

EVOH Deployment Suitability Assessment No. 1 Bristol Integrated Solid Waste Management Facility Solid Waste Permit No. 588



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02218208.05 | April 11, 2024

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EXECUTIVE SUMMARY

SCS Engineers (SCS) analyzed elevation data from settlement plates installed within the Solid Waste Permit (SWP) No. 588 Landfill to assess the suitability for deployment of the EVOH cover system. The settlement analysis considered three criteria established by the Virginia Department of Environmental Quality (VDEQ):

- **Criteria 1:** The rate of settlement of the waste has transitioned to a state of long-term secondary compression with the settlement varying approximately logarithmically with time.
- **Criteria 2:** Strain rate at all settlement plates is less than 1% per year, or a rate identified as consistent with secondary compression of municipal solid waste. Strain rate is defined here as the ratio of the change in vertical elevation of the surface of the waste at a given location to the thickness of the waste at that location per unit time.
- **Criteria 3:** Surface cracks due to settlement having a width less than 1-inch.

The EVOH deployment is to proceed once all three criteria have been satisfied or by the date of December 1, 2026 as set in the amendment to the Consent Decree.

To date, the analysis of the elevation data and inspection of the site condition show none of the criteria have been fully satisfied. Table 1 summarizes the findings for criteria 1 and criteria 2. Recent visual inspections of the site indicate that surface cracking is ongoing and criteria 3 is also not satisfied. At this time, severe ongoing settlement could compromise the integrity of the EVOH cover system.

Table 1 – Summary of Findings

Settlement Plate	Criteria 1	Criteria 2
SP-1	Satisfied	Not Satisfied
SP-2	Not Satisfied	Not Satisfied
SP-5	Not Satisfied	Not Satisfied
SP-6	Not Satisfied	Inconclusive
SP-8	Not Satisfied	Not Satisfied
SP-10	Not Satisfied	Satisfied
SP-11	Not Satisfied	Satisfied
SP-12	Not Satisfied	Satisfied

1.0 INTRODUCTION

SCS Engineers (SCS) has assessed the suitability for deployment of the EVOH cover system at the City of Bristol, Virginia's (City's) Integrated Solid Waste Management Facility (ISWMF) Solid Waste Permit (SWP) No. 588 landfill. The assessment is required by the Consent Decree between the City and the Commonwealth of Virginia as amended on March 21, 2024. Settlement data was analyzed based on the three criteria outlined in section 6.iv of Appendix A of the amended Consent Decree. The EVOH cover system deployment will proceed once the three settlement criteria are satisfied, indicating an acceptable rate of settlement, or by December 1, 2026, whichever date comes first.

Excessive settlement within the SWP No. 588 landfill could threaten the integrity of the EVOH geomembrane, which is the most important component of the EVOH cover system. Problems include the formation of voids underneath the geomembrane as localized depressions form due to differential settlement. The resulting low areas dispersed across the geomembrane surface will disrupt stormwater drainage, and repairs would require cutting the geomembrane to place soil fill. Additionally, the geomembrane surface will fall relative to the top elevation of vertical pipes installed within the waste mass. Landfill gas wells and temperature probes will be affected at a minimum. Excessive settlement may render the wells and probes unreachable, requiring widespread adjustments and repairs.

The long-term success of the EVOH cover system requires an acceptable rate of settlement to maintain the system's overall integrity. In accordance with the amended Consent Decree, the following three criteria are used to assess the landfill's suitability for the EVOH deployment:

- **Criteria 1:** The rate of settlement of the waste has transitioned to a state of long-term secondary compression with the settlement varying approximately logarithmically with time.
- **Criteria 2:** Strain rate at all settlement plates is less than 1% per year, or a rate identified as consistent with secondary compression of municipal solid waste. Strain rate is defined here as the ratio of the change in vertical elevation of the surface of the waste at a given location to the thickness of the waste at that location per unit time.
- **Criteria 3:** Surface cracks due to settlement having a width less than 1-inch.

