Ameren Services

Environmental Services
314.554.2388 (Phone)
314.554.4182 (Facsimile)
ppike@ameren.com

One Ameren Plaza
1901 Chouteau Avenue
PO Box 66149
St. Louis, MO 63166-6149

May 14, 2009

Mr. Larry Pierce, R.G., Unit Chief
Division of Geology and Land Survey
Missouri Department of Natural Resources
P.O. Box 250
Rolla, MO 65402

Re: Detailed Site Investigation Work Plan, Proposed Ameren Labadie Power Plant Utility Waste Landfill, St. Charles County, MO

Dear Mr. Price:

Attached for your review and approval are two (2) copies of a detailed site investigation work plan for the Labadie Power Plant Utility Waste Landfill. This work plan has been prepared in general accordance with guidance criteria promulgated as Appendix 1 under 10 CSR 80-2.015, effective January 29, 2007. The guidance criteria were further clarified at our meeting with you and your staff on April 21, 2009.

If you have and questions or require clarification on any element of this work plan that might expedite the review process, please contact either myself (314-554-2388) or Mr. Mike Carlson of Gredell Engineering (573-659-9078). We look forward to working with you and your staff on this project.

Sincerely,

Paul R. Pike
Strategic Analyst

Attachment

STATE OF MISSOURI Jeremiah W. (Jay) Nixon, Governor • Mark N. Templeton, Director
DEPARTMENT OF NATURAL RESOURCES
www.dnr.mo.gov

June 15, 2009

CERTIFIED MAIL #7008 0500 0001 0080 1978
RETURN RECEIPT REQUESTED

Mr. Paul Pike
Ameren Services
One Ameren Plaza
1901 Chouteau Avenue
St. Louis, MO 63166

Re: Detailed Site Investigation Workplan of the AmerenUE-Labadie Utility Waste Landfill, (Sections 17 and 20, Township 44 North, Range 2 East, Labadie 7.5 Minute Quadrangle, Franklin County)

Dear Mr. Pike:

The Geological Survey Program (GSP) has reviewed the document "AmerenUE Labadie Power Plant Utility Waste Landfill Detailed Site Investigation Work Plan" dated May 18, 2009. This plan details the workflow and requirements to characterize the 400 acre proposed utility waste landfill located adjacent to the existing AmerenUE Labadie power plant. It details how AmerenUE intends to characterize the alluvial aquifer in order to determine the hydrological conditions that exist below the site. This will include piezometer installation, geotechnical borings, cone penetrometer tests, in situ aquifer tests, bedrock characterization and piezometric surface characterization. The GSP concurs with investigation elements and methodology as proposed and hereby approves this work plan.

Questions regarding this review (Report ID F01709) may be directed to Blake Smotherman at 573-368-2132, P.O. Box 250, Rolla, MO 65402.

Sincerely,

DIVISION OF GEOLOGY AND LAND SURVEY

James W. Duley, RG
Deputy Division Director
Geological Survey Program

cc: Mikel Carlson, GREDELL Engineering Resources, Inc.
Jeffrey L. Fouse, Reitz & Jens, Inc.

Missouri Department Of Natural Resources
Division of Geology and Land Survey
P.O. Box 250
Rolla, Missouri 65402
Phone - 573.368.2161 Fax - 573.368.2111
E-mail -gspgeol@dnr.mo.gov

DATE
6/15/2009
Identification Number
F01709

Landfill Report

TO **Paul Pike**

FROM **Blake Smotherman, Geologist**

SUBJECT ***AmerenUE Labadie, Utility Waste Landfill***

Location

Quadrangle **LABADIE**

Section **17** Township **44N** Range **2E** County **FRANKLIN**

Latitude **0.000000** **38** Deg **34** Min **0** Sec North Longitude **0.000000** **90** Deg **49** Min **31** Sec West

Additional Location Information

Requested by **Paul Pike, One Ameren Plaza, 1901 Chouteau Ave., St. Louis, MO 63166-1419**

Previous Reports ☒ **Not applicable**

The Geological Survey Program (GSP) has reviewed the document "AmerenUE Labadie Power Plant Utility Waste Landfill Detailed Site Investigation Work Plan" dated May 18, 2009. This plan details the workflow and requirements to characterize the 400 acre proposed utility waste landfill located adjacent to the existing AmerenUE Labadie power plant. It details how AmerenUE intends to characterize the alluvial aquifer in order to determine the hydrological conditions that exist below the site. This will include piezometer installation, geotechnical borings, cone penetrometer tests, in situ aquifer tests, bedrock characterization and piezometric surface characterization.
The GSP concurs with investigation elements and methodology as proposed and hereby approves this work plan.

STATE OF MISSOURI
LARRY D. PIERCE
RG0179
REGISTERED GEOLOGIST

Ameren

Ameren Services

January 18, 2011

Mr. Jerry Prewitt, Director
Geological Survey Program
Missouri Department of Natural Resources
Division of Geology & Land Survey
P.O. Box 250
Rolla, Missouri 65402-0250

Re: Response to Public Comments on the Labadie Detailed Site Investigation

Dear Mr. Prewitt:

Ameren Missouri's draft Detailed Site Investigation report (DSI report) for the Company's proposed Utility Waste Landfill at our Labadie Plant was prepared consistent with the approved DSI work plan, and the requirements of 10 CSR 80-2.015 and associated Appendix 1 "Guidance for Conducting and Reporting Detailed Geologic and Hydrologic Investigations at a Proposed Solid-Waste Disposal Area". In addition, all field work was completed in accordance with the DSI work plan. The DSI report reflects a comprehensive summary of the analyses undertaken as part of the field work. Finally, the DSI report was prepared directly by, or under the direct supervision of, a qualified groundwater scientist (as defined by 10 CSR 80-2.010 and 10 CSR 80-2.015 (1)(C)) who is a Registered Geologist in the State of Missouri.

Our public outreach efforts have been extensive. As required by 260.205.1.(3) RSMo, a Community Involvement Session was held on November 17, 2010 at the Labadie Elementary School and a draft of the DSI report was made available to the public. A public comment period followed the Community Involvement Session and continued through December 20, 2010. Ameren Missouri received two written comments during this period: an anonymous handwritten comment submitted at the Community Involvement Session and a December 20, 2010 letter prepared by the Interdisciplinary Environmental Clinic of the Washington University School of Law on behalf of the Labadie Environmental Organization. The Company's responses to those comments are set forth below:

<u>Hand Written Comment Received During Community Involvement Session</u>

The following comment was received at the Community Involvement Session and our italicized response follows the comment. A copy of the original comment form is enclosed for reference.

> "I'd like to see Ameren develop a long-term plan for a park area in the landfill site. There is no way that the people who are concerned about this landfill want to shut the plant down. We just want it safe. We'd like to see Ameren correct some of the problems that have been happening at the plant, i.e. the leak from the old ash pond. If that happens, it shows that a "good neighbor" policy is achievable. Right now, Ameren appears to be the bully on the block. Could you put something on your website that would tell concerned people where they can have their water/air independently tested, or how we could contact someone to do air quality studies to be certain that Ameren is not adversely affecting the environment? It can't be Ameren who does the studies because then the studies appear to be slanted even if they are not. Thank you."

RESPONSE: While the Company appreciates the observations from the Commenter, none of the points relate to the technical aspects of the DSI report, the requirements of 10 CSR 80-2.015 or associated Appendix 1. Accordingly, the Company declines to address this comment.

Washington University letter dated December 20, 2010

The following comments were received in an e-mail and our italicized response follows the comment. A copy of this letter is enclosed for reference.

1. The second paragraph of this letter requested that Ameren Missouri provide the author a copy of the final DSI, and a copy of this response letter, when it is submitted to DNR.

   RESPONSE: The final DSI report will be directed to MDNR as required by 10 CSR 80-2.015 and Appendix 1. Copies of the reports can be obtained from MDNR.

2. Department of Natural Resources ("DNR") regulations require a "written narrative ... that details how the site-specific geology and hydrology will impact the design of the disposal area and groundwater monitoring system. The narrative must assess the inadequacies of the investigation and propose future investigations if needed." 10 CSR 80-2.015, Appendix 1, Presentation of Data and Interpretations, 5. Conclusions. There is no such discussion in the DSI. In fact there is no discussion of the site's suitability for use as a utility waste landfill. Neither is there any discussion of the potential impact of the contamination emanating from the plant's existing ash pond(s) on the ability to obtain valid "upgradient" groundwater monitoring samples.

   RESPONSE: The DSI report was developed to address the requirements of 10 CSR 80-2.015 and associated Appendix 1. The conclusion section of the report addresses the three geologic and hydrologic conditions that must be addressed to comply with 10 CSR 80-2.015(1)(A)1.B. Addressing existing water quality and potential contamination in the vicinity of a proposed landfill site is not required by 10 CSR 80-2.015 or Appendix 1. Rather, groundwater quality assessment of the proposed landfill area will occur as part of the MDNR permitting process.

3. DNR regulations require a map showing land use and ownership of properties within 1/4 mile of the site. 10 CSR 80-2015, Appendix 1, Presentation of Data and Interpretations, 7. Appendices, C. Maps (2). There is no map showing ownership of properties within 1/4 mile of the site. The notes in Figure 2 are inadequate to specify land use within 1/4 mile of the site.

   RESPONSE: Appropriate changes will be made to the final DSI Report to provide available property ownership and land use information within ¼-mile of the site.

4. DNR regulations require maps showing floodplains and wetlands.10 CSR 80-2.015, Appendix 1, Presentation of Data and Interpretations, 7. Appendices, C. Maps (8). There are no floodplain or wetland maps in the DSI.

   RESPONSE: Notes 7 and 10, respectively, of Figure 2 provides information regarding wetlands and floodplains within ¼-mile of the site. The Federal Emergency Management Agency Flood Insurance Rate Map and National Wetland Inventory Map for the site will be also added to the final DSI Report.

5. There is inadequate discussion of the distribution in time and space of surface water in the area of the site. There is no discussion of the volume of surface water discharge at any point or at any time. Without such data, a water balance for the site cannot be approximated as a tool toward verifying hydrologic interpretations set forth in the DSI.

   RESPONSE: 10 CSR 80-2.015 and Appendix 1 do not require analysis of the potential interrelation of the surface water and groundwater at the site to verify the hydrologic interpretations of the DSI report.

This analysis, as required by 10 CSR 80-11.010, will be provided with the Construction Permit Application.

6. Section 1.1 (p.1) of the DSI states: "This detailed site investigation (DSI) report examines the geologic and hydrologic character of the surface and near-surface Holocene (Recent) alluvial strata...." The stated scope of the DSI is too restrictive to conform to DNR requirements for conducting and reporting detailed site investigations for a solid-waste disposal area. See, e.g., 10 CSR 80-2.015, Appendix 1, PRESENTATION OF DATA AND INTERPRETATIONS. For example, relevant, older geological units bearing important aquifers occur within 110 vertical feet of the property surface, and border the property immediately south.

   RESPONSE: 10 CSR 80-2.015 and Appendix 1 require that the DSI report identify relevant geologic and hydrologic information within ¼-mile of the proposed solid waste boundary relative to the uppermost aquifer. The DSI report has identified the Missouri River alluvial aquifer as the uppermost aquifer. The report is not required to focus on older geologic units that may be considered regional aquifers.

7. Section 1.2 (p.2) of the DSI states that "disposal cells will be located so as to remain outside of applicable floodway boundaries." The DSI does not cite authority for this statement. Moreover, the DSI statement is inconsistent with the floodway designations in the current draft FEMA map of the site (FEMA 29071C0190D, Nov 2009).

   RESPONSE: 10 CSR 80-2.015 and Appendix 1 do not require detailed floodplain analysis as part of the DSI. This analysis, as required by 10 CSR 80-11.010, will be provided with the Construction Permit Application. However, we have verified that both the existing and draft 2009 FEMA map for the site show that all disposal cells will be outside the applicable floodway boundaries.

8. Section 1.2 (p.2) of the DSI states: "The nearest private well appears to be located approximately 1600 feet from the southern edge of the proposed UWL boundaries." To our knowledge, the nearest private well is within 1000 feet of the proposed UWL boundaries.

   RESPONSE: 10 CSR 80-2.015 and Appendix 1 stipulate that wells within ¼-mile (1320 feet) of the proposed disposal area boundary be depicted on a map. In response to this comment, available data utilized for the DRAFT DSI report was re-examined to determine if a well exists within the distance referenced in the comment. Appropriate modifications will be made to the final DSI report.

9. Section 1.2 (p.3) of the DSI states: "The closest sinkhole is located approximately two miles north of the site (north of the Missouri River) and the closest spring is located approximately two miles southeast of the site." This is not accurate. Several relevant karst features are closer to the site and moreover are located south of the river. For example, at least one perennial spring is located only one-half mile of the south boundary of the site. A pit cave in a sinkhole (Bunch Cave) is approximately two miles east of the site, and a well-known cave in a relevant formation (Labadie Cave, in the Jefferson City-Cotter Formation) is within five miles of the site.

   RESPONSE: 10 CSR 80-2.015 and Appendix 1 stipulate that "Springs, water courses, streams, lakes, caves, sinkholes, rock outcrops, and other significant geologic features are a required mapping element if they are located within ¼-mile of the proposed disposal area boundary". Similar features noted in the DSI report that exist beyond the ¼-mile boundary were presented for general informational purposes.

10. The "Previous Investigations" section of the DSI (section 2.0) does not cite any relevant, published geological work, and neglects to mention any of several published hydrologic studies of the alluvial aquifer of the Ozark aquifer. It also fails to mention any of several published geological maps or geological hazard maps of the area. Instead, the "Previous Investigations" section is actually based solely on contemporaneous "investigations" commissioned by Ameren and conducted by consultants for Ameren - the preliminary site investigation conducted by Reitz & Jens and a "Phase I Cultural

Resource Survey" conducted by Prairie Archaeology and Research, a private consulting company. We asked Ameren to provide a copy of the Prairie Archaeology and Research report. Neither was it provided to us nor was an explanation offered for Ameren's failure to provide it.

RESPONSE: Section 2.0 provides a review of site-specific investigations. Regional studies and similar published documents utilized during preparation of the DSI report are cited in Section 9.0 References. The DSI report references reports, studies, and publications that were found relevant to the scope of the DSI report. The Phase I Cultural Resource Survey was completed for other purposes and is not a requirement of the DSI report. All pertinent geological information has been included in the DSI report.

11. It is inappropriate for Ameren to ignore the independent published information about the site and rely solely on information provided by its consultants hired to assist its efforts to obtain a landfill construction permit. This approach resulted in many of the shortcomings of, and misconceptions presented in, the DSI report. It is also consistent with the failure of the DSI report to note critical shortcomings in the suitability of the proposed site.

RESPONSE: Contrary to the comment, the Company and its consultants did review pertinent "independent published information" in preparing this DSI, and the references are listed in Section 9.0. Ameren Missouri followed 10 CSR 80-2.015 and Appendix 1 in retaining independent qualified groundwater scientists who are also Registered Geologists to complete the DSI process. Our consultants have successfully completed several similar Detailed Site Investigations and Construction Permit applications for utility waste landfills, and are very familiar with both the technical and regulatory requirements for Utility Waste Landfills, and are fully qualified to address the requirements of 10 CSR 80-2.015 and Appendix I.

12. Section 2.0 (p.4) of the DSI states: "The [Prairie Archaeology] report concluded that the potential for deeply buried archaeological deposits was low...." However, archaeological deposits are rarely "deeply buried." Cultural remains are widely believed to be abundant in the Labadie area.

RESPONSE: 10 CSR 80-2.015 and Appendix 1 do not require evaluation of potential archeological sites as part of the DSI. However, the Missouri State Historic Preservation Office stated in a February 10, 2010 Cultural Resources Assessment, Section 106 review that "There will be no historic properties affected by the current project". Furthermore, the proposed landfill will be located in an area that has been used for agricultural purposes and is already disturbed.

