mine dynamics.

PHASE 2 – PRESENCE/PROBABLE ABSENCE SURVEYS

Surveys to Confirm Use of Suitable Winter Habitat

If suitable winter habitat is discovered as a result of the Phase 1 Habitat Assessment above, do not alter, modify, or otherwise disturb entrances or internal passages of caves, mines, or other entrances to underground voids (potential hibernacula) within the action area before completing a Phase 2 survey. The survey protocols for determining occupancy are detailed below. Some surveys may require modification (or clarification) of these guidelines; therefore, submittal of a study plan and coordination with the USFWS FO(s) and state natural resource agency is necessary prior to initiating suitable winter habitat/hibernacula surveys. Submit results of completed summer and/or winter surveys to the appropriate FO(s) prior to clearing or altering of identified bat habitat. The USFWS FO(s) will review the results of P/A surveys conducted according to these guidelines for the purposes of determining whether IBAT and/or NLEB are occupying hibernacula in the project area and whether they may be adversely affected by any proposed actions.

[69] A qualified biologist is an individual who holds a USFWS Recovery Permit (Federal Fish and Wildlife Permit) for IBAT and/or NLEB in the state/region in which they are surveying. Alternatively, in States within Region 5 of the USFWS, state agencies assess qualifications and provide authorization to net, handle, and conduct hibernaculum surveys of/for IBAT and/or NLEB in that State (authorization is only valid in the State that provides the authorization). Several USFWS offices maintain lists of qualified bat surveyors, and if working in one of those states with authorizations in lieu of a Recovery Permits, the individual will either need to be on that list or submit qualifications to receive USFWS approval prior to conducting any field work.

WINTER (INTERNAL), FALL, AND SPRING SURVEY PROTOCOLS FOR IDENTIFYING POTENTIAL BAT HIBERNACULA

White-nose syndrome (WNS) is a devastating fungal disease that has killed unprecedented numbers of hibernating bats in eastern North America. WNS and/or *Pseudogymnoascus destructans* (Pd), the fungus causing the disease has been detected throughout the range of the IBAT, as well as most of the range of the NLEB. Users of this guidance must follow the recommendations provided in the most recent USFWS Cave Advisory[70] as they relate to reducing the potential for humans to disturb hibernating bats or inadvertently transporting Pd to uncontaminated bat habitats. All surveys conducted at caves/mines should be coordinated with the USFWS FO(s) and appropriate state natural resources agencies prior to initiation (see example USFWS Project Proposal Form).

Winter (Internal) Survey

Working near and within abandoned mines and caves can be inherently dangerous due to a variety of potential hazards (e.g., ceiling collapse and presence of toxic gases)[71]. Therefore, surveyors must thoroughly assess their work sites for any known and potential health and safety hazards and must use appropriate personal protective equipment and take proper precautions to avoid and minimize identified risks. Only sites that are deemed safe should be entered at the surveyor's discretion.

Potential hibernacula that are deemed safe to enter should be entered and all its accessible passages visually surveyed for the presence of IBAT during mid-winter (i.e., beginning January 1st and ending prior to March 1st of the same calendar year (also see Appendix 4 of the USFWS 2007 Indiana Bat Draft Recovery Plan: first revision). **NOTE:** The use of direct internal surveys is not adequate for NLEB due to the difficulty in visually detecting the species inside hibernacula (i.e., it typically roosts in deep cracks and crevices). Only properly trained and qualified individuals with the appropriate federal and/or state permits and equipment should attempt internal P/A surveys for the IBAT. If the qualified biologist, who completed the Phase 1 Habitat Assessment, does not have the necessary experience/permits to complete internal survey work, then this portion of the project should be subcontracted to another individual or group that does. If a site is unsafe or too difficult to enter or it is believed that significant portions of the underground system are inaccessible, it should be surveyed using the Fall or Spring emergence survey guidance to determine presence or probable absence of federally listed bat species, including the IBAT and/or NLEB (also see Sample Data Sheet for Fall or Spring Surveys of Potential Hibernacula).

Fall or Spring Emergence Survey

1A. Fall surveys of mine/cave entrances must be conducted between September 15 and October 31[72] and prior to any tree clearing by the project applicant. A minimum of one night of harp trap sampling per week for 6 weeks (i.e., 6 nights of sampling) is required at each suitable entrance as determined by the Phase 1 Habitat Assessment. Each night of sampling should be separated by at least one week of the survey window if weather conditions allow it. However, multiple nights of sampling per week can be accepted in the last two weeks of October if forecasted weather conditions

[70] https://www.whitenosesyndrome.org/press-release/updated-cave-advisory-recommendations-for-managing-access-to-subterranean-bat-roosts-to-reduce-the-impacts-of-white-nose-syndrome-in-bats

[71] The Service highly recommends that surveyors seek counsel from an occupational health and safety professional(s) prior to working underground or under other potentially hazardous field conditions.

[72] Timing of fall surveys may need adjustment based on location and weather conditions leading up to the survey. Coordination with local USFWS FO(s) and State regulatory partners (when applicable) during development of the study plan/project proposal form is required.

require it, at least 3 nights of sampling were completed during the first 3 weeks of the survey period, and the modification is approved by the appropriate USFWS FO(s). Survey effort may be suspended if no bats (of any species) are captured after the first 2 nights of acceptable survey effort in the fall. Surveys of a potential hibernaculum are in addition to any summer P/A surveys that may be required for a proposed project.

OR

1B. Spring surveys of mine/cave entrances must be conducted between April 1 and April 21[73] and prior to any tree clearing by the project applicant. Conducting surveys during the spring emergence is typically more complex than conducting fall surveys due to a greater number of uncontrollable factors (e.g., weather related factors). Thus, a minimum of three nights of harp trap sampling per week for three weeks (i.e., 9 nights of sampling) is required at each suitable entrance as determined by the Phase 1 Habitat Assessment. Due to the need to monitor weather conditions closely, each proposed spring mine/cave survey must be coordinated with the USFWS FO(s) and appropriate state natural resource agencies prior to surveying to ensure that adequate survey results are achieved. Surveys of a potential hibernaculum are in addition to any summer P/A surveys that may be required for a proposed project.

2. Unless otherwise approved by the USFWS FO[74], the capture of an IBAT and/or NLEB during a fall or spring mine/cave survey requires that the applicant complete three additional nights of sampling per week for three consecutive weeks (9 additional nights LOE) to determine the relative significance of the mine(s) and/or cave(s) and their associated underground workings to the IBAT and/or NLEB. If the mine/cave survey season (i.e., September 15 to October 31 for fall sampling and April 1 to April 21 for spring sampling) ends prior to the completion of the required additional sampling, then sampling must be completed the following fall or spring.

3. Harp traps are the preferred method for sampling entrances as they are less stressful on captured bats. Mist nets can also be deployed along corridors immediately adjacent to the entrance to increase survey effectiveness. Mist nets may also be used at the entrance but only when the mine or cave configurations are not suitable to harp trapping. The use of mist nets must be approved by the USFWS FO(s) and appropriate state natural resource agency prior to initiation of survey. Mist nets should be made of the finest, lowest visibility mesh commercially available. Currently, this is 2-ply, 50-denier nylon (denoted 50/2). The mesh should be approximately 1.5-inch in size. No other specific mist netting hardware is required.

4. Entrances must be entirely enclosed by the survey gear when harp trapping. If mist nets are used, entrances should not be entirely enclosed by the survey gear.

5. All entrances that are potentially inter-connected should be surveyed on the same night. In cases where one team of surveyors cannot feasibly sample all entrances in one night, a modified method could also be used; however, a minimum of 100 feet should separate surveyed vs un-surveyed entrances in cases where numerous entrances to a potential hibernaculum exist. This method should only be used in situations where the entrances are known to be interconnected. In this modified method, half of the interconnected entrances are surveyed on the first night, and the other half of the entrances are completely blocked using bird- exclusion netting, plastic sheets, or other impervious material. On the second night, survey efforts are reversed. Any materials used to block the entrances must be removed each night immediately after conducting the survey. No entrances should be left blocked over-night.

[73] Timing of spring surveys may need adjustment based on location and weather conditions leading up to the survey. Coordination with local USFWS FO(s) and State regulatory partners (when applicable) during development of the study plan/project proposal form is required.

[74] Additional survey effort may not be recommended in cases where a project proponent agrees to modify their project to completely avoid adverse impacts to newly documented hibernacula and if abandoned mine openings can be closed with a USFWS FO approved bat friendly gate design.

Plastics or other materials used to block the entrances should be removed each night immediately after conducting the survey. Entrances that are not connected (e.g., as determined by existing mine maps) do not have to be surveyed simultaneously.

6. The sampling period should begin at sunset and continue for at least 5 hours each night. During this time, harp traps (most preferable method) and/ or mist nets (acceptable method, but less preferable from a bat-handling perspective) should be monitored for captured bats on 30- and 10-minute intervals, respectively, to minimize the number of bats that escape while limiting disruption of the swarm in the fall or emergence in the spring. Surveyors monitoring set-ups must minimize noise, lights and movement near the traps or nets. Monitoring with night vision or thermal cameras can be beneficial: (a) bats can be detected when they are captured, (b) any evidence of bats escaping the trap or net can be documented, and (c) monitoring with night vision or thermal camera also allows the biologist to assess the effectiveness of each trap/net placement (i.e., if bats are active near the set-up but avoiding capture), which may allow for adjustments that will increase capture success on subsequent nights. There should be no other disturbance near the set-up, other than to check traps/nets and remove bats. Biologists should be prepared to cut the net if a bat is severely entangled and cannot be safely extracted within 3 or 4 minutes or reduce harp trap check intervals to less than 30 minutes when capture rates are high. Capture and handling are stressful for bats. Emphasis should be on minimizing handling and holding bats to as short a time as possible to achieve field study objectives. Bats should not be held for more than 30 minutes after capture or as allowed in federal and state permits.

7. If captures increase during the survey or if 6 or more bats of any species were captured during the last hour of monitoring, the survey effort must continue until activity declines or fewer than 6 bats are captured per hour. A total of 30 (fall) or 45 (spring) hours of sampling should take place for a mine/cave survey to be approved.

8. Severe weather adversely affects the activity levels of bats. If any of the following weather conditions exist during the fall or spring mine/cave survey, the time and duration of such conditions must be noted on the data sheets and in the survey report, and the survey effort for that night must be repeated: (a) winds sufficiently strong and variable enough to move equipment (i.e., traps or nets) more than 50 percent of the time; and (b) precipitation, including rain and/or fog, that does not stop within 30 minutes or continues intermittently during the survey period; and (c) temperatures that are less than 50° F (10° C) for the first 2 hours, and that drop below 40° F (4.4° C) at any point during the survey.

9. All bats captured during fall or spring surveys must be temporarily marked with a USFWS FO-approved non-toxic material that will last for the remainder of the survey period to identify any recaptures during subsequent survey nights.

10. If IBAT and/or NLEB (or other federally listed species) are captured during fall or spring mine/cave surveys, notification to the local USFWS FO(s) is required within 48 hours (or in accordance with permit conditions), and the sex and reproductive condition of the bat and GPS coordinates of the capture site should be provided.

11. A bat detector/roost logger should be deployed at each entrance during sampling to monitor bat activity when trapping or netting. Bat passes should be monitored and tallied hourly. Bat tallies should be reported along with the time sampled. Report the beginning time and number of bat passes in hour blocks. Analysis of recorded bat calls to attempt species identification should not be completed as these calls are not expected to be foraging calls.

12. Noise, the use of lights, or other potential disturbances should be kept to, at a minimum, no closer than 300 feet (91.4 m) of the sampling site.

13. At least one member of each survey crew must hold, and have in his or her possession, a valid endangered species collection permit issued by USFWS[7581] and/or the appropriate state natural resource agency that allows the qualified biologist to collect bats, including federally listed species. All activities must be carried out with strict adherence to permit conditions and authorizations specified in your federal permit, as well as any State authorizations. A qualified biologist(s) must (1) select/approve harp trap/mist-net sets, (2) be physically present at each site throughout the survey period, and (3) confirm all bat species identifications. This biologist may oversee other biological technicians and manage set-ups near one another as long as the traps/nets are being monitored as defined in bullet 6 above.