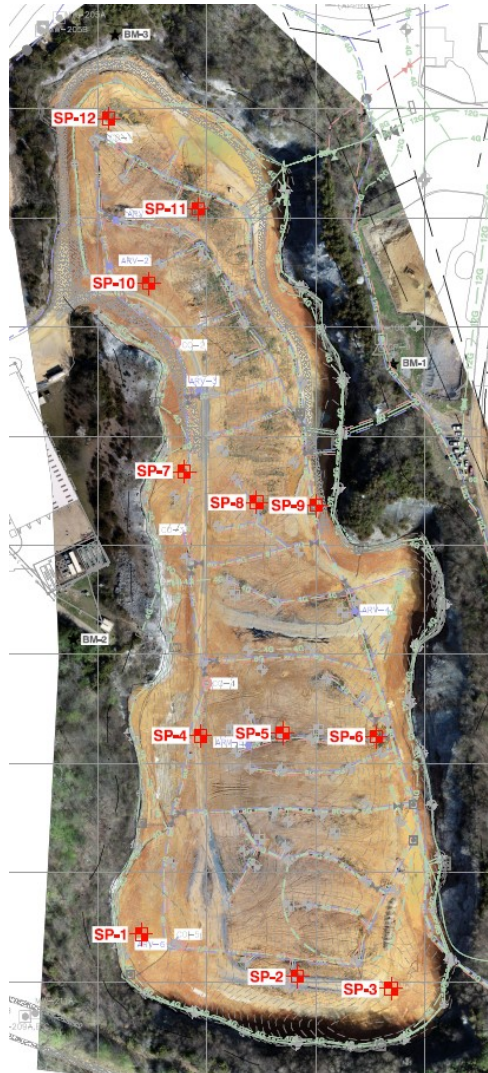
The three criteria are evaluated using elevation data from settlement plates positioned throughout the landfill. The City has completed monthly elevation surveys of the settlement plates since their installation in November 2022, and the compiled elevation data was plotted on graphs for each operational settlement plate. Regression analysis was used to assess criteria 1 by considering whether the data shows a linear or logarithmic (decreasing with time) trendline. Calculations were completed and tabulated to estimate if current strain rates satisfy criteria 2. Additionally, the landfill surface was monitored by personnel for evidence of surface cracking to assess criteria 3.

Overall, the analysis of the settlement plate elevation data and surface observations currently indicate ongoing excessive settlement. The three criteria are not currently satisfied.

2.0 METHODS

During November 2022, SCS Field Services installed 12 settlement plates on the Solid Waste Permit No. 588 landfill. The settlement plates are located throughout the landfill to include varying waste thickness and changes in the landfill's base grade (Figure 1). The City conducts monthly surveys of the settlement plates to monitor changes in elevation. Surveying is conducted on-foot using satellite-based GPS equipment.

Figure 1 - Settlement Plate Locations



Settlement plates are fixed points installed within the landfill surface that measure changes in elevation and identify the magnitude of on-going settlement. Settlement plates consist of a buried steel base plate and a steel standpipe or rod that extends above ground and provides an elevation reference point. The rod indicates the center of the base plate, and the initial location and elevation is surveyed by a professional surveyor. Subsequent surveys of the settlement plate measure the change in the vertical direction.

2.1 SETTLEMENT PLATE SURVEYS

The locations of the settlement plates were surveyed by the City's surveyor on November 14, 2022. The settlement plates were surveyed again on the following dates:

- December 13, 2022;
- January 3, 2023;
- February 6, 2023;
- March 8, 2023;

- April 3, 2023;
- May 11, 2023;
- June 5, 2023;
- July 10, 2023;
- August 17, 2023;
- September 11, 2023;
- October 11, 2023;
- November 6, 2023;
- December 12, 2023;
- January 11, 2024;
- February 6, 2024, and
- March 13, 2024.

The surveyed coordinates and elevation changes of the settlement plates are shown in Table 3.

2.2 ACCURACY OF SETTLEMENT PLATE ELEVATIONS

The settlement plate elevation measurements use a Javad Triumph-LS rover GPS, Javad Triumph-2 base GPS, and Javad HPT404BT 4-watt UHF radio. Measured elevations have an approximately ± 0.03 ft 95% confidence interval derived from the vertical RMS calculations done by the Triumph-LS unit. This value depends on the line of sight between the GPS equipment and overhead satellites, which may be obstructed by the quarry walls. The quarry walls also create signal reflections, which can increase the 95% confidence interval. A vertical range of the 95% confidence interval between ± 0.01 and ± 0.04 ft is considered acceptable under the conditions within the quarry.

The City of Bristol monitors the landfill's settlement with monthly measurements of the twelve settlement plate elevations. Not all settlement plates are available each month. Table 2 shows the current availability of each settlement plate.