13. Section 3.1 (p.5) of the DSI states that "...the bluffs bordering the site immediately to the south consist of the upper Ordovician (Mohawkian Series) Joachim Dolomite as well as the underlying St. Peter Sandstone." The Joachim Dolomite does not border the site. The DSI fails to mention the most important formation - the Jefferson City-Cotter Formation - that does border the site.

RESPONSE: Recently published geologic mapping of the Labadie area by Starbuck (2010) shows outcrops of the St. Peter Sandstone and underlying Jefferson City-Cotter Dolomite along the bluffs immediately south of the proposed disposal area, with outcrops of Joachim Dolomite located to the south of Highway T and along the bluffs farther to the east-northeast. The final DSI report will be amended to reflect this recently published information.

14. Section 3.2 (p.6) of the DSI states "... the axis of the anticline, which is located approximately five or six miles northeast of the site. Ancient faults are not shown to be associated with this anticlinal structure." This section of the DSI is incorrect and misleading. The relevant anticlinal structure is well known to be faulted, and is located much closer to the site. Moreover, the closest mapped fault is only a mile east of the site. Another fault is reported in the DNR's "Geological Evaluation" to occur along the railroad tracks, immediately south of the site.

RESPONSE: The fault referred to along the railroad tracks south of the site is a small drag fault with an estimated three (3) feet of throw. The final DSI report will be amended to reflect the recently published geologic mapping data of the Labadie area by Starbuck (2010).

15. Section 3.2 (p.7) mentions "[s]pasmodic earthquakes generally of low magnitude" in the area. This section of the DSI grossly understates seismic hazards at the site. The New Madrid fault zone is known to have produced some of the largest earthquakes ever experienced in the United States, and these caused profound liquefaction effects in floodplain alluvium including hundreds of sand volcanoes. The proposed utility waste site is shown on published geological hazard maps to lie within a zone of significant liquefaction potential, and also is adjacent to mapped zones of landslide hazard. Without reference to these published hazard maps, and acknowledgement of liquefaction hazards, the DSI is incomplete in critical respects.

    RESPONSE: The approximate location of the proposed disposal facility near the margin of the seismic impact zone as defined by regulation [10 CSR 80-2.010 (96)] is depicted on Figure 7. 10 CSR 80-2.015 and Appendix 1 do not require seismic analysis at the site as part of the DSI report. Stability and liquefaction analyses are required by 10 CSR 80-11.010 and will be provided with the Construction Permit Application.

16. Section 5.2.7 (pp. 38-29 [sic]) of the DSI purports to address groundwater velocity, and reports "velocity values ranging from 0.1 and 10 ft/yr..." The DSI misuses Darcy's law in a transient flow situation to arrive at this misleading conclusion, which is then repeated and emphasized in the DSI Conclusions section (p. 45). The rapid changes in the map of the groundwater table demand that groundwater flow is many orders of magnitude faster than claimed in the DSI. Low velocities are incompatible with the rapid fluctuations in river level, to which the water table quickly responds (e.g., DSI Fig. 31), and with the remarkably rapid recovery of water levels observed in the pumping tests (e.g., Drawdown Curve-P53, Appendix 9 p.16).

    RESPONSE: Both p. 39 and Table 8 of the DSI report show a range in calculated velocity values from 0.1 to 584 feet per year, depending on input variables. The maps of the water table elevations are approximately one month apart, therefore we do not consider the changes in water table elevations to be "rapid". Calculated hydraulic conductivity values developed for the DSI report are based in part on "5-5 Jacob's Approximation Solutions for the Nonequilibrium Equation" (i.e. transient flow) and "5-7 Recovery Analyses" from the U.S. Department of the Interior, Water Resources Service, "Ground Water Manual", 1981, pp. 112-115.

17. In light of the history of substantial leakage from the existing unlined ash pond at the Labadie plant site, and the fact that both of the existing ash ponds are episodically upgradient of the proposed landfill site, the DSI should include water quality data and, in particular, analysis of constituents that would represent likely contaminants from the ash ponds.

    RESPONSE: 10 CSR 80-2.015 and Appendix 1 do not require groundwater sampling or chemical analysis as part of the DSI report.

18. Bar scales should be added to the cross-section figures for horizontal distance. Written scales (e.g., l" = 200') are meaningful only if one is looking at a reproduction known to be at true aspect and at full scale. Neither condition is known in the pdf files that are available for review.

    RESPONSE: The final DSI report will be amended to include bar scales on the cross section figures as suggested by the comment.

19. Surface drainage from the south and southwest portions of the site are depicted (e.g., Figure 8) as funneling into a closed low near P-201 and against the southern bluffs, i.e., there is no outlet for the surface water to drain. Some discussion about this condition should be included. Figure 2 annotates a siphon pump at that approximate location. If that is the control exit for this portion of the site, it should

be discussed, including its capacity, its control, and the location of its outlet. If it is, as represented on the topographic maps, an area of localized infiltration of surface water, that condition should be noted and discussed in terms of site hydrogeology.

RESPONSE: The siphon pump located approximately 450 feet south of the P-201 is neither owned nor operated by Ameren Missouri. Monthly groundwater elevations measured at P-201 did not suggest a localized recharge condition at this location.
10 CSR 80-2.015 and Appendix 1 do not require more detailed analysis of surface drainage at the site as part of the DSI report. This analysis, as required by 10 CSR 80-11.010, will be provided with the Construction Permit Application.

20. The reason P-160 was inaccessible during the June monitoring event should be explained

    RESPONSE: P-160 could not be read in June 2010 because the well lock malfunctioned and the field crew did not have bolt cutters to remove the lock, nor did they have a replacement lock to secure the piezometer once a depth measurement was made. This lock was replaced during the subsequent month's water level monitoring event. The inability to obtain this single water level reading does not impact the overall DSI results.

21. The description of the results from a limited number of piezometers as in "error" (Table 3) or "suspected" and "considered not representative of groundwater conditions" (note 8 on water table surface maps) should be justified, or at least explained. For example, temporal patterns in the "suspected" piezometers appear consistent with the patterns of nearby wells. Why are these data rejected for this investigation?

    RESPONSE: In the few instances noted in Table 3, we suspect that field personnel either misread the graduated tapes used for gauging water levels or incorrectly transcribed the results in their hand-written field notes. These apparent errors are evident when plotted on the water table maps precisely because they were inconsistent with the temporal patterns displayed by surrounding piezometers. The inaccuracy of these few water level readings does not impact the overall DSI results.

22. Figures 9, 10, and 11, and the text discussion of them in Section 5.1, are labeled and discussed as "paleogeographic maps"' However, none is referenced to a time datum, as is implied and required by the term paleo, and each is referenced to a single elevation datum. If the individual reference elevations do in fact represent time-synchronous surfaces as well (an extremely unlikely condition, particularly for a floodplain environment), the age data establishing that relationship should be provided in detail. Absent age-dating of the elevation surfaces mapped, the term paleogeographic map should be stricken in figures and text.

    RESPONSE: Figures 9, 10, and 11 will be renamed to address the concern described in this comment.

23. The geologic interpretations provided on cross-sections E-E' and F-F' at the common point of intersection of these two lines are different and inconsistent. At least one of the interpretations is therefore presumably wrong. It is true that there is no assurance that any interpretation between control points is correct. However, in this case, the report provides inconsistent and mutually contradictory interpretations at a common point of interpretation and that is inappropriate. A single, best professional interpretation should be developed for the point of intersection, and the DSI should explain why that interpretation was selected. The interpretation should be presented on both E-E' and F-F'.

    RESPONSE: Cross-section F-F' will be revised so that it intersects with cross-section E-E' at a common reference point, P-122, to address the concern described in this comment.

24. Figures 18 through 29 are represented as being water table surface maps. The elevation of the water table can be determined only in a well or piezometer with the well screen set across the water table, i.e., the water level within the well occurs within the screened interval. As best as can be determined,

that is not the case in any of the piezometers for this site. The maps and the related discussion in the text should be revised to refer to these data as potentiometric maps or head maps representative of conditions approximately 35 feet below land surface.

RESPONSE: Use of the term, "water table surface" is preferred for the DSI report because of the unconfined characteristics of the alluvial aquifer. "Water table" is a common term for the phreatic surface. If the aquifer were confined and subject to a hydrostatic pressure gradient rather than atmospheric pressures, the term potentiometric would be more appropriate in describing the resulting groundwater surface.

25. The text and the "water table" surface maps respectively discuss and depict times and places where, if the heads that are mapped were the water table, there would be standing water at the times represented by the maps. At no point in time is standing water shown on the maps where the water table is depicted at higher elevation that the ground elevation. At no point in the text is the rate of discharge of groundwater to surface drainages discussed, suggesting this data may not have been collected. If it was collected, as would be appropriate for a valid detailed site investigation of hydrologic conditions, it should be included in the DSI report document and thoroughly discussed. If it was not collected, that omission should be explained. To the extent that the maps accurately depict conditions of no surface water and no groundwater discharge at the times mapped, then the representation of the data on the maps as elevations of a water table are demonstrably in error and the interpretations for the site that rely on such depictions must be re-evaluated.

RESPONSE: As noted on p. 32 of the DSI report, groundwater appeared to rise between 0.03 and 0.53 feet above ground surface mainly in the southwestern part of the site based on water level measurements made on June 8, 2010 (refer also to Cross Section B-B' for a representation of maximum water levels in this area). Similar occurrences were noted from supplemental groundwater level measurements made on May 18, June 15, June 21, and June 23, 2010 (refer to Table 4 of the DSI report). During this approximate same time period, a reported 5.57 inches of precipitation was recorded at the site (refer to Table 5 of the DSI report), resulting in relatively large areas of pooling. There is no practical way to discern between the contributions of standing water derived from precipitation versus groundwater outflow.

26. Units of hydraulic conductivity used in the text (feet per minute or ft/min) are not units typically used and readily understood by most technical readers, and are not consistent with the DNR regulations. See, e.g., 10 CSR 80-2.010(70) (discussing hydraulic conductivity in terms of centimeters per second, or cm/sec). Units of centimeters per second (cm/sec) or feet per day (ft/day) would be more appropriate for conveying information without requiring the reader to convert them to more standard units.

RESPONSE: Table 7 of the final DSI report will be amended to address the concern noted in this comment.

27. Footnote 3 of Table 6 is unclear. At face value, it implies the data in the column are irrelevant to the pumping test

RESPONSE: The referenced footnote will be removed from Table 6 of the final DSI report.

28. The pumping tests that were performed are inappropriately small. A pumping test program that produces a drawdown of as little as 0.3 feet and shows recovery times of as little as 4 seconds are not meaningful pumping tests. A four inch well (as was used) can take a bigger pump, pump longer, and generate substantially greater drawdown, all of which will produce more meaningful data.

RESPONSE: The aquifer testing conducted at the site is consistent with the approved DSI work plan as well as the methods outlined in section 2 (Aquifers) of the Field Investigations portion of Appendix 1. We understand that some of the field tests yielded less than optimum results, however this does not change the fact that the overall hydraulic conductivity values derived from all 25 piezometers tested *(i.e., one out of every four (25%) piezometers installed as required by Appendix 1) are consistent with the range in values reported in the literature for medium to coarse sands (c.f. Todd, 1980, p.71.) Todd reports values of 39 to 148 feet per day for medium to coarse sands. The values calculated in Table 7 of the DSI report range from 31 to 136 feet per day, which is a reasonably accurate reflection of the range in grain size of the materials encountered in the 4-inch piezometer borings (see sieve data presented in Table 6 of the DSI report). Limitations of the field testing are described in Section 4.4 and Section 5.2.6 of the DSI report.*

29. Cross-section F-F' would be more meaningfully located if it were drawn across the main disposal area along a line that included piezometer borings, instead of cone penetrometer borings as it is presently located. This would allow presentation of water elevation data associated with the piezometers to be depicted on the cross section, as is done with the other cross sections. Doing so would also eliminate the inconsistent interpretation of conditions at the intersection of cross sections E-E' and F-F' that is described above.

    RESPONSE: Cross-section F-F' will be revised in the final DSI report to reflect the suggestion made in this comment.

If you have questions, please contact me at 314-554-2388.

Sincerely,

Paul R. Pike /rkl

Paul R. Pike
Environmental Science Executive
Environmental Services
T 314.554.2388
F 314.554.4182
ppike@ameren.com

cc: Chris Nagel - MDNR Solid Waste Management Program
Maxine Lipeles – Washington University School of Law

bcc: T. R. Gredell, Gredell Engineering
P. H. Reitz, Reitz & Jens
D. L. Strubberg
K. D. Stumpe
M. A. Hanneken
T. J. Fox
M. J. Tomasovic
T. L. Hollenkamp
C. J. Giesmann
K. J. Gerhardt
S. B. Knowles
File WM 3.5.8.1

Ameren

Ameren Services

February 4, 2011

Mr. Larry Pierce
Missouri Department of Natural Resources
Division of Geology & Land Survey
P.O. Box 250
Rolla, Missouri 65402-0250

Dear Mr. Pierce:

Attached is the Detailed Site Investigation report (DSI report) for Ameren Missouri's proposed Utility Waste Landfill at our Labadie Plant. It was prepared consistent with the approved DSI work plan, and the requirements of 10 CSR 80-2.015 and associated Appendix 1 "Guidance for Conducting and Reporting Detailed Geologic and Hydrologic Investigations at a Proposed Solid-Waste Disposal Area". All field work was completed in compliance with the approved DSI work plan and the DSI report reflects the results obtained and observed during the field work. Finally, the DSI report was prepared directly by or under the direct supervision of a qualified groundwater scientist (as defined by 10 CSR 80-2.010) who is a registered geologist per section 256.453, RSMo, as required by10 CSR 80-2.015 (1)(C).

A draft of the DSI report was made available to the public on November 17, 2010. As required by 260.205.1.(3) RSMo, a Community Involvement Session was held on November 17, 2010 at the Labadie Elementary School. A public comment period was established to coincide with the Community Involvement Session and continue through December 20, 2010 during which written comments were accepted. Ameren Missouri received two separate comments (attached) during this period: an anonymous handwritten comment submitted at the Community Involvement Session and a December 20, 2010 letter emailed ("e letter") from Maxine I. Lipeles, Co-Director, and Peter W. Goode, P.E., Environmental Engineer, both with the Interdisciplinary Environmental Clinic of the Washington University School of Law on behalf of the Labadie Environmental Organization. We have already provided MDNR our response to the comments and have incorporated changes as necessary.

If you have questions, please contact me at 314-554-2388.

Sincerely,

Paul R. Pike /rkl

Paul R. Pike
Environmental Science Executive
Environmental Services
T 314.554.2388
F 314.554.4182
ppike@ameren.com

Cc: Charlene Fitch - MDNR Solid Waste Management Program

Ameren Services

March 30, 2011

Mr. Peter Price, R.G.
Missouri Department of Natural Resources
Division of Geology and Land Survey
P.O. Box 250
Rolla, MO 65402-0250

RE: Revisions to the Detailed Site Investigation for the Ameren Missouri Labadie Power Plant Utility Waste Landfill.

Dear Mr. Price:

On March 23, 2011, a teleconference meeting was held at 10:30 AM with you, Larry Pierce, R.G., and Chris Vierrether to discuss the progress of MDNR-DGLS' review of the Detailed Site Investigation (DSI) for the proposed Utility Waste Landfill (UWL) at Ameren Missouri's Labadie Power Plant. During that meeting, you discussed eight different issues that require clarification and submission of revised or additional information prior to finalizing MDNR-DGLS' review of the DSI. This letter and attachments represent Ameren Missouri's clarifications and revisions to the DSI in response to your comments.

The eight issues that you requested to be addressed are summarized below, followed by a brief summary of Ameren Missouri's response:

1. Provide well construction diagrams and well certification records for piezometers P1, P2 and P3. In addition, provide field notes from the field investigation.