14. All survey efforts must follow the most recent USFWS decontamination protocols regarding WNS.

[75] Surveyors working in States within Region 5 of the USFWS only require a permit from the State where the survey is taking place.

Phase I Habitat Assessment Sample Data Sheet

Location _____

Observers (include permit numbers) _____

Latitude _____ **Longitude**[76] _____

Date ___ **Time** _____ **Temp (outside)** _____

	Opening #1	Opening #2	Opening #3	Opening #4
Opening Type (e.g., cave, portal, shaft)				
Opening vertical or horizontal				
Opening Size: Height x Width (or Diameter)				
Internal Dimensions: Height x Width				
Slope (up or down from entrance)				
Entrance Stable?				
Direction of Airflow (In or out?)				
Amount of Airflow (e.g., none, slight, heavy)				
Internal air warmer or cooler than outside temp.?				
Evidence of collapse?				
Ceiling Condition				
Amount of water in opening				
Evidence of past flooding?				
Observed length of internal passage				
Distance to nearest water source				
% Canopy Cover at entrance				
Foraging Signs? (e.g., moth wings)				

Are any portals suspected or known to be connected? Which ones?

Any observable side passages?

Additional comments:

Entry of abandoned mine portals, quarries, or caves can be extremely dangerous because of the potential for ceiling collapse and presence of toxic gases. Safety or health problems may occur as a result of entering abandoned mines. The FWS does not authorize or require anyone to enter any potential hibernaculum that is or could be unsafe while implementing surveys. These guidelines do not require any applicant or applicant employee, consultant, lessee, or other such designee to enter any cave, quarry, or mine portal.

[76] Provide coordinates for each opening.

Sample Data Sheet for Fall or Spring Surveys of a Potential Hibernaculum

DATE:	TEMPERATURE	Start:	End:
PRECIPITATION*:		WIND*:	
MOONLIGHT:	TIME	Start:	End:
PERSONNEL (include permit numbers):		LOCATION (lat/long):	

Time	Species	Age	Sex	Repro Cond.	RFA (mm)	Mass (g)	Flight Direction (in or out)	Notes and General Comments

***Precipitation and Wind should be measured hourly**

****Repro. Cond (Reproductive Condition): (P) pregnant; (L) lactating; (PL) post-lactating; (NR) non-reproductive, (TD) testes descended**

APPENDIX I: CALCULATING LOE FOR A COMBINED ACOUSTIC AND MIST-NETTING SURVEY

Numerous publications discuss the general advantages of using acoustics and mist-netting in tandem for inventorying bat communities (Kunz and Brock 1975, Kuenzi and Morrison 1998, Murray et al. 1999, O'Farrell and Gannon 1999, Flaquer et al. 2007). One of the stated objectives of the IBAT and NLEB survey guidelines is to maximize the potential for detection/capture of these species at a minimum acceptable LOE. The USFWS has long recognized that offering a combination acoustic and mist-netting option has advantages over the current single technique options presented in Appendices B and C; however, developing the methodology to calculate an acceptable LOE for a combined approach is challenging because our recommended LOE approaches were calculated based exclusively on either mist-netting or acoustic datasets.

Some advantages of a combined approach are that it provides flexibility to address challenging survey conditions (e.g., situations where mist-net set-ups are limited or the reverse). These situations are not uncommon, especially for linear projects which can pass through highly variable habitats. A combined approach provides project proponents with the ability to reduce overall survey time and cost while still providing for a suitable LOE. Finally, a combined approach alleviates challenges associated with number of sites/acoustic locations and limits on number of survey nights per net-site for projects impacting smaller acreages of suitable habitat.

To calculate the mist-netting and acoustic LOE using the combined approach the surveyor must consider survey LOE as a percent, and then balance the netting percent against the acoustic percent, which is what the guidance inherently does in setting the existing sole mist-netting and acoustic LOE standards.

- X mist-net nights of effort/123 acres = Y acoustic nights of effort/123 acres

First, determine the proportion of effort that will be applied using either the mist-netting or acoustic method. The decision to use mist-netting or acoustic should be made with consideration to the project area and the total number of high-quality survey sites of each survey method available for the species (i.e., IBAT and/or NLEB) the survey is being conducted for. Next, refer to Table 2 of the guidance and identify the highest LOE for the selected method and species' being surveyed. Finally, use the information above to calculate the total survey LOE that would be accomplished by the previously selected method at high-quality mist-net sets or acoustic locations for the proposed P/A survey.

Proportion of Effort (PoE) for combined LOE should be calculated as follows:

A. PoE using mist-netting x highest mist-netting LOE for surveyed species' = Total survey LOE in nights accomplished by mist-netting

   – or –

   PoE using acoustics x highest acoustic LOE for surveyed species' = Total survey LOE in nights accomplished by acoustics

Once the number of nights of the total survey LOE to be conducted by either method is known, then it can be used to determine the minimum required LOE for the other survey method. To calculate the necessary LOE for the second survey method, simply subtract the calculated PoE (see A, above) from 1 and multiply that proportion by the highest overall LOE for the second method for the species' being surveyed from Table 2.

B. (1 - PoE used in A, above) x highest overall species LOE prescribed for the method not used in

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A = Total number of survey nights necessary to meet the recommended LOE using the second method.

C. Round nights calculated in A and B up to nearest whole number.

EXAMPLE: The construction of a new bourbon distribution center (non-linear project) in KY falls within the range of IBAT and NLEB according to IPaC. A Phase 1 Habitat Assessment (see Appendix A) determined that 95 acres of suitable habitat for both species would be permanently removed to construct the project. The permitted bat biologist contracted to complete the P/A survey calculated that 35% of the project area could be surveyed with high-quality mist-netting set-ups.
Using the simple equation in A above, a total of 3 nights of mist-netting effort (0.35 x 6 = 2.1; rounded up) are recommended for this project impacting under 123 acres of suitable habitat. Using equation B above, the proposed project would need a total of 10 nights of acoustic effort ([1 – 0.35] x 14 = 9.10; rounded up) for the proposed project.

For the USFWS to approve a combined mist-netting and acoustic survey, the survey must be completed as described below:

1) There must be a minimum of two mist-net sets and two acoustic locations proposed in the study plan and surveyed to be accepted by the USFWS FO(s).
2) Each mist-netting set may only be surveyed two nights (either consecutive or otherwise) if a combined mist-netting/acoustic survey is proposed.
3) Surveyors should distribute mist-netting sets and acoustic locations throughout the project area or adjacent habitats. In most cases, net sets and acoustic locations should be at least 656 feet (200 meters) apart. If closer spacing is determined to be necessary or beneficial (e.g., multiple suitable habitats and acoustic sites immediately adjacent to each other), sufficient justification must be provided in the study plan, approved by the USFWS FO(s), and submitted as part of the survey report to the USFWS FO(s).
4) The combined mist-netting and acoustic survey, including the calculation of LOEs for each method, must be proposed and submitted for approval to the USFWS FO(s) with the study plan. The study plan must also include written justification for the use of the mixed effort including how the proposal will lead to improved survey quality. The mixed LOE may be adjusted before the beginning of the survey with written approval from the USFWS FO(s); however, no modifications are allowed once the survey has started.
5) Because the combined approach represents a single LOE for individual project areas, under no scenario can a surveyor use either mist-netting or acoustic Phase 2 surveys to challenge the other methods results. If a species is documented to be present with one method but not the other, then the USFWS FO(s) will still consider it present in the context of a subsequent consultation or other decision-making process.
6) Except for 1-5 above, all other guidance provided in Appendices B and C apply to individual mist-netting sets and acoustic locations under this combined survey approach.

REFERENCES

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APPENDIX J: GUIDANCE FOR SURVEYING YEAR-ROUND ACTIVE NLEBs

A portion of the NLEB's range overlaps with coastal areas of the eastern and southern U.S. where NLEB behavior, habits and habitat use differ significantly from the rest of the species' range. Bats may be active in these areas (see Figure 7) at any time of year and have not been documented utilizing traditional hibernation strategies found in the rest of the species range. Because of this, the USFWS collated and analyzed mist-netting data from local partners and worked with USGS and Virginia Tech to calculate year-round active NLEB minimum recommended LOE for mist-net surveys to provide expanded survey opportunities where allowed (also see Armstrong et al. 2023). Both acoustic and mist-netting techniques may be used in this region as a presence/probable absence method (Phase 2 surveys). Alternatively, mist-netting can be conducted for the purpose of attempting to capture NLEBs after detection during acoustic presence/probable absence surveys (Phase 3 surveys). The same recommendations (e.g., habitat assessments, personnel, coordination with USFWS FOs, nightly survey period, equipment, net/detector placement, checking nets, weather and other environmental conditions (temperature and precipitation), analysis of recorded echolocation calls, radio-tracking, emergence surveys, linear project guidance, outer-tier guidance, etc.) provided in other guidance appendices apply for either use of mist-netting or acoustics in the year-round active portion of the NLEB's range unless specifically addressed below.

NOTE: Where we consider the TCB active year-round (see Appendix L, Figure 9), surveyors can use these survey protocols applying the year-round active NLEB level of effort (LOE) with the following limitations: (1) an acoustic or combined acoustic/mist-net survey must be completed in portions of the range where IPaC identifies TCB as the only species; and (2) qualitative analysis is necessary for linear projects when Kaleidoscope Pro software produces an MLE > 0.05 for all site-nights and 10 or more passes are auto-classified as potentially belonging to TCB at any site-night. If you choose not to manually vet calls meeting these criteria, then you should assume presence of TCB for the project. Coordinate with the local USFWS FO(s) if you are proposing to use this guidance to survey for TCB to determine which LOE is appropriate for the specific project area.

SURVEY SEASON FOR YEAR-ROUND ACTIVE NLEBs: March 1 – October 15

While NLEBs may be captured in every month of the year in occupied coastal plain regions, the late fall/early winter is not an optimal time to conduct surveys because of lower and inconsistent temperatures as well as reduced availability of insect prey. Capture of reproductive adult females[77] (i.e., pregnant, lactating, or post-lactating) and/or young of the year between March 1 – October 15 confirms year-round presence of NLEB and the presence of a maternity colony in the area. Since adult males and non-reproductive females have commonly been found summering with maternity colonies, radio-tracking results will be relied upon to help determine the presence or absence of a maternity colony or large concentrations of bats in the area when only males and/or non-reproductive females are captured.

[77] We recognize that the reproductive condition of captured female NLEBs in early spring may not be possible; however, available data indicates NLEBs are not migrating to different areas from summer to winter so it is likely many of those adult females are indicative of the presence of maternity colonies.

Likewise, detection of NLEBs using acoustic equipment and approved[78] software program(s) confirms year-round presence in the project area.

MINIMUM PRESENCE/ABSENCE LEVEL OF EFFORT

The level of mist-netting or acoustic survey effort required for a project in the year-round active portion of the NLEB range will be dependent upon the overall acreage of suitable habitat that may be impacted by the action (directly or indirectly). To determine the survey effort, quantify the amount of suitable habitat within the project area. For projects where impacts other than tree removal are likely (e.g., collisions with infrastructure), ensure that presence/probable absence surveys are designed to cover all suitable habitat within the entire project area (where exposure to any kind of impacts may be anticipated) and NOT just the locations where tree removal is planned. Additional guidance for linear projects is available in Appendix F.

Year-Round Active NLEB Mist-netting LOE: (also see Figure 1 and Table 2)

Linear projects: a minimum of 2 net nights per km (0.6 miles) of suitable habitat (see Appendix F).

Non-linear projects: a minimum of 6 net nights per 123 acres (0.5 km2) of suitable habitat.

After 2 consecutive nights of netting at the same location without capturing target species, you must change net locations or wait at least 2 calendar nights before resuming netting at the same location.

a) If no capture of NLEB(s), then no further surveys are recommended.

b) If capture of NLEB(s), then stop or proceed to Phase 4 as previously decided in coordination with the FO.

Range-wide NLEB Acoustic LOE: (also see Figure 1 and Table 2)

Linear projects: a minimum of 4 detector nights per km (0.6 miles) of suitable habitat (see Appendix F).

