UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 7
11201 Renner Boulevard
Lenexa, Kansas 66219

Mr. Paul V. Rosasco
Project Coordinator
Engineering Management Support, Inc.
25923 Gateway Drive
Golden, Colorado 80401

Re: West Lake Landfill Superfund Site, Operable Unit 3, 2022 Annual Hydrogeologic and Site Characterization Report

Dear Mr. Rosasco:

The U.S. Environmental Protection Agency has received the West Lake Landfill OU-3 2022 Annual Hydrogeologic and Site Characterization Report (Annual Report), submitted on March 1, 2023, by ERM Consulting & Engineering, Inc. (ERM) on behalf of Bridgeton Landfill, LLC, Cotter Corporation (N.S.L.), and the U.S. Department of Energy (Respondents).

Review of the 2022 Annual Report was coordinated with the Missouri Department of Natural Resources. Based upon the review, the EPA provides the enclosed comments.

The 2022 Annual Report contained significantly more data and information than the previous year, including the first quarter of off-site groundwater data. While this additional data helps begin to fill in existing data gaps, there is still a significant amount of data collection and evaluation to occur, and the Conceptual Site Model will continue to evolve. As previously stated by the EPA, final conclusions regarding the source, nature, and extent of site-related groundwater contamination will be presented in the Remedial Investigation report.

Where possible, the EPA drafted comments to be addressed in the upcoming 2023 Annual Report or other future deliverables such as the Remedial Investigation report, while others will need to be addressed in the 2022 Annual Report. These comments are separated in the enclosure, with the first set of comments intended to be addressed in a revised 2022 Annual Report.

In accordance with Section IX, paragraph 52 of the Administrative Settlement Agreement and Order on Consent (CERCLA-07-2018-0259), the Respondents shall prepare and submit a revised report that addresses the enclosed comments within 30 days of receipt of this letter. To expedite the EPA's review of the revised 2022 Annual Report, the EPA requests the Respondents submit a red-line version of the revised report. In addition to submitting a revised 2022 Annual Report, the EPA requests the Respondents document which comments provided for future deliverables will be addressed in the 2023 Annual Report and which will be addressed in the future Remedial Investigation Report.

If you have any questions or concerns, please contact me either by phone at (913) 551-7910 or by email at schwartz.jamie@epa.gov.

Sincerely,

JAMIE SCHWARTZ Digitally signed by JAMIE SCHWARTZ
Date: 2023.09.15 12:55:26 -05'00'

Jamie Schwartz
Remedial Project Manager
Remediation Branch
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Enclosure

cc: Alice Sandzén, ERM
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EPA Comments to be Addressed in the 2022 Annual Report, Submitted March 1, 2023
West Lake Landfill Superfund Site, Operable Unit 3

1. **Executive Summary, Page 2; Section 5 Next Steps, Page 115.** PSQ-2 states: "Additional data are needed … west of the Site." and PSQ-3, footnote 1 states "The organic COPCs … are found in downgradient groundwater samples collected along the western Site boundary." Revise to clarify that 1,4-dioxane also is detected in groundwater north of the northern site boundary (e.g., MW-406 monitoring well set) and to discuss the need for additional delineation in this direction.

2. **Executive Summary, Page 2; Section 5 Next Steps, Page 115.** PSQ-2 states: "If 1,4-dioxane is detected in bedrock at off-Site locations where it was detected in lower alluvium, additional data may be required to determine the lateral extent of 1,4-dioxane in bedrock." Because waste was placed in a bedrock excavation and, at the MW-406 monitoring well set directly north of the site, 1,4-dioxane is detected in bedrock but not in lower alluvium, requiring lower alluvium detections as a prerequisite for delineation appears inappropriate. Revise both the Executive Summary and Section 5 to delete this prerequisite and clarify that the need for step out wells in bedrock will be data driven.

3. **Section 1.1 Description of the Problem and Progress Update, Page 5.** Footnote 3 states: "The organic COPCs are not detected in upgradient groundwater samples collected along the eastern and southern Site boundaries…". Because there are J-qualified (estimated) 1,4-dioxane detections along the southern and eastern site boundaries, revise for accuracy as: "The organic COPCs are not detected at concentrations above laboratory reporting limits in upgradient groundwater samples collected beyond the southern and eastern site boundaries."

4. **Section 3.1 Vertical Profiling in Groundwater, Table 11, Page 27.** The last paragraph of Section 3.1 states "all analyte concentrations were comparable between the two sampling devices despite any differences in RLs" (reporting limits), except for vinyl chloride in MW-501-P3 and APS-015. Revise to note an additional exception. Toluene also was consistently detected in monitoring wells at concentrations above reporting limits while being non-detect or biased low in corresponding APS samples (see Table 11).

5. **Section 3.3 Geological Boring Logs, Page 29.** The last paragraph indicates that one groundwater screening sample was collected from each open bedrock borehole. Revise to clarify the purpose of these samples. Discuss whether any concentrations detected were not represented by APS or monitoring well sample results, and note where reporting limits are significantly elevated (e.g., 100 µg/L for 1,4-dioxane).

6. **Section 3.5.1 Monthly Monitoring Well Gauging, Page 30.** In the third paragraph of Section 3.5.1, revise the third paragraph from "… hydraulic influences on seasonal variability …" to "… hydraulic influences on temporal and seasonal variability… " to be inclusive of the hydraulic influence of landfill operations (e.g., leachate pumping).

7. **Section 3.5.2 Pressure Transducer Data, Page 32.** In the last paragraph of Section 3.5.2, revise the reference to the hydrographs from "Appendix K" to "Appendix M."

8. **Section 3.7 Groundwater and Leachate Analytical Results, Table 3-2, Page 37.**
   a. Consistent with Table 15b, revise the vinyl chloride range from NA to ND, or not detected.

   b. Revise Table 3-2 to indicate where non-detect (ND) results had reporting limits higher than the EPA maximum contaminant level (MCL), or EPA regional screening level (RSL) where no EPA MCL has been established.

9. **Section 3.7.1 Groundwater and Leachate Data Quality Summary, Table 3-3, Page 38; Tables 16a-16c.** The last paragraph on page 38 indicates that trip blanks and filter blanks were not included in Table 3-3, Frequency of Detections, due to lack of detections. However, this reasoning does not support the omission of a trip blank table from Tables 16a through 16c. Revise to include a Table 16 for trip blanks.

10. **Section 3.7.1 Groundwater and Leachate Data Quality Summary Page 42**.
    a. The second bullet on page 42 discusses the cause of PAH detections in select wells in Q3 2022. In addition to assessing historical and quality control results, revise to discuss whether changes in landfill operations, conditions, or concentrations may have contributed to these detections.

    b. The last bullet of Section 3.7.1 states: "A formal corrective action letter will be prepared by the laboratory." Include this letter with the final 2022 Annual Report.