   Response: Well construction diagrams have been added to the end of Appendix 5 of the REVISED DSI report. Well certification records have been added to the end of Appendix 7 of the REVISED DSI report. Copies of field notes from the field investigation have been included as a NEW Appendix E to the Geotechnical Report (Appendix 2 of the REVISED DSI report).

2. Abandonment records for the temporary borings were requested.

   Response: The required Abandonment Registration Records have been prepared and submitted to MDNR's Wellhead Protection Program for the temporary borings completed to obtain geotechnical data within or near the proposed UWL boundary between March 9, 2007 and January 19, 2010. Copies of each Registration Record have been included as a NEW Appendix F to the Geotechnical Report (Appendix 2 of the REVISED DSI report).

3. MDNR-DGLS noted that P-2 and P-3 are only 30 feet deep, while the remainder of the piezometers are 35 feet deep. In accordance with current rules, this would limit the maximum excavation at the site to 5 feet below ground surface. In addition, the landfill excavation depth must remain above the recorded groundwater elevations. The DSI needs to recognize this limitation.

   Response: Additional text has been added to Section 5.1.6 (p.29) of the REVISED DSI report to acknowledge that the bottom of the UWL cannot be excavated below the groundwater table and that the final depth of excavation must be resolved with MDNR's Solid Waste Management Program during the Construction Permit process.

4. The DSI report is missing a discussion about how the CPT data was correlated to the geologic borings for the purpose of completing a geologic interpretation of the proposed UWL.

   Response: Additional text has been added to Section 4.1 (pp. 12, 14-16) of the REVISED DSI report that discusses how the CPT data was evaluated for completion of the geologic interpretation of the site.

5. Figures 16 and 17 do not show the 'channel sands' on cross sections that are shown on Figure 10 in plan view.

   Response: Figures 16 and 17 have been modified in the REVISED DSI submittal to depict an interpretation of where the 'channel sands' would appear on Cross Section E-E' and F-F', respectively.

6. The headers in the tables included in Appendix 6 are illegible.

   Response: Legible copies of the tables are provided in Appendix 6 of the REVISED DSI submittal.

7. The discussion in Appendix 2 (Geotechnical Report) should be revised to clarify that the temporary borings were properly plugged.

   Response: Additional text has been added to Section 2.6 of the Geotechnical Report (Appendix 2 of the REVISED DSI report) to more clearly document the field methods used to properly abandon the temporary borings.

8. Revise a statement in Appendix 2 (Geotechnical Report) to clarify that the CPT borings were completed in accordance with the ASTM standards or that any substantive deviations to the ASTM standards be noted.

   Response: Additional text has been added to Section 2.5 of the Geotechnical Report (Appendix 2 of the REVISED DSI report) to clarify that the CPT borings were completed in accordance with the ASTM standards or that any substantive deviations to the ASTM standards be noted.

Additionally, Mikel C. Carlson, R.G., the registered geologist of record on the project, participated in a second teleconference with you and your staff later that same day to discuss less substantive questions and comments that you and your staff had regarding the DSI report. Mr. Carlson has made several wording changes to the text as well as to Tables 6, 7, and 8 and Figure 3 of the REVISED DSI report in response to that discussion. Specific pages of the REVISED DSI report where text has changed are pp. 3-4, 7-9, 19, 24-26, 28, 40-41, and 49.

A table is attached that identifies all portions of the DSI report were revised, as well as the portions remain unchanged. Three (3) copies of the revised portions of the DSI report are submitted with this letter for replacement in the copies of the DSI previously received on February 7, 2011.

Thank you for the opportunity to discuss your questions and comments and to submit a timely response. If you have any questions or require additional information about this issue, please contact me at (314) 554-2388 or Mikel C. Carlson, R.G. of GREDELL Engineering Resources, Inc. at (573) 659-9078.

Sincerely,

Paul R. Pike
Environmental Science Executive

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Enclosures

Cc: Charlene Fitch, P.E., MDNR Solid Waste Management Program

Bcc: M. C. Carlson, GREDELL Engineering Resources, Inc., w/enclosure
P. H. Reitz, Reitz & Jens, Inc., w/enclosure
T. R. Gredell w/enclosure
C. J. Giesmann w/enclosure
K. J. Gerhardt w/enclosure
M. A. Hanneken w/enclosure
M. J. Tomasovic w/enclosure
D. L. Strubberg, w/o enclosure
S. B. Knowles, w/o enclosure
C. R. Henderson w/o enclosure
M. L. Menne, w/o enclosure
S. C. Whitworth, w/o enclosure
File WM 3.5.8 w/enclosure

Detailed Site Investigation Report

For:

Ameren Missouri Labadie Power Plant
Proposed Utility Waste Disposal Area
Franklin County, Missouri

February 4, 2011

Prepared For:

Ameren Missouri
1901 Chouteau Ave.
St. Louis, Missouri 63166

Prepared By:

GREDELL Engineering Resources, Inc.
1505 East High Street
Jefferson City, Missouri 65101
(573) 659-9078

and

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(314) 993-4132

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1.0 Introduction

1.1 Purpose of Investigation

This detailed site investigation (DSI) report examines the geologic and hydrologic character of surface and near-surface Holocene (Recent) alluvial strata within and immediately adjacent to a proposed utility waste disposal area being considered for development by Ameren Missouri near their Labadie Power Plant facility in northeast Franklin County, Missouri. The purpose of the DSI is to identify and describe subsurface conditions in conformance with regulatory requirements set forth in 10 CSR 80-2.015 and 10 CSR 80-11.010(4)(A) as a critical step in the permitting process.

Field investigation activities commenced in September 2009 and, with the exception of survey work and monthly piezometric monitoring, were completed in January 2010. All activities were performed in accordance with a work plan entitled, "*AmerenUE Labadie Power Plant Utility Waste Landfill Detailed Site Investigation Work Plan*" (Appendix 1), which was approved by the Missouri Department of Natural Resources-Division of Geology and Land Survey (MDNR-DGLS) on June 15, 2009.

1.2 Site Location

The proposed Ameren Missouri Labadie Utility Waste Disposal area (UWL) is a 400-acre site located adjacent to the Labadie Power Plant and approximately two and one-half miles northeast of the town of Labadie and immediately southeast of the Missouri River in northeast Franklin County (Figure 1). The National Geodetic Survey indicates the site lies within the northwestern part of Township 44 North, Range 2 East. Portions of the proposed investigation area are part of the "historic" Spanish Land Grant survey system identified as "SUR". The site is located within sections 17 and 20, SUR 384, and SUR 1735. Reference to the Center for Applied Research and Environmental Systems (CARES) or similar mapping programs shows that the approximate midpoint of the proposed UWL is located at Latitude 38.5621 and Longitude –90.8168. The 400-acre site, as well as all land adjacent to the investigative area, constitutes an approximate 1,042 acre tract of land (as presented in the Preliminary Site Investigation request) that is owned by Ameren Missouri.

The proposed UWL site is located within an extensive area of Holocene-age alluvial deposits largely derived from the Missouri River, which bounds the site to the north (Figure 1). At its closest approach, the normal flow line of the river lies within approximately 1,400 feet of the northwest corner of the site. Scattered rock bluffs or outcrops showing approximately 100 feet of topographic relief relative to the alluvial plain are located in the area to the south and extend to within approximately 800 feet of the southern limits of the proposed UWL site.

Due to the alluvial setting, one aspect of the site is the low topographic relief, which varies less than ten feet. Based on the topography shown on Figure 1, existing ground surface elevations range from 460 to 471 feet above mean sea level (msl). Drainage through this very flat terrain is facilitated by the creation of small waterways and diversions. Within the northern part of the proposed site, surface runoff generally flows northeastward toward the Missouri River. Within the southern part of the site, surface runoff flows to the southeast through the constructed waterways toward Becker Creek, situated near the base of the river bluffs. From there, the runoff flows northeast and appears to ultimately enter the Missouri River approximately one mile north of the hamlet of St. Albans.

The proposed UWL site and surrounding areas to the north, south, and east are currently used primarily for agricultural (row-crop) production. The Ameren Missouri Labadie Power Plant facility is located immediately to the west (Figure 2). An agricultural levee along the Missouri River marks the approximate northern boundary of the investigative area, and an underground pipeline and another agricultural levee mark the approximate southern boundary of the investigative area. Labadie Bottom Road marks the approximate western boundary of the site and Davis Road marks the eastern boundary of the site. The agricultural levees serve as partial flood protection for the proposed UWL site. Although the site currently lies within the 100-year floodplain of the Missouri River, the regulatory floodway is riverward of the agricultural levee. Further protection of the site from at least a 100-year flood event will be provided through construction of a perimeter berm around the UWL. This design feature will be detailed in the Construction Permit application. Floodway Map information for the project site is included for reference in Appendix 11.

Relevant information concerning significant man-made and natural features within one-quarter mile of the proposed disposal area boundary is shown on Figures 1 and 2. Isolated residential structures are located within one-quarter mile on the river bluffs above the site, but structures do not exist within one-quarter mile of the site within the alluvial valley itself.

Available well data obtained from the Missouri Department of Natural Resources (MEGA 2007; MDNR-Water Resources Center, 2010; MDNR-Wellhead Protection Section, 2010) shows numerous water wells located on the bluffs south and east of the site. The reported locations of these wells as presented on the referenced data sources have been replicated on Figures 1 and 2. The raw data from these sources is presented in Appendix 12. These data consist of maps showing approximate well locations and reported well information. A summary table is also included showing pertinent well data. These data suggest the presence of six wells within one-quarter mile of the site, two of which are shown within proposed disposal area boundaries (Figure 2; well ID #'s 1, 2, 34, 35, 36, and 37). Further research into each of these six reported well locations reveals the following:

- Well #1 is reported as an industrial high-capacity well drilled in 1934 and owned by the Franklin County Distillery (Record ID #003211). The well was drilled to a total depth (T.D.) of 690 feet into the Gasconade Dolomite (Appendix 12). Well log information indicates that bedrock was not encountered until a depth of 100 feet, which is consistent with its placement in the alluvial bottoms. Whether or not the reported location is accurate is open to speculation inasmuch as current historical information has not revealed the presence of an old distillery in this area.

- Well #2 is reported as a private well drilled in 1959 and owned by James Heisel (Record ID #01817). It is reportedly located on the bluffs approximately 1,200 feet southwest of the DSI site (Figure 2). The well has a T.D. of 225 feet into the Cotter-Jefferson City Dolomite. It has a casing depth of 72 feet and a static water level depth of 135 feet, which equates to an elevation of approximately 404 feet based on the drill collar information provided (Appendix 12).

- Well #34 is reported as a heat pump well drilled in 1995 and owned by Tom Thompson (Record ID #118736A). The reported T.D. is 150 feet (no other information is available on MDNR databases; see Appendix 12). The referenced location of this well along Labadie Bottom Road on Ameren property is suspect (Figure 2). Given that the reported site address for this well is "Pacific" and that the owner address is 3628 Brown Rd, St. John, MO, it is believed that the well location as depicted on available databases is inaccurate.

- Well #35 is reported as a private well drilled in 1997 and owned by David Roth (Record ID #189167A). The well has a reported T.D. of 366 feet, a casing depth of 190 feet and a static water level depth of 100 feet (Appendix 12). As with the Thompson well described above, it is believed that the referenced location of this well within the DSI limits is in error. A review of the owner address information (1969 Fiddle Creek Rd, Gray Summit, MO) suggests that the correct location for the well is S-27, T-44N, R-2E, not S-17 as identified on the MDNR database sources.

- Well #36 is reported as a private well drilled in 1995 and owned by Marvin Newman (Record ID #143737A). Although this owner name is consistent with prior ownership of ground in and near the DSI site, the reported T.D. of 315 feet, casing depth of 105 feet, and static water level depth of 88 feet are consistent with a well location on the river bluffs rather than within the Labadie Bottoms. It is noted that the address information for this individual is simply “Highway T”.

- Well #37 is reported as a private well drilled in 1990 and owned by Jackie Barringhaus (Record ID #053051A). It is shown located on the bluffs approximately 1,250 feet southeast of the DSI site. It has a reported T.D. of 363 feet, a casing depth of 121 feet, and a static water level depth of 100 feet, which equates to an elevation of approximately 480 feet based on the drill collar information provided (Appendix 12). Although other wells exist in the same vicinity, the owner address that is included on the database (1 Riverbend Place, Washington, MO) suggests a location in T-44N, R-1E, not R-2E as identified on the database.

In addition, a non-potable irrigation well is located on property currently owned by Ameren near the northeastern corner of the site (Figure 2). This well was installed by others, presumably a previous landowner, and information concerning it is not available from the sources provided in Appendix 12.

A review of MEGA (2007) data also reflects that sinkholes, sinkhole areas, and springs do not exist within one-quarter mile of the site. Based on MEGA (2007), the closest reported sinkhole is located approximately two miles north of the site (north of the Missouri River) and the closest spring is located approximately two miles southeast of the site (Figure 1). The topographic base map also shows Tavern Rock Cave, which is identified in the extreme northeastern part of Figure 1. Historically, the principal land use of the proposed UWL site is agricultural since its settlement in the early 19th century (Held, 1989). However, agronomic practices within the site would have been interrupted by the northward shifting of the Missouri River channel as evidenced by late 19th century maps of the area (Hanson Professional Services, 2009). No evidence of industrial operations such as surface ("strip") mines or underground mines were discovered during literature searches or field investigation activities. However, a large sand pile reportedly created during clean up operations following the 1993 flood event is located partly within the one-quarter mile boundary along the northern part of the site (Figure 2).

A review of wetlands data from the National Wetlands Inventory Map provided in Appendix 13 shows that jurisdictional wetlands do not exist within the DSI boundary. However, several small wetlands features exist within one-quarter mile of the site. These areas are identified on Figure 2.

2.0 Previous Investigations

Previous investigations of the site and surrounding area include a preliminary site investigation conducted by Reitz & Jens, Inc. in March 2007. That evaluation consisted of developing eight borings to depths of between 20 and 104.5 feet and performing laboratory testing on select samples. Three of the borings were also converted into piezometers (P-1, P-2 and P-3), which constitute part of the 100-piezometer monitoring network used for the current DSI investigation. Two of the borings were advanced to bedrock or near the bedrock surface. In Boring B-7, limestone bedrock was encountered at a depth of 104.5 feet. Boring P-1 was extended to a depth of 91.5 feet before high-density gravel was encountered that precluded further advancement of the borehole. The locations of the borings within or near the DSI investigative area are identified on the geologic maps prepared for this report. Note that the results of that previous field effort were provided to MDNR-DGLS as part of the preliminary site investigation (PSI) request submitted in December 2008.

In December 2009, a Phase I Cultural Resource Survey report was prepared by Prairie Archeology and Research on behalf of Ameren Missouri. That report documents the historical development of the site including reference to plat maps developed in 1878, 1898, and 1919 showing the purported location of the main Missouri River channel at those periods in time. The report also contains an appendix summarizing a geomorphologic investigation conducted by Stratamorph Geoexploration, Inc. as a subcontractor to Prairie Archeology and Research. That investigation included 25 geoprobe borings to depths of between 7 feet and 16 feet to determine the presence or absence of archeological deposits. This probe hole data was not of sufficient depth to benefit the DSI investigation.

3.0 Regional Geology and Hydrology

Regionally, the Labadie area is located along the northeastern limits of the Ozark Plateau Physiographic Province. This province typically marks the extent of Cambro-Ordovician age outcrops constituting the "Ozark Hills" and transitions to the north into geologically younger rock formations assigned to the Mississippian and Pennsylvanian Systems, regionally known as the Glaciated Plains. The Missouri River marks the approximate boundary between these two provinces and is, in essence, an ice-marginal stream delineating the approximate southernmost extent of glaciation during the most recent glacial epochs. The proposed UWL site itself is located within the alluvial plain of the Missouri River and is within an area colloquially called the "Labadie Bottoms". This area essentially has the configuration of a large river-marginal or point bar deposit that has accreted along the south side of the river valley as the main channel of the Missouri River progressively migrated northward away from the site.