Non-linear projects: a minimum of 14 detector nights per 123 acres (0.5 km2) of suitable habitat.

A minimum of 2 detector locations per 123 acre "site" shall be sampled until at least 14 detector nights has been completed over the course of at least 2 calendar nights (may be consecutive).

[78]For surveyors planning optional TCB P/A acoustic surveys in western states where the TCB range overlaps with western bat species and TCBs are year-round active for 2024, note that no acoustic ID software programs are approved for this portion of the TCB range. Refer to optional TCB survey guidance (see FAQ) and use of candidate software programs for 2024.

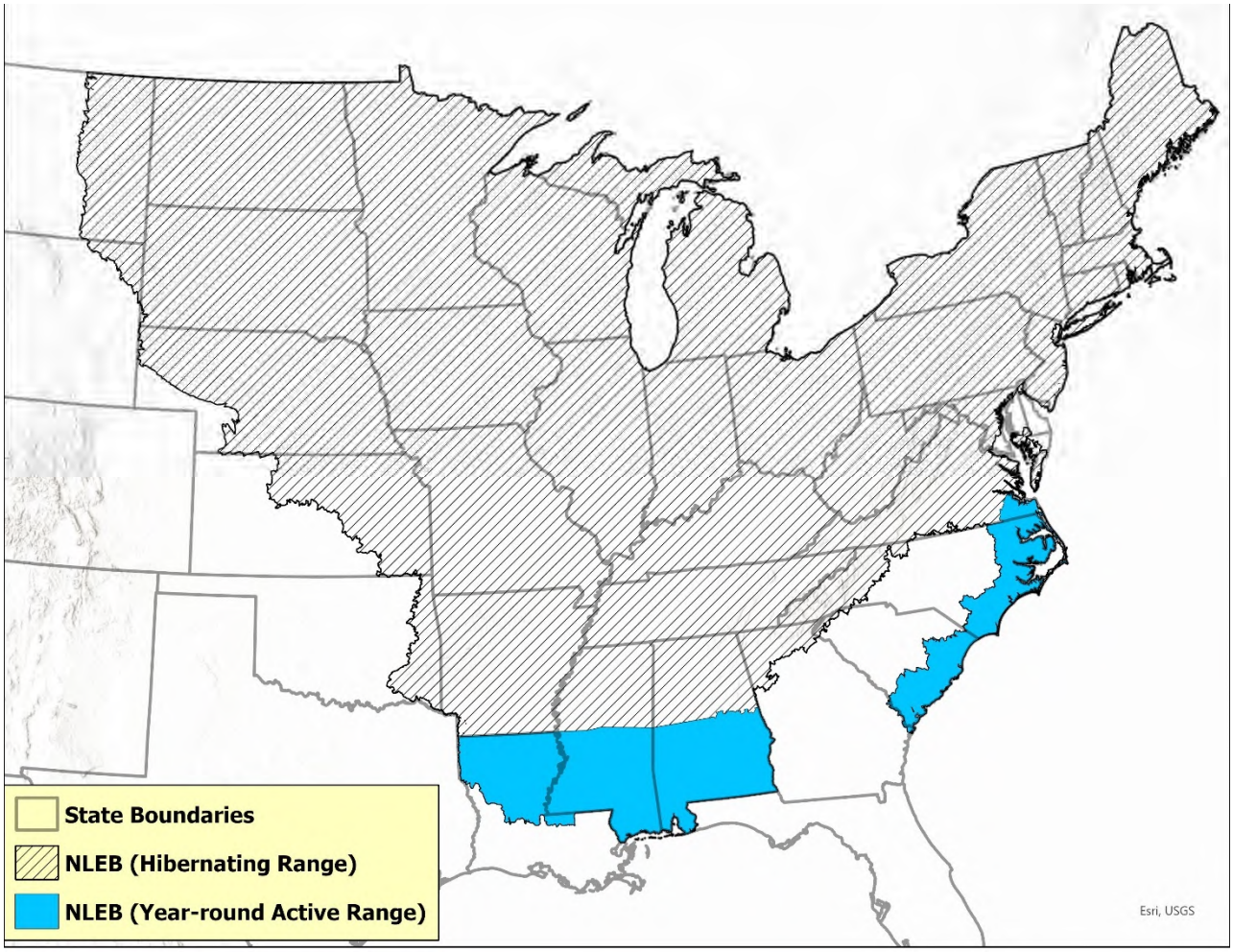


FIGURE 7. Areas delineated for use of year-round active NLEB survey guidance.

APPENDIX K: ASSESSING AND SURVEYING BRIDGES AND CULVERTS FOR BAT USE

Roadway transportation structures, specifically bridges and culverts, can provide suitable roosting habitat for bats. At least 24 North American bat species have been documented using bridges and culverts as roosting sites (Keeley and Tuttle 1999) and our understanding of the frequency of use improves as efforts increase to consider transportation structures as potential bat habitat. Georgia Department of Natural Resources reports presence of bats or guano at 20% of surveyed bridges and > 30% of surveyed culverts (GADNR, unpublished data 2023). Detweiler and Bernard (2023). conducted a literature review of 75 published studies finding that the use of bridges varies greatly across the landscape due to climatic factors, availability of natural roosts, and structural design. NLEBs and IBATs have been found using bridges and/or culverts throughout their ranges, as well as other species of conservation concern, such as the proposed endangered TCB. Use of this protocol is acceptable for TCB in 2024. Bats have been documented throughout the United States using bridges and culverts as maternity sites, hibernation sites, temporary resting sites during foraging, and during periods of staging and swarming. Often bridges are documented as important roosting locations during the active seasons (staging, maternity, and swarming; Detweiler and Bernard 2023, Keeley and Tuttle 1999) whereas culverts are often recorded as winter roost sites in areas where suitable cave habitat may be lacking, especially in the southern United States (USFWS 2022). However, there are exceptions to these generalizations and bats may use bridges or culverts at various times throughout their life histories.

A culvert[79] is a round or rectangular-shaped structure hydraulically and structurally designed to convey water, sediment, debris, and, in many cases, aquatic and terrestrial organisms through roadway embankments (Figure 8). Roadway culverts are usually composed of concrete or corrugated metal but can also be constructed of timber or PVC piping. Bridges[80] are vehicular or pedestrian structures that are larger and more structurally open than culverts and may span over waterways, various uplands, or urban areas. Bridges are constructed in numerous designs and are often composed of concrete, metal, wood, or a combination of these materials (Figure 9).

These guidelines describe who and what is needed to conduct surveys, and when and how to determine if bats, including IBAT, NLEB, and/or TCB, are using bridges and/or culverts as habitat. Bats' use of bridges and culverts as roosts varies considerably and depends on numerous factors such as structure type (including design and structural condition), area geography, surrounding habitat, availability of natural bat roosts in the

[79] The Federal Highway Administration (FHWA) defines a culvert as a structure comprised of one or more barrels or cells, beneath an embankment and designed structurally to account for soil-structure interaction. These structures are hydraulically and structurally designed to convey water, sediment, debris, and, in many cases, aquatic and terrestrial organisms through roadway embankments. Culvert barrels have many sizes and shapes and have inverts that are either integral or open, i.e., supported by spread or pile-supported footings. A culvert typically has soil materials (i.e., backfill) between the travel way (e.g., road or rail or trail) and actual culvert structure (i.e., barrels, cells). To support dead loads and live loads (e.g., cars, trucks, trains, pedestrians, etc.), the culvert consists of those barrels or cells (typically concrete, metal, or plastic material), backfill, and soil bedding underneath the culvert. In comparison, a bridge typically uses structural components and elements in the deck, superstructure and substructure (abutments and piers) to support those dead and live loads.

[80] FHWA defines a bridge as a structure including supports erected over a depression or an obstruction, such as water, highway, or railway, and having a track or passageway for carrying traffic or other moving loads. A bridge typically uses structural components and elements in the deck, superstructure and substructure (abutments and piers) to support dead and live loads. Bridges typically have an opening of more than 20 feet (measured along the centerline of the roadway) between under copings of abutments, spring lines of arches, or extreme ends of openings for multiple boxes.

vicinity, and seasonality of activity (e.g., year-round active range vs. hibernating range).Due to the numerous factors influencing bat use of bridges and culverts, both seasonally and geographically, the appropriate time of year for assessments should be coordinated with your local USFWS FO(s) and respective state wildlife agency(ies). Surveys resulting in probable absence for IBAT and NLEB are valid for two years[81] if this guidance is followed and the survey report is approved by the local USFWS FO(s). Validity timeframes for other bat species should be coordinated with your local USFWS FO(s) and respective state wildlife agency(ies). Those practitioners utilizing the Programmatic Biological Opinion in conjunction with Federal Highway Administration, Federal Railroad Administration, and Federal Transit Administration for Transportation Projects in the Range of the IBAT and NLEB, should follow these guidelines for completing assessments of bridges or culverts.

PERSONNEL

Before performing assessments for bats on bridges or culverts, surveyors should coordinate with their local USFWS FO(s) and respective state wildlife agency(ies) regarding potential field training opportunities that may be required. At a minimum, surveyors should view the USFWS's virtual bat and transportation structures training[82] before conducting field assessments. Additional trainings may be available in specific states.[83] We recommend individuals conducting reviews for bats use the included sample data form at the end of this Appendix to submit with your survey report as it will ensure all the necessary information is provided to the USFWS FO(s) and expedite review of your study plan and survey report. If you choose to submit a different data form with your survey report, please ensure, at a minimum, it includes all information requested in the sample data form. We also encourage the incorporation of the minimum data field requirements for contributing bridge and culvert assessment data into the North American Bat Monitoring (NABat) database; however, it is not required. Individuals assessing bridges and culverts should employ appropriate safety measures in conducting these reviews and avoid touching any bats.

EQUIPMENT

The following equipment is highly recommended at a minimum to complete bridge or culvert assessments for bats.

- A high-powered flashlight, headlamp, or spotlight (> 600 lumens)
- Binoculars and/or spotting scope
- Digital camera with video recording capability
- Data forms and writing utensil
- Sturdy footwear. Depending on conditions, waders or muck boots may be preferred
- Decontamination[84] equipment if within white-nose syndrome positive area
- Personal protective equipment, according to organizational or agency requirements

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[81] The timeframe of two years is to remain consistent with the Programmatic Biological Opinion for Transportation Projects in the Range of the IBAT and NLEB

[82] Virtual Training available at: https://www.youtube.com/watch?v=w3g9HDQFi3A

[83] In Georgia: To express interest in annual field training or additional online materials, please contact the USFWS Georgia Field Office or the Georgia Department of Natural Resources Nongame Conservation Section
In New Jersey: To express interest in field training, please contact the USFWS New Jersey Field Office or the New Jersey Department of Environmental Protection's Endangered and Nongame Species Program
In Indiana: Online training required by Indiana Department of Transportation is available here.

[84] Please refer to the White-nose Syndrome Decontamination Protocol available here.

APPENDIX K: ASSESSING & SURVEYING BRIDGES & CULVERTS FOR BAT USE

The following equipment may be beneficial or advisable depending on conditions at the site, level of difficulty in completing a thorough assessment, safety requirements of your institution, or other site-specific factors.

- Mirror with telescoping handle for viewing tight spaces
- Acoustic bat detectors
- Dust mask or KN95/N95 mask
- Cellular phone
- Handheld GPS
- Easily removed, protective coveralls and change of clothes if access requires crawling
- Guano sample collection materials
- Endoscope, borescope, or similar camera and light, perhaps attached to a telescoping pole. It is recommended to choose a camera with the option to view live footage in real time
- Specialized equipment such as ladders, kayaks or other floating equipment, or under bridge inspection vehicles, etc. may be useful in some circumstances



FIGURE 8. Representative culvert structures of various types, including a box culvert in Indiana (top; photo by USFWS); a round, concrete pipe culvert design in Georgia (bottom left; photo provided by Georgia Department of Natural Resources); and a corrugated metal pipe culvert design in Missouri (bottom right; photo provided by L. Droppelman).



FIGURE 9. Representative bridges with documented bat use, including a bridge with metal struts in Indiana (top; photo provided by Indiana Department of Transportation) and a concrete bridge in North Carolina (bottom; photo provided by North Carolina Wildlife Resources Commission).