11. **Section 3.8 Groundwater Field Parameter Data Quality Summary, Page 43; Appendix F Quarterly Groundwater Field Parameters, Appendix N Descriptive Statistics and Box Plots of Groundwater Samples by Analyte.**
    a. The third primary bullet on page 43 of Section 3.8 indicates that the Q3 2022 dissolved oxygen values of 50.7 mg/L (MW-213-P1) and 42.2 mg/L (MW-213-P2) were replaced with 5.07 mg/L and 4.22 mg/L, respectively. However, Table N-1 lists a maximum dissolved oxygen of 50.7 mg/L. Additionally, the maximum alluvium dissolved oxygen value presented in Table N-1 (50.7 mg/L) differs from the maximum alluvium dissolved oxygen value presented in Appendix F (4.22 mg/L or 9.12 mg/L if X-flagged [non-representative] values are considered). Revise Section 3.8, Appendix F and/or Appendix N as necessary to address any discrepancies.

    b. Summary statistics appear to be generated using dissolved oxygen values that are X-flagged as not representative. Revise to remove non-representative values from the summary statistics or present them separately.

12. **Section 3.9.1.2 Methane Results, Page 44, Table 19.** The second paragraph of Section 3.9.1.2 states: "The highest total methane concentration detected in SSV [sub-slab vapor] beneath the building was 0.24 percent, which is less than the methane alarm trigger value (i.e., 1.1 percent for methane)." However, Table 19 lists the highest methane result in sub-slab vapor samples as 240,000 ppmv in sample GB-002, collected beneath the engineering building conference room on October 28, 2021. A concentration of 240,000 ppmv (240,000/1,000,000 = 0.24) would be 24%, exceeding the methane alarm trigger value. Sub-slab soil gas sample GB-001, collected beneath the engineering building foyer on October 28, 2021, also exceeded the methane alarm trigger value with a concentration of 78,000 ppmv (78,000/1,000,000 = 0.078) or 7.8%. Revise to correct this discrepancy. If sub-slab methane concentrations exceeded the methane alarm trigger value in 2022 Q4, verify that the alarms functioned as intended and identify corrective actions taken to mitigate this potential hazard.

13. **Section 3.11.2 Evaluation of VI Impacts from Chemical Occurrence in Groundwater, Page 46.** The first sentence of Section 3.11.2 states: "Groundwater data will be compared to groundwater VISLs [vapor intrusion screening levels] after all proposed monitoring wells have been installed and sampled and sufficient data have been generated." Postponing this evaluation is unacceptable, as it is integral to ongoing contaminant delineation and risk assessment and mitigation efforts. Revise to indicate that vapor intrusion screening will be conducted as shallow groundwater data are received by comparing the results from the shallowest well in a nest or cluster to appropriate VISLs.

14. **Section 4 Conceptual Site Model Update, Page 51.** The fifth bullet on page 51 states, "These data indicate that RIM is not the source of radium in Site groundwater, and that radium detected in Site groundwater originates from the natural aquifer materials." Revise this statement as: "Ratios of radium isotopes in groundwater samples collected to date are not consistent with RIM being a significant source of radium detected in GW at the site." The claim that RIM is not a contributing source of radium in groundwater is premature and lacks strong, consistent supporting evidence. Some wells, for example, have had low Ra 228/226 ratios that could result from a mixture of RIM with naturally occurring groundwater. Additional data collection and evaluation, such as an evaluation of radium concentrations relative to landfill leachate indicators in groundwater, are needed to assess whether and how landfill leachate from the site affects groundwater geochemistry and mobilization of radium and trace elements from aquifer materials.

15. **Section 4.1 Conceptual Site Model Summary, Page 52.**
    a. The second paragraph on page 52 states, "… horizontal and vertical hydraulic gradients are very low (i.e., generally less than 0.0003 feet/foot in alluvium) …". The range of values was 0.002 to 0.039 feet/foot. Revise to clarify how the quoted value was obtained (e.g., average), including measurement precision and standard deviation, and discuss whether wells where the measured heads are effectively equal in value are within the margin of measurement precision.

    b. According to the last sentence of the second full paragraph on page 52, "… low solute concentrations … detected in shallow groundwater around these landfills …" suggest that "… any leachate currently migrating out of these landfills contains low solute concentrations." Remove this conclusion based on the following: The relative term "low" conflicts with language in the next paragraph describing "elevated solute concentrations … adjacent to the South Quarry"; some waste disposal areas extend into bedrock and may impact deeper groundwater; and the site-specific hydrogeologic relationship between groundwater concentrations and leachate concentrations is poorly supported here.

16. **Section 4.3.3.2 Earth City Levee District, Pages 59 – 60.**
    a. Figure 4-8b and the first sentence on page 60 indicate the maximum elevation of the ECLD surface water body is maintained around 432.56 feet above mean sea level (ft amsl) whereas the second to last sentence on page 60 and the last bullet on page 59 indicate that pumps are activated once the water body rises to 432.86 ft amsl. Revise to correct what appears to be a discrepancy regarding the maximum elevation of the ECLD surface water body.

    b. The explanation below Figure 4-9 "…shows that water levels in the Missouri River (blue line) rise after large precipitation events (gray bars)." The cause and effect implied in this statement is not possible, as there is insufficient drainage area in the St. Louis area to measurably affect the Missouri River over a single precipitation event. The Missouri River responds to cumulative spring rains across the entire Midwest and releases from dams on the Missouri River and Kansas River. Revise the explanation below Figure 4-9 accordingly and provide the source of the precipitation data.

   c. The report states "… the engineered water body is not a source of recharge to groundwater …" (page 60) and "groundwater in the underlying alluvial aquifer does not appear to be affected by the ECLD engineered water body" (page 82). These statements appear to conflict with other report content indicating the engineered water body is in direct communication with the groundwater. For example, page 60 also indicates that pumping down the engineered water basins prior to a storm event causes "a temporary depression in the water table adjacent to the engineered water body." Page 60 also notes relief well piping is directly connected to the engineered water body suggesting that a difference in water basin and groundwater elevations could result in short-term groundwater recharge from or discharge to the engineered water basin. Provide sufficient clarification in the final Conceptual Site Model (CSM) to ensure statements and conclusions do not appear contradictory and accurately reflect transport and fate potential in surface water.

17. **Section 4.4.1 Bedrock, Figure 4-11, Page 63.**
    a. The water-free zone at the St. Louis Formation – alluvium interface appears to be above "crypto-crystalline brecciated limestone." Revise to indicate regional continuity of this unit and any associated hydrogeological effects, such as whether this unit is a dense re-crystallized limestone breccia with sufficiently low porosity and permeability to act as a confining unit.

    b. Define the italicized unit markers in the St. Louis Formation (e.g., Bx, LdLs, Lb, and Lc).

18. **Section 4.5.2 Groundwater Response to Missouri River Stage, Page 77.**
    a. Comment 16 applies. At the end of the first paragraph of Section 4.5.2, remove the words "river stages and therefore."

    b. The last paragraph in this section references Figure 4-26. The correct reference appears to be Figure 4-24 rather than 4-26. Revise accordingly.

