STATE OF MAINE

DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF REMEDIATION AND WASTE MANAGEMENT

M E M O R A N D U M

TO: Michael T. Parker, Project Manager
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DATE: January 15, 2016

RE: Juniper Ridge Landfill Expansion Application
Volume II, Site Assessment Report and
Volume III, Design Report
Volume IV, Operations Manual, July 2015

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NEWSME Landfill Operations, LLC has prepared and submitted an application in support of its proposal to construct a 54 acre expansion of the existing 68 acre secure Juniper Ridge Landfill facility (JRL) located in Old Town, Maine. The proposed expansion, as designed, consists of six secure landfill cells (Cell 11 through 16). Cell 11 is positioned due east of the existing Cells 7 and 9 while the remaining proposed cells are located due north of the existing permitted facility **(DEP - Figure 1)**.

My technical review has focused primarily on the Site Assessment Report (Volume II) along with all of the relevant appendices. I have also reviewed sections of the Design Report (Volume III) that detail the contaminant transport analysis. Volume IV contains the proposed Environmental Monitoring Plan. I have completed a particularly thorough review of the hydrogeological investigation and the Environmental Monitoring Plan completed by Sevee & Maher Engineers, Inc., on behalf of its client (NEWSME Landfill Operations, LLC). Overall JRL's expansion application is well organized and documented. Based upon my review of the information presented in the expansion application, nearly all of the requirements of the Solid Waste Regulations have been satisfactorily addressed. I do, however, have a wide variety of comments and recommendations that will need to be addressed. The detailed memorandum that follows outlines my comments and recommendations.

The following comments and recommendations are preceded by the applicable section of the reports. If you have any questions about the content of this memorandum, please contact me.

Volume I – Maine Solid Waste Management Rules

Pg 3-28 3.12 Adequate Provision for Utilities and No Unreasonable Adverse Effect on Existing or Proposed Utilities I understand there are two existing water supplies (Scale House Well and Facility Well) on site but these wells are not shown on many of the relevant site plans. Both wells are located within the expansion footprint and will have to be abandoned and replaced if the facility expands. Therefore, the application should include details about abandonment of these wells and information about where the replacement wells may be located. In the meantime, JRL's Environmental Monitoring Program should be revised to include plans to sample both wells annually to characterize water quality. The well locations should also be shown on all the relevant site plans.

Volume II – Site Assessment Report

Pg 2-6 2.6.1 Surficial Soils The description of the surficial geology notes that the Maine Geological Survey's mapping suggests some of the elongated hills are glacial drumlins. The available LIDAR imagery may provide further evidence of the existence of glacial drumlins in the vicinity of the landfill. I have attached a LIDAR image that appears to depict linear features that may be interpreted to be drumlins **(DEP - Figure 2)**. It is also possible to see the boundary between the Presumpscot formation and the till deposits as well as some of the bedrock outcrops located along the western edge of the proposed expansion. I urge JRL to include this information in the section describing the regional geologic setting.

Pg 2-10 2.6.2 Bedrock The report states JRL obtained fracture orientation data from three of the four outcrops identified in the vicinity of the facility. Apparently fractures visible on OC-4 could not be measured. If measurements could not be obtained from OC-4, the text appearing on the following page should not indicate measurements were collected from all four outcrops.

Pg 2-16 2.9 Local Groundwater Resources This section includes data gathered by the Maine Geological Survey (MGS) about drilled wells in the neighborhood of the landfill. The MGS information is useful but it should be augmented with information JRL gathered when they sampled numerous residential wells along the West Old Town and Old Stagecoach Roads. JRL completed this sampling in 2004.

Pg 3-17 3.2.6 Groundwater Tracer Test in Glacial Till

To provide additional data about groundwater velocities in the till, JRL conducted a tracer test using sodium bromide. I have reviewed the details of the test contained in Appendix G. The analytical solutions produced an estimated velocity of 11 ft/year. Interestingly, the estimated velocity based on the arrival of the peak bromide concentration (i.e., graphic solution) yields a slightly higher velocity of 17 ft/year. I too analyzed the data graphically **(DEP - Figure 3)** and calculated a velocity of 15.5 ft/year.

It seems to me the graphically derived solution may be more representative of the in-situ velocity. Particularly since the well containing the highest bromide concentrations is likely not directly downgradient of the injection well. Perhaps more importantly, this test was not conducted within the proposed expansion area. I recognize the till in and around the proposed expansion may be relatively uniform, but ideally I would expect tests like this would be performed within the foot print or directly downgradient. JRL should, to the extent possible, explain why the results of a tracer test conducted several hundred feet from the expansion are representative of site conditions beneath the proposed expansion.

Pg 3-18 3.2.7 Groundwater Tracer Test in Bedrock The details of this test are provided in Appendix H. I provided detailed comments about this tracer test in an October 15, 2008 review memorandum [1]. Although I do not have record of a written response from JRL, review of the report included in Appendix H appears to address several of the concerns outlined in my memorandum.

My primary concern with the results of the tracer test was the failure to detect bromide at significant levels (i.e., > 1% of the injection fluid concentration) in any of the six downgradient observation wells. I agree with JRL that the detection of bromide in each of the six observation wells verifies the existence of an interconnected fracture network. However, my interpretation of the analytical results, based on discussions with my colleagues in the Department, lead me to conclude the majority of the tracer passed beneath the observation wells. Calculations supporting this interpretation **(DEP Attachment A)** are discussed later in this memorandum. I understand that JRL has revised its earlier interpretation and now believes the density of the introduced tracer induced a significant downward vertical flow of the introduced tracer. Regardless of the fate of the majority of the introduced tracer, I agree the tracer test data has produced a reasonable range of estimated groundwater flow velocities. However, uncertainty regarding the trajectory of the tracer demonstrates why multilevel wells are necessary to increase the likelihood of intercepting leachate constituents that may pass through the liner system.

Additional comments related to this test are found following the Appendix H heading.

Pg 3-18 <u>3.2.8 Groundwater Age-Dating</u> JRL used the tritium-helium groundwater age dating methodology to estimate the age of two groundwater samples. Results from these tests may provide invaluable information if one accurately estimates the age of groundwater at multiple locations along a groundwater flow path. The difference in the estimated ages divided by the distance yields an average groundwater velocity between the two sample points. This approach provides an estimate of groundwater velocity independent of the aquifer characteristic data commonly used to estimate groundwater velocity. In this case, it may provide an independent estimate of groundwater velocity in bedrock. The calculated groundwater velocity between P-04-06A and P-04-07B was 140 feet per year. This

[1] Technical Review Memorandum from Richard Behr to Cyndi Darling. October 15, 2008, Bedrock Tracer Test at Proposed Juniper Ridge Landfill Expansion Site, Old Town, Maine – NEWSME Landfill Operations, LLC. September 2008, Prepared by Sevee & Maher, Inc.

estimated bedrock groundwater velocity (140 ft/year) is significantly lower than the velocities used in the time of travel calculations. It is important for JRL to explain why they used significantly faster bedrock velocities in the time of travel calculations.

JRL also used the age of the groundwater sample collected at P-04-06A (14 years) to estimate the travel time through the till to the shallow bedrock. Assuming a downward vertical flow path through roughly 29 feet of till, the apparent travel time significantly exceeds six years. Based on the estimated age (14 years) and distanced travelled, the groundwater velocity is about 2 ft/year. JRL states the seepage gradients were determined to be vertical but it is not clear how they made this determination. Potentiometric head data from the two wells does indicate the potential for a downward vertical flow. It does not, however, demonstrate groundwater follows a vertical flow path through the till. In fact, while I don't dispute a vertical downgradient exists in the vicinity of P-04-6A, it is unlikely the flow path is straight down.

With this uncertainty in mind, I recommend JRL calculate a range of estimated groundwater velocities based on alternate flow paths leading to the screened interval of P-04-06A.

It is also necessary for JRL to improve this section by including a brief discussion of the tritium-helium dating methodology. It would also be helpful if JRL included information regarding its prior use at other Maine sites. This section should also include appropriate peer reviewed technical references. Most importantly, my concerns regarding the validity of the results, as detailed below (Appendix I comments), must be addressed to the Department's satisfaction.

Pg 3-19   3.2.9 Bedrock Pumping Test at MW-06-02   JRL performed a short term pumping test in MW-06-02 roughly two years before conducting the tracer test in the same well. This well is located nearly 700 feet north of the northern edge of the proposed landfill expansion boundary. Unfortunately, JRL initiated the test before conducting a step draw down test to determine a sustainable pumping rate. Consequently, without prior knowledge about the well's sustainable yield, the initial pumping rate of 3.5 gpm turned out to be far too high and resulted in periodic adjustments throughout the test. The estimated average pumping rate during the eight hour pumping test was 0.19 gpm. Despite this misstep, it appears the pumping test produced some useful information about the nature of the bedrock aquifer in the vicinity of the proposed expansion.

Appendix J provides a detailed description and analysis of the resulting data. I have reviewed the data contained in Appendix J along with the data interpretation. Additional comments related to this test are found below following the Appendix J heading. I also asked a colleague, Gail Lipfert, to review and comment on both the pumping test and tracer test. I have attached Gail's comments with the expectations JRL will address them as well **(DEP - Attachment B)**.

Pg 3-20 <u>3.2.10 Photolineament Survey</u> JRL should also consider using the LIDAR imagery to identify photolineaments. This imagery is available through the Maine Office of GIS.

Pg 3-21 <u>3.2.11 Bedrock Outcrop Survey</u> JRL collected fracture orientation data from five outcrops surrounding the facility. One vertically orientated outcrop (OC-AG) was selected for detailed mapping. The data from the detailed analysis are summarized in this section and the tabulated strike and dip data are found in Appendix K. On a technical note, I found the total measurements tabulated in Table K-1 (68) differ significantly from the summary (81) included in Appendix U (Bedrock Fracture Interconnectivity).

This mapping effort produced some important information about the bedrock at this site. First, the outcrop selected for the detailed mapping, although relatively small, contained a large number of closely spaced fractures. Second, JRL found all the fractures on the outcrop are connected to one another.

The mapping summary did not discuss the degree to which the data from this outcrop is or is not representative of the general site conditions. For example, how does the fracture spacing observed on the outcrop compare to the fracture spacing in the four deep bedrock boreholes? Was the OC-AG outcrop similar to the other four outcrops? Although JRL did not complete detailed mapping of the remaining four outcrops, a careful visual inspection coupled with photographs may allow for a valid comparison.

Pg 3-24 <u>3.2.13 Fracture Interconnectivity Pumping Test</u> In addition to the previously discussed pumping test, JRL conducted five pumping tests in the four 200 foot open bedrock wells installed by Goodwin Well & Water, Inc. The results from these pumping tests generated invaluable information about the characteristics of the fractured bedrock underlying and adjacent to the proposed expansion.

This section includes a brief description of the results of all of the pumping tests. Appendix M includes additional details and discussion of the long-term pumping test conducted on PW-08-01 and PW-08-02. The long-term pumping test began by pumping PW-08-01 for about a week. At the beginning of the second week, JRL continued to pump PW-08-01 but also began pumping PW-08-02. It would be helpful if the report described the rationale for the dual well pumping tests. Specifically, the report should outline what additional qualitative and quantitative aquifer characteristic data were obtained from the combined test.