Table 2 - Settlement Plate Availability

Settlement Plate	Condition
SP-1	Operational
SP-2	Currently non-operational, leaning
SP-3	Out of Service
SP-4	Out of Service
SP-5	Operational
SP-6	Operational
SP-7	Out of Service
SP-8	Operational
SP-9	Operational but currently inaccessible
SP-10	Operational
SP-11	Operational
SP-12	Operational

In some cases elevation data can still be collected from the settlement plates. However, the plates have been damaged to a point at which, the data may not accurately reflect the rate of settlement at the landfill. For this reason, some plates have been excluded from this analysis, even if elevation data is still collected from those plates.

3.0 SETTLEMENT DATA ANALYSIS

In accordance with the amended Consent Decree, the three criteria introduced in section 1.0 are used to assess the landfill's suitability for EVOH deployment:

- **Criteria 1:** The rate of settlement of the waste has transitioned to a state of long-term secondary compression with the settlement varying approximately logarithmically with time.
- **Criteria 2:** Strain rate at all settlement plates is less than 1% per year, or a rate identified as consistent with secondary compression of municipal solid waste. Strain rate is defined here as the ratio of the change in vertical elevation of the surface of the waste at a given location to the thickness of the waste at that location per unit time.
- **Criteria 3:** Surface cracks due to settlement having a width less than 1-inch.

The following sections analyze the settlement plate elevation data for conformance to the three criteria. Criteria 1 is considered using the cumulative settlement data, whereas criteria 2 and 3 are considered using the most recent settlement data and site inspections. Table 3 provides the most recent elevation data and calculated strain rates for the settlement plates. Non-operational or inaccessible settlement plates have been excluded from some analyses.

Table 3 - Elevation and Strain Data at Settlement Plate Locations

Settlement Plate	Northing	Easting	Elevation on March 13, 2024	Elevation Change Since February 6, 2024	Strain ¹ Since February 6, 2024	Estimated Current Rate for Strain/Year ²	Elevation Change Since Installation
SP-1	3,397,887.1	10,412,079.7	1,830.3	-0.1	-0.2%	-1.9%	-4.1
SP-2 ³	3,397,810.1	10,412,365.9	1,801.4	-0.4	-0.2%	-2.2%	-9.1
SP-3 ⁴	3,397,787.5	10,412,537.9	N/A	N/A	N/A	N/A	N/A
SP-4 ³	3,398,250.5	10,412,187.7	1,807.6	-0.5	-0.3%	-3.0%	-9.9
SP-5	3,398,255.7	10,412,339.0	1,792.4	-0.4	-0.2%	-1.6%	-8.4
SP-6	3,398,249.0	10,412,510.2	1,774.5	-0.1	-0.1%	-0.6%	-3.1
SP-7 ⁵	3,398,734.8	10,412,158.4	1,825.2	-0.2	-0.2%	-1.8%	-3.5

¹ Strain is defined as the change in elevation divided by the estimated original waste depth.

² Current stain rate per year is estimated as the strain rate between the two most recent surveys.

³ The steel rods for SP-2 and SP-4 are leaning and may have been disturbed during site activities. SP-4 has been excluded from some analyses since the damage appears to have affected the elevation data.

⁴ SP-3 was significantly damaged during site activities and are out of service.

⁵ SP-7 was significantly damaged during site activities. Data can still be collected, but due to the extent of the damage, SP-7 is considered out of service.

Settlement Plate	Northing	Easting	Elevation on March 13, 2024	Elevation Change Since February 6, 2024	Strain ¹ Since February 6, 2024	Estimated Current Rate for Strain/Year ²	Elevation Change Since Installation
SP-8	3,398,678.6	10,412,290.8	1,801.8	-0.3	-0.1%	-1.3%	-5.6
SP-9 ⁶	3,398,673.4	10,412,400.9	N/A	N/A	N/A	N/A	N/A
SP-10	3,399,080.0	10,412,092.9	1,837.9	-0.2	-0.1%	-0.6%	-2.3
SP-11	3,399,216.3	10,412,183.6	1,815.1	-0.2	-0.1%	-0.7%	-1.2
SP-12	3,399,382.0	10,412,019.6	1,810.0	-0.1	-0.1%	-0.6%	-0.7