19. **Section 4.5.3 Groundwater Response to Meteoric Recharge, Figure 4-25, Page 78.** The partial paragraph at the top of page 78 indicates that, except at PZ-202-SS, "there is very little correlation between changes in groundwater levels and precipitation" and "(g)roundwater recharge from infiltration of precipitation events does not appear to have a significant effect on water table elevations …". However, for all the wells graphed on Figure 4-25, many of the significant water level inflections appear to be in direct response to precipitation events. A significant example is the response to precipitation in July 2021, when groundwater levels typically would flatten or begin to decline with evapotranspiration and decreased rainfall. Revise the statement accordingly.

20. **Section 4.5.6.2 Horizontal Hydraulic Gradient, Vector and Flow Distance Analysis, Page 82; Appendix Q.** The first paragraph of Section 3.5.6.2 states "…no on-Site monitoring wells in the southernmost portion of the alluvial aquifer … were fitted with pressure transducers during the reporting period." Figure Q-2 (Appendix Q) shows multiple transducers in the southern portion of the on-Site alluvial aquifer. Revise to address this apparent inconsistency.

21. **Section 4.5.7 Bedrock Aquifers, Page 92.** The first sentence of the last paragraph on page 92 begins: "Horizontal hydraulic gradients in each of the bedrock formations in the upland area are to the north ...". Revise this statement for consistency with Figure 4-41, showing flow to the northwest.

22. **Section 4.5.8 Groundwater Flux, Figure 4-43, Page 95; Appendix R.** Table R-1 in Appendix R shows the average saturated thickness of both alluvial cross sections as 100 feet. However, this appears inconsistent with area boring logs (Fall = D83 to PZ-205; Winter = MW-303 to MW-404-P3), and bedrock in the southern part of the fall transect appears to be 30-50 feet higher than to the west and north. Revise to clarify the basis for using 100 feet in both transects or correct the thicknesses accordingly.

23. **Section 4.6.1.3 Nature and Extent of Radionuclide COPCs, Pages 99 – 101.** The last sentence on page 101 states: "… background bedrock well MW-600-P1 …". Revise to remove the term "bedrock" as this well is completed in the Upper Alluvium.

24. **Section 4.6.1.4 Potential Sources of Radionuclides in Groundwater, Page 104.** The partial paragraph at the bottom of page 104 states: "These data indicate that the radium present in the alluvium and bedrock groundwater samples was derived from alluvial sands and carbonate bedrock, respectively—not from RIM." Revise this statement to indicate that, while RIM may not be the primary source of radium, additional work is needed to determine whether RIM contributes some portion of the overall radium content. See also Comment 14.

25. **Section 4.6.1.4 Potential Sources of Radionuclides in Groundwater, Page 110.** The first paragraph of the Summary box on page 110 states, "… radium detected in Site groundwater originates from the natural aquifer materials rather than from RIM placed at the Site." Revise this statement to indicate that, while RIM may not be the primary source of radium, additional work is needed to determine whether RIM contributes some portion of the overall radium content. See also Comments 14 and 24, and related language in Section 4.6.4.

26. **Section 4.6.1.4 Potential Sources of Radionuclides in Groundwater, Page 110.** In the first full paragraph on page 110, revise to correct the reference from Figure 4-50 to Figure 4-52.

27. **Section 4.6.4 Summary of Nature and Extent of Select Groundwater COPCs, Page 113, Third Paragraph.**
    a. Revise the second sentence as, "… and in bedrock, radium-226 activities exceed the radium-228 activities".

    b. This paragraph indicates that similar radium isotope ratios between groundwater and aquifer matrix samples indicate no evidence of increased radium-226 activity from RIM. Revise this statement to qualify that isotope ratios cover a broad range (approximately 0.23 to over 9), suggesting the geologic and landfill materials represent a heterogeneous media. As noted, "evaluation of the various potential sources of radium in groundwater is ongoing."

    c. The last paragraph on page 113 indicates that four COPCs "were detected infrequently or at concentrations below the MCL and will not be discussed further in future annual reports." Revise to remove this sentence. Omission of select COPCs from future reports should be based on data received during the reporting period (i.e., if they continue to be detected, they should continue to be reported unless/until they are formally removed as a COPC). Further, the CSM and risk assessment should be based on all data obtained. Subsequently, final contaminants of concern will be identified based on additional considerations (e.g., frequency, location, exposure potential).

28. **Section 5 Next Steps, PSQ 3-4, Page 115.** To support PSQ-3 and PSQ-4, revise to include these critical next steps:
    a. Review previously developed criteria for, and identify and categorize, wells with landfill leachate effects versus those that do not have landfill effects.

    b. Conduct graphical and statistical comparison of the landfill leachate-affected versus the non-landfill leachate-affected well groupings, especially regarding radium concentrations and isotope ratios. Use these findings to guide next evaluation steps, in particular, the connection between landfill leachate effects and radium, arsenic, or some of the more widespread organics (such as 1,4-dioxane). Determine whether correlations or co-occurrences exist among arsenic and widespread organics such as 1,4-dioxane, especially in the Upper Alluvium. Assess whether the presence of reducing conditions alone can explain the distribution of high radium, or if further consideration of the landfill leachate-affected subset of wells is needed to define the distribution of the highest radium concentrations.

29. **Section 5 Next Steps, PSQ-4, Page 115.** To support PSQ-4, include evaluation of organic compound inter-relations as a next step. Consider the relationships among the more widespread organic compounds, dissolved organic carbon, and redox indicator constituents.

30. **Table 14.** Evaluation of third quarter analytical data for constituents which had a limited number of detections (as examples, fluorophenols, methylnaphthalenes, acenaphthalene, acetone, antimony, barium, benzene, beryllium) indicates the detections occurred almost exclusively at monitoring wells located along the south quarry boundary and the drainage channel from OU-1/North Quarry area toward the former leachate lagoon (as examples, PZ-302-AS, D-89, PZ-107-SS, MW-302 and PZ-205-AS). This pattern was not observed in other quarters, conflicting with the updated CSM conclusion that temporal variability in COPC concentration/activity level and composition in groundwater were generally consistent over time. Expand the CSM to evaluate the cause of the groundwater constituent distribution observed in the third quarter to better understand transport characteristics at the site. If this trend continued into 2023, the CSM can be updated in the 2023 Annual Report to address this; otherwise address in the 2022 Annual Report.

31. **Table 14a Validated Groundwater Data – Radiochemistry Analytical Results, Table 15a Validated Leachate Data – Radiochemistry Analytical Results, Section 3.7.1 Groundwater and Leachate Data Quality Summary, Pages 38 – 42; Appendix J-2.** As shown in Tables 14a and 15a, numerous radium results above planned (2 pCi/L) or actual minimum detectable concentrations (MDCs) are qualified as estimated (J), estimated with possible bias (J+/-), or non-detect (U). Revise Section 3.7.1 and, as appropriate, Appendix J-2 to better explain the basis for qualification and evaluate the potential for analytical bias.
    a. For some samples with radium concentrations high enough that they would not typically present an analytical challenge, matrix interference is noted. Assess whether the matrix issues are aligned with high total dissolved solids or other factors.

    b. A total of 33 radium-228 and 23 radium-226 results were qualified as estimated with potential high bias (J+) because of equipment blank or field blank contamination. Discuss sample management and equipment decontamination measures to reduce future sample contamination.