The report could be improved by providing the details about how each test was instrumented. For example, the report should identify all the wells where JRL measured hydraulic head using pressure transducers and the wells where manual water level measurements were made. I have not been able to locate the table(s) summarizing all of the manual measurements. I will need this information to complete my data analysis.

I also recommend the pumping test discussion in Appendix M be expanded to include an analysis of the four short-term pumping tests conducted prior to the long-term test. A detailed discussion of each pumping test should include all of the relevant data. For example, Appendix U (Bedrock Fracture Interconnectivity) states that during the 24 hour pumping test conducted at PW-04-01, JRL collected water level information at 24 bedrock wells and 25 till wells. The summary reports the range of drawdowns observed in the bedrock and till wells but I have not located the summary tables. Further, Appendix U appears to include a more detailed summary of the four short term pumping tests than what JRL presents in this section. Revisions to the application must address these issues.

Pg 3-29 PW-08-01 and PW-08-02 (Combined) Long-Term Pumping Test During the two week pumping test, precipitation totaled 1.15 inches. JRL believes recharge occurred due to the snowmelt and precipitation. Given the reported slow rate of groundwater movement through the till, I believe it is important for JRL to explain why potentiometric head levels may rise relatively rapidly in response to precipitation events. A similar explanation should be provided for the rebound in water levels observed in the observation wells during the MW-06-02 pumping test.

Pg 3-30 Not surprisingly JRL observed declining pumping rates (gpm) during these tests. The pumping rates are expected to decrease as the head on the pump decreases not “increases” as stated in the report.

Did JRL also analyze the recovery data collected during each of the five pumping tests? If not, please explain why the recovery data wasn’t also examined.

Pg 3-37 3.3.6 Effective Porosity Effective porosity data are needed to estimate groundwater velocity in the till, marine clay and bedrock. JRL conducted laboratory tracer tests to estimate the effective porosity of the basal till. Presumably the procedure is described in Appendix R. I have reviewed Appendix R and find that it provides insufficient information to properly document the experimental procedure used to estimate the porosity. It appears that the estimated effective porosity is based on a single experiment. If so, JRL must justify how a single measurement can be used to adequately describe the entire site.

Pg 4-4 4.1 Surficial Geology Figure 4-2, the isopach map, depicts the thickness of surficial sediments within and beyond the proposed expansion. As we previously discussed with JRL, the accuracy of this map could be improved if additional bedrock explorations are completed within the proposed expansion. I am particularly concerned about the relative absence of bedrock explorations within the eastern half of the proposed expansion. On **DEP Figure 4** I have depicted all of the bedrock explorations within and surrounding the proposed expansion. I understand the soil depths depicted on Figure 4-2 are based on a variety of data sources, including the modelled vertical resistivity profiles. To that end, JRL should augment this section with additional information about how the resistivity data was interpreted to refine the isopach map. This discussion could also include a discussion about how soil depths derived from the resistivity surveys compared to data obtained from explorations that penetrated the underlying bedrock.

Pg 4-4 4.1.1 Basal Till JRL describes the sand and gravel deposits located along the Stillwater River as outwash deposits formed in depositional environments beyond the ice margin. The Maine Geological Survey maps I have reviewed depict ice contact deposits (i.e., eskers) along the Penobscot River **(DEP - Attachment C)**. This section may require some clarification.

Pg 4-6 4.2 Bedrock Geology As we discussed during the December 2, 2015 meeting with JRL and its consultant, SME, I am concerned that a sufficient number of bedrock explorations have not been completed within the eastern half of the proposed expansion. My specific concern relates to the absence of bedrock explorations within at least 50% of the proposed expansion **(DEP - Figure 4)**. DEP – Figure 4 depicts all the bedrock explorations within and adjacent to the proposed expansion boundary. There are no bedrock explorations within the eastern half of the proposed expansion located north of the existing landfill.

Information obtained from surficial explorations, including borings, monitoring wells and test pits, appears to provide sufficient data regarding the thickness of surficial sediments for landfill design purposes. However, additional bedrock explorations are needed to refine the interpreted bedrock surface figure (i.e., Figure 4-5). I further contend that additional information about the nature of groundwater flow within the fractured bedrock is required to develop a defensible environmental monitoring program.

This section includes photographs (Figure 4-3) of the three prominent rock types encountered during the drilling program. Providing photographic documentation is an excellent idea but the photographs are too small and dark to be useful to the reviewer. Larger photographs, perhaps 8” x 10”, would provide adequate detail. Larger photos would also permit JRL to annotate the photos with some of the important characteristics (e.g., foliation, calcite and quartz veins, relic bedding and fractures).

Pg 4-8 The bedrock investigation identified two primary fracture sets. One fracture set strikes northeast-southwest and the other northwest-southeast. According to the text both fracture sets are steeply dipping but no information about a predominant dip direction, if one exists, is given.

Pg 5-1 5.1 Groundwater in Soils Appendix D contains tables of monthly water level data for select wells. In addition to the data tables found in Appendix D, I recommend JRL graphically depict the water level information for a representative selection of monitoring wells. This information could be used to supplement the groundwater depth discussion in Section 5.1.3.

Pg 5-2 <u>5.1.1 Horizontal Groundwater Flow Through Soils</u>

JRL's interpreted phreatic surface (Figure 5-1) demonstrates flow directions do not change significantly between seasonal high and low groundwater levels. However, what happens as liner construction reduces groundwater recharge? Will a decrease in the elevation of phreatic surface alter groundwater flow directions? Will it alter the location of the groundwater divide?

Pg 5-4 <u>5.1.3 Groundwater Depth</u> Construction of portions (12.7 acres) of the proposed expansion will require an underdrain because the base grade are expected to be below the water table. The text states, "….this will induce upward groundwater seepage into the excavations…." This description is misleading based on the interpretive vertical equipotential profiles. The profiles indicate groundwater movement is not upward throughout most of the underdrain. Rather, the excavation base grade simply extends beneath the surface of the water table. It's best to simply view the excavation as creating a groundwater outcrop. In fact, if JRL's interpretive vertical equipotential profiles accurately represent in-situ conditions, I expect flow in the underdrains will be short lived as recharge decreases with construction of cell 13.

Pg 5-23 <u>5.3 Regional Hydrologic Setting</u> JRL's conceptual model of groundwater flow in the vicinity of the proposed expansion and existing landfill is consistent with my understanding of the expected regional groundwater flow in the area. Due to the existence of the till ridge trending northward beyond the proposed expansion boundary, JRL expects the identified north-south oriented groundwater divide to cause groundwater beneath the northern edge of expansion to flow away from the divide (i.e., toward the northeast or northwest). I believe the report mistakenly stated groundwater west of the divide flows in a southwesterly rather than in a northwesterly direction. The interpreted potentiometric surface depicted on Figure 5-8 indicates a northwesterly flow.

Pg 5-26 JRL's conceptual model of regional groundwater flow, based on the site's hydrgeologic setting and supported by the hydrogeological investigations, along with the computer simulations of regional groundwater flow, demonstrate the private water supplies located along routes 16 and 43 are isolated from groundwater flow paths originating in the vicinity of the JRL facility. I therefore agree with the concluding statement that there is little risk the water quality of the existing water supplies would be compromised in the unlikely event of a failure of the proposed secure facility.

Pg 5-26 5.4 Post-Construction Groundwater Flow Directions

As groundwater recharge is gradually eliminated as the facility expands, the elevation of the water table surface will decrease. JRL expects the water table surface will also flatten as recharge decreases. Are these changes expected to alter current flow directions? This section could be improved by augmenting the verbal description of the anticipated future groundwater flow directions, with a figure depicting current and future flow directions. The computer model used to simulate current groundwater flow in the vicinity of the landfill could be used to further refine our understanding of groundwater flow directions and how they may change when recharge is ultimately reduced to zero beneath the entire 122 acres. These simulations may help us determine how the location and orientation of the groundwater divide may change in the future. Knowledge regarding the location of the groundwater divide is particularly important to the design of the facility’s long term monitoring program.

Pg 5-27 5.5 Protection of Off-Site Groundwater and Surface Water The results of the pumping tests definitely demonstrate a relatively well connected bedrock fracture system. Like JRL, I too interpret this as an important finding since it certainly suggests that pumping wells could be used to capture contaminants in the unlikely event of a liner failure.

The long term pumping test conducted using PW-08-01 and PW-08-02 produced measureable drawdown in many of the observation wells, some located a considerable distance from the pumping wells. However, it is not accurate to equate drawdown with groundwater capture. For example, the roughly 7.0 feet of drawdown measured in P-04-07A, located 1,900 feet from PW-08-01, does not imply groundwater from this location will be captured. The apparent interconnected bedrock fracture system does suggest appropriately located bedrock recovery wells could be used to control and capture contaminants at this site.

The Department has consistently encouraged JRL to use the surface geophysical technique (2-D electrical resistivity) to identify potential transmissive bedrock fracture zones. Given the success of this technique at this site, it would be prudent to complete additional geophysical lines to identify additional fracture zones before further site development reduces the technique’s effectiveness.

Pg 6-1 6.1 Expansion Water Quality Monitoring Locations
This section provides an overview of the Environmental Monitoring Plan (EMP) for the proposed expansion. The complete EMP is included in Volume IV of the application. My comments about the EMP are included here and following the Volume IV heading.

As currently proposed, the EMP described will include the addition of 23 monitoring wells, two new surface water sample locations and several leak detection and underdrain locations. JRL states that many of the proposed new well locations would not be installed until JRL constructs the cells they are intended to monitor. This is a commonly accepted approach for an expansion of this size. In large part I agree with this approach but I contend some of the proposed bedrock wells should be installed as soon as possible. On **DEP Attachment D** I have highlighted the proposed wells that I recommend JRL install as soon as possible to further refine our understanding of groundwater flow in the underlying fractured bedrock. To maximize the usefulness of these explorations, I also recommend extending the target depth of the proposed wells. All of the proposed bedrock wells should extend 200 feet into bedrock. Data from the traditional suite of borehole geophysical tools can be used to determine the appropriate well screen intervals. Because JRL has completed few bedrock explorations within the proposed footprint, it may be prudent to locate some of the additional bedrock borings within the footprint. I would like to have a detailed discussion with JRL about the locations I propose for additional bedrock exploration/observation wells.

It is important for JRL to recognize that information gathered during the installation of these wells may ultimately result in further refinements to the EMP.

Pg 6-2 6.1.1 Leachate Monitoring for the Expansion Leachate characterization at the existing licensed landfill calls for the collection of three samples per year from the leachate storage tank. The current parameter list includes: field parameters, geochemical parameters (i.e., Detection parameters) and volatile organic compounds. This program has successfully characterized the bulk leachate but it yields little information about how the leachate chemistry evolves as the waste volume within a cell accumulates and matures. In an effort to assess any significant difference in leachate character between the existing leachate stream and the leachate generated by the expansion, I recommend JRL also sample the leachate generated by the first cell (Cell 11) of the expansion. Initially I expect the chemical leachate characteristics of Cell 11 will differ markedly from the mature leachate generated by the existing landfill.