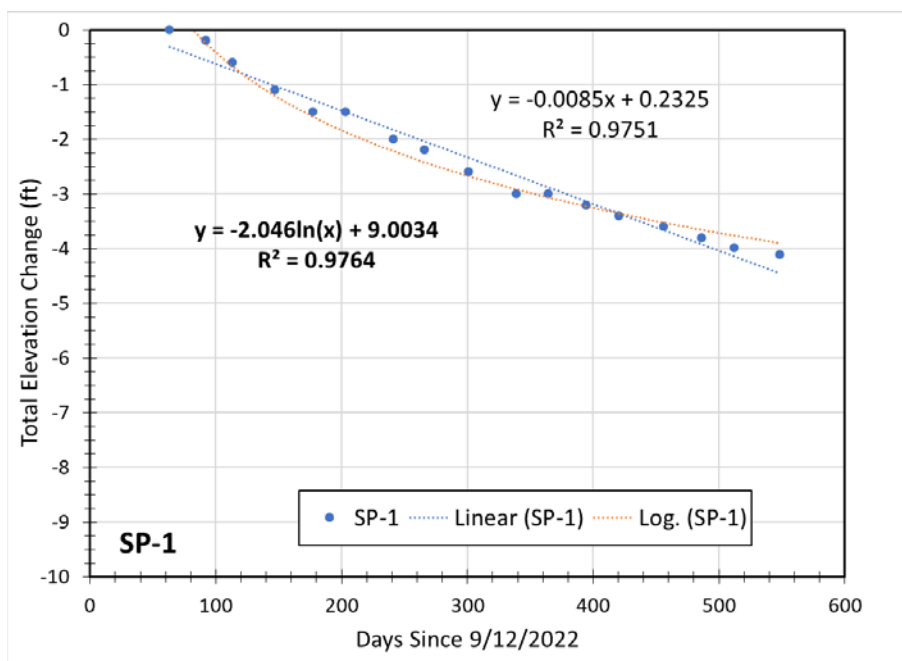
3.1 CRITERIA 1 – TRANSITION TO SECONDARY COMPRESSION

Secondary compression of municipal solid waste is typically characterized by long-term settlement at a decreasing rate due primarily to decomposition. Settlement data for secondary compression follows a logarithmic trend over time. Regression analysis of the complete elevation data for each undamaged settlement plate currently shows prevalent linear trends. Current measurements do not indicate a generally decreasing rate of settlement. The regression analysis results for eight settlement plates are presented herein.

Figure 2 shows the plot of total elevation change versus elapsed time for SP-1. Linear and logarithmic trendlines were fitted to the data, and the coefficients of determination (R^2) were computed. SP-1 is the only location to show a greater R^2 for the logarithmic trendline, which may be related to its location. SP-1 is located in the southwest corner of the quarry, atop a bench in the sidewall with approximately 67 feet of underlying waste. The sidewall bench and small waste depth separates the SP-1 area from nearby portions of the landfill experiencing elevated temperatures. However, SP-1 has recorded significant settlement (6.2% strain since installation), likely due to the surrounding soil placement during the construction of the sidewall odor mitigation system.

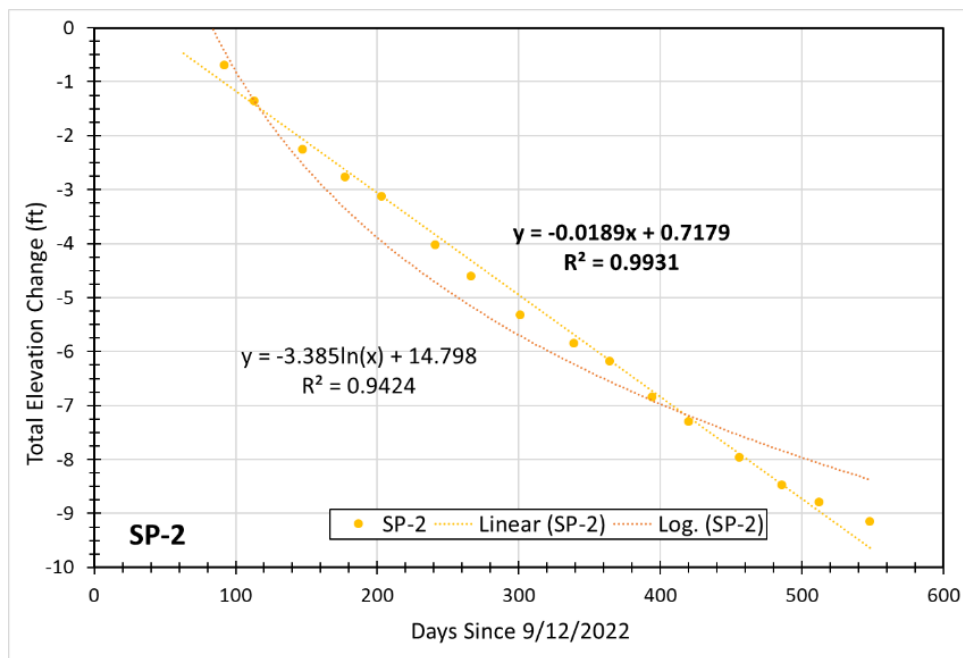
⁶ SP-9 is currently inaccessible due to site conditions.