ASSESSING BRIDGES/CULVERTS FOR BATS

Bridges and culverts can have many characteristics suitable for bat occupation. Many bat species will take advantage of cracks, crevices, voids, and other openings within structures. These can include cracks and openings caused by structural deterioration (e.g., cracking in concrete, rusted metal, etc.) and typical spaces existing via structural design (e.g., expansion joints). Bats may also roost in the open on rough surfaces or within drain or weep holes, along guardrails, and within jersey barriers or other voids. Additionally, many bridges and culvert designs create artificial “cave-like” environments where conditions are generally stable, thus allowing bats to use for extended periods of torpor, particularly in areas where natural cave-like habitats may be limited.

Step 1. Initial Assessment of Suitability and Safety

Prior to conducting any bridge or culvert assessment, a thorough safety assessment of each structure should be conducted to identify any potential health or safety hazards to surveyors and bystanders. Road traffic, unstable surfaces (e.g., riprap, deep sediment, ice, and swift moving water), or enclosed spaces are examples of some potential safety concerns. Surveyors should use appropriate personal protective equipment and take proper precautions to avoid and minimize identified risks according to their own comfort level and following the safety recommendations and guidelines required by their organization and local authorities. Only structures that are deemed safe should be entered at the surveyor's discretion.

Upon determining that a site is safe to enter, the bridge or culvert should be evaluated to determine whether it is generally suitable for bat roosting. Because most bridges will contain cracks and crevices that are of suitable size for bat roosting, any bridge that is safe to assess should be considered potential habitat for IBAT and NLEB, as well as TCB. Culvert suitability may vary by species. Table 5 includes the minimum diameter measurements for each species for consideration (adapted from USFWS 2022). The minimum length culvert that any of the species of interest has been documented is 23 feet (N. Anderson, personal communication), and should generally be considered the minimum suitable length for all three species. However, for safety reasons we do not recommend entry of any site less than 3 feet in diameter at the entrance, regardless of whether the site is greater than 23 feet in length. Practitioners should coordinate with local USFWS FO(s) and respective state wildlife agency(ies) to determine if local guidance deviates from these minimums when additional species may need to be considered. Additionally, culverts that are fully enclosed or blocked (e.g., under roadway or soil), enclosed with grills or grates, or fully obstructed in any other manner should not require an assessment. Partially enclosed or obstructed structures may be suitable and should be inspected if of the appropriate size. Uncertainties in suitability should be coordinated with the local USFWS FO(s) and respective state wildlife agency(ies).

TABLE 5. Suggested minimum culvert dimensions for determining IBAT, NLEB, and TCB suitability. If a site meets 1) the minimum entrance height/diameter for a particular species and 2) is 23 feet or greater in length*, it may be considered suitable to survey.

Species	Minimum Culvert Entrance Height/Diameter (feet)	Source
IBAT	4	L. Pattavina & E. Ferrall, personal communication, Georgia 2022
NLEB	4.5	N. Anderson, personal communication, Louisiana 2014
TCB	3*	USFWS 2022

* TCBs have been documented in culverts as small as 2 feet in diameter as reported in USFWS 2022; however, instances of TCB in culverts this small are expected to be rare. We do not recommend entry of sites less than 3 feet in height/diameter, regardless of length.

Step 2. Inspections of Bridges/Culverts and Indicators of Bat Presence

After an initial assessment if the bridge/culvert would be suitable for bats, surveyors should submit a completed USFWS Project Proposal Form or Study Plan to the local USFWS FO(s) for approval before they begin inspecting it for evidence of bat occupancy. The most ideal vertical crevices for bats are those that are 0.5 – 1.25 inches wide and > 4 inches deep (if sealed at the top) or >12 inches deep if not sealed. Although these characteristics represent the most ideal size of cracks and crevices for bat roosting, bats may be found in spaces that are larger and smaller than this range. Assessments should identify and inspect all cracking, crevices, spaces, and voids along the under deck of the bridge and support beams and inner walls, such as

below a fillet (a concrete filling between ceiling and vertical beam). Additionally, expansion joints that are unobstructed by debris or other blockages should be identified and inspected. Additional features to inspect include vertical spaces between end walls and bridge deck, areas of spall repair, guardrails and gaps in concrete parapet, plugged drainpipes, and weepholes. During the assessment, individuals should use high-powered flashlights, headlamps, or spotlights to examine all accessible parts of the bridge or culvert. Cave-like areas, recesses, and other similar features inside bridges or culverts (e.g., deck in the case of a bridge; see photos) should be searched in a similar fashion, although these areas may require the use of specialized equipment such as endoscopes. There are numerous indicators that can be used to determine bat use and presence within a bridge/culvert.

Visual

- ***Roosting Bats:*** Upon entry of the bridge/culvert, check for bats roosting out in the open. Open-roosting bats will typically be near the ceiling or on the ceiling itself of a culvert or similarly along the underdeck of a bridge. Bats will occasionally roost on or within bird nests, such as those composed of dried mud and created by various species of swallow (CBWG 2022). Bats may also take flight when disturbed and can be quickly accounted for during the assessment. Use binoculars/spotting scopes when attempting to locate bats roosting in higher areas of the bridge/culvert. If bats are present, record species (if determinable), total number, a description of the respective roosting locations, and representative photographs of the individuals (see Figure 10). Additionally, provide a sketch map, if possible, showing the locations of where the bat roosts exist on the bridge/culvert (use the bridge/culvert plan sheet as base for sketch). If any dead or injured bats are observed, take photographs and promptly notify the local USFWS FO(s) and respective State Agency(ies).



Figure 10 A TCB roosting on the ceiling of a culvert in Georgia (left; photo provided by Georgia Department of Natural Resources) and IBATS roosting in an expansion joint in Indiana (right; photo provided by USFWS).

- ***Urine and/or Body Staining:*** Urine or body oil stains may appear wet when bats have recently used the structure as a roost and are usually found in dark places. When dry, urine staining may have light-colored mineral deposits, but it can be difficult to differentiate from water staining (the latter often has presence of green algae). Dry urine staining can also be difficult to differentiate from concrete efflorescence (a deposit of soluble salts and bases, usually white in color, that sometimes

appears along cracks in concrete or masonry). For body oil staining, look for 4-6 inches-wide dark stains located on concrete support beams and walls immediately below the underdeck of the bridge, and beneath joints (Figure 11). It's important to note that staining on bridges and culverts can be caused by a wide variety of things other than bat presence. Guano deposits almost always accompany bat urine or body staining at structures, so "suspect" staining alone may not be sufficient evidence of bat presence (with the notable exception of structures with roost locations situated over waterways, where guano deposits would be washed away).



Figure 11. Open-roosting Indiana bats (*Myotis sodalis*) and associated urine staining on the underside of a bridge in Indiana (photo provided by R. Yaeger).

- ***Presence of Guano (bat droppings):*** Guano deposition is a relatively quick visual indicator of recent bat use of a structure. Individual bat guano pellets are small, brown/black in color, and unlike fibrous rodent droppings are more easily crushed and contain notable insect parts[85](Figure 12). Older droppings may be gray in color. These droppings will accumulate on the ground, floor of a covered bridge, pier caps, or on other horizontal structural components below where bats roost (Figure 13). Droppings may also adhere to vertical surfaces (e.g., support beams and walls) below roosts. Searches for bat droppings should be performed via the use of a high-powered flashlight. Surveyors should wear a dust mask (e.g., N95), and rubber boots are recommended for traversing

[85] Insect parts may be difficult to see without magnification. Low magnification handheld field microscopes or hand lenses are recommended for those practitioners regularly conducting guano sampling as part of bridge and culvert assessments.

through large guano deposits. All accessible cracks, cave-like areas, and expansion joints should be checked for the presence of guano. Confirmed and suspected bat droppings should be noted and their location within the bridge/culvert should be documented. Additionally, representative photographs should be taken of guano deposits in-situ, with a ruler or other object for scale, prior to crush-testing or collecting any guano samples (note: if guano samples are intended to be collected, refer to the guano sampling section of this Appendix). It is notable that in many cases, guano accumulation in culverts or at bridges over water will be minimal due to the regular inflow and outflow of water. In these situations, urine and body staining may be a more important indicator of bat use than guano accumulation.



Figure 12. Examples of guano accumulations on bridges. (photos provided by Georgia Department of Natural Resources (top) and Indiana Department of Transportation (bottom)).



Figure 13. Examples and comparative sizes and characteristics of bat guano from little brown bat (*Myotis lucifugus*) and big brown bat (*Eptesicus fuscus)* (left; photo provided by Vermont Fish and Wildlife Department)*;* Guano deposit from colony of Yuma bats (*M. yumanensis*) on horizontal bridge structure (right; photo provided by P. Crawford/ Oklahoma Department of Transportation).

Sound and Smell

Bats occupying bridges/culverts may audibly vocalize when approached, thus high-pitched squeaking or chirping can be a quick indicator of current use. Surveyors that have difficulty hearing high pitch noises may find an acoustic detector with an external speaker or headphone jack helpful for detecting bat chatter, but use of this equipment during visual inspections is not required. Guano deposits, especially large amounts, also have an ammonia odor that can be apparent in some situations.

Step 3. Inaccessible Areas and Additional Assessment Options

In some situations, there will be portions of a bridge/culvert that may be inaccessible or unsafe for thorough inspections. In these instances, we recommend coordinating with the USFWS FO, State Agency(ies), and/or local Department of Transportation to determine if any of the following inspection methods or alternate assessment methods included here are recommended.

- ### Acoustic Surveys

  Note: In some circumstances, acoustic surveys can be used to assist in assessing and characterizing bat colony use of a bridge or culvert. However, acoustic surveys should be conducted with caution and only by experienced practitioners. Detectors may also need to be placed further back from the structure to avoid ultrasonic noise associated with vehicle traffic, powerlines, and other nearby infrastructure. Acoustic collections should only be used as a supplement to a larger suite of structural survey/assessment approaches and cannot be used to determine species identification as a

stand-alone method (refer to Appendix C for performing acoustic surveys to determine P/A of IBAT and NLEB). An example scenario where an acoustic survey at a bridge or culvert may be appropriate includes the use of acoustic equipment to assist in an emergence survey for a structure that has been determined to be unsafe to enter or inspect using traditional methods.

- **Emergence Surveys**

  Emergence surveys may be used as a supplementary tool to determine use of a structure and can only be used once IBAT and/or NLEB colony presence has been confirmed. If emergence surveys are planned for the structure for TCB, contact the local USFWS FO(s) and respective State Agency(ies) to determine if Appendix E of the Survey Guidelines is applicable, or if a modified approach is appropriate for the situation.

- **Alternative Techniques**

  Assessments from kayak/boat with binoculars to inspect areas over deep water, as well as ladders or construction equipment (cherry pickers, snooper truck, etc.; Figure 14) to access high areas of structures or areas over deep water may be necessary in certain situations.



Figure 14. Biologists use a snooper truck to assess expansion joints and concrete caps over deep water (photo provided by Georgia Department of Transportation).

SPECIES IDENTIFICATION

Visual Identification

Visual identification of species may be possible by experienced practitioners, such as those individuals that have Section 10(a)(1)(A) permits to conduct bat surveys. However, voucher photos should be taken with high-quality cameras for inclusion in survey reports regardless of the experience of the surveyor. If species identification cannot be verified visually, in photographs, or by other methods when bats are known to use a structure, it may be appropriate to assume presence of IBATs or NLEBs. Please coordinate with the local USFWS FO for guidance about assuming presence.

Acoustic Identification

Species identification may not be reliable using acoustic detectors to confirm occupancy at a bridge. Bats just emerging from roosts are often making social calls, which cannot always be reliably identified to species. Detectors may need to be set further back from suspected roost locations to record "search phase" calls that bats make while navigating/foraging. Automatic or qualitative acoustic identifications from bridges or culverts should only be performed following coordination with and approval from the local USFWS FO. Surveyors can use timestamps of acoustic recordings to glean insight into whether the recorded bats may have been made by bats emerging from the roost, but caution should be used in interpreting acoustic data as the detector may have also recorded bats not using the structure.