Pg 6-2 6.1.2 Leak Detection and Underdrain Monitoring for the Expansion JRL clearly recognizes routine monitoring of the leak detection systems represents the primary method to evaluate liner performance. The current monitoring program for the existing landfill with leak detection includes monthly measurements of specific conductance and flow. JRL also collects samples for the full suite of laboratory and field parameters three times per year. The EMP for the expansion calls for monthly flow and specific conductance as well. I propose increasing these measurements from monthly to every two weeks. I also think it would be instructive to be prepared to measure the head in the leak detection system if the flow measurements warrant. Based on discussions with the Department's project engineer, Steve Farrar, I understand it would not be difficult to place pressure transducers in the lower portion of the leak detection system.

Pg 6-3 6.1.3 Groundwater Monitoring Locations around the Expansion As discussed earlier in this memorandum, I do not agree with portions of JRL's interpretation of the bedrock tracer test. I do not dispute that the introduced tracer was detected in the downgradient observation wells nor that the results demonstrate that the bromide tracer spread out over a wide arc as remnants of the injected tracer travelled toward the observation wells. I understand JRL currently contends the majority of the bromide tracer "dropped" out of the injection well due to the initial density of the tracer solution. Despite the significant loss of tracer, JRL believes the remaining tracer travelled horizontally toward the observation wells. It is also possible the tracer may have followed hydraulically transmissive fractures that pass beneath the downgradient fence of observation wells. My calculations support the contention that the observation wells virtually failed to detect the plume as far less than 0.1% of the expected bromide was observed. If my interpretation is correct, it has important ramifications for locating downgradient bedrock wells in the flow path contaminants may follow in the event of a release.

Pg 6-6 In the discussion of the rationale for well placement JRL refers to large spreading of the tracer plume within 50 feet of the injection point. Specifically, JRL contends the solute spreading observed during the tracer experiment justifies spacing downgradient wells at distances ranging from 350 to 2,000 feet. To their credit, JRL has reduced the well spacing to 500 to 600 feet. However, all parties must recognize that dilution and dispersion of a contaminant plume will significantly reduce the concentration of the primary indicator parameters. The resulting "signal" in the observation wells may be difficult to observe above the groundwater quality changes resulting from site development. With this reality in mind, I would like to discuss the possibility of further decreasing the spacing of monitoring wells.

In recognition of the importance of monitoring background groundwater quality, JRL has included four wells in its proposal. Two of the wells/piezometers are located south of the existing landfill and are included in the EMP. The two existing piezometers that are new to the program are located north of the proposed expansion (MW-04-09A/P-04-09A and MW-04-09B/P-04-9B). With time, water quality data from these wells may be particularly useful as they appear to be located beyond the influence of all site activities with the exception of the access road. I am, however, concerned that 1 inch piezometers may not yield sufficient water. In fact, I recall the low yield from P-206A has made it difficult to collect sufficient water for all of the required analyses. Traditional 2 inch wells should serve as the standard monitoring well as required by Chapter 405 of Maine's Solid Waste Management Regulations.

Pg 6-7 <u>6.2 Future Sampling Parameters</u> I recommend modifications to the initial characterization parameter list summarized in Table 6-2. Boron has seldom been monitored at this landfill, but it is commonly found at elevated levels in landfill leachate and it is a relatively conservative parameter.

Methane is another parameter I wish to add to the characterization parameter list summarized in Table 6-2. Because the wastes proposed for disposal will ultimately generate large quantities of methane, it is imperative to establish predevelopment levels of methane in groundwater in the vicinity of the proposed expansion. This is particularly important because methane is found occasionally in Maine's groundwater under natural conditions. In fact, JRL's current program has detected methane in the pore-water samples within the wetland west of the existing landfill.

Pg 6-8 JRL has proposed an alternative analytical program for some wells. The proposal calls for sampling the wells designated with the prefix “OW” for field parameters twice each year and once for the complete list of laboratory parameters. This protocol will also be followed for the underdrain and leak detection sample locations. I approve of this approach. It will, however, be necessary to include a protocol (e.g., increasing parameter trends) that will trigger the collection of samples for laboratory analysis three times per year.

Pg 6-10 <u>6.4 Groundwater Level Monitoring</u> In an effort to monitor the expected drop in the phreatic surface beneath the expansion footprint, JRL plans to install two vibrating wire pressure transducers. Providing the transducers operate reliably for the expected timeframe, the transducers will generate the empirical head data necessary to quantify how the phreatic water levels decrease with time. To ensure these measurements can be obtained for an extended time period, JRL may want to consider installing additional transducers to provide some redundancy in case of equipment failure.

Pg 7-1 <u>7.0 Travel Time Analysis</u> This section outlines JRL’s approach to conducting the required travel time analysis. The written summary is thorough and is supported by the spreadsheets included in Appendix X. In its response to comments, JRL should provide the Department with an electronic copy of the worksheets. I also recommend the revisions to this section include schematic cross-sections to illustrate the travel paths to each of the chosen sensitive receptors.

Pg 7-2 <u>7.1 Selection of Site Sensitive Receptors</u> JRL’s analysis of potential sensitive receptors for the time of travel calculations identified the following receptors: three locations for potential future private water supplies; one location characterized with saturated sandy zones within the glacial till; and three locations where groundwater discharges to the surface water. The seven locations are shown on Figure 7-1. I generally concur with the sensitive receptors JRL has identified for the analysis. One might reasonably argue that the sandy zones within the glacial till represent a marginal sensitive receptor given its limited extent and the fact it is not connected to the mapped sand and gravel deposits. However, based on data obtained during the pumping tests, some of the wells (e.g., MW-06-01) screened in the sandy till are hydraulically connected to the fractured bedrock. Given the potential connection between the sandy till and a future private water supply (location B on Figure 7-1), including the sandy till as a sensitive receptor represents a level of conservatism in JRL's time of travel analysis.

<u>Nearest Existing Water Supply</u> Given the considerable distance between the closest water supply and the proposed expansion, I agree with JRL that the existing private water supplies do not represent sensitive receptors. I do, however, believe JRL's simplified description of the area providing water to a single family home is misleading. I don't disagree that there may be sufficient recharge from an area within 300 feet of a well but this assumes the borehole penetrates a homogeneous and isotropic bedrock aquifer. In most instances, the fracture characteristics of the primary water bearing fractures dictate the area of influence of a pumping well. The other important point relates to the position of the well in the hydrogeologic system. For example, bedrock wells located at the toe of a gentle slope may intercept groundwater that has travelled a considerable distance from the point of recharge. In fact, JRL has identified wells located along the western edge of the expansion footprint that intercept groundwater that has travelled in excess of 1,000 feet. Providing my questions about the groundwater ages determined using the helium-tritium age dating method are satisfactorily addressed, JRL will have provided an independent estimate of a substantial travel distance/time.

Pg 7-6 <u>7.2 Improvement Allowances</u> The improvement allowances for the liner design allows for a two year offset for the majority of the expansion footprint and three years for the two areas where the secondary liner includes a geosynthetic clay liner and one foot of compacted clay. The two areas with the augmented secondary liner are shown on Figure 7-1. JRL's proposal also includes 12 inch of compacted marine clay beneath the entire footprint which qualifies for an additional three years of travel time. In summary, the total offsets provide for either five or six years of travel time for the entire footprint.

Pg 7-8 <u>7.4 Calculated Travel Time to Site Identified Sensitive Receptors</u> I have reviewed the travel time calculations summarized in this section and the worksheets provided in Appendix X. Overall the technical approach and the resultant calculations appear straightforward and logical. Perhaps more importantly, the input values for the calculations are based on well documented site specific information.

I identified one minor error in the offset credits included in Tables 7-3 and 7-4. After speaking to Mike Booth of SME I have concluded the tables mistakenly included a three year rather than a two year offset for the travel time calculations from the Cell 13 Leachate Sump (Point C) to the surface water discharge point. Reducing the calculated travel time by one year isn’t critical since the travel time calculations in the till and bedrock exceeds 35 years to the discharge point. All of the relevant tables, however, should be revised to include the correct offset value.

Notwithstanding the minor error, the calculated travel times range from 6.2 to 41.8 years. In summary, the calculated travel times to all of the identified sensitive receptors exceed the required six year time of travel required by the regulations.

Pg 7-12 <u>7.5 Sensitivity Analysis</u> To provide additional information about the range of estimated travel times to the sensitive receptors, JRL has completed a sensitivity analysis. The sensitivity analysis has used a range of effective porosities and hydraulic conductivities for both the till and bedrock. I concur with the range of values used in the analysis but the explanation, presentation and documentation must be improved. I also believe it is necessary to expand the sensitivity analysis to include estimates of travel times while using a combination of the low range porosities along with the highest hydraulic conductivities.

The report indicates the results of the analysis can be found in Appendix X. It appears Appendix X does not contain spreadsheets for all of the sensitivity runs used to populate the table (Summary of Sensitivity Analysis, JRL Expansion Application) summarizing the results of the sensitivity analysis. Rather than outline the specifics for the additional analysis in this memorandum, I would prefer to discuss my objectives directly with JRL and its consultant.

Juniper Ridge Landfill Expansion Application

Volume II, Site Assessment Report – Appendices A-X

Appendix H – Field-Scale Bedrock Tracer Test Results

The results of the bedrock tracer test were first reported in SME's September 2008 Bedrock Tracer Report. I reviewed this report and outlined my comments in an October 15, 2008 memorandum. I believe the most significant finding of the tracer test was the relative absence of the bromide tracer in the downgradient observation wells. The absence of tracer in the downgradient observation wells indicated the bulk of the introduced tracer did not travel through the well screens of the observation wells. My memorandum included a couple of explanations for the relative absence of tracer in the observation wells. First, the predominant flow direction in the fractured bedrock may not be horizontal. Rather, it is possible groundwater flow in the shallow bedrock may have a significant vertical component of flow and the tracer simply travelled beneath the observation wells. Another plausible explanation is the tracer traveled vertically through the bottom of the well as a result of density driven flow. This may have occurred because the mass of bromide introduced into the injection well resulted in an initial salinity close to seawater.

The revised report contained in Appendix H concludes the majority of bromide was lost due to the density of the tracer slug introduced into MW-06-02. Just the same, JRL believes the "residual" tracer remaining in the injection well (MW-06-02) ultimately moved downgradient through the fence of observations wells. I agree that density driven flow helps explain the observed results. However, I am not convinced the tracer test data demonstrate groundwater flow is predominantly horizontal between the injection well and the observation wells. In fact, I believe the pumping test results revealed, at best, a relatively poor connection between the pumping (injection) well and the downgradient observation wells. Regardless of the correct explanation, it is possible the tracer's predominant flow path was toward the observation wells but the mass travelled beneath the observation wells. This is based on a series of calculations **(DEP - Attachment A)** used to provide a rough estimate of the expected bromide concentration one would expect to observe within the test volume. If the tracer's path was directly intersected by the observation wells, one would expect to measure bromide levels in excess of 100 mg/L, perhaps as high as 1,000 mg/L. In fact, the highest bromide concentration measured was 0.095 mg/L, a level far lower than the value I estimated. The bromide measured in the observation wells may represent the upper portion of the tracer plume as it travelled beyond and largely below the observation wells. Again, I don't dispute that the tracer travelled in the direction of the observation wells. The point of dispute relates to the tracer's trajectory. The data may, in fact, demonstrate a significant downward component of flow. Regardless, the uncertainty regarding the tracer's path underscores the importance of using nested monitoring wells (completed at varying depths) to detect possible leachate releases.