3.1 Stratigraphy

The proposed UWL site is situated within Holocene-age deposits of alluvium chiefly derived from the Missouri River. Lesser amounts of detritus derived from the adjoining bluffs have undoubtedly been transported short distances via local drainages and contribute to the overall accumulation of sediment in the area. Collectively, these alluvial materials largely consist of sand and highly angular to well rounded gravel with lesser amounts of silt and clay. These deposits have an aggregate thickness of approximately 100 feet based on site-specific borings. This thickness is consistent with those determined elsewhere within the lower Missouri River valley (Emmett and Jeffery, 1968).

Information concerning the local bedrock geology is derived from the inspection of the rock bluffs bordering the site to the south, geologic well log data available from the MDNR-Water Resources Center website at *www.dnr.mo.gov/env/wrc/logmain*, as well as MEGA (2007) and other literature sources available from MDNR-DGLS (e.g. Brill, 1991; Thompson and Robertson, 1993; Thompson, 1995; Starbuck, 2010). These data indicate that the bluffs bordering the site immediately to the south consist of upper Ordovician (Mohawkian Series) St. Peter Sandstone and underlying middle Ordovician (Ibexian Series) Cotter-Jefferson City Dolomite (Figure 3). Younger bedrock formations (i.e. Joachim Dolomite, Plattin Limestone) occur on ridge tops immediately south of the river bluffs. The water well data summary provided in Appendix 12 suggests that the Plattin Limestone ranges from 15 to 120 feet in thickness. The underlying

Joachim Dolomite typically is less than 120 feet thick. The underlying St. Peter Sandstone is also typically less than 120 feet thick. The Cotter-Jefferson City Dolomite, which is shown by Starbuck (2010) to be the uppermost bedrock formation below the site (Figure 3), has an aggregate thickness of between 370 and 410 feet (Appendix 12). The Cotter-Jefferson City, as well as the overlying Powell Dolomite, are lithologically very similar and for that reason are not readily differentiated from one another in this part of the state. The inability to differentiate between these three formations may perhaps explain why the Powell Dolomite is not depicted on the recently published geologic map by Starbuck (2010) (Figure 3), whereas it is consistently shown on local water well log data (Appendix 12). Older bedrock formations encountered in wells drilled the vicinity of the site include the Roubidoux Formation and underlying Gasconade Dolomite, at depths ranging from 530 to 765 feet below ground surface (Appendix 12).

Groundwater resources in the vicinity of the proposed site include the Holocene-age alluvium and Ordovician age bedrock. The alluvial aquifer system is marked by a shallow water table surface (<20 feet in depth) and retains predominantly unconfined hydraulic characteristics. Yields ranging from 1,000 to 2,000 gallons per minute (gpm) have been reported. However, the preponderance of local water usage is from bedrock water wells drilled on the bluffs overlooking the site (Figure 1). Wells in this area produce water from multiple Ordovician age bedrock units (i.e., St. Peter Sandstone, Powell Dolomite, Cotter-Jefferson City Dolomite, Roubidoux Formation) that are collectively referred to as the “Ozark Aquifer”. These rock units typically possess weakly developed, intercrystalline pore networks and low formation permeability with the result that groundwater movement is relatively slow. This is demonstrated by the relatively low yields (i.e., <30 gpm) reported for many of the wells in the area despite being completed at depths typically in excess of 300 feet (Appendix 12).

Although the alluvium is in contact with underlying bedrock, the alluvial and bedrock aquifers are considered distinct due to their physical characteristics. Groundwater movement in alluvial materials is much faster due to the predominance of highly permeable sand and gravel. When groundwater moving within the alluvial aquifer encounters less permeable bedrock, the bedrock largely impedes flow due to its lower permeability and the groundwater will preferentially flow parallel to the barrier through the more permeable sands and gravels and remain in the alluvial aquifer system.

3.2 Structural and Depositional Setting

The Labadie area resides along the southwestern flank of a bedrock structure known as the Eureka-House Springs Anticline (McCracken, 1971). Bedrock dips at a relatively uniform rate of 60 to 65 feet per mile away from the axis of the anticline, which is located approximately five to six miles northeast of the site. Recent geologic mapping of the Labadie area by Starbuck (2010) shows the existence of a structural feature termed the "Klondike Monocline" on the river bluffs north and east of the site (Figure 3). This feature has a strike of approximately N. 45^{o} W. and dips to the northeast, toward the Eureka-House Springs Anticline. Starbuck (2010) states that, *"No faulting is apparent along this feature for most of its extent but deformation of the St. Peter Sandstone in a quarry face in Klondike Park (northwest part of land grant 1721) suggests that faulting may be associated with the Klondike Monocline at this location"*. A fault referenced in the Preliminary Site Investigation (PSI) Report (DGLS, 2009) as occurring within the St. Peter Sandstone and underlying Everton Formation along the bluffs south of the site was jointly reviewed by both representatives of DGLS and the author of this report on January 6, 2009. The referenced fault had the appearance of a small drag fault related to compressional deformation of the rock units and had an estimated three feet of throw. As noted in the PSI report, such "*inactive bedrock faults are not uncommon*". No other reported occurrences of ancient faults within the immediate vicinity of the site were found in available published literature. Holocene-age (i.e. active) faults, as defined by regulation, are not known to exist within the DSI site or within one-quarter mile of the area.

The local depositional setting is fluvial in nature and the types of sediment deposited at the site are to a large degree influenced by both the present-day and ancestral courses of the Missouri River. Fluvial environments have a host of depositional settings or facies, with channel-fill sands and gravel bars being perhaps the most widely known. However, other facies include natural levees, crevasse splays, channel lag, floodplain, flood basin, and cut-off meanders (i.e. ox-bows) each with its own subtle but distinct characteristics (Reineck and Singh, 1980).

Of particular interest in examining the ancestral course of the river are a series of plats dating from the years 1878, 1898, and 1919 (Figures 4, 5, and 6). Examination of the plat for 1878 (Figure 4) shows the apparent main channel of the Missouri River abutted against the south bluff within the southern margin of the site. Two prominent creeks, or perhaps distributaries of the main channel, appear to drain into the river within the southwestern part of the site. Examination of the plat for 1898 (Figure 5) shows that the main channel has moved considerably north of its previous location and resides within the northeastern part of the site. Small creeks flowing northward from the river bluffs appear to drain eastward along the base of the bluff rather than directly toward the river. The plat for 1919 (Figure 6) shows further northward migration and apparent straightening of the main river channel beyond the northern margin of the site. A lake is shown residing within the western part of the DSI site along with a slough (i.e. cut-off meander) immediately to the southwest. The plat also identifies an old river bed near the south bluff and shows the local creeks draining northward toward the lake as well as through the southeastern part of the site. Although these plat maps convey the impression of a steady and continuous northward migration of the main river channel, it is perhaps more prudent to consider the diagrams as generalizations and that the northward migration of the channel was episodic and heavily influenced by flood events, thus allowing the formation of interceding depositional settings reflecting lower current velocities and consequent finer grained sediment accumulation.

Although the geologic and hydrologic settings are relatively straightforward, the proposed site and surrounding region are located along the northern margin of an area of potential seismic activity known as the New Madrid Seismic Zone. That seismic activity is embedded in deeply buried Paleozoic and Precambrian basement rocks beneath the Mississippi Embayment (i.e. “bootheel”) and reflects the vestiges of a failed rift system believed related to the early Pennsylvanian (Morrowan-Atokan Series) Oklahoma Aulocogen (Houseknecht and Kacena, 1983). Spasmodic earthquakes generally of low magnitude are a relatively common occurrence in the “bootheel”, and energy released from such seismic events propagates northward through bedrock and is amplified in the loosely consolidated alluvium along the Mississippi and Missouri River valleys. It is for that reason the proposed UWL site is within a region considered part of the “seismic impact zone” as defined by regulation under 10 CSR 80-2.010(69) or as otherwise described under the criteria for Holocene age fault displacement found in 10 CSR 80-11.010(4)(B)3. (Figure 7).

4.0 Field Investigation Methodology

This investigation was conducted consistent with the DSI work plan approved by MDNR-DGLS on June 15, 2009. The site investigation for the proposed 400-acre UWL facility included the development of unconsolidated materials borings, sample collection and description, field and laboratory testing, piezometer installation and development, surveying, aquifer testing, and water level monitoring. Bedrock investigation was limited owing to the significant depth of burial of pre-Holocene geologic formations. Site activities were performed by and/or under the direction of a qualified groundwater scientist (as defined by 10 CSR 80-2.010(83) and 10 CSR 80-2.015(1)(C)) who is a Registered Geologist in the State of Missouri. The DSI work plan and related correspondence are presented in Appendix 1.

Field investigation activities as described in the work plan consisted of the following tasks:

- Drill, log and install 97 piezometers to a depth of approximately 35 feet (piezometers are designated as P-9 through P-201 throughout this report; piezometers P-1, P-2, and P-3, which were installed in 2007, were also used for the acquisition of geologic and hydrologic data as authorized by DGLS in the approved work plan);
- Drill and log 22 temporary "geotechnical" borings, including one extended to bedrock in order to supplement data from two existing deep (i.e. bedrock) borings (P-1 and B-7) as per the approved work plan. Ten of the temporary borings were drilled to a minimum depth of 35 feet. The other 11 temporary borings were advanced to depths of between 40 and 60 feet. The temporary borings are designated by a "B" throughout this report;
- Perform cone penetrometer testing (CPT) in 93 locations in lieu of temporary borings as per the approved work plan (this total includes 16 extra CPT soundings used to verify other borings or CPT soundings; three adjacent to newly installed piezometers, four adjacent to temporary borings, and nine adjacent to other CPT soundings). The CPT soundings are designated by a "C" throughout this report;
- Install two-inch, schedule 40 PVC well screen and riser pipe in 72 of the piezometers;
- Install four-inch, schedule 40 PVC well screen and riser pipe in 25 of the piezometers;

- Perform continuous sampling using split-spoon and Shelby tube techniques during the installation of the piezometers and temporary borings;
- Develop each piezometer;
- Perform aquifer testing in each of the four-inch piezometers, and;
- Perform monthly water level monitoring in all 100 piezometers for a period of twelve consecutive months; in addition, supplemental groundwater measurements were obtained from select piezometers during periods of peak flow of the Missouri River (April-June 2010) to further assess the relationship between river stage and water table behavior.

Procedures used for each of the major field investigation tasks are described in the following paragraphs.

4.1 Drilling and Sampling Procedures

Max's Enterprises of Fort Scott, Kansas (Missouri Well Drillers Permit No.002836M) performed the piezometer drilling, sampling, and installation under the supervision of a Missouri Registered Geologist employed by Gredell Engineering (Missouri Well Drillers Permit No.002876M). Drilling equipment used included a truck-mounted Mobile B-57 and an all-terrain CME 750, both employing standard auger drilling and sampling techniques. Equipment was mobilized to the site on September 14, 2009 and drilling activity was initiated that same day. Drilling activity continued, except during periods of inclement weather, through December 15, 2009. Representatives of MDNR-DGLS were on site September 22nd, September 28-30th, October 6-7th, October 21-22nd, October 28th, November 3-4th and November 10-12th to observe the work and to provide guidance. Field notes documenting daily drilling activity are provided for review in Appendix 3.

The temporary borings and CPT soundings were performed concurrently with piezometer installation activities by Reitz & Jens, Inc. Procedures used in that effort are detailed in the "Geotechnical Report" included as Appendix 2.

A summary of all 220 borings either used by or developed for this investigation is presented in Table 1. Given the large number of boreholes involved in this investigation, it serves as a ready reference to such important drilling information as type of boring, date completed, drill depth, and hole location information.

Table 1 is supplemented by Figure 8, which depicts the surveyed location of each of the borings developed for this investigation. Each boring is numbered sequentially and, with the exception of those borings drilled in 1997 (1 through 8), begin along the northernmost tier of the drilling pattern and progress from west to east along each successive tier to the south. Piezometer borings are noted by the prefix “P”. Temporary borings are noted by the prefix “B”. CPT soundings are noted by the prefix “C”. That alpha-numeric convention of has been retained throughout this report.

Initially, the planned drilling location for each boring or CPT sounding was field-located using global positioning system (GPS) techniques to ensure conformance with the grid-system described in the DSI work plan. Once the center of each four-acre grid was determined in the field, the location was staked with a wooden lathe marked with the appropriate borehole or sounding number. Each stake then served as a reference point that enabled any repositioning of a boring or sounding location to be readily tracked on a field map for later documentation purposes. That procedure was particularly relevant for piezometers that had to be moved from the originally staked locations due to wet ground conditions that precluded drill rig access. Those piezometers where minor deviations in location were necessary included P-126, P-138, P-162, and P-195. Piezometer P-126 was shifted approximately 150 feet south, P-138 was shifted approximately 60 feet east, P-162 was shifted approximately 75 feet south, and P-195 was shifted approximately 50 feet north from the planned locations.

Procedures used to advance each piezometer borehole to completion depth varied depending on work plan objectives and geologic constraints. First, five-foot continuous samplers were advanced until there was no sample recovery (typically non-cohesive sand zones or the top of the water table). Each borehole was then re-entered using nominal 8-1/4 inch (o.d.) hollow-stem augers (HSA) and advanced in five-foot increments. Split-spoon samples were then obtained at the approximate five-foot intervals to a depth of 35 feet. Blow counts were recorded for each sample interval. In some instances “grab” samples were obtained from the auger cutting head when it was retracted following completion of drilling. This is particularly true for those borings where an apparent change in texture or grain size was observed at total depth. For the four-inch piezometer borings, the borehole was again re-entered using 10-1/4 inch HSAs and reamed to total depth. Either two-inch or four-inch diameter piezometers were then constructed within the interior of the HSAs. In those areas where appreciable clay deposits were observed, the drill rig was offset a short distance from the piezometer borings and Shelby tube samples were collected at pre-determined depths. Those piezometer borings where Shelby tube samples were collected include P-29, P-45, P-57, P-106, P-128, P-150, P-175, P-177, P-181, and P-195.

Both recovered whole-core samples from the CME continuous samplers and split-spoon samples were carefully halved to reveal depositional structures and immediately described in terms of color, predominant lithology, fabric, and texture. Selected samples from the CME continuous sampler and all split-spoon sample halves were placed in glass jars, labeled, and provided to Reitz & Jens, Inc. for geotechnical analysis (Appendix 2). The other halves were placed in Ziploc® baggies, labeled and transported to Gredell Engineering for subsequent examination. The CME continuous sampling effort was particularly important in that the recovered whole-core samples revealed much about the vertical and lateral distribution of discrete sedimentologic units, which in turn allowed insight into apparent, larger scale facies and/or depositional trends. At the request of MDNR-DGLS during field activities, sample splits were also obtained from the temporary borings, which were subsequently described in the same fashion as the piezometer samples.

All bagged samples, including sample splits obtained from Reitz & Jens, Inc. for the temporary “geotechnical” borings, are currently stored at Gredell Engineering and are available for further inspection.

Boring logs for the 97 piezometers installed for this investigation, as well as those three previously existing piezometers, are presented in Appendix 4. Color designations used in the descriptions are from the Geological Society of America Rock-Color Chart (GSA, 1995) and/or the Munsell® Soil Color Charts (2000). Stratification nomenclature is based on the criteria of McKee and Weir (1953). Grain size designations are based on the scale developed by Wentworth (1922). Sorting descriptions for sands are based on the comparison data of Beard and Weyl (1973). The logs emphasize vertical grain size changes and include a series of interpretative columns intended to convey apparent facies relationships between sequences. Narrative descriptions for the 22 temporary borings are included at the end of this appendix.

Logs for the 22 temporary borings are presented on standardized Reitz & Jens, Inc. drilling log templates (Appendix 2) to better convey the geotechnical data obtained from the holes. In addition to material descriptions, the logs include information on split spoon and Shelby tube sample intervals, SPT data, and Atterberg limits. Note that the material symbols used for those logs, as well as the CPT logs differ from what is presented on the piezometer drilling logs developed during this investigation.