32. **Figures 9a-16a Summary of Results in Groundwater, Appendix F Quarterly Groundwater Field Parameters.** Several of the wells with sampling results in Appendix F (e.g., PZ-114-AS, PZ-205-AS, PZ-207-AS, PZ-302-AS, PZ-304-AS) are not shown on the map-view figures summarizing analytical results in groundwater (Figures 9a to 16a). Revise to include these data on the figures.

33. **Appendix F Quarterly Groundwater Field Parameters, Page 2.** The MW-113 sample from November 17, 2021, has an unusually high turbidity reading (143.22) compared to subsequent sampling events, potentially indicating incomplete development or purging. Revise to explain, and flag associated analytical data as appropriate.

34. **Appendix I, Figure I-2, Pages I-2 and I-3.** The second paragraph on page I-2 states: "… relatively low concentrations of barium were observed in the Middle Alluvium TSU," and the WATERLOO APS^{TM} groundwater chemistry data on Figure I-2 appear to support this statement. However, further review of the dissolved barium data indicates that while the lower alluvium has higher barium concentrations, the middle and upper alluvia have very similar barium concentrations. See the box plot of all alluvial well designations, and a simple T-test (assumed normality) of alluvial wells classified in a single time stratigraphic unit (upper, middle, or lower). Revise the second paragraph on page I-2 accordingly.

35. **Appendix K Groundwater Elevation Summary and Data Quality Review, Table K-1, Page 1; Appendix P Monitoring Well Time Stratigraphic Unit Assignments.** On Table K-1, monitoring well MW-406-P5 is assigned to the Warsaw geologic interval but the Salem time stratigraphic unit. Similarly, monitoring well MW-408 is assigned to the Alluvium geologic interval but the Salem time stratigraphic unit. Revise to correct these apparent discrepancies or explain the redesignation in the notes. This comment also affects the well time stratigraphic unit designations in Appendix P.

36. **Appendix L Potentiometric Surface Maps.**
    a. MW-504 was installed May 2022 and gauging data are provided for August and September 2022, yet the potentiometric surface maps do not include gauging data for this well. Revise to include this data or explain why it was omitted.

    b. Monthly potentiometric surface maps were drawn for the composite alluvium though May 2022 and, subsequently, for the three newly defined time stratigraphic units. Revise to replot the "composite" potentiometric surface maps using the newer time stratigraphic units (at a minimum, compare an "average" with extremes of seasonal high precipitation and drought cases).

37. **Appendix M OU-3 Hydrograph Time Series Plots.**
    a. A number of alluvial wells have dramatic drawdowns (e.g., MW-502-P1, -P2, and -P3), which seems unusual given the high hydraulic conductivity of the alluvium and low purge rates. Revise the CSM and/or include a discussion in Appendix M indicating why this might be occurring.

    b. A few hydrographs (e.g., MW-112-P3, MW-401-P1, MW-600-P2) show differences of greater than 0.5 foot between the manual measurement and transducer reading. Revise to explain these differences in the Observation bullets of Appendix M. Note: Although MW-112 and MW-401 are discussed, the noted transducer repairs do not correlate with these discrepancies. Likewise, MW-600-P2 is discussed, but no timeframe is established for the calibration and transducer issues that would allow correlation.

38. **Appendix P Monitoring Well Time Stratigraphic Unit Assignments, Appendix C Boring Logs (Monitoring Wells and Piezometers) and Well Construction Logs.** Some of the boring depths on the Appendix P table appear to conflict with the well logs in Appendix C. As examples: Boring depths for MW-600-P1/P2/P3 are 30.00/70.00/117.50 in Appendix C but 30.00/58.00/95.00 in Appendix P. Boring depths for MW-602-P1/P2/P3/P4/P5 are 190.00 feet in Appendix C but 188.00 in Appendix P. Revise Appendix P to correct or explain these apparent discrepancies.

EPA Comments to be Addressed in the 2023 Annual Report or Other Future Deliverables
West Lake Landfill Superfund Site, Operable Unit 3

1. **Section 2.6 Transducer Deployment and Monitoring, Pages 18 – 19.** Section 2.6 documents multiple pressure transducer issues resulting in missed data collection. Acknowledging the efforts already made to replace these pressure transducers with more rugged units, consider whether remote data transfer or alarms would further avoid downtime.

2. **Section 2.10.1 Bridgeton Landfill Submittals to MoDNR, Page 23.** The last paragraph indicates that most Bridgeton Landfill data are not included because they are not needed to answer the OU-3 Principal Study Questions. However, additional data would be beneficial to directly support the assertion in Section 2.2.2 that subsurface conditions do not yet support leachate collection sump (LCS) replacement and to assess potential correlations between landfill conditions (e.g., temperature, pressure) and contaminant concentrations and distributions. Consider these data in future reports.

3. **Section 3.2 Geophysical Logging, Page 28.** The last two paragraphs of Section 3.2 discuss how the combination of gamma and electrical conductivity data can be used to identify elevated inorganic solute concentrations that may indicate landfill seepage. Future submittals should include tables and/or figures to more clearly indicate where these conditions are observed.

4. **Section 3.5.3 Groundwater Elevation Data Quality Review, Page 32.** Section 3.5.3 describes a QA/QC process for groundwater elevation data quality review. This process should be included in the next revision of or addendum to the site QAPP.

5. **Section 3.8 Groundwater Field Parameter Data Quality Summary, Pages 42 – 43, Appendix F.**
    a. The first paragraph of Section 3.8 indicates that dissolved oxygen (D.O.) values for samples from multi-level wells are not representative because of "the aeration that occurs during the collection of field parameters at multi-level wells." This appears to be an oversimplification, as many redox sensitive constituents would be impacted by aeration of the well water. Field oversight in August 2022 found that allowing sufficient time for purging and stabilizing appears to improve the representativeness of D.O. results. For example, at MW-502-P1, ERM recorded 3.32 mg/L D.O. after less than a minute of stabilization; however, after 2 to 3 minutes of stabilization, the U.S. Geological Survey recorded <1 mg/L D.O. with YSI ProDSS and <0.05 mg/L with a CHEMetrics low-range vial. Moving forward, the Respondent should improve the reliability of field D.O. readings by ensuring purge times are sufficient to produce representative aquifer water and allow field meters to stabilize, and using a dissolved oxygen test kit to verify low D.O. levels in the field. Flag any results that are not representative of field or landfill conditions in Appendix F and the database.