Appendix I – Helium-Tritium Groundwater Age Dating Results

As I have noted earlier in this memorandum, additional information must be included to support the use of this technique. In addition to providing relevant peer reviewed references on the subject, JRL should provide details about the sampling protocol followed to ensure the collection of representative samples for dating groundwater using the helium-tritium method. The chain-of-custody sheets for the samples collected are also needed.

The analyses were performed by the University of Rochester's Noble Gas Laboratory. Appendix I contains one laboratory sheet for each of the groundwater samples. The laboratory report for the sample collected from P-04-06A includes a comment stating the "Correction is too large to provide valid age. Large amount of terrigenic helium - may be mixed water." This comment suggests the age determination is not valid. I also find the tritium data puzzling as the tritium activity (TU) of the sample collected from P-04-07B is higher than that of P-04-06A. Given tritium's 12.3 year half-life, the older sample (P-04-07B) should be characterized by a lower tritium activity than that of P-04-06A. JRL must clarify these apparent discrepancies so the Department can determine if the age estimates are valid.

Appendix J – MW-06-02 Groundwater Pumping Test Results

Pg 1 1.0 Purpose I understand the primary purpose of this test was to determine the interconnectivity of the fractures intersecting the pumping well (MW-06-02) and the downgradient observation wells. Presumably information about the fracture network helped JRL design and implement the bedrock tracer test. It is not evident, however, how JRL used the results from this pumping test to design and implement the tracer test.

Pg 2 3.0 Test Data The graph in Attachment B depicts the pumping rates throughout the pumping test. This figure should be revised to include the initial pumping rate of 3.5 gpm that was subsequently determined to be too high.

Please provide an explanation for the telog data displayed on the drawdown versus time for the pumping well Specifically, there is a considerable amount of telog data collected between 200 and 500 minutes that is not correlated with the manual measurements.

Pg 4 4.0 Analysis of Results As the report notes, the time-drawdown graphs for three of the observation wells indicate the water levels began to recover before the pumping test ended. The water level data for OW-06-08 clearly illustrate this phenomenon. The report mistakenly describes this as a decrease in drawdown rather than recovery of water levels (i.e., increase in head). This distinction is important as water levels in three of six wells began to recover as pumping continued. JRL believes the afternoon rain event provides an explanation for the recovering water levels. However, based on the estimated slow travel time through the till, these shallow bedrock wells are not expected to respond so quickly to a rain event. Please provide further explanation.

My synthesis of the pumping test data suggests the pumping well is at best poorly connected to the observation wells. The relatively long lag period between the on-set of pumping and observed drawdowns in the observation wells indicates a less than well connected fracture system. Further, while drawdown in the pumping well ranged from 10 to 15 feet, maximum drawdown in the observation wells did not exceed 1.0 ft during the eight hour pumping test. Contrast these results with the drawdowns observed during the 24-hour pumping test performed on PW-08-01. Within 20 minutes of the 24-hour pumping tests, drawdowns were observed in an observation well located more than 1,200 feet from the pumping well. Overall, in my view, the results of the pumping test on MW-06-02 did not suggest it was well suited for the subsequent tracer test.

Appendix M – Hydraulic Analysis of Data from Long-Term Bedrock Pump Test at PW-08-01

Pg 3 3.0 Pump Test Analysis Water levels in some of the wells screened in the till responded to pumping PW-08-01. Although the hydraulic conductivity of the till is generally significantly less that the underlying bedrock, it is capable of supplying water. JRL’s revised report should specify the wells where this occurred. Likewise, the shallow till wells where they observed little change in water level should also be noted.

I believe the data presentation would be improved if JRL summarized the pumping test data by depicting the maximum drawdown data observed at each well on a site plan. Later in this memorandum I outline suggested additional data analysis.

Appendix U – Bedrock Fracture Interconnectivity

Pg 4 4.0 Detailed Description of Bedrock Fracture Features at the Expansion Site This section summarizes the bedrock characterization data collected in and around the expansion. At this time it bears repeating that JRL has only completed five bedrock explorations within the proposed expansion footprint **(DEP - Figure 4)**. Further, only one (PW-08-02) of the four 200 foot bedrock borings is located within the footprint. A detailed justification for the relatively small number of borings within the 56 acre expansion is required. The degree to which the data collected beyond the footprint adequately characterize the bedrock underlying the proposed expansion is not adequately addressed in the current application.

Pg 5 4.1 Bedrock Fracture Orientation Figure U-2 provides a rose diagram containing all of the orientation data for fractures observed on four bedrock outcrops and the “fracture” data obtained from the four bedrock borings logged using the optical televiewer. As JRL points out, there are two dominant fracture trends (i.e., northeast-southwest and northwest-southeast) and they are consistent with the results from the regional photolineament analysis.

Unfortunately, I was unable to locate the table containing the strike and dip data for three of the four outcrops.

Pg 8 The fracture data collected with the optical televiewer for each of the four borings are depicted on Figures U-4 through U-7. The strike and dip data for the four boreholes are remarkably uniform. It is also noteworthy that the boring (PW-08-03) located on a resistivity high (i.e., low transmissivity) contained far fewer fractures than the three borings located on the resistivity anomalies.

Pg 13 The two photographs (Figure U-8 and U-9) along with the fracture attitude data illustrate how two closely spaced fractures intersect to help create a relatively well interconnected fracture system.

Pg 15 JRL determined the fracture spacing for four bedrock cores (P-04-07, P-04-12, P-04-13 and P-04-14) collected from explorations outside the proposed expansion footprint. This section should also specify the total core length examined. I don't underestimate the importance of this data, but how do we know that it is representative of the bedrock underlying the proposed landfill?

Pg 22 5.0 Pump Test Proof of Bedrock Interconnectivity

The pumping tests performed on the four 200 foot open bedrock boreholes certainly demonstrated the usefulness of conducting the 2-D Resistivity surveys to locate potential fracture zones. Interestingly, JRL suggests additional bedrock explorations may be located using this technique. After carefully reviewing the modeled 2-D resistivity lines, I urge JRL to consider locating additional bedrock explorations at several apparent anomalies. One of the additional bedrock explorations should target the low resistivity area identified on Line 6 **(DEP - Attachment E).** This apparent anomaly is located about 500 feet south of PW-08-01 along the eastern boundary of the proposed expansion. This is within the general area I have previously noted requires additional bedrock explorations and monitoring wells. Another apparent prominent low resistivity area appears on Line 8, roughly 500 feet south of P-04-09A,B **(DEP – Attachment F)**.

Pg 25 On Figures U-14 and U-15 JRL has illustrated the range of drawdowns observed in bedrock wells during each of the pumping tests performed on the four 200 foot bedrock boreholes. Additional illustrations are warranted to more fully convey the data collected during the tests. For example, the text states water levels were measured in 24 bedrock wells but the Figure only includes 20. Figure U-15 also appears to include drawdown data for some of the till wells although the Figure's title implies it is bedrock data only. This raises another point. It is also necessary to include figures illustrating the observed drawdown in the till wells during each of the pumping tests. The text states that significant drawdown occurred in some till wells during each pumping test. Comparing the drawdowns observed in both the till and bedrock wells during each test, may reveal locations where the hydraulic connection between the till and underlying bedrock is most pronounced.

As I have previously noted, I couldn't locate the tabulated drawdown data. It is important to obtain this data in an electronic format so the department can thoroughly analyze the data.

Pg 28 JRL has combined all of the drawdown data (normalized to drawdown in the pumping well) collected during the five pumping tests to generate Figure U-16. This rose diagram provides an excellent illustration of the relatively uniform network of transmissive fracture that exists on a site-wide scale. Transmissive fracture pathways appear to encompass all azimuths, albeit not from a single location.

JRL must include the tabulated data used to generate Figure U-16. Again, JRL should provide the data in an electronic format also.

Pg 30 6.0 Theoretical Confirmation of Bedrock Fracture Interconnectivity In this section JRL makes the case the fracture density exceeds the so-called "percolation threshold" and therefore supports advective groundwater flow. I am concerned that JRL's analysis assumes the fracture network observed and mapped at the OC-AG outcrop is representative of the entire site. It is not clear to me how one extrapolates the findings from a single outcrop to an entire site. Please elaborate.

Pg 31 7.0 Conceptualization of the Bulk Bedrock Groundwater Flow JRL, in my view, makes a compelling argument for treating the fractured bedrock, at least on a site-wide scale, as an equivalent porous medium. Therefore, JRL has reasonably chosen to model groundwater flow in the surficial and bedrock aquifers using the USGS' MODFLOW numerical model. MODFLOW can be expected to model current conditions and evaluate future scenarios. An important future scenario includes an evaluation of how groundwater flow directions may change once recharge is reduced to zero beneath the landfill's footprint.

Appendix V – Groundwater Simulation Juniper Ridge Landfill Expansion Old Town, Maine July 2015

Pg 15 5.0 Simulation Results The last sentence in the first paragraph states, in part, "….that the anisotropy of groundwater flow through the shallow and deep bedrock is evident." Without additional explanation this statement has no significance.

Model simulations included reducing the recharge to zero over the existing facility and the proposed expansion. These simulations incorporated particle tracking to determine the potential fate of groundwater originating in the vicinity of the landfill. The particle tracking simulation is shown on Figure V-6 and demonstrates groundwater originating from beneath the landfill ultimately discharges to the surrounding streams.

I strongly recommend JRL expand this aspect of the modelling to include pre and post equipotential head data and the estimated groundwater flow directions. Using the model to quantitatively determine how the water table changes in response to reducing recharge to zero seems like a particularly important question to address. As stated previously, predicting the future location of the drainage divide is important to the facility's long-term environmental monitoring plan. I recognize it may require a finer discretization of the model domain to produce output meaningful at the scale of interest.

Juniper Ridge Landfill Expansion Application

Volume III, Design Report

Pg 4-1 4.0 Contaminant Transport Analysis As required by the Solid Waste Regulations (401.2 G), an expansion application requires a contaminant transport analysis. This analysis is required to evaluate the potential of a variety of hypothetical failure scenarios to pose an unreasonable threat to the identified sensitive receptors. In my view, information obtained regarding the potential threats to sensitive receptors is conservatively addressed by the completion of a thorough time of travel analysis which JRL has completed. Regardless, this section describes the hypothetical failure scenarios evaluated, the analytical methods used for the analysis and the results.

Based upon my review, it appears JRL has completed a satisfactory contaminant transport analysis. The failure scenarios evaluated do not reveal an unreasonable risk to the sensitive receptors.