Raw geotechnical data are presented in Appendix 2. In addition to Atterberg Limits, analyses were performed for moisture content, dry density, and grain size. Grain size analyses were also performed on 65 samples from the piezometer borings, including samples corresponding to the screen interval in each of the 25 four-inch piezometers used for aquifer testing and analysis (Appendix 2).

4.2 Piezometer Installation

In addition to the three piezometers established in 2007, 97 piezometers were installed during the DSI investigation, at depths ranging from 32.9 feet to 35.7 feet, and averaging 34.5 feet below ground surface. This slight variation in depth is attributable to the non-cohesive, saturated character of the formation sands encountered at total depth, which typically “flow” upward through the interior of the HSAs to varying degrees during construction of the piezometers. Piezometer installation initially began September 14, 2009 and continued through December 15, 2009. A complete summary of piezometers installed during the investigation is presented as Table 2.

Piezometer installation was performed in accordance with the approved work plan. Well screen and riser pipe consisted of either two-inch or four-inch (nominal) diameter, flush-threaded, schedule 40 polyvinyl chloride (PVC). Well screens were machine slotted and had an aperture size of 0.01 inch (10-slot) for all two-inch piezometers and 11 of the four-inch piezometers. Twenty-slot (0.02 inch) well screen was used in the remaining four-inch piezometers to enable a greater potential volume of groundwater inflow in anticipation of aquifer testing. Those piezometers where 20-slot screen was used include P-9, P-22, P-42, P-61, P-73, P-81, P-104, P-120, P-128, P-144, P-164, P-165, P-193 and P-197. Ten-foot screen lengths were used in all piezometers. The base of each screen for the two-inch piezometers was fitted with a four-inch (0.33 ft) flush-threaded end cap to serve as a sump for particulate matter. For the four-inch piezometers, the base of each screen was fitted with a five-inch (0.41 ft) flush-threaded end cap. To the extent practicable, the base of each piezometer was set at a depth sufficient to ensure complete or near-complete submersion of the well screen in the water table.

Primary filter pack materials used for construction of the piezometers utilizing 10-slot well screen consisted of poorly graded (well-sorted), rounded, high-quartz sand conforming to the U.S. Standard sieve range of 20-40 (0.85 to 0.425 mm). For the piezometers utilizing 20-slot well screens, the primary filter pack consisted of poorly graded (well-sorted), rounded, high-quartz sand conforming to the U.S. Standard sieve range of 10-20 (2.00 to 0.85 mm). Secondary filter pack materials used for construction of the piezometers consisted of poorly graded (well-sorted), rounded, high-quartz sand conforming to the U.S. Standard sieve range of 30-50 (0.60 to 0.300 mm) through 30-70 (0.60 to 0.212 mm).

The primary filter sand was emplaced in approximate two- to three-foot lifts using bottom-discharging tremie methods. After each lift, the HSAs were retracted a proportionate distance uphole to prevent sand bridging or locking the well screen and riser pipe into the augers. In addition, the tremie pipe was constantly douched with potable water to prevent bridging. This procedure continued until both the primary filter sand and secondary sand extended a requisite distance above the top of the well screen, as determined by use of a weighted, graduated tape. In most instances, due to the non cohesive, highly saturated nature of the geologic materials encountered while drilling, the introduction of natural formation sands into the well screen environment due to collapse as the HSAs were retracted was inevitable. Such occurrences manifested themselves in lower-than-predicted volumes of filter pack material used during construction. Similarly, in those piezometers where natural formation sands occurred at levels above the top of the filter pack, some apparent collapse tended to be noted above the filter pack once the HSAs were removed. It was in anticipation of this aspect that the approved work plan (p.10) requested use of natural sand packs as an alternative to artificially emplaced filter packs, as allowed for under 10 CSR 23-4.060(8)(B).

Following installation of the secondary filter sand, bentonite slurry consisting of high-solids (20-30 percent by weight) bentonite was used as both the bentonite and annular seal for each piezometer. The slurry was tremied from bottom to top in one continual operation, allowed to settle, and topped off to within one foot of ground surface. Volume calculations were made beforehand and compared to quantities actually used. In some piezometers, more grout than predicted was used. This is attributable to wash outs within the formation during the drilling, sampling, and well construction process. Alternatively, in other piezometers less grout was used than predicted. This is apparently due to natural swelling and/or collapse of the formation materials, resulting in a reduced borehole diameter relative to the size of the augers used while drilling and on which calculations were based.

Piezometer construction details are provided for review in Appendix 5. The details include information on well construction quantities used during installation, as well as notes on natural sand collapse. The references to groundwater elevations pertain to the maximum and minimum levels recorded in each piezometer during the 12-month monitoring period.

Surface completions for the two-inch piezometers included the installation of four-inch x four-inch steel protective casing embedded in concrete pads at least eight inches larger than the casing diameter. The four-inch piezometers were completed with six-inch diameter, schedule 80 PVC protective casings. The thickness of the concrete pads was sufficient to guard against frost heaving, which extends to a depth of approximately 15 inches in east-central Missouri. Each protective casing was labeled, equipped with a locking cap, painted black for visibility, and marked by a ten-foot length of three-quarter inch PVC flagged with fluorescent streamers to assist with the prevention of damage by farming equipment (the majority of piezometers at the time of installation were located in agricultural fields consisting of either soybeans or corn). The protective casings were filled with coarse sand and a small diameter weep hole was drilled near the base of each casing.

Each piezometer was subsequently surveyed to establish x, y, and z-coordinate information. Kuhlman design Group, Inc. (KdG) of St. Louis, Missouri completed the survey work primarily using GPS techniques during the week of December 31, 2009. Both ground surface and top-of-casing elevations were obtained (Table 2). KdG also established the location and ground surface elevation for each of the temporary borings and CPTs drilled during the investigation using stakes marking each hole location as reference points. Because of the slight mounding, surveyed elevations may be slightly higher than original ground surface. Raw survey data are presented for review in Appendix 6.

Copies of Well Certification Records for the piezometers constructed for this investigation are contained in Appendix 7.

4.3 Piezometer Development

Piezometer development was initiated on October 12, 2009 and continued through December 22, 2010. It was performed in accordance with the approved work plan. Non-dedicated, submersible pumps and/or disposable, polyethylene bailers were used during development. A minimum of three well volumes of groundwater were removed from each piezometer. Well volumes were calculated beforehand, based on the apparent static water level of the piezometers as measured prior to purging. Well volumes include both casing and annular volumes. Annular volume calculations assumed 30 percent effective pore space within the saturated zone. In most instances, significantly more groundwater was removed than the minimum requirement. This was necessary not only to ensure potable water introduced into the piezometers during well construction was removed, but also to reduce turbidity in piezometers screened across high percent clay units. Piezometer development summaries are presented in Appendix 8.

4.4 Aquifer Testing

Aquifer testing was performed as proposed and accepted in the approved work plan on all 25 four-inch piezometers installed as part of this investigation. Initial tests were conducted on October 29, 2010 in P-53 and P-57, and the remaining piezometers were tested during the time period December 14-16, 2010. The intent of the testing was to provide a representative depiction of apparent hydraulic behavior throughout the investigative area. Seven of the piezometers tested (P-9, P-53, P-57, P-73, P-128, P-165, and P-197) are located along the margins of the proposed waste disposal boundaries (Figure 8). The other 18 piezometers (P-19, P-22, P-31, P-42, P-61, P-81, P-85, P-104, P-114, P-120, P-126, P-136, P-144, P-162, P-164, P-169, P-193, and P-199) are evenly distributed throughout the interior of the site (Figure 8). Both presumably high-yield (i.e. coarse sand) and low-yield (i.e. silt/very fine sand) materials were evaluated, as were formation materials intermediate between the two (i.e. fine-medium sand). Table 6 notes the principal geologic materials comprising the monitoring horizon for the 25 piezometers tested during the field investigation.

As described in the approved work plan, based on the anticipated quick recovery rate of alluvial sands, rising head (recovery) methods of analysis were used. Four-inch wells allowed use of a large diameter submersible pump capable of suppressing the groundwater level to a degree that enabled recovery curves to be analyzed. The tests were conducted by first measuring static water level. The submersible pump was then inserted into the casing and stabilized at a point approximately two feet above the base of the well screen, followed by the pressure transducer, and groundwater was allowed to equilibrate. Once the transducer showed a more or less constant water level, the submersible pump was engaged and the test conducted for a period of approximately five minutes to ensure maximum sustained suppression of the groundwater surface. During each test cycle, the pressure transducer provided continuous water level measurements recorded at one-half second intervals. Once the five minute period elapsed, the pump was shut off and the transducer was allowed to continue recording until groundwater levels recovered to at least 90 percent of the initial water level measurement.

Overall, recovery was quite rapid and in most wells was obtained in less than ten seconds (Table 6). The longest period of time to recover 90 percent was observed in P-136 (20 sec). The amount of drawdown varied from 0.34 feet to 2.14 feet and was partly dependent on pump rate, which ranged from an estimated 9.8 and 17.5 gallons per minute (pump rate itself was dependent on the wattage of the generators used during analysis).

Raw aquifer test data are presented in Appendix 9. The data consist of drawdown curves, semi-log plots of the recovery curve, and a print out of transducer measurements recorded over the length of time the groundwater level in a given well recovered to at least 90 percent of its initial static water level measurement.

4.5 Monthly Groundwater Level Monitoring

Initial groundwater level measurements of all 100 piezometers were recorded on December 21, 2009. Hand-held electronic water sensors, graduated in 0.01-foot increments, were used. Measurements were made using a mark at the top of the each PVC casing as a reference point. Recorded values were subsequently converted to elevations following the completion of surveying. Thereafter field personnel performed monthly measurements using identical techniques. Monthly groundwater level data and calculated groundwater elevations are presented in Table 3. These data are supplemented by monthly groundwater table surface maps presented as Figures 18 through 29 and by groundwater hydrographs presented in Appendix 10. Insight into seasonal variation can also be gained by comparing these data with the precipitation data presented in Table 5 and Figure 30.

5.0 Site Investigation Findings

The field activities resulted in the acquisition of substantial amounts of data concerning the geology and hydrology of sediments comprising the Holocene (Recent) alluvial deposits underlying the proposed UWL site. Approximately 8,047 linear feet of strata were penetrated by the 200+ borings and/or CPT soundings developed for this investigation in the effort to document the character of the deposits. Both whole-core and split-spoon samples enabled close examination of the vertical sequencing, depositional texture, and lateral distribution of principal sediment types. The installation of 100 piezometers within the uppermost, continuous water-bearing zone beneath the proposed UWL site permitted subsequent examination of such salient aquifer parameters as water table surface, hydraulic gradient, and hydraulic conductivity. Together, these data are believed sufficient to present a well-founded depiction of the hydrogeologic characteristics of sediments underlying the proposed UWL site.

The following sections detail the geologic and hydrologic findings of the investigation. Geologic findings are described first, beginning with a detailed examination of depositional units encountered while drilling and ending with information on the distribution and thickness of each major depositional unit. Hydrologic findings are then presented for the alluvial aquifer that underlies the site and constitutes the uppermost, continuous water-bearing body within the confines of the investigative area. Throughout these sections, reference is made to the supporting hydrogeologic data presented in Figures 9 through 32, Tables 1 through 8, and Appendices 2, 4, 9, and 10.

5.1 Geologic Findings

The geologic materials underlying the proposed Labadie UWL site are best described as a complex sequence of gravel, sand, silt, and clay. Sand is the predominant sediment, followed by gravel, silt, and lesser amounts of clay. The sand deposits range from very fine- to very coarse-grained sequences spanning almost the entire depth of investigation to intervals of thin, discontinuous, relatively fine-grained material marked by a high degree of interbedding with silt and clay. Coarser grained sequences commonly contain highly variable amounts of granule- to pebble-sized gravel (2-30 mm) consisting of well-rounded to subangular clasts of igneous and metamorphic derivation. Angular clasts of limestone and/or dolostone of probable local origin were also observed in several of the borings (i.e. P-134, P-162, and P-173). In places, the proportion of gravel is such that the materials encountered are more properly considered sandy gravel. “Pure” gravel was encountered at total depth in four of the piezometer borings developed for this investigation (P-114, P-134, P-142, and P-146). Based on samples recovered from the auger cutting head, the gravel consisted of well-rounded, prolate to oblate clasts measuring up to three inches (75 mm) in diameter. Finer grained sand sequences typically possess low-angle cross laminae and climbing ripple laminae defined by thin partings of silt and clay. Large carbonized wood fragments (up to 30 mm) and smaller macerated carbonaceous matter are other common features. Preserved contacts recovered from split-spoons suggest the transition from coarse- to fine-grained sand sequences is sometimes abrupt and likely erosional. Although petrographic studies were not undertaken, field observations of rock composition suggest the sands are most probably subarkoses to sublitharenites in classification (Folk, 1980).

Brownish silts and clays predominate in the upper seven to ten feet of most borings. Typically, they show a high degree of interbedding defined by thin laminae and the proportion of each sediment type varies greatly in a given vertical sequence. Relatively homogenous intervals of clay and/or silty clay were also observed. They tend to be most common in the southern part of the site, where up to eight-foot thicknesses were recorded. Elsewhere, these shallow, finer sized deposits generally are less than four feet thick. Homogeneous sequences of silt are uncommon and, where they occur, generally are confined to the uppermost surface deposits and appear to be eolian (i.e. wind-blown) in origin. The silts and clays tend to dissipate down section over a gradational boundary as ever-increasing proportions of fine sand constitute the predominant sediment type.

Irregularly distributed throughout the site and extending to relatively deep depths are distinctive, “gley”-colored (i.e. “steel” blue or “gun-barrel” gray) intervals of clay, silt, and sand. The clays in this interval tend to be highly plastic and would be colloquially considered as “gumbo”. Like their shallower counterparts, the clays and silts tend to be highly interbedded with well defined laminae. Very thin to thin beds of very fine- to medium-grained sand are common and, with increasing depth in many places, relatively “clean” sands retain the gley coloration to the total depth of investigation (e.g. P-71, P-138, P-173, P-187, P-195). Note that the distinctive gley coloration is indicative of prolonged anaerobic conditions wherein iron has been chemically reduced to compounds that have low chroma colors, which impart a grayish, bluish, or grayish green hue to the soil (Brady and Weil, 2002). Such conditions typically develop within backswamp areas or within isolated, cut-off meander loops of a river.

These principal depositional units show a considerable degree of lateral variation from place to place across the investigative area. Few adjoining borings show identical sedimentological sequencing, and it is common for a coarse-grained sand sequence in one boring to be followed by a relatively fine-grained sequence or even a predominantly silt/clay sequence at comparable depths in a successive boring. Despite the irregular lateral distribution, most borings encountered what is best described as a “fining upward” depositional pattern, or vertical sequencing, of principal sedimentologic units. Although not necessarily all represented in any one boring, relatively homogeneous sequences of medium- to coarse-grained sand are in general overlain by sequences of very fine- to fine-grained sand, which in turn are overlain by very fine-grained sand interbedded with silt and clay, followed by interbedded silt, silty clay, and clay. This vertical sequencing is typical of fluvially derived sediments deposited during the ebb and flow of flood events or during shifts of the main channel and associated distributaries and reflects the fact that the investigative area resides within a portion of the pre-channelization drainage pattern of the Missouri River alluvial plain (Figures 4, 5, and 6).

Fluvial depositional sequences are complex. They can be subdivided into a wide range of discrete sedimentological units, or facies, based on the prevailing energy of the environment of deposition (e.g. sands connote high-energy deposition; clays connote low-energy deposition; cf. Reineck and Singh, 1980; Cant, 1982; Pettijohn et al., 1973). However, for the purposes of this report, and based on careful examination of drill log data, five principal facies, or depositional sequences, have been identified. They are termed, in rough ascending order: 1) channel deposits; 2) channel margin/splay deposits; 3) flood plain/levee deposits; 4) flood basin deposits, and; 5) backswamp/cut-off deposits. These five principal depositional sequences are described in the following paragraphs. Reference is made throughout the descriptions to the boring logs contained in Appendices 2 and 4.