    b. Under the Section 3.8 discussion of potentially anomalous field parameters, the first primary bullet on page 42 identifies elevated pH readings at 4 of 13 locations sampled on February 26, 2022, and the second bullet identifies an anomalous temperature reading (low). A review of the data in Appendix F indicates a number of elevated temperature readings as well, which also warrant discussion. The elevated pH and temperature readings may be attributed to a meter or calibration issue, or, similar to the anomalous D.O. readings, insufficient time for the meter and flow-through cell temperature to equilibrate to groundwater. Landfill conditions like leachate and increasing temperatures from the subsurface reaction occuring in the south quarry of Bridgeton landfill may also increase or decrease pH. The Respondents should work to improve the reliability of field pH and temperature readings by ensuring purge times are sufficient to produce representative aquifer water and allow field meters to equilibrate. Where pH values or temperatures are outside of the normal range, distinguish whether this is the result of landfill conditions (e.g., leachate, subsurface reaction) or a field issue (e.g., meter, calibration, transcription, stabilization), and flag any results that are not representative of field or landfill conditions in Appendix F and the database.

c. A review of Appendix F indicates that Keokuk wells PZ-104-KS and PZ-106-KS have consistently elevated temperatures (>22 degrees C). While the SSE likely contributes to elevated temperatures at shallower PZ-104 and PZ-106 well depths, it is unclear why Keokuk wells below the Warsaw formation would have similarly elevated temperatures. Consider whether the PZ-104-KS and PZ-106-KS temperature data are representative of Keokuk groundwater or attributable to field issues (e.g., insufficient purging, warming as water in a PZ-104-KS or PZ-106-KS casing moves through the subsurface reaction zone). Conduct verification temperature measurements using modified procedures as appropriate (e.g., longer purging, in situ measurement with a downhole probe). If temperatures are representative of Keokuk groundwater, discuss how this alters the current understanding of the subsurface reaction in the south quarry of Bridgeton Landfill and the broader CSM.

6. **Section 4 Conceptual Site Model Update, Pages 50 – 114; Table 15.**
   a. Although leachate data are presented in the Table 15 series, these tables are not referenced within the report or discussed within the CSM Update. Include a discussion of the leachate data in future annual reports.

   b. The eighth bullet on page 50 notes an "improved understanding of the bedrock structure." Clarify in future deliverables what is intended by "bedrock structure" and where the improved understanding is presented. Is definition of the Salem Shoal considered "structure"? If this discussion will not be part of the revised conceptual site model in the 2023 Annual Report, revise the 2022 Annual Report accordingly.

   c. The fourth bullet on page 51 states, "COPC concentration/activity level and composition in Site groundwater were evaluated and found to be generally consistent over time." Support for this statement appears limited to the time-series plots of select COPCs in Appendix T. No trend calculations are provided with the plots, and no standard deviation or coefficient of variability values are included in the descriptive statistics tables in Appendix N. See also comment 30 of the comments to be addressed in the 2022 Annual Report, which notes inconsistency between the Q3 2022 data set and the data sets of other events. Include descriptive statistics and trend calculations in future reports to support such findings.

7. **Section 4.1 Conceptual Site Model Summary, Page 52.** The second paragraph on page 52 states, "… horizontal and vertical hydraulic gradients are very low (i.e., generally less than 0.0003 feet/foot in alluvium) …" and "… the direction of the hydraulic gradient over a calendar year varied by as much as 225 degrees (from southwest to northeast) in the northern portion of the alluvial aquifer …". Future CSM updates should discuss how these small gradients affect confidence in gradient determination. Consider use of a 3PE or a similar three-point problem tool to check for inconsistencies in flow direction. Also discuss how these small gradients affect potentiometric surface contouring at a 0.25-foot interval and whether it would be more appropriate

to contour groundwater at this Site at a smaller interval, such as 0.1-foot intervals. Comment 31 below on Appendix Q applies.

8. **Section 4.3.3.2 Earth City Levee District, Figures 4-8a, b, Page 60.** Recognizing that Figures 4-8a and 4-8b are presented as cartoon schematics, consider the following when developing schematics for the 2023 Annual Report for consistency with known site conditions and to avoid misrepresentation of the CSM. Should similar schematics not be provided in the revised CSM in the 2023 Annual Report, provide revisions accordingly as part of the 2022 Annual Report.
   a. Page 61 states: "The Missouri River is incised into and constrained on both sides by bedrock and is the ultimate discharge boundary for the alluvial aquifer." Illustrate the Missouri River channel as incised into the alluvium with a bottom elevation around 400-405 feet NGVD.

   b. On Figure 4-8a, remove the "upward" flow arrow, which would not be expected to occur during baseflow conditions.

   c. Although the figures are identified as “not to scale”, revise to present the vertical elevations in consistent increments to show relationships between water bodies appropriately. The difference between the 2022 low Missouri River level (~420 feet) and the engineered water body level (432.56 feet) is considerably less than the approximate 10-foot increments shown between flood stages. Additionally, the difference between the 2022 low Missouri River level (~420 feet) appears to be above the base of the engineered water body (reportedly ~429 to 427 feet).

   d. Consider an additional figure or text to compare conditions at normal non-flood operations to historical low river stage. The Missouri River level can drop lower than the land surface, groundwater, and the engineered water body on the outside of the levee berm causing groundwater to flow toward the Missouri River.

9. **Section 4.3.3.2 Earth City Levee District, Pages 59-60, Figures 4-8a, b.** Clarify how often groundwater levels exceed the height of the Engineered Water Body (reported as 432.86 NGVD) and whether this only coincides with the Missouri River cresting (April-May).

10. **Section 4.4.1 Bedrock, Figure 4-12, Page 64.**
    a. Hydraulic conductivity (K) values for alluvium are predominantly shown with red dots (>200). Figure 4-27 indicates that K values for alluvium commonly range from 50 to 500 ft/d. Future deliverables should use a color scheme to show at least one additional division in K values between 200 and 500+ ft/d.

    b. The small scale makes distinguishing between color shades difficult for the mobile and capillary porosity. Future deliverables should include scale of the image to distinguish mobile and capillary porosity.

11. **Section 4.4.1.2 Salem Formation, Figure 4-16, Page 68.** Future iterations of this figure should address the following comments. If this figure will not be presented in future deliverables, revise the 2022 Annual Report accordingly.
    a. Indicate the hydraulic conductivity units on the figure or in the notes.
    b. Reported hydraulic conductivity values range from 2.48E-02 to 9.60E-09. Precision is presumed to decline with smaller values. Appropriately reflect the precision of the hydraulic conductivity data.

   c. Indicate the thickness for each measurement (e.g., 1.5 feet).
   d. List the elevation of the datum of the top of the Salem for the respective wells.
   e. Even within the Salem Shoal, the hydraulic conductivity appears 10-100 times greater at MW-205 than PZ-106-SD. Discuss implications for site hydrogeology, and how these logs correlate with shoal carbonate depositional environments at various energy levels.

12. **Section 4.4.1.3 St. Louis Formation, Page 70.** In the Summary box, the next to last sentence states: "Due to the physical properties of the Salem Shoal Sequence, more groundwater flows through this portion of the bedrock aquifer than through the other bedrock units." Future deliverables should demonstrate, if necessary, what is intended by "more" (e.g., total quantity, higher flow rate, a proportionality). The NMR data indicate larger K values, so higher groundwater velocities are expected, but demonstration is needed that a larger volume of groundwater flows through the Salem Shoal Sequence compared to the total of other bedrock thickness above the top of the Warsaw.