Pg 4-9 4.4 Hypothetical Failure Scenarios This section describes the three failure scenarios along with a summary table (Table 4-3) of the contaminant transport analysis. Table 4-3 contains a portion of the summary data for the analytical solute transport equation used in each of the failure scenarios. In its current form Table 4-3 includes the alkalinity, arsenic and nitrate data. Table 4-3 should be revised to include the analytical solutions for all six of the leachate constituents in Table 4-1.

Juniper Ridge Landfill Expansion Application

Volume IV, Operations Manual

Appendix I – Environmental Monitoring Plan

I have completed a comprehensive review of JRL's Environmental Monitoring Plan (EMP) for the proposed expansion. In the following section I have outlined a number of comments related to the proposed EMP but perhaps more importantly I have outlined a variety of alternatives to the generally accepted approach used to monitor potential releases from secure facilities. Because the JRL facility is State owned and privately operated, it represents a unique opportunity to cooperatively explore one or more alternative monitoring approaches. Once JRL and its consultant, SME, have an opportunity to consider my suggestions, I recommend we meet to discuss the potential to implement one or more of the alternative approaches.

Pg 3-1 3.1 Groundwater Monitoring In general, I agree with both the number and locations of the proposed new wells. Based upon my earlier comments, it will not come as a surprise that I recommend deeper bedrock explorations and wells along the eastern boundary of the proposed expansion. To provide a couple of specific examples, OW-604A and OW-605A should be paired with deeper bedrock wells. The use of air rotary drilling techniques would enable JRL to cost effectively complete boreholes extending to target depths in the neighborhood of 200 feet below the bedrock surface. The subsequent characterization of the bedrock explorations will enable JRL to screen the appropriate fracture systems.

Pg 3-1 3.2 Surface Water Monitoring The expansion will include two additional surface water monitoring locations. Because flow in these headwater streams is maintained, in part, by discharging groundwater, I strongly recommend JRL consider installing permanent pore-water samplers to monitor the quality of discharging groundwater at each of these locations.

Pg 4-1 4.0 Selection of Monitoring Parameters The parameter list summarized in Table 4-1 should be revised to incorporate the comments contained in this memorandum. At this time I recommend the addition of the following parameters: boron, methane and tritium.

Recommended monitoring alternatives for evaluation

1) Researchers have found leachate generated by municipal solid waste may contain significant tritium [2]. A preliminary survey completed by the Department found Maine’s landfill leachate was characterized by tritium activity [3] in excess of expected background. In fact, the Department’s survey found JRL’s leachate contained significant tritium activity. Tritium may therefore serve as a valuable tracer. To evaluate the potential usefulness of tritium, I recommend JRL determine the tritium content of the current leachate. JRL can initiate this characterization in 2016.

[2] Hackley, K.C., C.L. Liu, and D.D. Coleman. 1996. Environmental Isotope Characteristics of Landfill Leachates and Gases. Groundwater: Vol. 34, No 5.
[3] Behr, R.S. and R Heath. December 2010. Tritium activity in landfill leachate and contaminated groundwater in Maine

2) On several occasions during the past year I have suggested the possibility of incorporating a tracer into the protective base layer of the liner system. Because the proposed expansion will be constructed in phases, we will have an opportunity to explore this possibility using a variety of approaches. For example, JRL could incorporate a tracer into cell 11. Once waste disposal begins, JRL could analyze both the leachate generated by this cell and its leak detection system for the introduced tracer. An ideal tracer will be soluble, conservative and not generally detected in Maine’s groundwater. During the past several years researchers have developed techniques that embed synthetic DNA in polylactic acid microspheres [4]. These techniques are in their infancy but hold tremendous promise in part because the particles can be uniquely labeled, detected at extremely low levels and are not prohibitively expensive. Since the JRL facility is a privately operated state owned facility, it is a particularly good site for which to evaluate the usefulness of tracers.

3) Historically, monitoring well networks have been successfully used to detect and monitor the level of contamination downgradient of *unlined* landfills. Today we routinely characterize downgradient groundwater at double–lined secure landfill facilities, but the traditional downgradient fence of monitoring wells no longer represents the initial means to detect a liner failure from a secure double-lined landfill.

   JRL’s proposed liner design incorporates a leak detection layer positioned between a primary and secondary liner system. Today, robust monitoring of the leak detection system represents the primary method of detecting a failure in the primary liner. In the event of a significant leachate release, I expect the most soluble components would be detected by the downgradient groundwater monitoring well network. However, long before there are any indications of contamination in downgradient

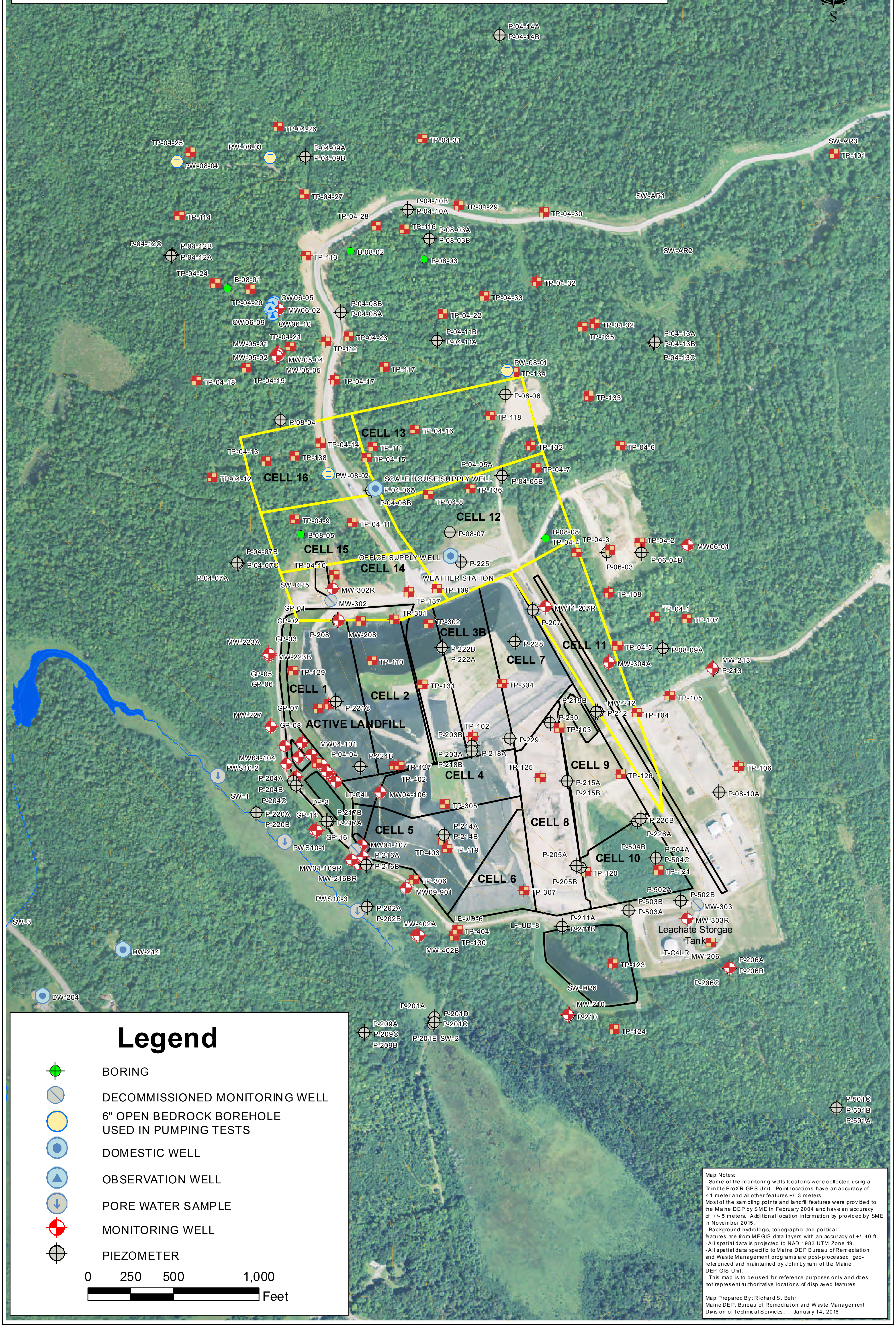
[4] Sharma, A. N., D. Luo, and M.T. Walter. 2012. Hydrological Tracers Using Nanobiotechnology: Proof of Concept. ES&T. Vol 46 (16) pp 8928-8936.

groundwater, monitoring data from the leak detection system will provide an early warning.