Guano Collection & Analysis

Genetic material in bat guano can be analyzed to determine which species deposited the pellet(s). However, samples must be collected in a manner that minimizes contamination and maintains their integrity for lab analysis. If possible, guano should be collected in sufficient amounts to maximize the ability for species to be properly identified.

Recommended standard equipment for performing guano sampling includes a high-powered flashlight (> 600 lumens, preferably a headlamp), hard hat, dust mask, digital camera, writing utensil(s) (e.g., fine- to medium-point permanent marker or pen; pencil for sketches), disposable latex gloves, collection vials (*e.g.*, 1.5 or 15 ml in size), and a collection utensil (e.g., plastic spoon).

Guano collections should only be performed after coordinating with the local USFWS FO(s) and respective State Agency(ies) to develop a collection plan, which may be included in the overall survey Study Plan. The primary goal of a guano collection plan is to obtain samples that provide a full representation of bat use of the structure. Additionally, it should include the following elements: 1) number of distinct areas of guano present in the structure; 2) guano condition (e.g., old vs. fresh), 3) map of guano locations within structure and collection sample points (see Figure 15); 4) photographs of structure, guano deposits, on the ground at the time of sample collection; 5) time of year[86] that samples will be obtained; 6) equipment that will be used to safely collect and curate guano (*e.g.*, sample collection vials, gloves, collection utensils, writing utensils, camera, etc.).

The following protocols* should be followed when collecting guano samples (**check with the institution, lab, or entity you are using to perform guano analysis for any additional protocols, if needed*). Collect the freshest guano possible (freshest guano is likely on walls/sides of the structure, as well as piers vs. the ground). Old guano deposits may be too degraded to be identifiable.

1) Obtain a minimum sample size of 6 pooled samples or 10 individual samples. However, additional pellets and/or more samples covering each location is ideal (for smaller sample sizes, coordinate with local USFWS FO(s) and respective State Agency(ies)). Each sample must be labeled with a unique identifier to link it to the specific location where it was collected.
2) Number of vials collected should be proportional to the surface area of guano under a bridge; 10-20 pellets per ft^2 is ideal. For a linear line of guano, collect 10 pellets per 15feet or collect a few pellets every 5 feet, depending on the length of the guano deposit. For individual guano piles, collect pellets off the top and around the entire surface of the pile (NOTE: If possible, fill an entire sample

[86] It is recommended to obtain guano samples during bridge and structure use or as close to movement to hibernacula (if applicable) as possible to avoid sample degradation.

vial per single guano pile; do not combine multiple, separate guano pile samples into one vial so that specific roost sites of federally listed bats can be identified.)

3) Per the guano collection plan, work with your local USFWS FO(s) and respective State Agency(ies) to determine which institution or entity will analyze the guano results for species identification.

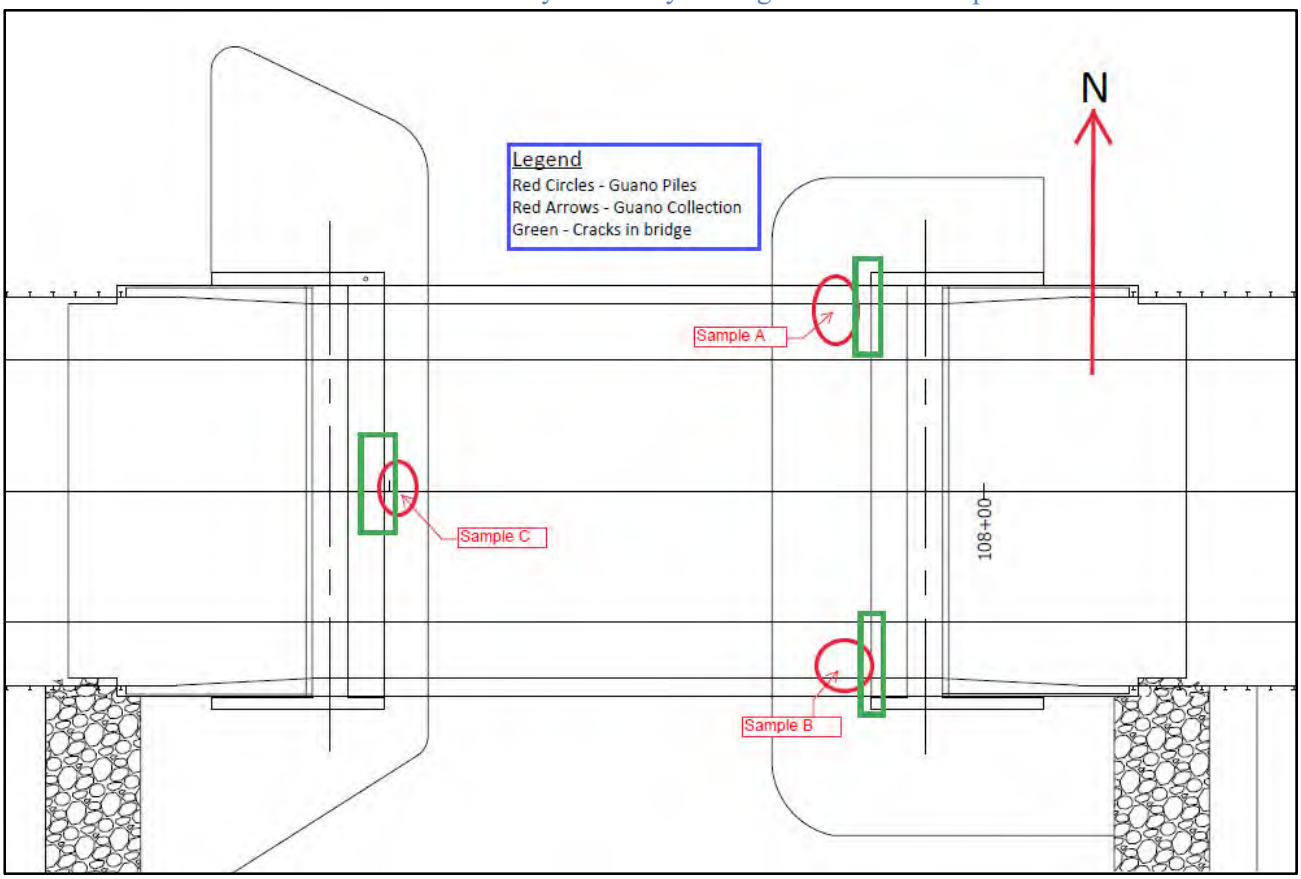


Figure 15. Example map for a guano collection plan, showing top-down view of a bridge, showing linear guano piles located along the abutment walls (underneath the structure's expansion joins). Arrows indicate proposed sample collection locations (Photo provided by Indiana Department. of Transportation).

NEXT STEPS—WHAT TO DO IF BATS ARE FOUND

Findings of bridge or culvert assessments should be submitted to the local USFWS FO(s) and respective State Agency(ies) in a survey report. If IBAT, NLEB, or TCB are positively identified during a bridge or culvert assessment or if species identification cannot be verified at a bridge or culvert with evidence of use, coordinate with your local USFWS FO within 24 hours to determine next steps. For other species, coordinate with your appropriate state agency(ies) (e.g., state wildlife and transportation agencies).

SURVEY REPORTING CHECKLIST

- Completed survey data form
- Annotated photo log w/representative images of surveyed structure (including areas with no indication of bat presence)
- Detailed information on location(s) where roosting bats and/or signs of bat use (e.g., staining, guano, etc.) was documented
- Information pertaining to any guano samples collected and locations within the structure where samples were obtained.

Additional information, photos, results, etc. relevant to any other previously agreed upon survey methods for the structure (e.g., emergence surveys, mist-netting, harp-trapping, acoustics).

DATA MANAGEMENT[87]

USFWS FOs and respective state wildlife agency(ies) may prefer that bridge and culvert assessment data be submitted electronically, in hard copy survey reports, or both. An example data form that can be printed is available on the next page [88][89].

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[87] The submission procedures are not required to be used under the Guidance but are highly recommended. Use of these forms will ensure all the necessary information is provided to the USFWS FO and expedite review of your study plan and survey report. Regardless of the form that is used, please ensure that the necessary data is submitted to the local USFWS FO and appropriate state wildlife agency(ies).

[88] Data submission from bridge and culvert assessments to the North American Bat Monitoring Program (NABat) database is encouraged but not required. The minimum required fields for submission to NABat are highlighted on the sample form.

[89] A template electronic data form that incorporates the minimum fields required for submission to NABat is found at: https://drive.google.com/drive/folders/1U3wCk6EIb8ZtWXSXUlBhkfANOHMJytW4?usp=sharing

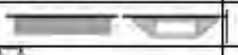
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Bridge/Culvert Bat Assessment Form

Date & Time of Assessment	DOT Project Number or IPaC Code	Route/Facility Carried	County
Federal Structure ID	Structure Coordinates (latitude and longitude)	Structure Height (approximate)	Structure Length

Structure Type (check one)

Bridge Construction Style

☐ Cast-in-place		☐ Pre-stressed Girder	
☐ Flat Slab/Box		☐ Steel I-beam	
☐ Truss		☐ Covered	
☐ Parallel Box Beam		☐ Other:	

Culvert Type

☐ Box	
☐ Pipe/Round	
☐ Other:	

Other Structure

Structure Material (check all that apply)

Deck Material	*Beam Material*	*End/Back Wall Material*
☐ Metal	☐ None	☐ Concrete
☐ Concrete	☐ Concrete	☐ Timber
☐ Timber	☐ Steel	☐ Stone/Masonry
☐ Open grid	☐ Timber	☐ Other:
☐ Other:	☐ Other:	

Creosote Evidence

☐ Yes	☐ No	☐ Unknown

Culvert Material

☐ Metal
☐ Concrete
☐ Plastic
☐ Stone/masonry
☐ Other:

Notes:

Crossings Traversed (check all that apply)

☐ Bare ground	☐ Open vegetation
☐ Rip-rap	☐ Closed vegetation
☐ Flowing water	☐ Railroad
☐ Standing water	☐ Road/trail - Type:
☐ Seasonal water	☐ Other:

Surrounding Habitat (check all that apply)

☐ Agricultural	☐ Grassland
☐ Commercial	☐ Ranching
☐ Residential-urban	☐ Riparian/wetland
☐ Residential-rural	☐ Mixed use
☐ Woodland/forested	☐ Other:

Areas Assessed (check all that apply)

Check all areas that apply. If an area is not present in the structure, check the "not present" box.
Document all bat indicators observed during the assessment. Include the species present, if known, and provide photo documentation as indicated.