13. **Section 4.4.2.1 Alluvium Saturated Thickness, Figure 4-19, Page 71; Appendix C.** As presented, Figure 4-19 indicates deep alluvium north of the site. However, the drilling log for piezometer PZ-701 (see Appendix C) indicates bedrock was encountered at a very shallow depth (<18ft). This data is consistent with a U.S. Geological Survey cross section (Emmett and Jeffery, 1968) of the Missouri River alluvium downstream of the site indicating some shallow alluvium on the east side of the river. If the alluvium thins considerably between the northern site boundary and the river, this might explain why groundwater flow in the alluvium is at times more perpendicular to the river than might normally be expected.
    a. In future deliverables, expand the map of alluvial thickness to cover the entire area where wells have been installed and the groundwater flow model is anticipated. Show water levels for the greater investigation area in context with the site.

    b. Consider whether additional data collection is needed in the area between PZ-700, PZ-701, and MW-504 to characterize the thinning alluvium and better establish boundary conditions for groundwater modeling. A groundwater model boundary north of the site would need to be in the vicinity of PZ-701.

14. **Section 4.5.1 Groundwater Response to Landfill Operations, Page 76**.
    a. The first paragraph of Section 4.5.1 indicates that bedrock monitoring wells surrounding the Bridgeton Landfill "did not identify measurable hydraulic responses to operation of the landfill liquid collection system …". In the 2023 Annual Report, provide further discussion of the reasons for this. Conductance and storativity are lower in the bedrock than in the alluvium, which would typically magnify the bedrock response, and apparent leachate effects in bedrock wells indicate a hydraulic connection.

    b. This section addresses groundwater response to current landfill operations, but neither this section nor the broader CSM consider the potential impact of historical operations on site constituent transport (as examples, waste placement creating preferential groundwater flow pathways through the landfill, or quarry blasting and excavation creating secondary porosity in localized areas around the landfill). Revise the CSM in future deliverables to discuss the potential for historical quarry and landfill operations to have influenced site constituent migration.

15. **Section 4.5.2 Groundwater Response to Missouri River Stage, Page 77; Figures 4-8, 4-24, 4-25, 4-31.** To improve the effectiveness of the CSM, the 2023 Annual Report should discuss more directly the link between groundwater flow schematics (Figure 4-8), generalized groundwater heads (Figures 4-24 and 4-25), and changing gradients and flow directions throughout the year (Figures 4-29 to 4-31). In particular, clarification is needed with respect to the following:
    a. Is a flow direction to the southwest (generally up-river) at high water levels in early summer 2021 consistent with what is known about the hydrogeological framework?

    b. The schematics (Figure 4-8) indicate the seasonal rise and fall of river levels have the most influence on groundwater gradient and flow directions. If this is the case, why do flow directions not return to the southwest in early summer 2022, when river levels are almost equally high?

    c. In later summer (between July and August 2022), potentiometric surface maps show a dramatic shift further west, though not quite southwest, when the Missouri River stage is relatively stable. Could this be the result of the very heavy rains in August?

    d. Could the gradient yielding southwesterly flow be an artifact of the limited number of transducers?

16. **Section 4.5.3 Groundwater Response to Meteoric Recharge, Figure 4-25, Page 78.** Because the bedrock fracture flow system has low storativity, it can "fill" and "drain" relatively quickly in response to local precipitation (Figure 4-25) compared to the Missouri River and alluvial aquifer levels. Evaluate whether short-term severe precipitation events contribute to changes in vertical gradients, flow direction, and associated constituent dispersion in bedrock, and whether/how this is linked to changes in the alluvial aquifer flow direction as river levels change through the year.

17. **Section 4.5.5 Howard Bend Levee District Groundwater Level Response to Missouri River Stage, Figure 4-26, Page 79.**
    a. The description of Figure 4-26 states: "during flood events, groundwater elevation in piezometers located farther away from the Missouri River (i.e., PZ-10 and PZ-8) is temporarily higher than in piezometers located closer to the Missouri River (i.e., PZ-5 and PZ-4)." While the water level at PZ-10 does consistently seem higher than that at PZ-5 when the Missouri River levels are highest, the relation is inconsistent for the pair of PZ-8 and PZ-4. This should be further evaluated, and future deliverables should explain this difference in behavior using the geohydrologic framework.

    b. On Figure 4-26, the Missouri River stage and the well water levels appear to be measured at different frequencies, making them difficult to compare. For future deliverables consider revising the presentation to improve comparability.

18. **Section 4.5.6.2 Horizontal Hydraulic Gradient, Vector and Flow Distance Analyses, Page 83 – 87; Figures 4-30 to 4-34; Appendix L.** While the information provided in the referenced sections is useful, additional work is needed to support the very low net flow rates computed. The following should be considered in development of the 2023 Annual Report.
    a. The analyses assume perfect radial uniformity for conductivity values, and thus equal vectorially additive flows in all directions with changing head. Discuss whether the hydrogeologic framework supports this or whether enhanced directional conductivity in the

horizontal plane is likely (e.g., Do flows shift with equal ease in all directions with rising and falling seasonal water levels? Is there any evidence of preferential flow paths?).

b. Groundwater flow to the northwest instead of the northeast (down-river direction) is not well supported by the current presentation of the hydrogeologic framework. Following the contaminant distribution to the northwest, discuss the most likely hydrogeological control(s) moving groundwater in that direction. Expand the presentation of the hydrogeologic framework and/or identify data gaps needing to be filled.

c. Groundwater flow to the southwest (up the alluvial valley) appears even less well supported by the hydrogeologic framework, and it is unclear why the hydraulic gradient is to the southwest in the high flows in spring 2021 but to the northeast in high flows in spring 2022 (Figures 4-29 to 4-31). Discuss the most likely hydrogeological control(s) pulling or diverting groundwater flow to the southwest. Expand the presentation of the hydrogeologic framework and/or identify data gaps needing to be filled.

d. The analyses assume relative uniformity in data distribution, and bias may creep in when interpreting a cluster of data that has a few “outlier” points (both in terms of spatial distribution and the relative distribution of the measured values). Figures in Appendix Q show the transducers to be inconsistently grouped in the alluvial basin, such that a single upgradient well point can have disproportionate influence on the calculated flow orientation. Similarly, the figures show use of a simple 3-point problem to represent an area of where the potentiometric surface has complex geometry (e.g., the southern portion of the middle time stratigraphic unit), such that disproportionate weight is given to the upgradient well selected for the transducer. Discuss any such “outlier” biases in the annual report data, and what limitations these place on the understanding of the site hydrology (heads and flows).

e. Demonstrate the cycling pattern of groundwater gradients and flow directions for more than one rising and falling Missouri River level cycle. Extend the x-axis on Figure 4-31 accordingly.

f. Specifically discuss the limitations and uncertainties of the approach being used and evaluate whether an alternative approach would yield different results. Comment 31 below applies.