Figure 2 - Settlement Plate 1



SP-2 is located near the southern central edge of the quarry. The elevation data for SP-2 shows ongoing steady settlement at an estimated current strain rate of 2.2% (Figure 3). The SP-2 data strongly follows a linear trendline ($R^2 > 0.99$).

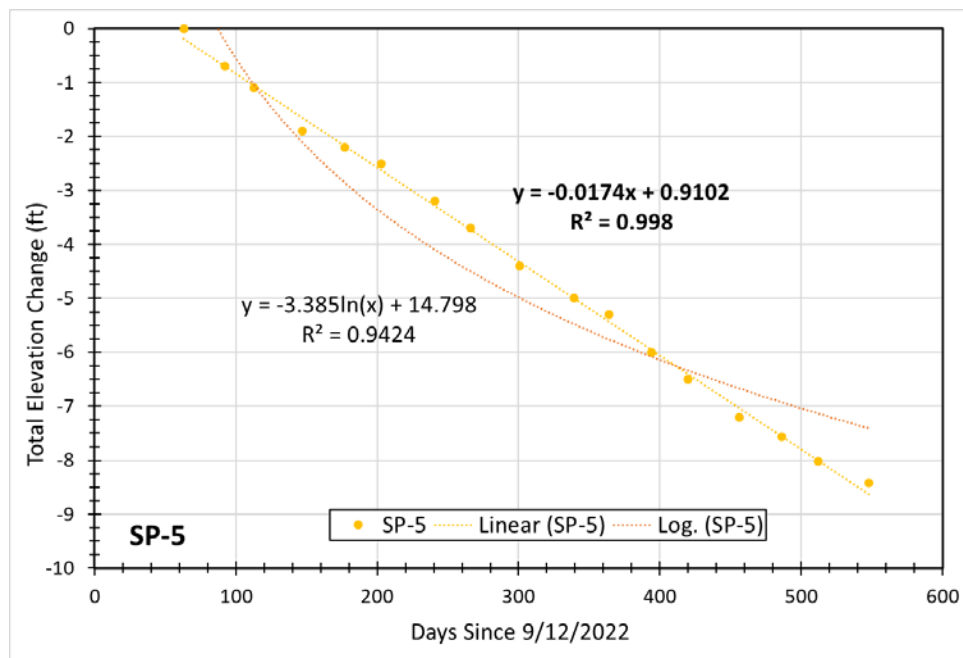
Figure 3 - Settlement Plate 2



SP-3 is excluded due to suspected damage and a lack of recent data for the plate. SP-4 has been excluded from the regression analysis due to suspected damage; however, the available data does indicate a linear trend for the plate.

Applying a linear trendline to the data for SP-5 produces an R^2 equal to 0.998, indicating the strongest linear fit of all the settlement plate data (Figure 4). Settlement appears steadily ongoing at SP-5, and the nearby temperature probe TP-4 continues to show elevated temperatures.

Figure 4 - Settlement Plate 5



The data for settlement plates 6 and 8 fit linear trendlines (Figure 5 and Figure 6). The elevated temperatures measured by TP-4, 100 feet east of SP-6, suggests that SP-6 will continue to settle significantly. SP-8 is positioned north of the highest temperature area and may stabilize prior to the southern settlement plates. The logarithmic trendline for SP-8 gives an R^2 of 0.96 versus 0.99 for the linear trendline. SP-7 was excluded from the analysis due to suspected damage, and SP-9 was excluded due to unavailable data.