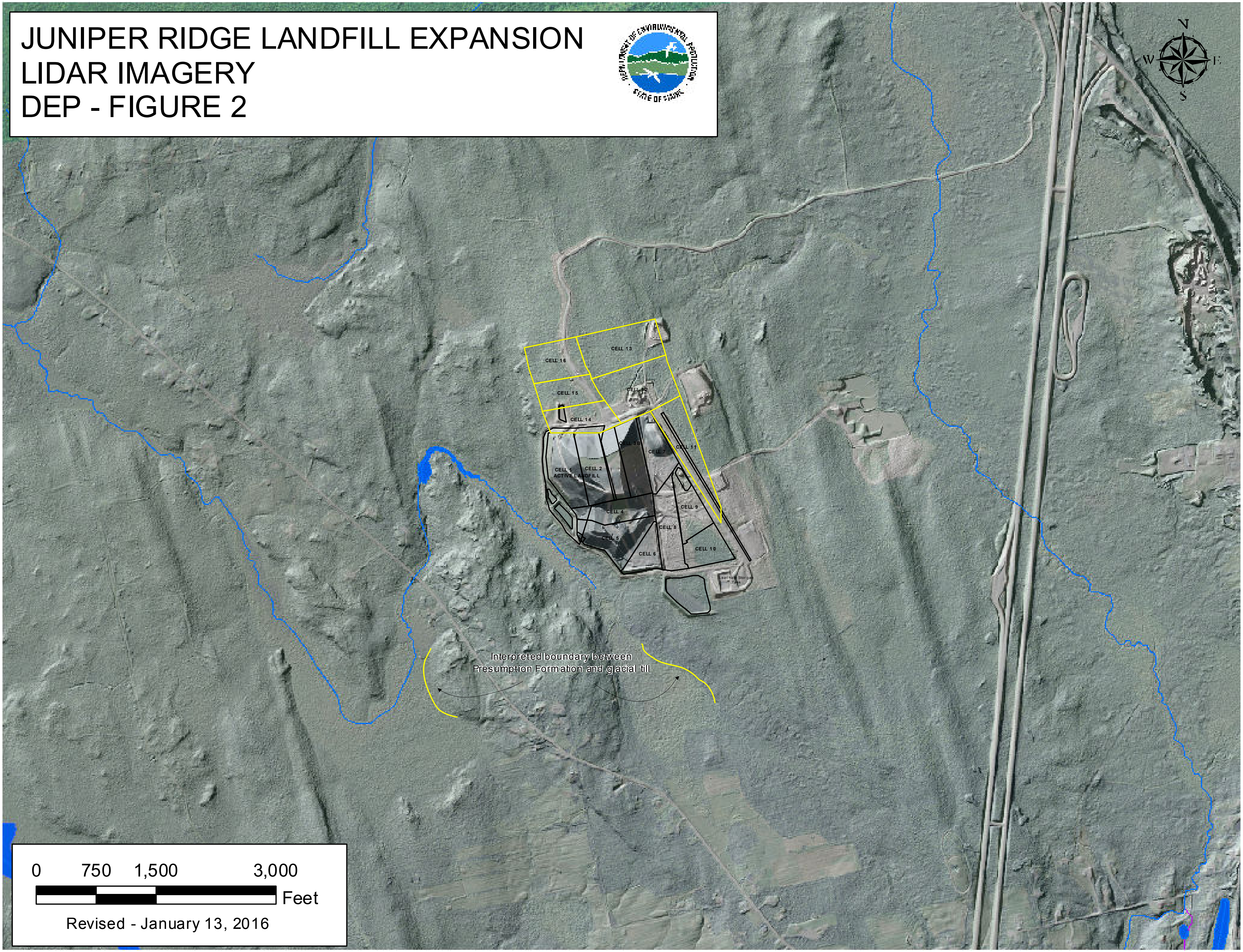
Attachments

Email: Richard Heath
Steve Farrar
Kathy Tarbuck
Victoria Eleftheriou

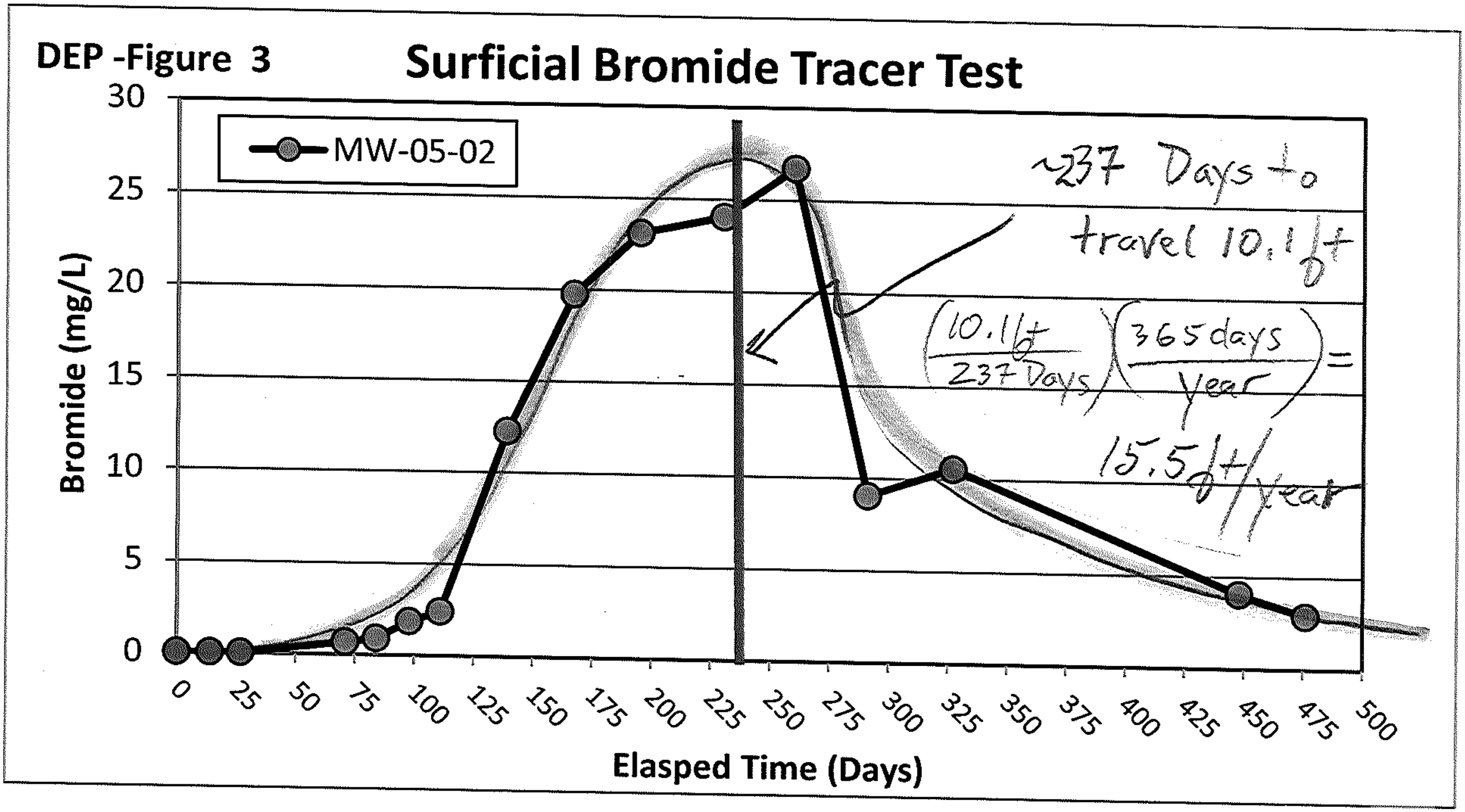
JUNIPER RIDGE PROPOSED LANDFILL EXPANSION
DEP - FIGURE 1



JUNIPER RIDGE LANDFILL EXPANSION
LIDAR IMAGERY
DEP - FIGURE 2

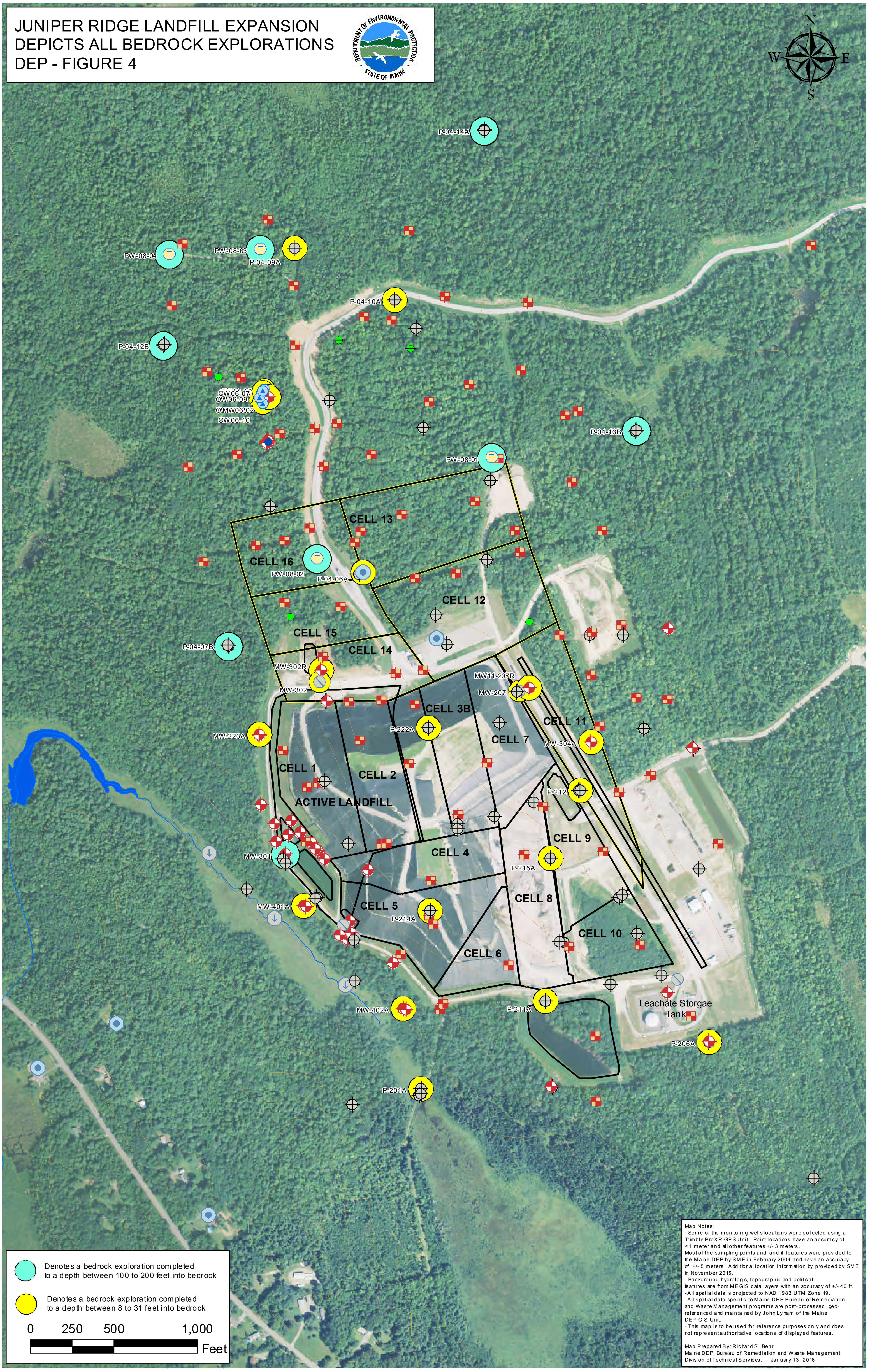


Revised - January 13, 2016



DEP -Figure 3
Surficial Bromide Tracer Test
MW-05-02
Bromide (mg/L)
30
25
20
15
10
5
0
0
25
50
75
100
125
150
175
200
225
250
275
300
325
350
375
400
425
450
475
500
Elasped Time (Days)
~237 Days to travel 10.1 ft
(10.1 ft / 237 Days)(365 days / year) =
15.5 ft/year

JUNIPER RIDGE LANDFILL EXPANSION
DEPICTS ALL BEDROCK EXPLORATIONS
DEP - FIGURE 4



Denotes a bedrock exploration completed to a depth between 100 to 200 feet into bedrock