19. **Section 4.5.6.3 Vertical Hydraulic Gradient Analyses-Flow Net Analyses, Pages 88-90.**

a. The last sentence on page 88 states: "At the MW-205/PZ-205 cluster (Figure 4-39), the upward gradient between the well screened in the Salem Formation and wells screened in the overlying St. Louis Formation and alluvium is much more pronounced, due to a layer at the top of the Salem Formation that exhibits very low hydraulic conductivity …". Because the low hydraulic conductivity layer also seems to be present at the PZ-113/MW-113 cluster (see Figure 4-38), future deliverables should explore other causes for the more pronounced upward gradient apparent at the MW-205/PZ-205 cluster.

    i. Calculate vertical gradients rather than compare groundwater elevations. The vertical difference between screens is about 82 feet for the PZ-113/MW-113 cluster and about 120 feet for the PZ-205/MW-205 cluster, indicating that direct comparison of groundwater elevations may not be appropriate. The EPA’s vertical gradient calculator is found here: https://www3.epa.gov/ceampubl/learn2model/part-two/onsite/vgradient02.html.

    ii. Discuss whether increased groundwater and vapor temperatures adjacent to the subsurface smoldering event may increase hydrostatic pressure. Groundwater temperatures are about 10°C warmer at MW-205 (25°C), adjacent to Bridgeton Landfill, than at MW-113.

  b. In the 2023 Annual Report provide an expanded consideration of the hydrologic implications of the uneven erosional surface of the carbonate bedrock and its contact with the overlying alluvial aquifer. Where the conductive Salem Shoal sits at or within a few feet of overlying alluvium (Figures 4-38), hydrologic connectivity among these units is likely (as evidenced by the similar heads). Where the conductive Salem Shoal is capped by thick non-conductive carbonate rock and is a considerable distance (e.g., 50 feet) below the overlying alluvium (Figure 4-39), hydrologic connectivity among these units is unlikely (as evidenced by large head differences). The uneven erosional surface of the carbonate bedrock (paleotopography of the eroded valley) and the varied nature of the bedrock in contact with alluvial aquifer above it likely has as much or more to do with hydrologic connection and head gradients between the bedrock and the alluvium than the presence of a single thin non-conductive bedrock layer. The paleotopography of the buried carbonate bedrock valley likely enhances the effect of the non-conductive bedrock layer by the spatial and stratigraphic positioning and may have a substantial impact on the overall hydrogeology.

  c. The graphs in Figures 4-35 to 4-39 are low resolution, making it difficult to differentiate the text and lines as presented. Future iterations of similar figures should include vertical gradients (ft/ft) or average gradient, and clarification of the time interval plotted (e.g., biweekly).

20. **Section 4.5.7, Bedrock Aquifers, Page 92.** The second paragraph of Section 4.5.7 states: "Groundwater flow in bedrock outside of the Bridgeton Landfill in this area occurs primarily through bedrock fractures, except within the Salem Shoal Sequence, where matrix flow is dominant."
  a. Historical site documents indicate that fractures within the bedrock, at least around the South Quarry, are primarily oriented to the northeast and southwest. Revise the CSM to discuss fracture size and orientation encountered historically and during this remedial investigation.

  b. Given this information and the stated potential for groundwater to move to the southwest, discuss whether the existing monitoring well network is adequate to fully evaluate the extent of contamination or whether additional work is needed to support CSM determinations.

21. **Section 4.5.8 Groundwater Flux, Figure 4-43, Pages 94 – 95; Appendix R, Table R-2.** The water balance report described on page 94 and presented on Table R-2 (Appendix R) suggests that water removal from the Bridgeton Landfill exceeds groundwater inflow by approximately 40,000 gallons per day. Despite consistent removal at this significant estimated rate, Section 4.5.1 of the report notes that the wells surrounding the Bridgeton Landfill did not provide evidence of water well drawdown and recovery from leachate recovery pumping. The 2023 Annual Report should provide additional explanation and data to support the determination that landfill leachate pumping volumes exceed the groundwater inflow rate without exhibiting drawdown at nearby wells. See also Comment 14 (2023 Annual Report/Other Future Deliverable).

22. **Section 4.6 Groundwater Constituents of Potential Concern, Page 96.** Improve the discussion of groundwater constituents of potential concern by including the following:

   a. More detailed descriptions and images of spatial distribution of redox sensitive inorganic contaminants and other redox indicator compounds. Note where data could be biased by inaccurate D.O. readings or purge times insufficient to provide stable parameter readings. See also comments on Section 3.8 for suggested improvements moving forward.

   b. More detailed descriptions and images of spatial distribution of tritium as an indicator of whether water could contain landfill leachate.

23. **Section 4.6.1.3 Nature and Extent of Radionuclide COPCs, Pages 99 – 101.**
   a. Report text indicates “Given that only one round of background well samples have been collected, detailed comparison of Site and background data has not yet been conducted. This comparison will be completed during the 2023 reporting period.” However, the following paragraph states, “Combined unfiltered (total) radium-226/radium-228 activity levels in wells located along the eastern and southern Site boundaries are consistent with the background well data presented on Figure 4-45.” Based on the initial statement regarding the current ability to compare background data with site monitoring results, and since only one total radium 226/radium 228 background groundwater ratio is based on individual parameter data which is not either U or J qualified, additional documentation for the CSM conclusion will be needed in the CSM.

   b. To support evaluation of radium nature and extent, include the following in the 2023 Annual Report.
      i. Details of the geochemical environments in the alluvial and bedrock units where the highest radium is found.

      ii. Landfill tracer (e.g., Cl, Br, I, DOC, tritium) data that could show landfill leachate impact.

      iii. Consider an on-site and off-site aquifer-by-aquifer Radium-226:Radium-228 ratio frequency distribution diagram (similar to conductivity frequency distribution in Figure 4-27) to help contextualize the aqueous radium isotope ratios and evaluate possible bias for samples with J values.

      iv. Also consider a frequency diagram or percent detected table for each of the radium-226 and radium-228 radionuclides (see Szabo et al., 2012; Supplemental Table S-1).

24. **Section 4.6.1.4 Potential Sources of Radionuclides in Groundwater, Figure 4-51, Page 106, Page 108.** The following comments are intended to support evaluation of radium source contributions and should be considered in developing the 2023 Annual Report.
   a. The discussion of aquifer matrix samples on page 108 suggests radionuclide-bearing intervals are more argillaceous. Provide further evaluation of this hypothesis. The caption to Figure 4-51 (page 106) indicates matrix sampling focused on intervals where spectral gamma readings were higher. Evaluate whether this approach may have biased sampling toward intervals that also tended to be higher in clay or shale than the surrounding carbonate rock matrix. Discuss how Radium-226:Radium-228 and Uranium:Thorium ratios compare between clay/shale and carbonate rock matrix samples.

   b. Consider using a mixing curve with hypothetical radium isotope ratios of RIM to test the "sensitivity" of groundwater from bedrock or alluvium source to being detectably altered by

RIM source. Assess what percentage of RIM source, mixed with alluvium source, is needed to mimic bedrock radium isotope ratios. Assess what percentage of RIM source, mixed with alluvium or bedrock source, is needed to clearly detect RIM contaminant in the mixture, and what the radium isotope ratios of such a mixture would be.