Figure 5 - Settlement Plate 6

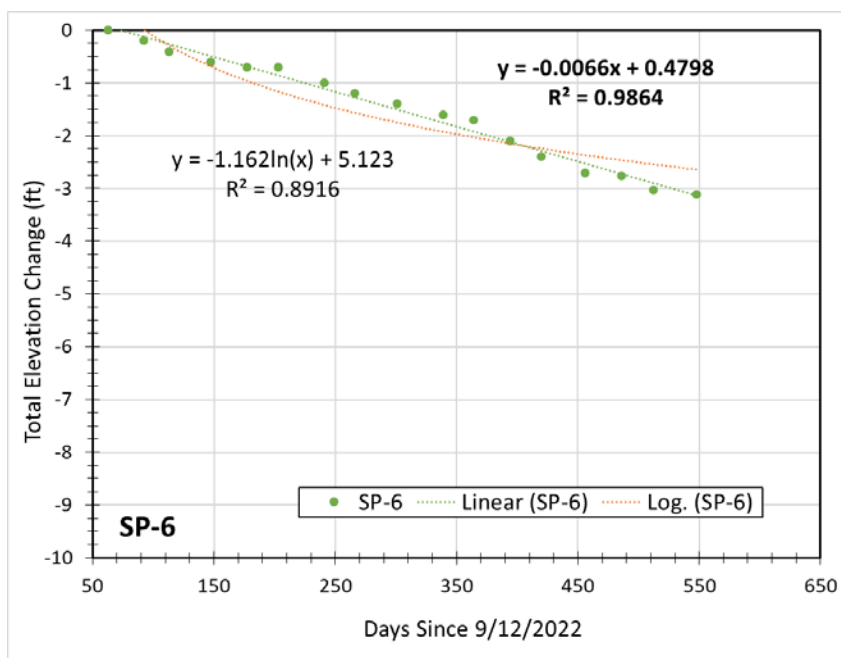
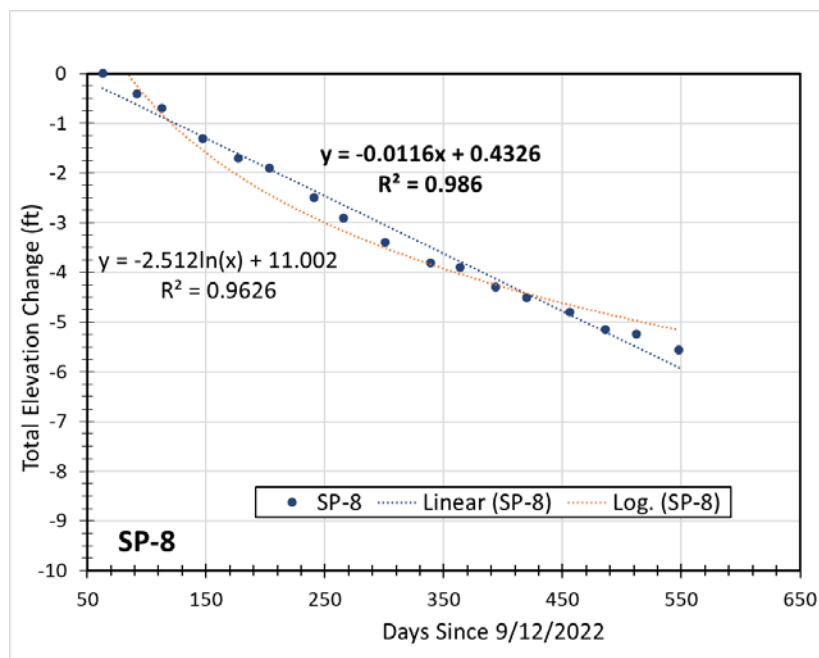


Figure 6 - Settlement Plate 8



SP-10, SP-11, and SP-12 are positioned in the north end of the quarry. The northernmost temperature probe (TP-9) indicates lower, more stable temperatures in this area relative to the south. The elevation data from these settlement plates shows less overall settlement and lower strain rates (less than 1% per year) relative to the southern plates (Figure 7 through Figure 9). The temperature and elevation data together suggest the northern area may be transitioning to secondary compression, but settlement remains linear with respect to time. Elevation variability,

potentially due to vertical accuracy limitations of the GPS measurements, appears more noticeable for these settlement plates due to the smaller settlement rates.