5.1.1 Channel Deposits

Channel deposits are herein defined as those intervals consisting almost exclusively of poorly to moderately sorted, coarse to very coarse-grained, quartz-rich sand. Clay and other fine-grained constituents are almost completely absent. Granule to small pebble-sized gravel (<10 mm) is invariably present and typically constitutes over ten percent by weight of the samples recovered during field operations. The gravel mainly consists of well-rounded to subangular clasts of basaltic, granitic, and metamorphic derivation, but angular carbonate clasts of apparent local provenance were also observed (i.e. P-134, P-162, and P-173). Gravel up to three inches (75 mm) in diameter was noted, but appears less common, perhaps because of the size limitations imposed by split-spoon sample recovery. Gravel is so prevalent in some samples that the sands are more appropriately considered gravelly sand or sandy gravel. Such accumulations connote the development of channel lag or bar deposits, which are intrinsically related to the channel depositional environment. Color varies from pale yellowish brown to grayish orange to dark gray. Bedding generally is indistinct or poorly preserved. The channel sand deposits readily yield groundwater as noted during development and aquifer testing of the piezometers.

Channel sand deposits were recognized in 64 of the piezometer borings developed for this investigation. They were also recognized in 19 of the 22 temporary borings, where the thickest recorded accumulation is roughly 76 feet in boring B-100. Similar sands were identified in 69 of the CPT soundings largely based on the reported presence of gravelly sand deposits in association with relatively homogenous sand sequences (e.g. C-11, C-79, and C-200). The sands occur at depths greater than 20 feet below ground surface and typically extend to the base of investigation within a given boring. However, in places, the deposits are underlain by finer grained materials and are less than ten feet thick (e.g. P-15, P-49, B-50, B-52, P-61, P-83, P-124, P-136, B-176, P-181, P-191, and B-200), suggesting the development of minor distributaries to the main channel environment. The fact that these sands do not have a ubiquitous presence throughout the site lends credence to the idea that, at least within the depth intervals examined, a singular, progressively northward moving river channel did not exist within the investigative area.

The geologic interpretation that these sands exclusively depict channel deposits is open to discussion. That they reflect a relatively high-energy environment of deposition within a fluvial setting is incontrovertible. Nomenclature used to describe such high-energy environments is vast in the literature and any attempt to elucidate the specific genesis of a given sand deposit is beyond the scope of this report. Rather, the choice of terminology was made largely for ease of narrative and on the recognition of the limitations of scale imposed by the size of the investigative area. That channel lag and point bars (essentially subfacies of a channel deposit) occur within the site has already been mentioned, and it is equally probable that coarse sand sequences transitional with associated crevasse splay, natural levee, and similar deposits exist within the confines of the site.

5.1.2 Channel Margin/Splay Deposits

Channel margin/splay deposits are closely allied with channel deposits. They are differentiated here on the basis of a slightly finer grain size and the overall paucity of gravel in the recovered samples and perhaps depict transitional environments between the more distinctive channel and flood plain depositional settings. These deposits typically are medium grained. Although they contain appreciable amounts of fine- and coarse-grained sand, the degree of sorting is higher than in the channel deposits. Gravel constitutes less than ten percent (by weight) of a given sample and, where present, consists almost entirely of granules (<4 mm). These deposits are believed to have developed along the lee side of channels, where current velocities are relatively low. In places, they may depict true crevasse splay deposits derived from episodic flood events of the Missouri River.

The channel margin/splay deposits were identified in 37 of the piezometer borings and seven of the temporary borings developed during this investigation. They were tentatively identified in 16 of the CPT soundings. Thicknesses generally range between five and ten feet although the deposit identified in P-102 exceeds 18 feet. They are irregularly distributed within the site and show no predictable pattern of sedimentation. Depths of occurrence exceed 15 feet and in most places exceed 25 feet below ground surface. Deposits were also identified at depths of 47 feet and 54 feet in B-101 and B-200, respectively. The deposits typically overlie more clearly discernable channel sands, but are themselves in places overlain by relatively thin channel deposits (e.g. B-50, B-52, P-136, P-181, P-191), reflecting a return to relatively high-energy conditions within a dynamic river environment. What may be more reflective of true crevasse splays is suggested by the overlap of these deposits on top of finer grained flood plain deposits as evidenced in the vertical sequencing documented in B-52, B-56, P-87, P-120, P-152, P-183, P-191, P-193, and P-197.

5.1.3 Flood Plain/Levee Deposits

Flood plain/levee deposits constitute the most widespread sand sequence encountered within the investigative area. They were recognized in all but seven of the borings developed for this investigation (exceptions are P-61, P-95, P-138, P-150, P-155, P-177, and P-187). They were also noted on 89 of the CPT logs based on the subtle intermixing of units interpreted as representing sand, sand to silty sand, and silty sand to sandy silt. The deposits generally consist of relatively thick, homogeneous sequences of well-sorted, very fine- to fine-grained sand.

However, the upper parts are commonly marked by admixtures of silt and clay in varying proportions showing well-defined small scale cross laminae and climbing ripple laminae. These interlaminated units invariably transition upward into predominantly silt and clay intervals interpreted as flood basin deposits. Flood plain and natural levee deposits are closely allied depositional environments, hence use of the combined term. Both develop due to overtopping of a river embankment during flood events, with levee deposits forming wedge-shaped accumulations adjacent the river and flood plain deposits representing finer sized sediment that accumulates in areas more remote from the main river channel(s).

The flood plain/levee deposits generally are encountered at depths less than ten feet. They typically exceed ten feet in thickness and it is not uncommon for the sequence to extend to the total depth of investigation (e.g. P-17, P-27, P-51, P-79, P-104, P-169, and P-185). Where complete sections are represented, the deposits generally grade downward into coarser grained sands representative of channel or channel margin facies. However, at the base of some boreholes, a second flood plain sequence was identified beneath the coarser grained deposits (P-38, B-52, B-56, P-59, P-83, P-87, P-120, P-124, P-152, P-191, P-193, P-197, and B-200). In boring B-56, this lower sequence is 15 feet thick and extends to a depth of approximately 42 feet. In boring B-200, the lower sequence is ten feet thick and extends to a depth of approximately 47 feet. The existence of these deeper deposits suggests an older period of flood plain development rather than pervasive, historical channelization and, like their shallower counterparts, again lends credence to the idea that the ancestral Missouri River system should not be viewed as a singular, progressively northward migrating river channel within the area of investigation.

5.1.4 Flood Basin Deposits

Flood basin deposits constitute predominantly silt and clay sequences that lie at ground surface and are ubiquitous throughout the site. The deposits reflect a period of extremely quiescent deposition and are consistent with the low-energy/high sediment loading seen in the backwaters of major flood events. They are considered separately in order to differentiate them from the predominantly sandy sequences of the flood plain/levee, channel margin/splay, and channel deposits lying at deeper depth. The deposits consist of highly variable mixtures of interbedded clay, clayey silt, silty clay, and silt that are up to 15 feet thick. The degree of interbedding is complex and discrete units cannot be traced with confidence from borehole to borehole. Clays typically are olive gray to dark brown whereas silty intervals tend to be light olive gray to pale yellowish brown. Very thin to thin beds of sand are occasionally present and likely denote episodic increases in bed load capacity due to flood events of short duration. Relatively thin, homogeneous units of silt were also recognized. These units are believed to be the result of wind-blown (i.e. eolian) deposition but no attempt was made to differentiate them for the purposes of this report. It is possible that some of the finer sized sand layers are also the result of this depositional process.

The flood basin deposits typically grade downward into interlaminated sand, silt, and clay sequences interpreted as flood plain/levee deposits. In most instances, this transition is subtle, making placement of the boundary between the two styles of deposits somewhat arbitrary. However, the deposits are also commonly in direct contact with distinctive gley colored sequences of highly interlaminated clay, silt, and sand (e.g. P-40, P-61, P-95, P-126, P-138, P-177, P-201). These boundaries are sharp and possibly erosional in nature.

5.1.5 Backswamp/Cut-Off Deposits

Backswamp/cut-off deposits constitute one of the more distinctive sequences recognized at the site. They possess a characteristic gley coloration, which develops as a result of residence within an anaerobic (i.e. oxygen deficient) depositional setting. The deposits consist of complex, repetitive cycles of thinly laminated to cross-laminated silt and sand interbedded with layers of highly plastic clay. The silt and sand intervals are highly variable in thickness and are mainly found incorporated into the clay as discrete, relatively homogeneous units that display little or no vertical gradation in grain size. The sands generally are brownish and very fine- to fine grained, but thin layers of medium-grained sand also were noted. Where preserved, contacts with other depositional sequences invariably are sharp and in many places can best be described as “knife-edged”. The highly plastic clays, which provide the sequence with its distinctive gley coloration, are most appropriately characterized as “gumbo”. Clay and silt tends to be the predominant particle size in the upper part of the deposits. With depth, particle size commonly increases and borings possessing a preponderance of sand were noted in many places (e.g. P-43, P-63, P-136, and P-173). Because the degree of interbedding is so finely complex, the boring logs represent these deposits schematically as alternating bands of black and white “layers” and emphasize the predominant lithology in the descriptive section (Appendix 4). An exception to this is where relatively coarse grained, gley-colored sands were described.

Sequences interpreted as backswamp/cut-off deposits were recognized in 56 of the piezometer borings and six the temporary borings developed during this investigation. They were also tentatively identified in 37 of the CPT borings based on the interpreted presence of fine-sized materials (i.e. clay, clayey silt to silty clay, silty sand to sandy silt) at depths typically below which flood basin deposits would be expected (e.g. C-28, C-103, and C-196). The deposits have an apparently erratic distribution and appear at variable depths throughout the site. The shallowest depth of occurrence was found to be six feet below ground surface (P-142). The deepest was noted 42 feet below ground surface (B-176). Most commonly, these deposits are between five and ten feet thick and are bounded above and below by flood basin and flood plain/levee deposits, respectively. However, relatively shallow pockets as thin as one foot were also recorded (P-102). Sequences that grade downward into gley-colored sand generally are in excess of 20 feet thick and are in contact with underlying channel deposits. They exceed the depth of investigation in several places (i.e. P-43, P-71, P-173, P-187, and P-195). In addition to the deeply buried sequence in B-176, other borings that encountered the backswamp/cut-off deposits at depth include P-36, P-49, and P-181.

5.1.6 Distribution and Thickness of Principal Depositional Sequences

The distribution and thickness of the five principal depositional sequences identified in this report are described in the following paragraphs using a series of facies map reconstructions and cross sections presented as Figures 9 through 17. The facies map reconstructions are intended to convey an idea of the distribution of the principal fluvial environments within the investigative area at discrete intervals of geologic time. Three maps were developed (Figures 9, 10, and 11), based on the interpreted origin of the deposits found coinciding with the present day elevations of 435 feet, 445 feet, and 455 feet, respectively. These three elevations roughly correlate with drill depths of 10 feet, 20 feet, and 30 feet and were selected to provide the widest possible span of geologic information obtained from the bulk of the boreholes.

The cross sections developed for this report enable inspection to be made of thickness trends, as well as better illustrate "*in toto*" the distribution of the major depositional sequences not obvious from the facies map reconstructions. Six representative intersecting cross sections were constructed for this purpose (Figures 12 through 17). They were selected to provide an idea of the range in sedimentologic variability from place to place across proposed waste boundaries. Cross-section A-A' (Figure 12) is aligned east-west roughly parallel to Labadie Bottom Road and is oriented such that the reader views the site looking south. Cross-section B-B' (Figure 13) is aligned northwest-southeast along the western perimeter of the site and is oriented such that the reader views the site looking east. Cross-section C-C' (Figure 14) is aligned east-west through the southern part of the site and is oriented such that the reader views the site looking north. Cross-section D-D' (Figure 15) is aligned roughly north-south along the eastern margin of the site and is oriented such that the reader views the site looking west. Cross-section E-E' (Figure 16) trends diagonally from northeast to southwest and is oriented looking northwest. Cross-section F-F' (Figure 17) trends diagonally from northwest to southeast and is oriented northeastward. Note that the large number of borings used to compose this final cross-section necessitated a change in scale on the figure to accommodate all geologic information on a single plan sheet.

The facies identification map presented as Figure 9 shows the prevailing fluvial environments at the 435-ft elevation. This represents the deepest, or oldest, sediments penetrated by most of the 35-ft borings. Channel deposits are the prevalent facies. They highlight what appear to be three or perhaps four discrete channels that trend roughly west to east across the site. The northernmost channel is largest with a width of approximately 600 to 1,000 feet. The channel trending through the middle of the site is roughly 400 to 600 feet in width and the southernmost channel is approximately 600 feet wide before it bifurcates into a relatively small (200-300 ft) northeasterly trending distributary channel and an apparent larger channel to the south. Each of these channels is bounded, at least in part, by either channel margin/splay or flood plain/levee deposits. The channel margin/splay deposits generally display outlines suggestive on "fine-grained" point bar development. The deposit centered on P-150 has more the shape and positioning of a crevasse splay. The somewhat linear trends displayed by the flood plain/levee deposits suggest the development of ill-defined natural levees that presumably have been breached in many places. Backswamp/cut-off deposits are also shown in association with each of the flood plain/levee deposits depicted on the map. These deposits have limited extent and most do not appear to measure larger than two to three acres in size. However, a somewhat larger expanse (five to six acres) has been partially delineated in the extreme southeastern part of the site. The outlines of the deposits marked by P-138 and P-173 have the appearance of being truncated by the channel deposits. Sediments representative of the flood basin facies are not present at this lower elevation.

The facies identification map depicting the fluvial sediments at the 445-ft elevation (Figure 10) shows considerable development of the flood plain/levee facies, at the expense of both the channel and channel margin/splay facies. The channel deposits noted previously have disappeared and in their place a narrow, northward trending channel has developed. This channel, which may in fact depict a northward flowing creek, is approximately 100 to 200 feet wide to a point in the central part of the site where it is intersected by a similarly sized channel trending east-west. The deposits widen north of this point and again appear to be intersected by another east-west trending channel deposit, which gives the overall aspect of a “T” in outline. Whether or not each of these relatively narrow channel deposits denotes local creek development or is part of the overall Missouri River drainage pattern is open to discussion. Regardless, where these channels enter or exit site boundaries could not be determined with certainty. Ill-defined channel deposits are also apparently located along the western margin of the site. Backswamp/cut-off deposits continue to be randomly distributed throughout the area. However, in places they appear more extensively developed than at the 435-ft elevation and at least two of the deposits measure in excess of eight acres in size. Those deposits located adjacent to channels have the appearance of being erosionally truncated and in-filled by channel sand deposits. The outline of the relatively expansive backswamp/cut-off deposit located in the northwestern part of the site is not unlike the outline shown for the unnamed lake on Figure 6. Again, predominantly clay and silt sequences constituting flood basin deposits are not present at this elevation.

The uppermost facies identification map reconstruction drawn at the 455-ft elevation (Figure 11) reveals a major shift in environmental conditions. Channel sand deposits have completely disappeared and flood basin deposits become a major feature of the landscape. Flood plain/levee deposits showing a southerly or southeasterly trend also remain extensively developed, but are not quite as widespread as at the 445-ft elevation. Isolated backswamp/cut-off deposits remain relatively common, but a large expanse measuring approximately 40 to 50 acres in size has developed in the east-central part of the site. Many of the backswamp deposits are peripheral to the flood basin deposits, suggesting perhaps the progressive infilling and consequent demise of anaerobic conditions in those areas.