Area (check if assessed)	Assessment Notes	Evidence of Bats (include photos if present)
☐ All crevices and cracks: **Bridges/culverts**: rough surfaces or imperfections in concrete **Other structures**: soffits, rafters, attic areas	☐ Not present	☐ Visual - live # dead # ☐ Guano ☐ Staining ☐ Audible ☐ Odor ☐ Photos ☐ Species
☐ Concrete surfaces (open roosting on concrete)	☐ Not present	☐ Visual - live # dead # ☐ Guano ☐ Staining ☐ Audible ☐ Odor ☐ Photos ☐ Species
☐ Spaces between concrete end walls and the bridge deck	☐ Not present	☐ Visual - live # dead # ☐ Guano ☐ Staining ☐ Audible ☐ Odor ☐ Photos ☐ Species
☐ Crack between concrete railings on top of the bridge deck 	☐ Not present	☐ Visual - live # dead # ☐ Guano ☐ Staining ☐ Audible ☐ Odor ☐ Photos ☐ Species
☐ Vertical surfaces on concrete I-beams	☐ Not present	☐ Visual - live # dead # ☐ Guano ☐ Staining ☐ Audible ☐ Odor ☐ Photos ☐ Species
☐ Spaces between walls, ceiling joists	☐ Not present	☐ Visual - live # dead # ☐ Guano ☐ Staining ☐ Audible ☐ Odor ☐ Photos ☐ Species
☐ Weep holes, scupper drains, and inlets/pipes	☐ Not present	☐ Visual - live # dead # ☐ Guano ☐ Staining ☐ Audible ☐ Odor ☐ Photos ☐ Species
☐ All guiderails	☐ Not present	☐ Visual - live # dead # ☐ Guano ☐ Staining ☐ Audible ☐ Odor ☐ Photos ☐ Species
☐ All expansion joints	☐ Not present	☐ Visual - live # dead # ☐ Guano ☐ Staining ☐ Audible ☐ Odor ☐ Photos ☐ Species

Name:	Signature:

APPENDIX L. BAT ACTIVITY PERIODS TABLE FOR IBAT, NLEB, AND TCB

State	Hibernation	Winter Torpor[90]	Spring Staging[91]	Summer Occupancy	Pup Season	Fall Swarming[92]
	Timeframe when most bats are hibernating (i.e., inactive[93] season)	Timeframe when mean winter temperatures fall below 40° F and bats roosting in trees are in torpor[94]	Timeframe when most bats are emerging from hibernation, roosting near hibernacula, and preparing for migration to summer home range	Timeframe when bats are present on their summer home range and/or roosting in colonies[95]	Timeframe during late pregnancy and when most young are born until they can fly and forage independently	Period of increased activity near hibernacula (including foraging, roosting in trees, and mating) prior to hibernation
Alabama: Hibernating Range	Nov 16 – Mar 14	N/A	Mar 15 – Apr 30	Mar 15 – Sept 30	May 15 – July 31	Sept 1 – Nov 15
Alabama: Year-round Active Range (Zone 1)[96]	N/A	Dec 15 – Feb 15	N/A	Mar 15 – July 15	May 1 – July 15	N/A
Alabama: Year-round Active Range (Zone 2)	N/A	N/A	N/A	Mar 15 – July 15	May 1 – July 15	N/A
Arkansas	Nov 16 – Mar 14	N/A	Mar 15 – Apr 30	Mar 15 – Sept 30	May 15 – July 31	Aug 16 – Nov 15
Colorado	Nov 16 – Mar 31	N/A	Apr 1 – May 14	Apr 1 – Sept 30	May 15 – July 31	Aug 16 – Nov 15
Connecticut	Nov 1 – Apr 14	N/A	Apr 15 – May 14	Apr 15 – Sept 30	June 1 – Aug 15	Aug 16 – Oct 31

[90] Only applies in Zone 1 of the year-round active range (see Figure 16).
[91] We currently have no information to inform spring staging timeframe near winter roosts within the year-round active portion of the NLEB or TCB range; consequently, the Service will consider new information in the future that may inform spring staging timeframe.
[92] We currently have no information to inform fall swarming timeframe near winter roosts within the year-round active portion of the NLEB or TCB range; consequently, the Service will consider new information in the future that may inform fall swarming timeframe.
[93] The "active season" is the inverse of the hibernation period. If no hibernation period is listed, bats in this area are active year-round.
[94] State of lowered body temperature and metabolic activity.
[95] IBAT (rangewide) and NLEB (hibernating range) often remain in colonies until the end of Summer Occupancy. TCB (rangewide) and NLEB (year-round active range) roost singly once young can fly and forage independently (i.e., the end of the pup season).
[96] If your project falls within suitable summer IBAT habitat and IBATs are assumed or confirmed present, then default to using the more protective activity periods (AL: hibernating range).

APPENDIX L: BAT ACTIVITY TABLE

State	Hibernation	Winter Torpor[90]	Spring Staging[91]	Summer Occupancy	Pup Season	Fall Swarming[92]
	Timeframe when most bats are hibernating (i.e., inactive[93] season)	Timeframe when mean winter temperatures fall below 40° F and bats roosting in trees are in torpor[94]	Timeframe when most bats are emerging from hibernation, roosting near hibernacula, and preparing for migration to summer home range	Timeframe when bats are present on their summer home range and/or roosting in colonies[95]	Timeframe during late pregnancy and when most young are born until they can fly and forage independently	Period of increased activity near hibernacula (including foraging, roosting in trees, and mating) prior to hibernation
Delaware	Nov 16 – Mar 31	N/A	Apr 1 – May 14	Apr 1 – Sept 30	May 15 – July 31	Aug 16 – Nov 15
District of Columbia	Nov 16 – Mar 31	N/A	Apr 1 – May 14	Apr 1 – Sept 30	May 15 – July 31	Aug 16 – Nov 15
Florida	N/A	N/A	N/A	Mar 15 – July 15	May 1 – July 15	N/A
Georgia: Hibernating Range	Nov 16 – Mar 14	N/A	Mar 15 – Apr 30	Mar 15 – Sept 30	May 15 – July 31	Sept 1 – Nov 15
Georgia: Year-round Active Range (Zone 1)	N/A	Dec 15 – Feb 15	N/A	Mar 15 – July 15	May 1 – July 15	N/A
Georgia: Year-round Active Range (Zone 2)	N/A	N/A	N/A	Mar 15 – July 15	May 1 – July 15	N/A
Illinois	Nov 16 – Mar 31	N/A	Apr 1 – May 14	Apr 1 – Sept 30	May 15 – July 31	Aug 16 – Nov 15
Indiana	Nov 16 – Mar 31	N/A	Apr 1 – May 14	Apr 1 – Sept 30	May 15 – July 31	Aug 16 – Nov 15
Iowa	Nov 16 – Mar 31	N/A	Apr 1 – May 14	Apr 1 – Sept 30	May 15 – July 31	Aug 16 – Nov 15
Kansas	Nov 16 – Mar 31	N/A	Apr 1 – May 14	Apr 1 – Sept 30	May 15 – July 31	Aug 16 – Nov 15
Kentucky	Nov 16 – Mar 31	N/A	Apr 1 – May 14	Apr 1 – Oct 15	May 15 – July 31	Aug 16 – Nov 15
Louisiana: Year-round Active Range (Zone 1)	N/A	Dec 15 – Feb 15	N/A	Mar 15 – July 15	May 1 – July 15	N/A
Louisiana: Year-round Active Range (Zone 2)	N/A	N/A	N/A	Mar 15 – July 15	May 1 – July 15	N/A

APPENDIX L: BAT ACTIVITY TABLE

State	Hibernation	Winter Torpor[90]	Spring Staging[91]	Summer Occupancy	Pup Season	Fall Swarming[92]
	Timeframe when most bats are hibernating (i.e., inactive[93] season)	Timeframe when mean winter temperatures fall below 40° F and bats roosting in trees are in torpor[94]	Timeframe when most bats are emerging from hibernation, roosting near hibernacula, and preparing for migration to summer home range	Timeframe when bats are present on their summer home range and/or roosting in colonies[95]	Timeframe during late pregnancy and when most young are born until they can fly and forage independently	Period of increased activity near hibernacula (including foraging, roosting in trees, and mating) prior to hibernation
Maine	Nov 1 – Apr 14	N/A	Apr 15 – May 14	Apr 15 – Sept 30	June 1 – Aug 15	Aug 16 – Oct 31
Maryland	Nov 16 – Mar 31	N/A	Apr 1 – May 14	Apr 1 – Sept 30	May 15 – July 31	Aug 16 – Nov 15
Massachusetts (Inland)	Nov 1 – Apr 14	N/A	Apr 15 – May 14	Apr 15 – Sept 30	June 1 – Aug 15	Aug 16 – Oct 31
Massachusetts (Coastal)[97]	Dec 1 – Mar 14		Mar 15 – May 14	Mar 15 – Sept 30	June 1 – Aug 15	Aug 16 – Nov 30
Michigan (Outside Indiana Bat Range)	Nov 1 – Apr 14	N/A	Apr 15 – May 14	Apr 15 – Sept 30	June 1 – Aug 15	Aug 16 – Oct 31
Michigan (Within Indiana Bat Range)	Nov 16 – Mar 31	N/A	Apr 1 – May 14	Apr 1 – Sept 30	May 15 – July 31	Aug 16 – Nov 15
Minnesota	Nov 1 – Apr 14	N/A	Apr 15 – May 14	Apr 15 – Sept 30	June 1 – Aug 15	Aug 16 – Oct 31
Mississippi: Hibernating Range	Nov 16 – Mar 14	N/A	Mar 15 – Apr 30	Mar 15 – Sept 30	May 15 – July 31	Sept 1 – Nov 15
Mississippi: Year-round Active Range (Zone 1)	N/A	Dec 15 – Feb 15	N/A	Mar 15 – July 15	May 1 – July 15	N/A
Mississippi: Year-round Active Range (Zone 2)	N/A	N/A	N/A	Mar 15 – July 15	May 1 – July 15	N/A
Missouri	Nov 16 – Mar 31	N/A	Apr 1 – May 14	Apr 1 – Oct 15	May 15 – July 31	Aug 16 – Nov 15
Montana	Nov 1 – Apr 14	N/A	Apr 15 – May 14	Apr 15 – Sept 30	June 1 – Aug 15	Aug 16 – Oct 31
Nebraska	Nov 16 – Mar 31	N/A	Apr 1 – May 14	Apr 1 – Sept 30	May 15 – July 31	Aug 16 – Nov 15

[97] Coastal Massachusetts includes Martha's Vineyard, Nantucket, and Cape Cod.

APPENDIX L: BAT ACTIVITY TABLE

State	Hibernation	Winter Torpor[90]	Spring Staging[91]	Summer Occupancy	Pup Season	Fall Swarming[92]
	Timeframe when most bats are hibernating (i.e., inactive[93] season)	Timeframe when mean winter temperatures fall below 40° F and bats roosting in trees are in torpor[94]	Timeframe when most bats are emerging from hibernation, roosting near hibernacula, and preparing for migration to summer home range	Timeframe when bats are present on their summer home range and/or roosting in colonies[95]	Timeframe during late pregnancy and when most young are born until they can fly and forage independently	Period of increased activity near hibernacula (including foraging, roosting in trees, and mating) prior to hibernation
New Hampshire	Nov 1 – Apr 14	N/A	Apr 15 – May 14	Apr 15 – Sept 30	June 1 – Aug 15	Aug 16 – Oct 31
New Jersey	Nov 16 – Mar 31	N/A	Apr 1 – May 14	Apr 1 – Sept 30	May 15 – July 31	Aug 16 – Nov 15
New Mexico: Hibernating Range	Nov 16 – Mar 31	N/A	Apr 1 – May 14	Apr 1 – Sept 30	May 15 – July 31	Sept 1 – Nov 15
New Mexico: Year-round Active Range (Zone 1)	N/A	Dec 15 – Feb 15	N/A	Apr 1 – July 15	May 1 – July 15	N/A
New Mexico: Year-round Active Range (Zone 2)	N/A	N/A	N/A	Apr 1 – July 15	May 1 – July 15	N/A
New York (Inland)	Nov 1 – Apr 14	N/A	Apr 15 – May 14	Apr 15 – Sept 30	June 1 – Aug 15	Aug 16 – Oct 31
New York (Long Island)	Dec 1 – Feb 28		Mar 1 – May 14	Mar 1 – Sept 30	June 1 – Aug 15	Aug 16 – Nov 30
North Carolina: Hibernating Range	Nov 16 – Mar 31	N/A	Apr 1 – May 14	Apr 1 – Sept 30	May 15 – July 31	Aug 16 – Nov 15
North Carolina: Year-round Active Range (Zone 1)	N/A	Dec 15 – Feb 15	N/A	Apr 1 – July 15	May 1 – July 15	N/A
North Dakota	Nov 1 – Apr 14	N/A	Apr 15 – May 14	Apr 15 – Sept 30	June 1 – Aug 15	Aug 16 – Oct 31
Ohio	Nov 16 – Mar 31	N/A	Apr 1 – May 14	Apr 1 – Sept 30	May 15 – July 31	Aug 16 – Nov 15
Oklahoma	Nov 16 – Mar 14	N/A	Mar 15 – Apr 30	Mar 15 – Sept 30	May 15 – July 31	Aug 16 – Nov 15
Pennsylvania	Nov 16 – Mar 31	N/A	Apr 1 – May 14	Apr 1 – Sept 30	May 15 – July 31	Aug 16 – Nov 15