Figure 7 - Settlement Plate 10

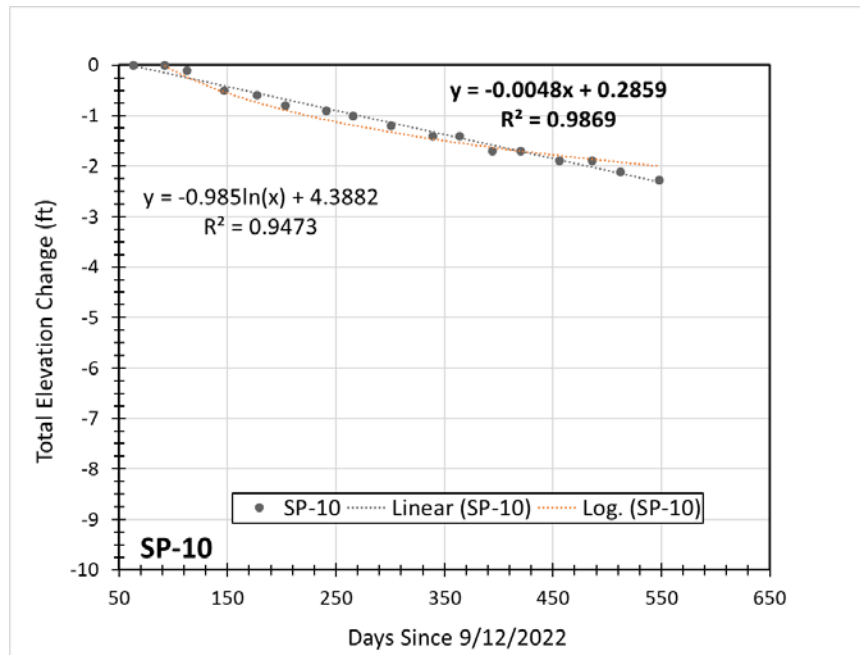


Figure 8 - Settlement Plate 11

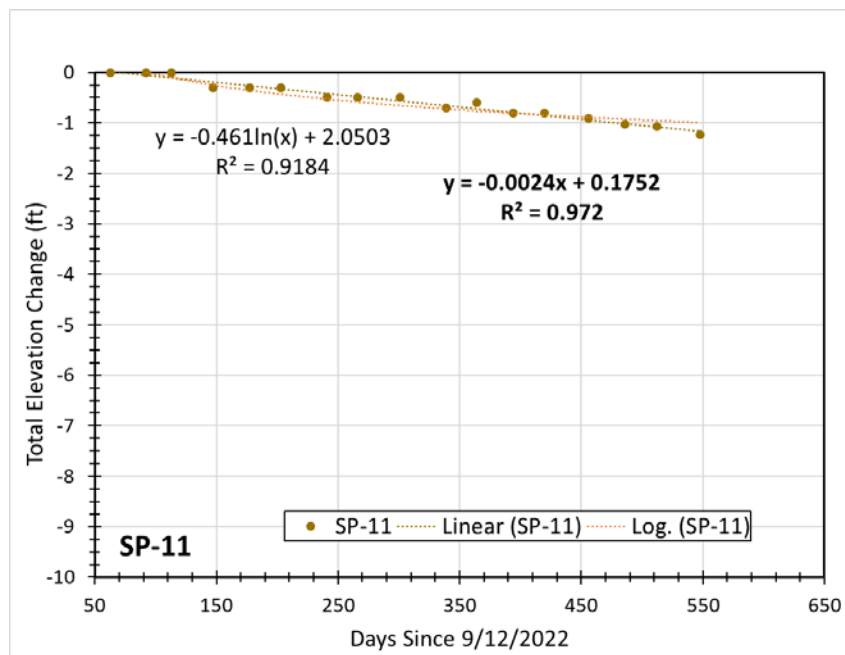
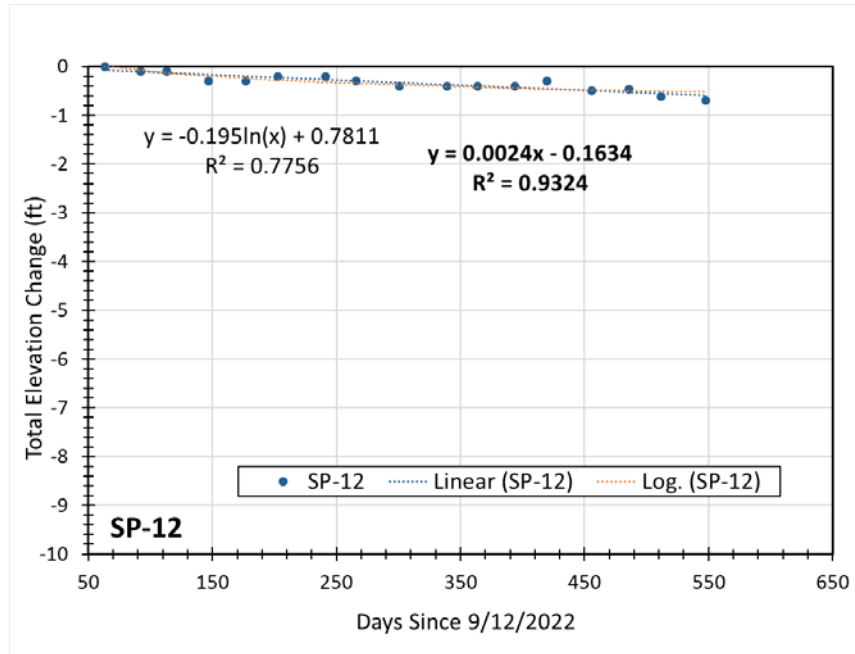