The cross sections developed from this investigation (Figures 12 through 17) further illustrate the distribution and thickness of the fluvial sediments underlying the proposed UWL site. Six cross sections rather than the more standard four were developed mainly due to the size and somewhat irregular shape of the site. Two of the cross sections (sections B-B' and D-D') trend north-south along the eastern and western margins of the site. Two of the cross sections (sections A-A' and C-C') trend east-west along the northern and southern parts of the site and the remaining two (sections E-E' and F-F') trend diagonally from northeast to southwest and from northwest to southeast, respectively. These last two cross sections also trend roughly parallel and/or perpendicular to groundwater flow direction, which varies considerably in overall flow direction beneath the site.

Cross-section A-A' (Figure 12) was constructed using data from 11 borings (C-37, P-38, C-39, P-40, C-41, P-42, P-49, P-51, P-53, P-55, and P-57). It shows the ubiquitous presence of flood basin deposits, which thicken slightly in a westerly direction. Underlying flood plain/levee deposits are also ubiquitous, but the thickness of these deposits varies greatly. They are at least 25-ft thick in P-55 and exceed the depth of investigation in P-51. Eastward, they thin and are less than five feet thick in P-38. The scattered, isolated nature of the backswamp/cut-off deposits is also apparent. They generally are less than 10 feet thick and are bounded both above and below by flood plain/levee deposits. The relatively thick deposit noted in P-38 includes appreciable coarse sand towards its base that may reflect a relict channel deposit. The persistence of this vertical sequence through time helps to explain the thinning of flood plain/levee deposits in that area. Note that gley-colored materials interpreted as representing backswamp/cut-off deposits appear to extend beyond total depth in boring P-49. Relatively fine-grained flood plain/levee deposits were also noted at, and presumably below, total depth in P-38. Channel deposits in the east thin rapidly westward and are completely absent in P-51. Farther west, channel sand deposition becomes more continuous and accumulations in excess of 15 feet thick were noted. Associated channel margin/splay deposits overlap the channel sands noted along the eastern side of the cross section. The relatively thick deposit noted in P-40 may reflect, at least in part, development of a fine-grained point bar.

Cross-section B-B' (Figure 13) was constructed using data from 14 borings (P-5, B-58, P-73, P-88, B-101, B-115, P-128, B-141, B-154, P-165, P-177, B-188, C-198, and P-3). It shows flood basin deposits extending from north to south throughout the western part of the site. The deposits generally are less than seven feet thick, but locally increase to 15 feet in thickness in the vicinity of P-3, B-115, and B-58. Flood basin deposits are underlain by flood plain/levee deposits everywhere but in the vicinity of P-177, where they are in contact with a relatively thick sequence of backswamp/cut-off sediment. Except for that area, the flood plain/levee sediments form a continuous deposit that ranges in thickness from roughly ten to 24 feet. Underlying channel sands are also continuous within this area. They are at least 28 feet thick in B-101 and are capped in several places by slightly finer grained sequences interpreted as channel margin/splay facies deposits.

Cross-section C-C' (Figure 14) east-west through the southern part of the site and was created using data from 11 borings (P-177, C-178, P-179, C-180, P-181, C-182, P-183, C-184, P-185, C-186, and P-187). It depicts a continuous blanket of flood basin deposits seven to ten feet thick. Underlying flood plain/levee deposits have considerable variation in thickness from two feet in C-180 to in excess of 30 feet in P-185. The flood plain/levee deposits are bounded both east and west by thick accumulations of backswamp/cut-off sediment. Backswamp deposits appear to also have developed at the expense of flood plain/levee deposits in the area of C-180 and P-181. Channel sand deposits are discontinuous but appear particularly well developed in the vicinity of C-182. To the west, at the base of P-181, the channel deposits appear underlain by backswamp/cut-off deposits. To the east, at the base of P-183, flood plain/levee deposits occur. Channel margin/splay deposits form a thin veneer between the channel deposits depicted in C-182 and C-184. They are more extensively developed to the west of that area.

Cross-section D-D' (Figure 15) reflects the distribution and thickness of the various depositional sequences along the western margin of the site. It was developed based on data derived from 12 borings, including one deep temporary boring that was extended to the top of bedrock (P-57, B-72, P-87, B-100, P-114, B-127, P-140, B-153, P-164, B-176, P-187, and P-197). Flood basin deposits extend across the area. They are between five and 15 feet thick and are underlain by sediments reflective of both flood plain/levee and backswamp/cut-off deposition. Flood plain/levee sediments appear discontinuous due to the presence of the backswamp/cut-off deposits. In most places, the flood plain/levee deposits are between ten and 25 feet. They are slightly thinner to the north. Relatively fine-grained sandy intervals noted at the base of B-72, P-87, and P-197 are also interpreted as flood plain/levee deposits. Relatively well-developed backswamp/cut-off deposits are between 16 and 28 feet thick in the southern part of the area. Northward, they are less than eight feet thick. Boring B-176 penetrated a partial thickness of gley-colored, relatively fine-grained sediment at a depth of 42 feet below ground surface.

Channel deposits appear particularly prevalent in the central part of the cross section. Data from B-100 suggest that they extend to the top of bedrock in that area. Associated channel margin/splay deposits are locally present and appear to overlap the more deeply buried flood plain levee sequences identified on the cross section.

Cross-section E-E' (Figure 16) was constructed using data from 11 borings extending diagonally from northeast to southwest through the main part of the DSI site (P-57, P-71, P-85, P-97, P-110, P-122, P-134, P-146, P-156, P-167, and P-177). The uppermost deposits consist of flood basin sediments, which are generally between four and ten feet thick. They thicken locally to almost 14 feet in P-167 and were observed between a depth of ten and 16 feet in P-71. Underlying flood plain/levee sequences are between 14 and 22 feet thick. They are separated into thinner intervals where they bound the backswamp/cut-off deposit noted in P-146 and P-156. They are also thinner to the north. Backswamp/cut-off deposits appear more continuous here than in areas shown on the other cross sections. They generally are less than eight feet thick, but extend below the base of investigation in P-71. Underlying channel deposits were noted in almost every boring. They appear more extensively developed in the region of P-134 and P-146, as well as to the north in P-57. Channel margin/splay deposits are shown above the channel deposits in both the northeastern and southwestern parts of the site.

Cross-section F-F' (Figure 17) uses data from 15 borings (P-9, P-15, P-22, P-29, P-35, P-42, P-79, P-93, P-108, P-122, P-136, P-150, P-162, P-175, and P-187). It extends from northwest to southeast across the widest part of the site and because of its length, the scale used to depict the cross section has been reduced by one-half to accommodate the geologic data on a single plan sheet (the vertical exaggeration of 40:1 remains the same as on other cross sections). Flood basin deposits remain ubiquitous and constitute the uppermost sediments seen at the site. Local thickening is apparent in P-35, P-93, and P-122. To the northwest, flood basin deposits are mainly in contact with underlying flood plain/levee deposits. To the southeast, they generally are in contact with backswamp/cut-off deposits. The flood plain/levee deposits appear to thin southeastward as backswamp/cut-off deposits become more prevalent. However, local thickening occurs where the backswamp/cut-off deposits are noted to be absent (P-162, P-175). More deeply buried channel deposits appear continuous across the site to a point northwest of P-187. There, backswamp/cut-off deposits are present at total depth. Channel margin/splay deposits appear particularly well developed in P-108 and P-150. However, it is possible that the lower parts of these intervals transition into channel sand sequences along an ill-defined boundary.

5.2 Hydrologic Findings

The hydrologic findings presented below document the hydraulic character of the alluvial aquifer underlying the proposed UWL site. Depth to water table is described first, followed by a description of the water table surface configuration. Monthly variability in groundwater level is then discussed and related to influences from precipitation events and the rise and fall of Missouri River levels. An assessment of hydraulic conductivity and groundwater velocity completes the section. The data presented support the interpretation that the alluvial aquifer constitutes the uppermost, continuous water-bearing body within the confines of the investigative area.

5.2.1 Depth to Alluvial Aquifer

Monthly measurements made over the 12-consecutive month time period since the completion of field activities (December 2009 through November 2010) are summarized in Table 3. Those data reveal that the water table surface residing in the alluvial aquifer fluctuated during the monitoring period. Overall water table elevations ranged from a maximum of 464.66 feet in P-20 (June) to a minimum of 456.43 feet in P-9 (December) during routine monthly measurements, but supplemental measurements made in select piezometers during the months of April, May, and June showed a maximum recorded elevation of 468.87 feet in P-9 on May 18, 2010 (Table 4). When topographic differences across the site are considered, actual water table depth below ground surface (bgs) typically ranged from two to 13 feet during a given month, but in some instances groundwater rose up to, and in some cases, slightly exceeded ground surface elevation (Table 3, June 8, 2010 data for P-102, P-155, P-165, P-167, and P-177). Groundwater levels were relatively uniform across the site during a given monitoring event. The maximum variability recorded was during the month of December 2009 (3.94 feet) and the minimum variability recorded was during the month of May 2010 (0.95 feet). From month-to-month, variability within a given piezometer was greatest in those located in the northwestern part of the site, closest to the Missouri River (Table 3). It was least variable in those piezometers clustered in the southeastern part of the site, farthest from the Missouri River.

In general, water table depth appears independent of grain size or depositional unit. It is present at comparable depths regardless whether or not a given piezometer is screened across predominantly sand, silt, or clay intervals of the channel, channel margin/splay, flood plain/levee, or backswamp/cut-off deposits as defined in this report.

5.2.2 Water Table Surface

The water table surface of the alluvial aquifer is depicted in a series of groundwater contour maps presented as Figures 18 through 29. They were developed from 12 consecutive months of monitoring in accordance with the approved work plan. The monthly measurements used for mapping are summarized in Table 3.

Groundwater within the alluvial aquifer travels along a variable axis of flow. During the first three months of monitoring (December 2009 to February 2010), groundwater flow generally was north and northwestward toward the Missouri River (Figures 18 to 20). Over the next six months (March to August 2010), groundwater flow generally was eastward (Figures 21 to 26). Beginning in September 2010, groundwater flow shifted to the northeast and by November 2010 it had resumed a northwesterly flow direction similar to that documented during the initial three months of monitoring (Figures 27 to 29). Groundwater flow in the northwestern part of the site, nearest the Missouri River, was typically marked by an increased hydraulic gradient (Figures 18, 19, 20, 21, and 29). This is demonstrated by a closer spacing of groundwater contours than elsewhere within the site. More commonly, the groundwater contours are widely spaced, indicating a much shallower hydraulic gradient was prevalent over the majority of the site during the 12-month monitoring period.

Due to the relatively flat water table surface, differences between monthly maximum and minimum groundwater elevations are less than four feet; they are commonly less than two feet (Table 3). Taken from northwest to southeast across the confines of proposed waste disposal boundaries, this roughly equates to an overall hydraulic gradient of one and one-half to three feet per mile (ft/mi). Hydraulic gradients calculated by Surfer® (a widely used software program to develop groundwater contour maps) are presented as note 6 on each of the water table maps (Figures 18-29). Both maximum and minimum values are presented. Minimum values range from 1.990×10^{-6} ft/ft to 6.161×10^{-5} ft/ft (0.015 to 0.33 ft/mi). Maximum values range from 3.517 $\times 10^{-3}$ ft/ft to 5.534×10^{-4} ft/ft (3 to 18 ft/mi). Although the hydraulic gradient increases at times in the northwestern part of the site, some of these higher values are believed to reflect local anomalies in measured groundwater elevation, as suggested by some of the groundwater flow directional arrows on the maps. The shallow water table surface is the reason that the groundwater maps were created using a contour interval of only 0.5 feet (six inches). Otherwise, subtleties in groundwater flow direction from month to month could be overlooked.

5.2.3 Monthly Groundwater Fluctuations

Monthly fluctuations in groundwater level are summarized in Table 3. They are also illustrated by a series of hydrographs presented in Appendix 10. The summary data presented in Table 3 identifies the maximum intra-well variability in each piezometer over the monitoring period. It also indicates the maximum inter-well variability during each monthly monitoring event. The individual piezometer data show that groundwater fluctuations were between three and nine feet. Piezometers located in the northwestern part of the site, closest to the Missouri River, showed the greatest variability (P-1, P-9, P-15, P-17, P-20, P-22, P-27, P-31, P-33, and P-43). Piezometers located in the southeastern part of the site, farthest from the Missouri River, showed the least variability (P-140, P-162, P-164, P-173, P-175, P-183, P-185, P-187, P-195, and P-197). The average variability for all 100 piezometers during the 12-month monitoring period was 4.85 feet.

During the month of June 2010, groundwater measurements indicated that the water table rose above ground surface elevation in piezometers P-102, P-150, P-155, P-165, P-167, and P-177 (Table 3). The amount of rise was slight, between 0.03 and 0.53 feet, and was concentrated mainly in the southwestern part of the site, where visual observations confirmed the presence of standing water. Supplemental measurements (Table 4) also indicated similar occurrences in P-118, P-128, P-167, and P-187 for the events immediately prior and subsequent to the June 8, 2010 “routine” monthly monitoring event.

During a given monthly monitoring event, inter-well fluctuations ranged from 0.78 feet to 3.94 feet. They were greatest during the month of December 2009 and lowest in October 2010. The average inter-well fluctuation during the 12-month monitoring period was 1.98 feet.

The hydrographs illustrating monthly fluctuations in groundwater elevation (Appendix 10) reveal that all 100 piezometers essentially behaved in identical fashion. Each piezometer generally showed a progressive increase in water level of three and six feet over the first five months of monitoring (December 2009 to April 2010). This was followed by a site-wide decrease in water level of one to two feet during May 2010. Groundwater rose two to three feet in June 2010 then dropped steadily one to five feet through the month of September 2010. Levels rose again one to three feet in October 2010 and then dropped three to five feet in November 2010. Note that the few "anomalies" on the graphs (e.g. P-35 in April 2010, P-83 in February 2010, and P-162 in February 2010) are believed attributable to field measurement transcription errors of groundwater readings.

5.2.4 Response to Precipitation

An evaluation of the alluvial aquifer's response to rainfall was made using the precipitation data presented in Table 5. The results of that evaluation are graphically illustrated on Figure 30. The graph presents monthly precipitation totals as a series of bar graphs. Monthly water table elevation, expressed as the average value for all 100 piezometers, is presented as a line plot. It is accompanied by two roughly parallel dashed-line plots depicting average water table elevations in the northwestern and southeastern parts of the site, respectively. The plot depicting the northwestern average is derived from piezometers P-1, P-9, P-15, P-17, P-20, P-22, P-27, P-31, P-33, and P-43. The plot depicting the southeastern average is derived from piezometers P-140, P-162, P-164, P-175, P-183, P-185, P-187, P-195, and P-197 (Table 3). As previously noted, the overall average water table elevation line plot indicates that groundwater levels increased during the first five months of monitoring (December 2009 to April 2010), dropped during May 2010, rose again in June 2010, dropped progressively from July to September 2010, rose during October 2010, and then dropped again in November 2010. The initial five-month rise in groundwater level spanned a relatively "dry" winter period wherein monthly precipitation ranged from 2.19 to 4.26 inches. Accounting for a degree of time lag for precipitation to enter the aquifer system, it is possible that the rise in groundwater levels seen in April 2010 may be partly attributable to the higher amount of precipitation seen in March, combined with thawing conditions. A similar time lag aspect can be seen for succeeding months.

Review and comparison of groundwater levels as recorded in the southeastern part of the site, where groundwater fluctuations are least variable, to groundwater levels in the northwestern part of the site, where groundwater fluctuations are most variable, show similar trends in response to precipitation (Figure 30). The most notable aspect seen in the comparison is that groundwater in the northwestern part of the area appears more sensitive and reacts to a greater degree to apparent precipitation influences than groundwater in the southeastern part of the site. Although these data suggest that precipitation influences exist, it is believed that a greater influence on the local water table is the Missouri River, which is located approximately 1,400 feet (0.25 mi) beyond the northwestern margin of the DSI site.