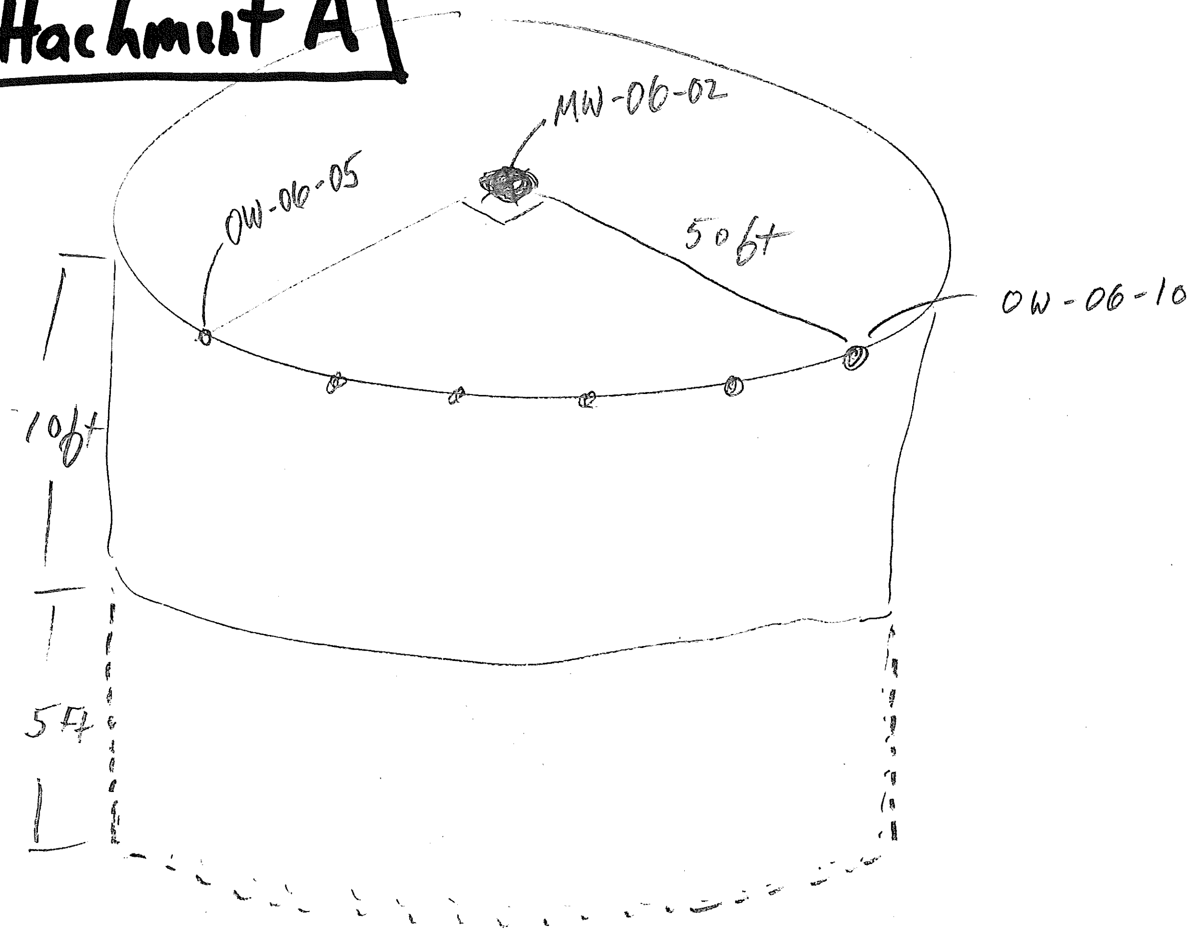
Denotes a bedrock exploration completed to a depth between 8 to 31 feet into bedrock

0 250 500 1,000 Feet

Map Notes:
- Some of the monitoring wells locations were collected using a Trimble ProXR GPS Unit. Point locations have an accuracy of < 1 meter and all other features +/- 3 meters.
Most of the sampling points and landfill features were provided to the Maine DEP by SME in February 2004 and have an accuracy of +/- 5 meters. Additional location information by provided by SME in November 2015.
- Background hydrologic, topographic and political features are from MEGIS data layers with an accuracy of +/- 40 ft.
- All spatial data is projected to NAD 1983 UTM Zone 19.
- All spatial data specific to Maine DEP Bureau of Remediation and Waste Management programs are post-processed, geo-referenced and maintained by John Lynam of the Maine DEP GIS Unit.
- This map is to be used for reference purposes only and does not represent authoritative locations of displayed features.

Map Prepared By: Richard S. Behr
Maine DEP, Bureau of Remediation and Waste Management
Division of Technical Services, January 13, 2016

DEP-Attachment A



Volume of Cylinder $= \pi r^2 h$ $\qquad$ $\pi r^2 h$

$= \pi (50)^2 \cdot 10$ $\qquad$ $\pi (50)^2 (15 ft)$

$= 78,539 \, ft^3$ $\qquad$ $117,810 \, ft^3$

$\times 0.25$ $\qquad$ $\times 0.25$

$19,635 \, ft^3$ $\qquad$ $29,452 \, ft^3$

$$(19,635 \, ft^3)\left(\frac{7.48 \text{ gallons}}{ft^3}\right)\left(\frac{3.8 L}{1 \text{ gallon}}\right) = 558,098 \, L$$

Assumes a 10 ft Test Volume

$$29,452 \, ft^3 = 837,144 \, L$$

Assumes a 15 ft Test Volume

Mass of Bromide Introduced to MW-06-02 **NOV 20, 15** (α)

$$\left(\frac{250\,g\ NaBr}{L}\right)\left(\frac{1000\,mg\ NaBr}{1\,g\ NaBr}\right)\left(\frac{80\,mg\ Br}{103\,mg\ NaBr}\right)(2\,L) = 388{,}349\ mg\ of\ Bromide$$

This is about double the mass of Bromide added to the surficial well

Estimated Test Volume

$$10ft \rightarrow 558{,}098\,L \times \underbrace{0.001}_{\text{effective porosity}} = 558\,L$$

$$15ft \rightarrow 837{,}144\,L \times 0.001 = 837\,L$$

Estimated Bromide conc. if all the Bromide was distributed throughout the test volume?

With 10 ft section $\frac{388{,}349\ mg\ Br}{558\,L} = 696\ mg\ Br/L$

With 15 ft section $\frac{388{,}349\ mg\ Br}{837\,L} = 464\ mg\ Br/L$

Since these conc. are several orders of magnitude greater than the highest conc. detected in an observation well, it suggests the tracer's path did NOT directly intersect the observation wells.

$464\ mg\ Br / 0.095\ mg\ Br = 4{,}884$ Therefore during the test we only observed ~1/5,000 of an expected estimated conc.

ATTACHMENT B

STATE OF MAINE

DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF REMEDIATION AND WASTE MANAGEMENT
DIVISION OF TECHNICAL SERVICES

M E M O R A N D U M

TO: Dick Behr, Hydrogeologist

FROM: Gail Lipfert, PhD, C.G. # GE506, Certified Environmental Hydrogeologist

DATE: January 14, 2016

RE: Juniper Ridge Landfill Pumping and Tracer Test Evaluation

CC: Rob Peale, C.G., Senior Geologist

****

1. 1.0 Purpose. The purpose is stated as determining to what extent bedrock fractures are integrated or hydraulically connected. It is not clear if they mean to assess the nature of bedrock fractures across the site or only those between the pumping well and the observation wells involved in this test.
2. 2.0 Pump Test Procedure. The pumping test does not appear to be very well-designed for several reasons:
    a. Groundwater elevations were recorded every 5 minutes, whereas it is recommended that pumping tests within fractured bedrock be monitored more frequently at the very beginning to see the effects of fracture control on drawdown, then monitored less frequently later on.
    b. The initial pumping rate was only sustainable for 1 minute 20 seconds, which is not very long. They should have conducted a step-drawdown test first to establish the pumping rate.
    c. They only monitored wells immediately downgradient of the pumping well, but they could have monitored the surrounding wells to see if there was any effect.
    d. There is no mention of borehole geophysical results to help understand the fracture system in any of the wells.
    e. They started monitoring one minute after pumping started instead of monitoring for a day or two before the test to establish any background water level changes and trends.
    f. They conducted the test during a thunder storm. The responses at OW-06-08, OW-06-09 and OW-06-10 to the rain storm at 200 minutes are abrupt and almost instantaneous, which indicates poorly-constructed wells.
    g. The Telog and manual water level measurements do not match at MW-06-02 between 200 and 500 minutes in Attachment C.
    h. They don’t seem to have Telog data from a couple of the wells (OW-06-05 and -06)/
3. 4.0 Analysis of Results.
    a. I have several observations regarding the drawdowns:
        i. The time at which the observation wells responded to the pumping are in the following order, from shortest to longest: OW-06-09, -10, -05, -07, -08, and -06

(9, 20, 35, 45, 45, and 75 min, respectively). The wells with the shortest response time would be the wells with a more direct fracture pathway.

ii. The depth to which the water levels responded to the pumping are in the following order, from greatest to least: OW-06-07, 09, 05, 10, 06, and 05 (0.78, 0.65, 0.54, 0.43, 0.16, 0.15 ft). The wells with the greatest responses would be the tightest wells.

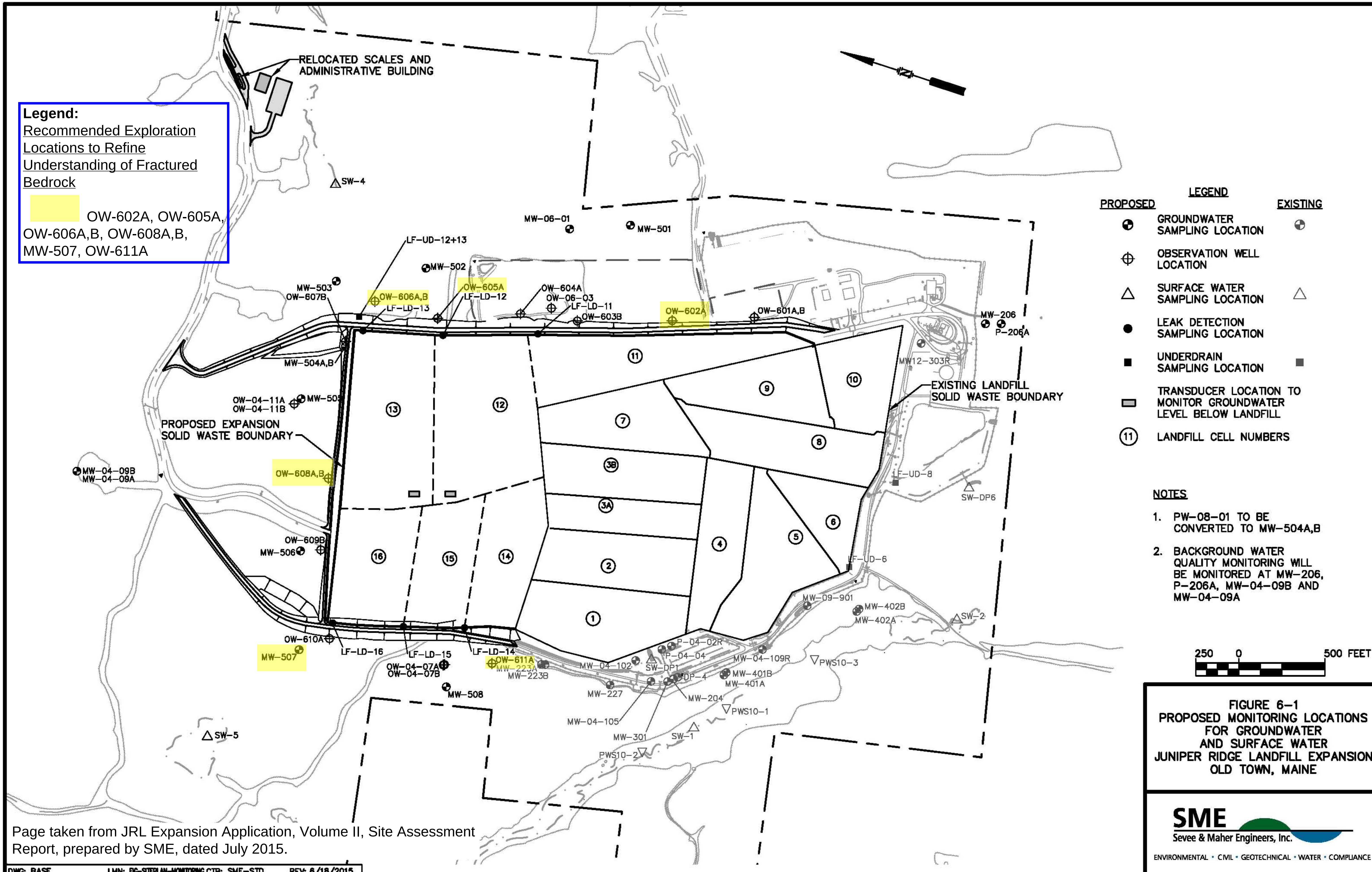
b. Table J-1. I don't understand what they mean by the "approximate radial azimuth for the various observation wells relative to the two predominant fracture set strike orientations (northeast/southwest and northwest/southeast)". There is only one azimuth value listed, but there are two strikes that they are described as being relative to. I would be more interested in the azimuth of the strike between the observation wells and the pumping well relative to true north.