APPENDIX L: BAT ACTIVITY TABLE

State	Hibernation	Winter Torpor[90]	Spring Staging[91]	Summer Occupancy	Pup Season	Fall Swarming[92]
	Timeframe when most bats are hibernating (i.e., inactive[93] season)	Timeframe when mean winter temperatures fall below 40° F and bats roosting in trees are in torpor[94]	Timeframe when most bats are emerging from hibernation, roosting near hibernacula, and preparing for migration to summer home range	Timeframe when bats are present on their summer home range and/or roosting in colonies[95]	Timeframe during late pregnancy and when most young are born until they can fly and forage independently	Period of increased activity near hibernacula (including foraging, roosting in trees, and mating) prior to hibernation
Rhode Island	Nov 1 – Apr 14	N/A	Apr 15 – May 14	Apr 15 – Sept 30	June 1 – Aug 15	Aug 16 – Oct 31
South Carolina: Hibernating Range	Nov 16 – Mar 31	N/A	Apr 1 – May 14	Apr 1 – Sept 30	May 15 – July 31	Sept 1 – Nov 15
South Carolina: Year-round Active Range (Zone 1)	N/A	Dec 15 – Feb 15	N/A	Apr 1 – July 15	May 1 – July 15	N/A
South Dakota (Plains)	Nov 1 – Apr 14	N/A	Apr 15 – May 14	Apr 15 – Sept 30	June 1 – Aug 15	Aug 16 – Oct 31
South Dakota (Black Hills)	Oct 1 – April 30	N/A	May 1 – June 1	May 1 – Aug 31	June 15 – Aug 31	Aug 16 – Sept 30
Tennessee	Nov 16 – Mar 31	N/A	Apr 1 – May 14	Apr 1 – Sept 30	May 15 – July 31	Aug 16 – Nov 15
Texas: Hibernating Range	Nov 16 – Mar 14	N/A	Mar 15 – Apr 30	Mar 15 – Sept 30	May 15 – July 31	Sept 1 – Nov 15
Texas: Year-round Active Range (Zone 1)	N/A	Dec 15 – Feb 15	N/A	Mar 15 – July 15	May 1 – July 15	N/A
Texas: Year-round Active Range (Zone 2)	N/A	N/A	N/A	Mar 15 – July 15	May 1 – July 15	N/A
Vermont	Nov 1 – Apr 14	N/A	Apr 15 – May 14	Apr 15 – Sept 30	June 1 – Aug 15	Aug 16 – Oct 31
Virginia: Hibernating Range	Nov 16 – Mar 31	N/A	Apr 1 – May 14	Apr 1 – Sept 30	May 15 – July 31	Aug 16 – Nov 15
Virginia: Year-round Active Range (Zone 1)	N/A	Dec 15 – Feb 15	N/A	Apr 1 – July 15	May 1 – July 15	N/A
West Virginia	Nov 16 – Mar 31	N/A	Apr 1 – May 14	Apr 1 – Sept 30	May 15 – July 31	Aug 16 – Nov 15

APPENDIX L: BAT ACTIVITY TABLE

State	Hibernation	Winter Torpor[90]	Spring Staging[91]	Summer Occupancy	Pup Season	Fall Swarming[92]
	Timeframe when most bats are hibernating (i.e., inactive[93] season)	Timeframe when mean winter temperatures fall below 40° F and bats roosting in trees are in torpor[94]	Timeframe when most bats are emerging from hibernation, roosting near hibernacula, and preparing for migration to summer home range	Timeframe when bats are present on their summer home range and/or roosting in colonies[95]	Timeframe during late pregnancy and when most young are born until they can fly and forage independently	Period of increased activity near hibernacula (including foraging, roosting in trees, and mating) prior to hibernation
Wisconsin	Nov 1 – Apr 14	N/A	Apr 15 – May 14	Apr 15 – Sept 30	June 1 – Aug 15	Aug 16 – Oct 31
Wyoming (Plains)	Nov 1 – Apr 14	N/A	Apr 15 – May 14	Apr 15 – Sept 30	June 1 – Aug 15	Aug 16 – Oct 31
Wyoming (Black Hills)	Oct 1 – April 30	N/A	May 1 – June 1	May 1 – Aug 31	June 15 – Aug 31	Aug 16 – Sept 30

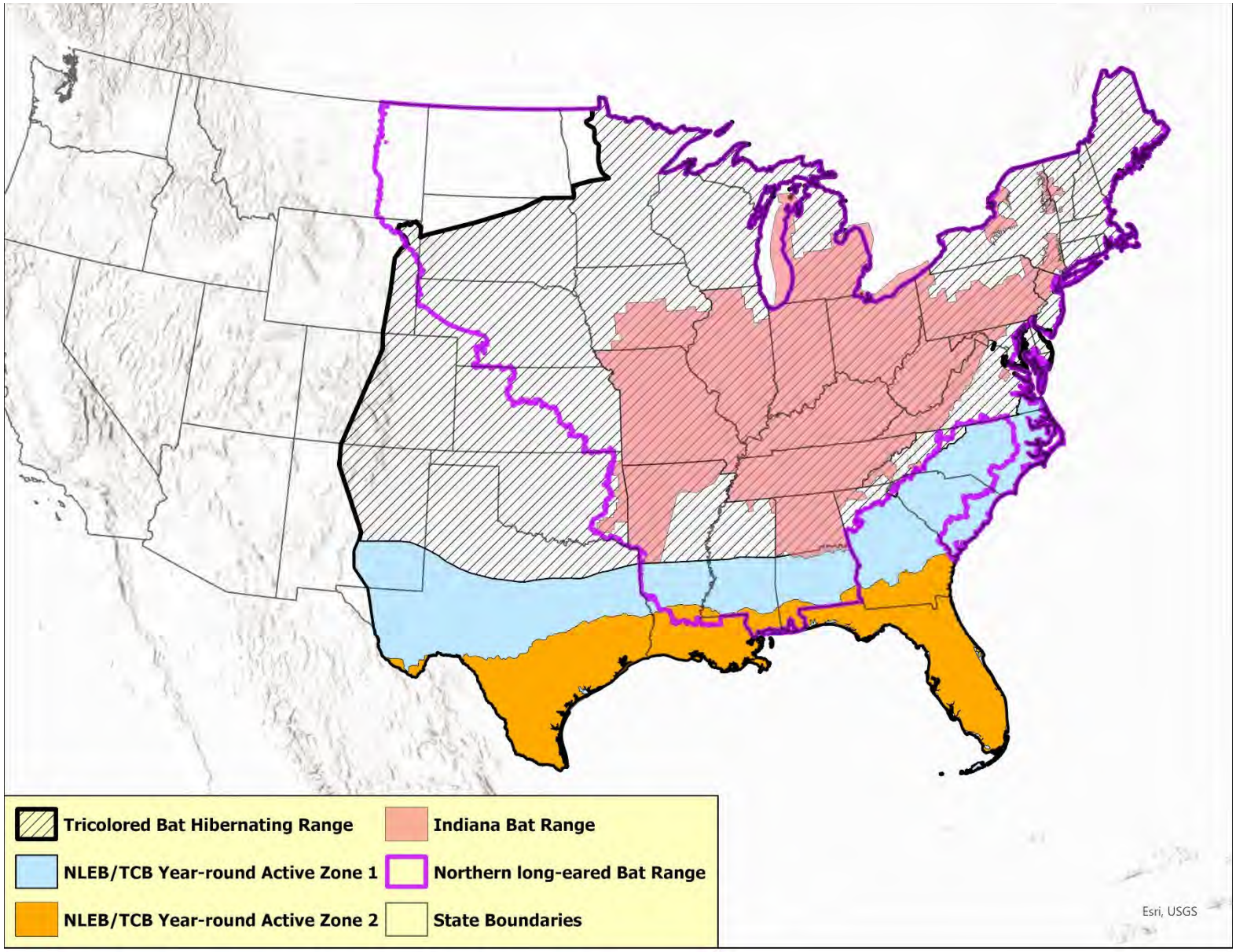


FIGURE 16. Hibernating and/or year-round active ranges of IBAT, NLEB, and TCB.

APPENDIX M: GLOSSARY OF TERMS

Above ground level (AGL) – height at which an acoustic detector microphone is elevated above the top of ground-level vegetation present at the detector deployment location.

Acoustic bat survey – bat sampling conducted through recording and analyzing echolocation calls.

Acoustic location – actual site where an acoustic detector and microphone is deployed; multiple acoustic locations may be used for a full acoustic bat survey.

Approved software program - bat acoustic program (see also *automated bat call ID software*) approved through the USFWS software testing procedures for stand-alone use in presence/probable absence surveys for Indiana bat and/or northern long-eared bat.

Automated bat call ID software – a form of echolocation identification in which recorded files are filtered and identified within a software program; the program compares the statistical properties of a recorded call to a library of known calls to classify to species.

Bat detector – equipment capable of detecting ultrasonic echolocation calls of bats that are above the range of human hearing.

Call quality – how closely the sequence matches typical search-phase behavior for the species.

Call sequence – a series of bat echolocation call pulses.

Candidate software program – bat acoustic program (see also *automated bat call ID software*) submitted to USFWS for software testing, but not yet approved for stand-alone use in presence/probable absence surveys for Indiana bat and/or northern long-eared bat.

Clutter –obstacles present in an area that can affect recording of bat echolocation calls; may be caused by either scattering echolocation calls from sound bouncing off obstacles (thereby reducing call quality) or by bats adjusting their normal search phase calls in response to additional obstacles resulting in changed bat echolocation call parameters.

Detection probability – the likelihood of detecting the presence of a species when that species is present.

Detector sensitivity – measures the ability of a bat detector to detect an echolocation call.

Detector - see *bat detector*.

Directional microphone – a microphone that is more sensitive to sound arriving from certain directions; compared to omni-directional, may detect sounds from a further distance away, but within a narrower cone of detection.

Echolocation – use of ultrasound and the returning echoes to orient and navigate in the environment.

Emergence survey – a survey method that involves visually counting bats that emerge from a known or suspected roost; usually conducted in early evening (e.g., 30 minutes before sunset) when bats exit to forage.

False negative – the failure to detect a bat species when it is present in the area; statistically a type II error in hypothesis testing.

Forest canopy openings – gaps in the continuous forest cover formed by tree crowns, where sunlight

reaches the forest floor.

Forest corridor – Three-dimensional corridors that bats use to travel within forests (also known as flyways).

Forest interior – forest areas surrounded by forest edge, typically 50-300 feet inside from an outer edge.

Forest strip – narrow area with trees. Examples include visual buffers or forest fragments dominated by edge effects.

Forest/woodland edge – transition area between forest and open spaces. Edges create edge effects impacting the species communities and growth of vegetation extending into the forest from the edge. Edge can occur whenever there is a 30-foot break in canopy cover.

Forest/woodland gap – area between intact forest areas that form small open areas. These areas are partially shaded by forest areas and natural regeneration will likely fill the gap.

Frequency filter – pre-programmed range of sound frequencies (in kHz) set for acoustic bat detectors to record.

Full-spectrum detector – bat detectors in which all desirable information about the recorded sound is preserved, including time, frequency, and amplitude.

Harp-trapping – capture method by which a device (harp-trap) composed of a metal frame, multiple strands of equally-spaced nylon strings, and a catch bag at the bottom, is deployed near the entrances of caves, cave-like openings, and mines. Bats are captured as they exit a restricted opening to forage.

Hemispherical microphone – see *omni-directional microphone*.

Hibernaculum (*pl.* "hibernacula") – a thermally-stable roost used by bats for extended periods of torpor during winter. Typically, a cave, natural cave-like feature (e.g., sinkhole, fissure, talus opening, etc.), or anthropogenic structure (e.g., mine, tunnel, bridge, etc.).

High-frequency calls – a general classification of calls that refers to those with minimum frequencies >35 - 40 kilohertz.

Kilohertz (kHz) – a unit of measure of the frequency of sound; one thousand hertz.

Level-of-effort (LOE) – Minimum number of survey nights required (using a particular survey methodology) to determine probable absence of a target bat species; statistically set at a particular confidence level (e.g., 90%, 95%, etc. – depending upon species and region) by USFWS.