25. **Section 4.6.2.1 Arsenic, Page 111; Appendix S.** The 2023 Annual Report shall provide additional discussion regarding arsenic distribution to consider redox driven mobilization. Note that occurrence patterns generally do not align with radium. High pH can mobilize arsenic, either as arsenate or arsenite, as a consequence of competitive desorption, especially if sulfates, silica, and to a lesser degree bicarbonates are high. In contrast, high pH with high sulfates may lead to radium sequestration. See also comments on Appendix S.

26. **Section 5 Next Steps, Page 116.** The last bullet on this page indicates that monthly potentiometric surface maps will be replaced by daily gradient and flow calculations consistent with Figures 4-32 to 4-34. Clarification is needed, as Figures 4-32 to 4-34 are potentiometric surface maps. Assuming Figures 4-29 to 4-31 are intended, the limitations in comment 18 (2023 Annual Report/Other Future Deliverable) are noted. Considering these limitations, continue to draw potentiometric surface maps as an additional line of evidence.

27. **Table 14a Validated Groundwater Data – Radiochemistry Analytical Results, Table 15a Validated Leachate Data – Radiochemistry Analytical Results, Section 3.7.1 Groundwater and Leachate Data Quality Summary, Pages 38-42; Appendix J-2.** As shown in Tables 14a and 15a, numerous radium results above planned (2 pCi/L) or actual minimum detectable concentrations (MDCs) are qualified as estimated (J), estimated with possible bias (J+/-), or non-detect (U). Revise Section 3.7.1 and, as appropriate, Appendix J-2 to better explain the basis for qualification and evaluate the potential for analytical bias. In doing so:
    a. Evaluate and discuss the relative detection capability of the radium isotopes. Consider a table (similar to Table S-1 in Szabo et al., 2012) showing frequency of concentrations considered "detected" for the two different isotopes among various concentration intervals (for example, 0.5-0.75, 0.75-1.0, 1.0-1.25) until about 97.5% detection frequency is reached.

    b. Radium-228 has a higher detection level than radium-226. Assess whether the higher radium-228 detection level results in an analytical artifact: fewer radium-228 detects relative to radium-226.

    c. Contextualize the frequency of radium isotope detection by alluvial and bedrock aquifer units (see Figure 13a). Assess whether lower radium-226 concentrations in alluvium (geological source) are reflected in a lower frequency of radium-226 detection in groundwater.

28. **Appendix A Summary of Multi-Level Well Maintenance.** When wells are flagged for next steps, but no action is taken, include additional details clarifying why no additional action is necessary (e.g., measurement error, additional water added).

29. **Appendix I Well Data Correlation Methodology for Time Stratigraphic Marker Identification, Figure I-2, Page I-3.** Present more careful definition of relations of radium with barium and sulfate in future deliverables. For example, sulfates are redox sensitive and can selectively inhibit aqueous radium concentrations by precipitating mineral solids (radio-barite) that sequester radium. Discuss whether there is evidence for precipitating barite, such as zones with high sulfate and low barium. Figure I-2 would be a good model for illustrating redox constituent

depth distributions. Though not well supported by the data tables in Appendix F, Figure I-2 identifies relatively low concentrations of barium at a middle alluvium location that might be a result of either barite precipitation or cation exchange, both processes limiting aqueous radium concentrations. The presence of cis-1,2-dichloroethene at the same depths might argue for a fairly reducing environment.

30. **Appendix L Potentiometric Surface Maps.** On Figures L1 to L6, revise to provide shading to indicate surface water features west and southwest of the Superfund site boundary.

31. **Appendix Q Alluvium Horizontal Gradient and Flow Analysis Methods, Figure Q-1.** Revise in future annual reports to demonstrate the appropriateness of this vectorially additive flow distribution model in an area with small, apparently variable head differences or remove this line of evidence. In particular:

    a. Define the assumptions and limitations of this model calculation. (https://www3.epa.gov/ceampubl/learn2model/part-two/onsite/gradient4plus-ns.html).

    b. Define the limitations of the data inputs (reference to other appendices is acceptable).

    c. Assess whether calculated shifts in flow direction reflect actual groundwater conditions appropriate for model inclusion (e.g., Are differences in hydraulic head greater than the margin of measurement error? Are the hydraulic head anomalies identified in Appendix K excluded from calculations? Do the flow directions in well-adjacent 3-point problems show consistent flow directions? Are the wells applied to in such problems appropriately located for the conceptual site model?).

32. **Appendix S Fate and Transport Properties of Select Constituents of Potential Concern.** Expand the descriptions of mobilizing mechanisms in Appendix S to note the following additional mobilizing processes, which may or may not be active at the site.

    a. Uranium: soluble carbonate ion-pair complexing, microbial oxidation.

    b. Radium: soluble sulfate ion-pair complexing, competitive desorption or exchange with divalent cations or with high concentrations of monovalent (sodium) ion, dissolution of radio-barite in sulfate-reducing environments, cation exchange, and alpha recoil.

    c. Arsenic: competitive desorption with phosphates, redox transformations with manganese, thiol complex formation in reducing waters (thioarsenic species).
    Note that sulfides are redox sensitive species that can selectively inhibit aqueous arsenic concentrations through the precipitation of amorphous mineral solids such as amorphous arsenopyrite that sequesters arsenic. Conditions reducing enough for the formation of sulfides may thus limit aqueous arsenic concentrations, but serve to lead to barite dissolution, which may be a condition that increases radium concentrations (mobilization, lack of sequestration). Expanded consideration is consistent with Principal Study Questions 3 and 4.

    d. Although the process is poorly defined in the literature, complexation with dissolved organic compounds appears to be a possible solubilization mechanism for thorium and, to a lesser extent, radium. Expand Appendix S in future documents to note the need for improved scientific understanding of this mechanism.

33. **Appendix T Time Series Plots of Select Constituents of Potential Concern.**
   a. The Time-Series plots in Appendix T provide visual graphics of temporal change in contaminant concentrations. However, the following comments are intended to improve the usefulness of these data in addressing the PSQs.
      i. Define the high, medium, and low categories presented for y-axis ranges, which vary by analyte. The ranges for these categories appear to overlap among plots, which may be acceptable depending how the criteria are defined.

      ii. For those wells with sufficient analytical data, test the statistical significance of concentration trends and rates of change (e.g., Mann-Kendall, Sen Slopes).

      iii. Compare contaminant and concentration data (e.g., group comparisons, Kruskall-Wallis, Tukey Test) among wells grouped to support evaluation of PSQs (e.g., presence or absence of landfill leachate impacts, site center or boundary, hydrostratigraphic unit).

      iv. To better understand the residence time and movement of site groundwater, assess tritium distribution and identify decreasing concentration gradients indicating tritium dispersion and decay through time. Moving forward, consider using tritium/helium-3 isotope pairs to improve understanding of residence times and estimate groundwater flow velocities for water that contains landfill leachates.