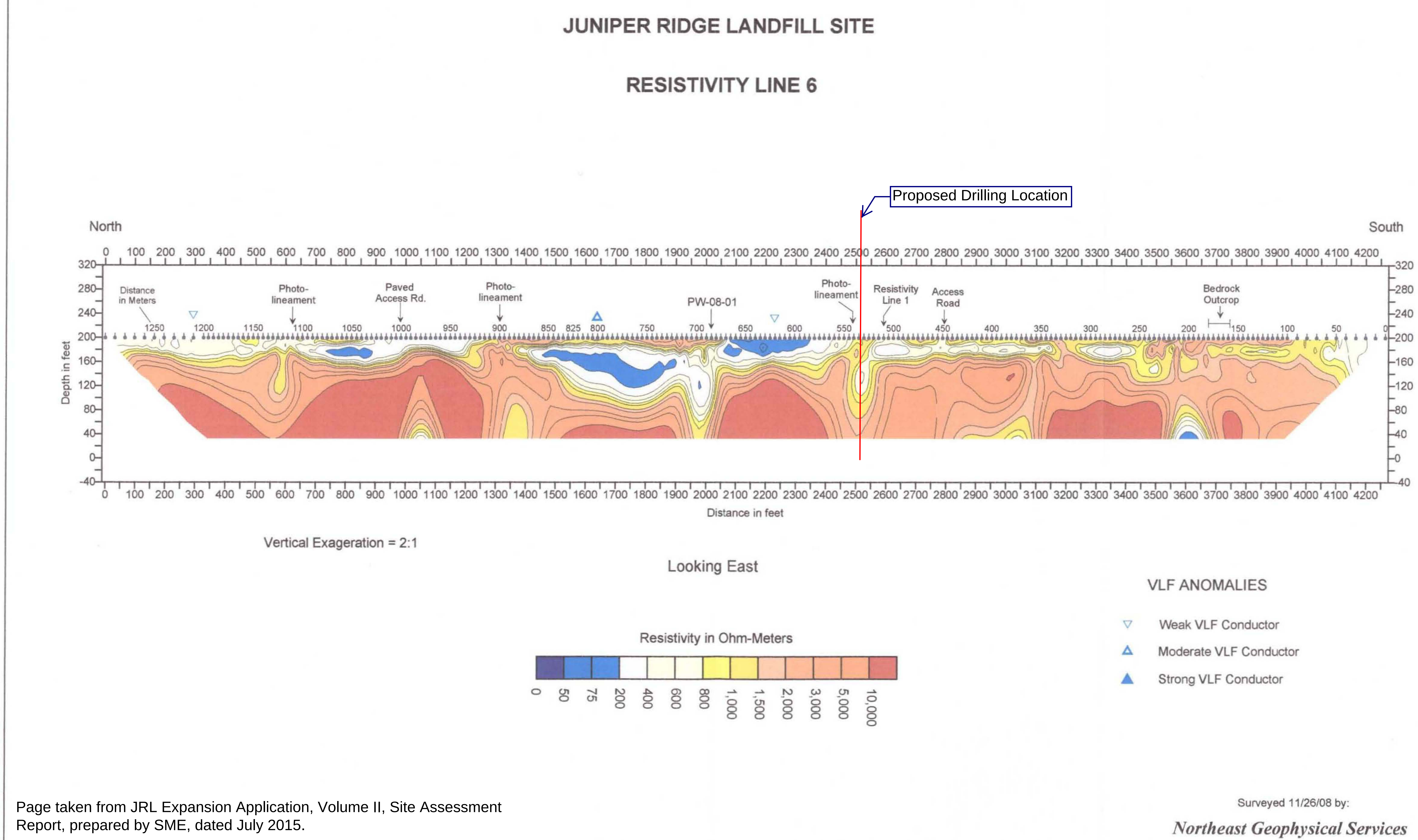
c. The analysis of maximum and minimum principal transmissivities using the Papadopoulos method has been presented only for five well groupings because these "provided meaningful results". How did they determine which results were meaningful?

d. Last paragraph states that the hydraulic conductivities estimated from dividing the transmissivities in Table J-1 by the well screen length are greater than measured at the observation wells. I do not understand this statement – what are the hydraulic conductivity values that were measured at the observation wells?

4. Appendix H, 4.0, second paragraph. OW-06-10 and OW-06-07 are aligned with the two dominant fracture orientations, but these wells have later arrival times (3 and 3.6 days, respectively) than OW-06-09 and OW-06-08, which received tracer after 0.8 and 1 days, respectively. SME interpret these results along with the fact that the wells with the steepest groundwater gradients have the longest travel times, to indicate that the predominant fractures had more influence on tracer velocity than groundwater gradients. I don't see that the predominant fracture orientations have much influence at all. I would say that it appears that there are fractures outside the predominant orientations that are hydraulically connected between MW-06-02 and OW-06-08 and OW-06-09.
5. Appendix H, 4.0 third paragraph. This paragraph suggests that the early arrival of tracer at OW-06-09 is consistent with the interplay between the principal hydraulic conductivity orientation (along predominant fracture sets) and the hydraulic gradient. I agree that the interplay between the principal hydraulic conductivity orientation and the hydraulic gradient controls plume direction, but using this logic, the tracer should arrive at OW-06-07 first instead of OW-06-09. This paragraph doesn't really explain why tracer arrived at OW-06-09 first.
6. Overall conclusions. One of the major assumptions in this analysis is that there are two principal transmissivities along two axes of an ellipse, but examination of the drawdowns at 200 minutes (before recharge affected the drawdowns) shows that the pattern of drawdowns is very irregular and cannot be described as an ellipse of anisotropy. The drawdowns also clearly indicate that the site is heterogeneous, which negates an underlying assumption for Papadopoulos's method. In general, it appears that the interconnectivity of the observation wells to the pumping well is quite variable and cannot be explained by the predominant fracture orientations or principal hydraulic conductivity orientations.

DEP - Attachment D

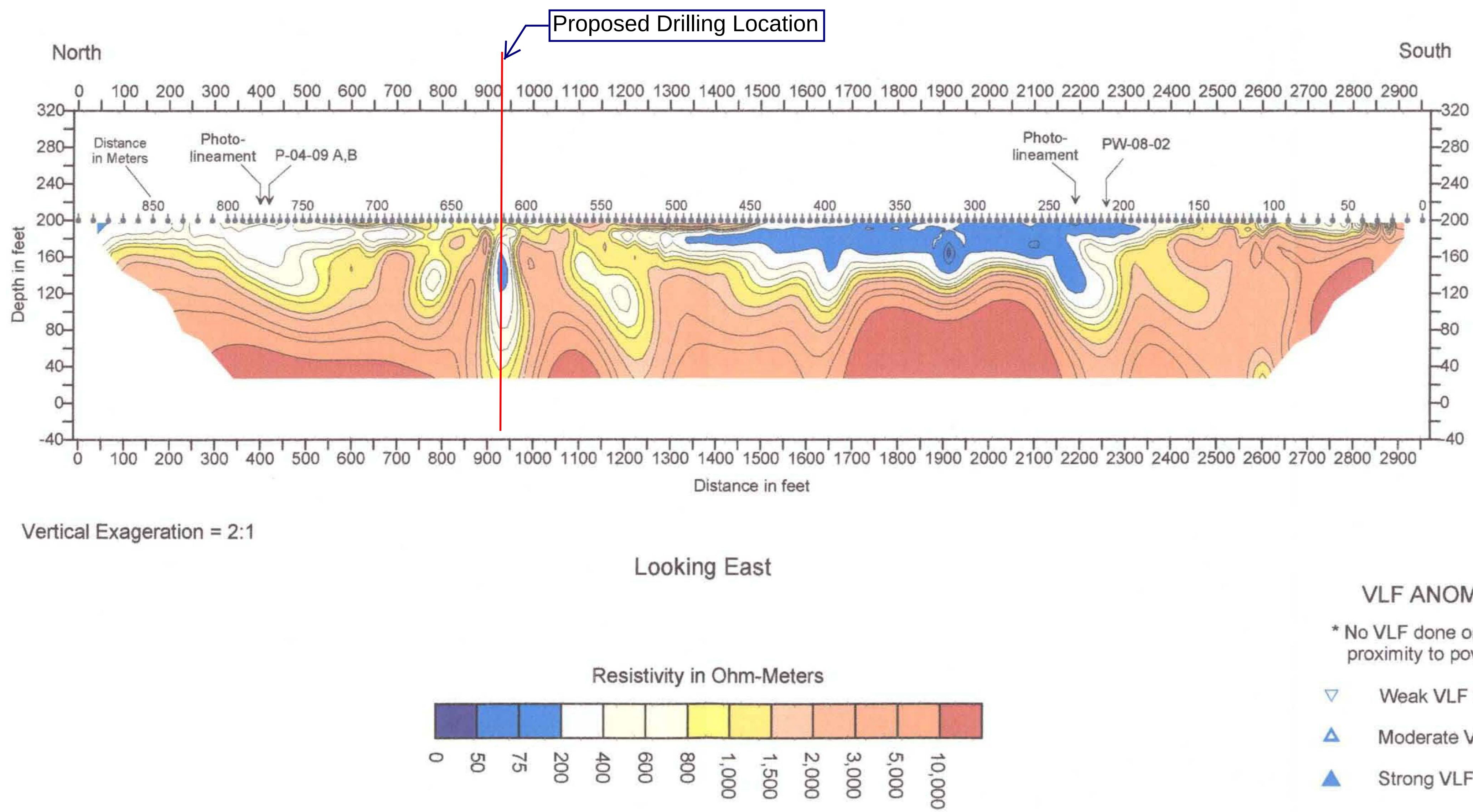




Page taken from JRL Expansion Application, Volume II, Site Assessment Report, prepared by SME, dated July 2015.

JUNIPER RIDGE LANDFILL SITE

RESISTIVITY LINE 8



VLF ANOMALIES

* No VLF done on this line due to proximity to power line.

Weak VLF Conductor

Moderate VLF Conductor

Strong VLF Conductor

Page taken from JRL Expansion Application, Volume II, Site Assessment Report, prepared by SME, dated July 2015.

Surveyed 12/4/08 by:

Northeast Geophysical Services