Linear project – a project with a footprint greater in length than width (e.g., pipeline, roadway, or right-of-way) with ≥ 1 km (0.6 mi) of suitable habitat; may contain contiguous and fragmented patches of suitable habitat, but only segments at least ≥ 1 km in length can be considered for presence/probable absence survey sites.

Manual-vetting – see *qualitative call identification*.

Maximum-Likelihood Estimate (MLE) – a statistical method of estimating the parameters of a statistical model. For our purposes, the MLE is a statistical method that can be used to determine species presence or probable absence at a particular site on a particular night by means of a classification matrix.

Microphone sensitivity – the minimal amplitude required at a given frequency for a microphone to

detect a sound.

Microphone orientation – the direction in which the microphone is pointing' thereby affecting the cone of detection.

Mist-netting – survey technique that uses low-visibility, mesh nets affixed between two poles to capture foraging bats in areas of increased activity (e.g., travel corridors, ponds, etc.)

Net set – one mist-net deployment consisting of two poles and typically from 1-3 affixed mist-nets stacked onto one another. A typical net set is at least 5 m to 9 m high consisting of two or more nets stacked on top of one another (without gaps) and from 6 m to 18 m wide.

Net site – see *site*.

Noise – unwanted or extraneous environmental sound or electronic interference detected by a bat detector.

Non-linear project – any project generally not linear in nature or linear and < 1 km in length; may contain contiguous and fragmented patches of suitable habitat, but only blocks ≤ 123 acres can be considered for presence/probable absence survey sites.

North American Bat Monitoring Program (NABat) – A multi-national, multi-agency coordinated bat monitoring program across North America that was created to monitor bats at local to rangewide scales. It incorporates winter hibernaculum counts, maternity colony counts, mobile acoustic surveys, and stationary acoustic surveys (https://www.nabatmonitoring.org).

Omni-directional microphone – a microphone that can detect equally in all directions (e.g., has a spherical cone of detection). Hemispherical microphones are a type of omni-directional microphone.

Out-tier project guidance – a USFWS discretionary survey guidance scenario that can be applied when an Indiana and/or northern long-eared bat has been captured or acoustically-detected, but no known roosting areas have been identified. Under "out-tier" guidance, 2.5 and 5-mile or 1.5 and 3.0- mile buffers are placed around the Indiana bat or northern long-eared bat capture or detection location. Surveyors are allowed to perform a standard P/A survey to help refine a maternity colony's true location and/or document roost trees if the project area is more than 2.5 or 1.5 (for NLEB) miles away from the Indiana bat capture/detection site, but within the 5- or 3-mile (for NLEB) buffer.

Pass – a single crossing of a bat through a bat detector's cone of detection; see *call sequence*.

Probable absence – using the appropriate Level of Effort (LOE), a determination that survey protocols are not 100% likely to detect IBAT or NLEB when present and that identification errors may occur.

Pulse – a brief, continuous emission of sound; see *call sequence*.

Qualified biologist – For activities involving the handling of bats, an individual who holds a USFWS Section 10(a)(1)(A) Recovery Permit (Federal Fish and Wildlife Permit) for federally-listed bats in the state/region in which they are surveying. For qualitative analysis of acoustics, an individual that has completed one or more of available bat acoustics trainings/workshops and/or able to show similar on-the-job or academic experience; furthermore, have demonstrated multiple years of experience in 1) gathering known calls of the target species, 2) have identified bat calls recorded in numerous habitat types, 3) are familiar with species likely to be encountered within the project area, and 4) must have stayed current with qualitative identification of bat calls.

Qualitative call identification (manual vetting) – identification of call sequences through visual comparison with a known call library. Qualitative analysis must also include and present within a written

report a comparison of the results of each acoustic ID program by site and night. Qualitative analysis of each acoustic site and night with probable detections of IBAT and/or NLEB should include the entire night's high frequency call data, including "no ID" files, and not just those files making it through the acoustic analysis tools as probable IBAT and/or NLEB; accuracy can be highly variable based on researcher experience; also referred to by some as manual vetting (see *qualified biologist*).

Roost tree – A live or dead standing tree (snag) occupied by one or more bats. Throughout most of the IBAT and NLEB range, trees are typically occupied by bats outside of the hibernation period (spring, summer, fall), although see Appendix J regarding year-round active populations.

Roost – see *roost tree*.

Site – an area containing one or more individual net sets or harp traps in relatively close proximity that can be efficiently walked to and checked by a survey team (typically two people) within a 10- minute window from a central bat-processing location.

Site-night – The standard unit of time for operating an acoustic detector at one site for one calendar night during an acoustic P/A survey. The MLE should be assessed for a target species on a site-night basis.

Ultrasonic/ultrasound – sounds made of frequencies that are beyond the range of human hearing (often arbitrarily set at 20 kilohertz, although most adults have trouble hearing sounds above 15 kHz.)

Weather proofing – various methods/materials used to protect a bat detector/microphone from the elements (primarily rain).

Winter habitat – see *hibernaculum*.

Zero-crossing detector – a detector type that calculates frequencies by measuring the time between moments of zero sound pressure, which corresponds to the period of the wave.

Surface Water Withdrawal
Intake Design and Operation Standards

VA Dept. of Wildlife Resources

Surface Water Intake Working Group

July 7, 2023

The Virginia Department of Wildlife Resources (DWR) is responsible for reviewing and providing input on many surface water intake applications and reissuances. To minimize impacts upon resident aquatic fauna we typically recommend that the intake meet the following Intake Design and Operation Standards (standards) which serve to minimize impingement and entrainment and are considered reasonably protective of aquatic resources given the currently available knowledge base:

- **That the intake is fitted with a screen that has openings no larger than 1 millimeter (mm).**
- **That the approach velocity, as measured across the entire screen at 6" or closer to the screen, not exceed 0.25 fps.** If measuring the approach velocity at 6" or less from the screen cannot be accomplished, it should be measured as close to the screen as possible and as approved by DWR.
- **That sweeping velocity, which protects the earliest life stages (eggs, larvae) from impingement and entrainment, be considered as part of project design and implemented where and as often as practicable. To best protect these life stages, seeping velocity, as measured across the entire screen at 6" or closer to the screen, should exceed 0.25 fps as often as possible.** If measuring the approach velocity at 6" or less from the screen cannot be accomplished, it should be measured as close to the screen as possible and as approved by DWR.

In addition, to ensure continued access to necessary instream habitats by resident aquatic species, we recommend the following:

- **That the intake not withdraw more than 10% of instantaneous flow* (90% flowby)**

*in most situations what is referred to as "instantaneous flow" is actually mean daily flow, often based on the previous days flows. Also this is meant to represent a 10% cumulative flow reduction, taking into consideration all withdrawals from, and inputs to, the system.

While our preference is that surface water intakes meet the above standards, we recognize that there may be situations for which adherence to the standards is not necessary or practicable. In such situations we are supportive of the applicant performing site- or system-specific analyses, in coordination with the appropriate resource agencies, which may find alternate intake design and use parameters as protective of the aquatic fauna as the standards above. Additional analyses could include literature reviews, empirical data collection, further analysis of project impacts, and/or mitigation methods that may further minimize and/or offset any unavoidable adverse impacts to aquatic fauna and their habitats resulting from intake installation and operation.

We note that the standards listed above are not meant to apply to most hydropower projects and that each water use/supply project is considered on its own merits. We may recommend that projects with storage or that manage large reservoir systems adhere to certain standards and not others, depending on the nature of the project, the aquatic system on which the project relies, and any applicable laws or regulations. However, if a project is designed and operated using the standards above, DWR would not request further analysis to ensure minimization of impingement and entrainment and loss of habitat

access or availability resulting from flow alterations due to operation of the intake.

History of our Intake Design and Operation Standards development:
In the early days of surface water intake standards development, our priorities for wildlife protection were focused on ensuring that minimum instream flows were available during operation of the intake. In the 1970's, it was typical practice to determine instream flow requirements for intakes using the water quality 7Q10. As we moved into the 1980's we began using the Tennant Method, which determined flows based as a percentage of Mean Annual Flow (MAF) and derivatives. During this same time period we began to consider intake design as a way to minimize impingement and entrainment. The intake design standards were first only related to screen opening size, with the typical recommendations at the time being that the intake screen have openings from 3/8 – 1/2 –inch.

During the 1990's our learning progressed rather quickly, resulting in recommendations for instream flows being based on seasonal or monthly exceedance flows and intake screen openings of 2mm becoming more routine. Also during this timeframe, we saw intake velocities being considered, and recommendations that it not exceed 0.5 fps. The late 1990's brought use of Instream Flow Incremental Methodology (IFIM) / Physical Habitat Simulation (PHABSIM) / Habitat Suitability Index (HSI) and other studies to inform instream flow requirements. Also during the late 1990's, Dr. Gowan (Randolph Macon College) Dr. Garman (Virginia Commonwealth University; VCU), and Will Shuart (VCU grad student) studied the issue and found that even stricter standards are more appropriate and better protected our aquatic fauna. The standards recommended by Gowan et al are those we use today: intake screens with openings no larger than 1mm and intake velocities no greater than 0.25 fps. However, in their paper, they mention that at some point in the future, when intake design has improved, a standard of intake screens with openings no larger than 0.5 mm and maximum intake velocities of 0.1 fps should be considered for adoption.

As our learning about intake design improved, our recommendations regarding instream flows evolved. By the early 2000's we, and our conservation partners, had adopted the use of seasonal or daily flows (instantaneous flow) to inform instream flow requirements, using a 90% flow by as the accepted standard. Analyses of PHABSIM data collected in multiple Virginia streams demonstrates that a 10% alteration in stream discharge begins to impact habitat quality/availability for the most flow-sensitive species/life stages present. Thus, alterations in stream discharge of <10% are considered to have no significant impact on even the most sensitive fauna. This standard also maintains the natural hydrograph (magnitude, duration, timing, etc.) of flow events, which have been shown to be critically important for maintaining the integrity of stream biota.

Ongoing consultation with our federal conservation partners, other US state fish and wildlife agencies, non-governmental organizations, and academia indicates that the standards above fall in line with how water intake design and operation is being approached across the US and Canada. As consultation continues and our library of literature grows, this document will be updated to reflect that learning.

The following papers and assessments have informed the development of our Intake Design and Operation Standards:

- Benner et al. 2013. Recommendations for Estimating Flows to Maintain Ecological Integrity in Streams and Rivers in North Carolina. North Carolina Ecological Flows Science Advisory Board.
- Canadian Science Advisory Secretariat. 2013. Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada. National Capital Region, Science Advisory Report. Ottowa, Ontario.
- Electric Power Research Institute. 2006. Field Evaluation of Wedgewire Screens for Protecting Early Life Stages of Fish at Cooling Water Intake Structures. Chesapeake Bay Studies, Technical

Report. Palo Alto, CA.
- Freeman, Mary C. and Marcinek, Paula A. 2005. Effects of Water Supply Development on Stream Fishes in the Piedmont Region of Georgia. Athens, GA.
- Gowan et al. 1999. Design Criteria for Fish Screens in Virginia: Recommendations Based on a Review of the Literature. Richmond, VA.
- Hamilton, D. A., and P. W. Seelbach. 2011. Michigan's Water Withdrawal Assessment Process and Internet Screening Tool. Michigan Department of Natural Resources, Fisheries Special Report 55. Lansing, MI.
- Holt et al. 2017. Division of Water Technical and Operational Guidance Series. New York State Department of Environmental Conservation.
- Leonard, Paul M. 2011. *Proceedings of the 2011 Georgia Water Resources Conference*. Emerging Trends in Environmental Flow Science. Athens, GA.
- Maloney et al. 2021. *Environmental Management*. Linking Altered Flow Regimes to Biological Condition: an Example Using Benthic Macroinvertebrates in Small Streams of the Chesapeake Bay Watershed.
- McManamay, Ryan A. and Bevelhimer, Mark S. 2013. A Holistic Framework for Environmental Flows Determination in Hydropower Contexts. Oak Ridge, TN.
- National Oceanic and Atmospheric Association. 1997. Fish Screening Criteria for Anadromous Salmonids. National Marine Fisheries Service, Southwest Region.
- Richter et al. 2011. A Presumptive Standard for Environmental Flow Protection. Charlottesville, VA.