Figure 9 - Settlement Plate 12



A summary of the settlement trends is presented in Table 4 for the operational plates. The graphs of the elevation data for SP-2, SP-5, SP-6, SP-8, SP-10, SP-11, and SP-12 demonstrate prevalent linear trends, and the waste has not transitioned to an overall state of long-term secondary compression. Criteria 1 is not satisfied.

Table 4 - Settlement Plate Condition

Settlement Plate	Apparent Settlement Trend (Linear or Logarithmic)
SP-1	Logarithmic
SP-2	Linear
SP-5	Linear
SP-6	Linear
SP-8	Linear
SP-10	Linear
SP-11	Linear
SP-12	Linear

3.2 CRITERIA 2 – STRAIN RATE

Table 3 lists the current estimated strain rate for each settlement plate. The current strain rate is estimated using the change in elevation between the two most recent surveys (March 13, 2024 and February 6, 2024) divided by the original waste thickness, normalized to a yearly rate. SP-6⁷, SP-10, SP-11, and SP-12 are estimated to have a current yearly strain rate of less than 1%. The remainder of the intact plates (SP-1, 2, 5, 8) show current strain rates in excess of 1% per year, with SP-2 exceeding 2% as of the most recent measurement.

As an alternative to the current strain rate, Table 5 presents the approximate strain over the last year by comparing the March 2023 elevation data to March 2024. SP-10, SP-11, and SP-12 are the only plates which did not exceed 1% strain during this time period.

Table 5 – Strain between March 8, 2023 and March 13, 2024

Settlement Plate	Estimated Strain
SP-1	4.0%
SP-2	3.9%
SP-5	2.4%
SP-6	1.8%
SP-8	1.6%
SP-10	0.6%
SP-11	0.4%
SP-12	0.4%

The estimations indicate that the current strain rates for at least four of the settlement plates exceeds 1% per year, and criteria 2 is not satisfied.

3.3 CRITERIA 3 – SURFACE CRACKS

Personnel working in the quarry continue to observe surface cracks due to settlement exceeding 1-inch width. Settlement cracks and a scarp were observed during March in the southern region of the quarry between settlement plates SP-1 and SP-4, approximately 20 to 40 feet from the sidewall. The cracks and scarp extended along a linear region, approximately 100 feet long, which follows an abrupt change in the base grade elevations and corresponding waste thickness.

Figure 10 shows a photo of the settlement cracks and scarp, facing northwards. Settlement cracks measuring approximately 2 to 4 inches are visible in the foreground. The scarp, visible in the background, measures approximately 3 feet. Figure 11 shows the same scarp, facing westwards.

The observed surface cracks and scarp indicate that criteria 3 is not satisfied.

⁷ Estimates of the current yearly strain rate for SP-6 for the previous three months (02/2024, 01/2024 and 12/2023) were 2.7%, 0.8%, and 2.1%. Due to the variability of the estimates, SP-6 is considered inconclusive for criteria 2.

Figure 10 - Scarp and Settlement Cracks



The scarp is located above the edge of a bench in the rock wall created by quarry operations. The bench remained in place when the facility was converted to a landfill. SCS estimates that the waste thickness transitions from approximately 10 feet to 136 feet over a horizontal distance of 42 feet. If waste at both thicknesses settles at a similar, nonzero strain rate, it creates a differential in elevations. SCS believes that this differential waste thickness is the cause of these cracks at the surface.

Figure 11 - Scarp



4.0 CONCLUSION

The analyses of the settlement plate elevation data, strain rates, and presence of surface cracking together indicate that none of the three settlement criteria have been satisfied. The quarry has not reached an acceptable rate of settlement for the EVOH cover system deployment based on the established criteria. A subsequent assessment will be prepared by June 28th, 2024 and submitted to VDEQ within 10 business days.