5.2.5 Response to Missouri River Elevation

The influence of the Missouri River on local water table elevation was evaluated utilizing gauging data provided by the Ameren Missouri Labadie Power Plant facility, who maintains a gauging station adjacent to the plant site. The results of this evaluation are presented graphically on Figure 31. The line-plot of the Missouri River represents the daily reported flow elevation. The line-plot of the water table as recorded at the investigative area represents the monthly average reading for all 100 piezometers. This line plot is also accompanied by two roughly parallel dashed-line plots depicting average water table elevations for the ten piezometers located in the northwestern and southeastern parts of the site, respectively. The most noticeable feature of the graph is the large fluctuation in river elevation, which varies from approximately 451 feet to 473 feet during the 12-month monitoring period. During the first three months of monitoring (December 2009 to February 2010), river levels generally remained below 460 feet and were commonly below 455 feet. A few short-term rises above 462 feet are noted by the "spikes" coinciding with the dates of December 27, 2009, January 27, 2010, and February 23, 2010. Thereafter, through the month July 2010, river levels rose and remained consistently above 460 feet and generally remained above 465 feet. Levels in excess of 470 feet were noted in mid-May, mid to late June, and the day of July 10, 2010. River levels began to decrease in late July, and dropped below 460 feet beginning in late August 2010. They rose again above 460 feet in mid-September and remained above that level until early October, eventually dropping to a 456-ft elevation at the end of the 12-month monitoring period.

At the beginning of the monitoring period (December 2009), river elevation clearly was below the water table surface as documented at the project site (Figure 31). It remained more or less below the local water table throughout the succeeding three months (January to March 2010) except for relatively short-term periods (4 to 9 days) coinciding with the dates of December 26-29, 2009, January 23-February 1, 2010, and February 23-25, 2010. Average water table elevation remained slightly above 459 feet during this period and, as demonstrated by the water table surface maps for December 2009 through February 2010 (Figures 18-20), overall groundwater flow direction was northward, toward the Missouri River. However, beginning in mid-March 2010, river level surged above 460 feet and generally remained above that elevation through late

August 2010. During that same time period, average water table elevation also rose above 460 feet, where it remained throughout the five-month time span. Water table maps for this time period (March-August 2010) (Figures 21-26) show overall groundwater flow direction with a strong easterly component. Northeasterly trends, depicted for the months of March and May 2010 (Figures 21 and 23), coincide with relatively "low" average water table elevations (460.41 to 461.98 feet) and the southeasterly trend depicted for July 2010 (Figure 25) coincides with a relatively high and sustained water table exceeding 463 feet (Figure 31). By November 2010, as both the water table and river levels dropped below 460 feet, overall groundwater flow direction "reverted" to the northwest (Figure 29), essentially mirroring groundwater behavior observed during the first three months of monitoring. These data strongly suggest that the Missouri River influences local water table behavior. The alluvial aquifer appears to discharge toward the Missouri River during periods of relatively low flow and appears to be recharged by the river during periods of high flow.

A comparison of groundwater levels in the southeastern part of the site (farthest from the river) to groundwater levels in the northwestern part of the site (closest to the river) lends additional insight into the relationship between the local water table and the Missouri River. During periods of relatively low Missouri River base flow (i.e. December 2009-March 2010), average water table elevations in the southeast are between one and three feet higher than those in the northwest. Beginning in early to mid-March 2010, as river level rose, water table elevations "reversed" themselves and groundwater to the northwest remained consistently higher in elevation than groundwater to the southeast through the month of August 2010 with one small exception. That exception was in early May 2010 when the average water table elevation in the southeast (461.97 feet) exceeded the average water table elevation in the northwest (461.86 feet) by a slight margin. During that same time period, the Missouri River fell to levels approaching 460 feet. Subsequently, during the months of September and November 2010, groundwater in the northwest again clearly fell below levels in the southeast, coincident with an overall drop in river elevation below the 460-ft elevation. Those data suggest that the reversal in groundwater flow occurs when the Missouri River level attains a more or less sustained elevation of between 461 and 463 feet.

In order to evaluate whether or not the river gauge data obtained during the 12-month monitoring period were representative of recent historical conditions, a comparison was made to Missouri

River gauging data from the Labadie Power Plant for the preceding ten-year time period. Those data, graphically presented as Figure 32, indicate that river levels in 2010 were higher on average than in preceding years. In 2010, the average elevation of the Missouri River was 462.41 feet. Average annual river elevations in the preceding three years (2007-2009) were somewhat lower and ranged between 455.67 and 459.53 feet. They were noticeably lower in the preceding seven years (2000-2006), with an annual average elevation that ranged between 449.19 and 455.24 feet.

5.2.6 Hydraulic Conductivity

Estimates of hydraulic conductivity within the alluvial aquifer were made utilizing pump/recovery test data acquired from the 25 four-inch piezometers installed specifically for this purpose. The 25 piezometers represent 25 percent of the total number of 100 piezometers at the site. Seven of the four-inch piezometers (P-9, P-53, P-57, P-73, P-128, P-165, and P-197) are located along the margins of the proposed waste disposal boundaries (Figure 8). The remaining four-inch piezometers (P-19, P-22, P-31, P-42, P-61, P-81, P-85, P-104, P-114, P-120, P-126, P-136, P-144, P-162, P-164, P-169, P-193, and P-199) are evenly distributed throughout the interior of the site (Figure 8). Both presumably high-yield (i.e. coarse sand) and low-yield (i.e. silt/very fine sand) materials were evaluated, as were formation materials intermediate between the two (i.e. fine-medium sand). An aquifer test data summary is provided as Table 6. Calculations used to derive hydraulic conductivity are presented as Table 7. Raw test data including drawdown and recovery curves are provided in Appendix 9.

The aquifer test results reveal that the calculated hydraulic conductivity of the fluvial sediments ranges from 9.47×10^{-2} to 2.15×10^{-2} feet per minute (ft/min). Piezometer P-73 possesses the largest calculated hydraulic conductivity value and P-197 the smallest value. The 25 values yield a geometric mean of 4.51×10^{-2} ft/min. A geometric mean value is presented because an arithmetic mean tends to bias the results toward the more permeable values. Note that the values obtained fall within the range of hydraulic conductivity values typically ascribed to coarse and medium sand deposits (Todd, 1980, p.71).

In general, there is a tendency toward higher hydraulic conductivity values where at least part of the screened interval intersects with relatively coarse-grained sands interpreted as channel deposits. However, definitive trends could not be established due to the overall complexity of the vertical sequences, which is reflected in the fact that most of the 25 four-inch piezometers encountered more than one depositional unit at the level of the screened interval (Table 6). Calculated hydraulic conductivity values are similar between piezometers screened across relatively homogeneous channel deposits (P-42, P-57, P-114, and P-165) and piezometers screened across both channel and flood plain/levee sequences (P-9, P-19, P-22, P-73, P-81, and P-85). However, for relatively homogenous flood plain/levee sequences (P-104 and P-169), calculated values are demonstrably lower, from 4.27×10^{-2} to 2.15×10^{-2} ft/min. Similarly, most piezometers where the well screen intersects at least partial sequences of relatively fine-grain material interpreted as backswamp/cut-off deposits also show lower hydraulic conductivity values. An exception to this is P-164, which had the second highest calculated hydraulic conductivity value of 8.20×10^{-2} ft/min. However the backswamp/cut-off deposits enclose only the upper three feet of well screen with the remainder enclosed by channel sands (see boring log for P-164, Appendix 4). Thus, the resulting hydraulic conductivity value appears to be more of a reflection of these coarser grained sand deposits as it perhaps is in the other piezometers where similar deposits are present.

A review and comparison of the locations of the four-inch piezometers (Figure 8) does not show a definitive geographic pattern for the development of preferential areas of possible increased groundwater movement. As might be expected by reference to the facies identification maps presented as Figures 9 through 11, the patterning appears random, with relatively high calculated hydraulic conductivity values interspersed with relatively low calculated hydraulic conductivity values throughout the site.

One variable purposely introduced into the aquifer testing program was the use of 20-slot well screens in lieu of 10-slot well screen in 14 of the four-inch piezometers (Table 6). This was done to promote a more rapid recharge rate into the piezometers during testing due to the coarse-grained nature of the channel deposits. Based on past experience within similar geologic settings, 10-slot well screen may be a limiting factor when evaluating aquifer test data from apparent channel deposits. In other words, test results may be more a reflection of the well screen acting as a governor on fluid flow than true formation permeability in coarse-grained sands and gravels. In those instances, hydraulic conductivity results are typically reported as minimum values. If true, 20-slot well screen ideally should provide more representative results because groundwater is less impeded.

This comparison can be made by looking at the data summarized in Table 6. There is a tendency for the 20-slot piezometers to yield higher hydraulic conductivity values, but this observation is by no means consistent and in fact the lowest calculated hydraulic conductivity value is also from a 20-slot piezometer (P-197). Several other piezometers installed with 20-slot screens yielded relatively low results (i.e. P-104, P-144, and P-193). Five of the six piezometers where calculated hydraulic conductivity values are highest (P-22, P-73, P-81, P-164, and P-165) all used 20-slot well screen. Comparison to piezometers installed with 10-slot well screens in what are believed to be similar geologic materials (i.e. P-19, P-57, P-85, and P-114) showed values approximately 25 percent less than the 20-slot well screens. These observations do not invalidate use of 10-slot well screen for aquifer testing, particularly given the rather complex sequencing of geologic materials at this site. Rather, they simply suggest that minor but measurable differences may occur within similarly sized formation materials.

Two other aspects that should be noted from review of the aquifer test data include what appears to be cavitation of the groundwater during the five minute pump test in some of the piezometers (see pump curves included in Appendix 9). This may be an indication that pump rate was exceeding the recharge capacity of the formation (or the well screen) and was particularly apparent in those piezometers where the estimated pumping rate was reported as 17.5 gpm (Table 6; Appendix 9). Less rigorous pumping produced acceptable levels of drawdown without introducing apparent turbulence in the well environment. Some pump curves also show a small “spike” in groundwater level at the tail of the recovery curves. Approximately 15 of the piezometers tested show this aspect, particularly those with relatively quick recovery rates (i.e. <10 sec.; see Appendix 9). The source of this “spike” is indeterminate. It could reflect surging of the groundwater due to the quick recharge rates. Alternatively, it could reflect the relatively small volume (approximately 0.30 g) of groundwater backwatering into the piezometers from the tubing once the pump test was completed (a one-half inch ID flexible hose 30-ft in length was used). If this latter aspect is true, it would generally result in a shorter time lag to achieve 90 percent recovery, which in turn, would maximize the calculated hydraulic conductivity values.

5.2.7 Groundwater Velocity

The velocity with which groundwater contained in the alluvial aquifer moves can be estimated using the data presented in this report for hydraulic conductivity and hydraulic gradient, together with an estimate of effective porosity. Velocity data are important in that they allow insight to be gained into the time it takes groundwater to move from place to place across the investigative area. It can be estimated using the formula presented by Nielson (1991, p.428):

$$v = Ki / n \qquad \text{where,}$$

v = Average linear velocity in feet per year (ft/yr)
K = Hydraulic conductivity in feet per minute (ft/min)
i = Hydraulic gradient in feet per foot (ft/ft)
n = Effective porosity (percent interconnected void space)

The results of this calculation are summarized in Table 8. Several variables were used to demonstrate the overall range in values obtained from the site. Hydraulic conductivity values used include the overall geometric mean value as presented in Table 6 along with the maximum and minimum values as calculated for P-73 and P-197 (Table 6). Hydraulic conductivity values used are those calculated by Surfer® as shown on Figures 18 through 29. Because Surfer® presents a range in hydraulic gradient value both the maximum and minimum "low" values were used, as were the maximum and minimum "high" values. Three effective porosity values were also used: 30, 35, and 40 percent. This range in porosity is consistent with published values for fluvial sands (Peck et al., 1953).

These variables result in a wide range in possible groundwater velocity with values ranging from extremes of 0.1 to 584 feet per year (ft/yr). This wide range is chiefly attributable to both calculated hydraulic gradient and effective porosity values. The low ranges in hydraulic gradient (i.e. 6.161×10^{-5} to 1.990×10^{-6} ft/ft), which are believed more representative of prevailing groundwater movement at the site, result in velocity values ranging between 0.1 and 10 ft/yr, dependent on effective porosity. Lower effective porosity values result in higher velocities due apparently to less tortuosity in the pore-throat network. Except for the northwestern part of the site, higher hydraulic gradient values appear attributable to local anomalies in groundwater elevation and are not considered as representative of overall site conditions.

6.0 Summary

6.1 Investigation Objectives

This Detailed Site Investigation has resulted in the accumulation of substantial amounts of data concerning the geologic characteristics and hydraulic behavior of the Recent (Holocene) age alluvial sediments underlying the Ameren Missouri Labadie Power Plant proposed UWL site located in northeastern Franklin County, Missouri. The investigation was required by regulation 10 CSR 80-2.015 and 10 CSR 80-11.010(4)(A) as a critical step in the landfill permit process. Methods used to collect the geologic and hydrologic data are consistent with the work plan approved by MDNR-DGLS on June 15, 2009 (Appendix 1). Fieldwork was initiated in September 2009 and, with the exception of survey work and monthly water level measurements, was completed in January 2010. Objectives outlined in the work plan and completed for this report are summarized as follows:

- The drilling and sampling of each piezometer boring and ten of the temporary borings to depths of 35 feet and resulting inspection of over 3,745 linear feet of geologic materials, which enabled a detailed examination of vertical sequencing, depositional texture, and grain size to be made of the sediments comprising the alluvial deposits. These data are presented on the boring logs and accompanying descriptions contained in Appendices 2 and 4.
- The drilling and sampling of the 12 remaining temporary borings to depths ranging from 40 feet to bedrock refusal (107.7 feet in B-100) to better characterize older geologic materials and to enable a more thorough assessment of geotechnical considerations to be made for future design purposes. These data are contained on the boring logs presented in Appendix 2 and the geologic descriptions contained at the back of Appendix 4.
- The advancement of 93 cone penetrometer test soundings (CPTs) to depths ranging from approximately 19 to 65 feet and averaging approximately 35 feet to supplement geologic descriptions and interpretations of materials recovered from the piezometer and temporary borings. Sixteen of the CPTs were advanced to confirm results in adjacent piezometer borings, temporary borings, and/or CPT soundings (Table 1). The CPT data are contained in Appendix 2.

- The installation of 97 piezometers and use of three existing piezometers, spaced approximately four-acres apart, to enable monitoring of the shallow alluvial aquifer that underlies the site and constitutes the uppermost continuous source of monitorable groundwater encountered during the investigation. Installation included the construction of 17 piezometers located outside of proposed waste disposal limits for potential use as long-term monitoring points of compliance. Construction details for the piezometers are presented in Appendix 5. A summary of piezometer construction can be found in Table 2.
- The withdrawal of at least three well volumes of water from each piezometer during development, as detailed in the records presented in Appendix 8.
- The completion of aquifer testing in 25 piezometers distributed throughout the site and representative of the variable depositional units encountered below the water table surface. Aquifer test data are presented in Appendix 9. The data are summarized in Tables 6 and 7.
- The completion of 12 consecutive months of groundwater level measurements, as well as supplemental measurements from the piezometers in an effort to characterize flow direction and seasonal variation. These data are summarized in Table 3 and 4. They are illustrated by a series of water table maps presented as Figures 18 to 29, and by comparative graphs presented in Appendix 10.
- The evaluation of influences on local water table elevation from precipitation and the Missouri River as illustrated on Figures 30 and 31.

6.2 Geology

The unconsolidated alluvial deposits within the investigative area consist of complex sequences of sand, silt, and clay that show a high degree of lateral variation across the site. Few adjoining borings show identical vertical sequencing, and for that reason, discrete and easily identifiable marker beds cannot be traced with confidence from borehole to borehole across the investigative area. Sand is the predominant sediment, followed by gravel, silt, and lesser amounts of clay. The sand deposits range from very fine- to very coarse-grained sequences spanning almost the entire depth of investigation to intervals of thin, discontinuous, relatively fine-grained material marked by a high degree of interbedding with silt and clay. Coarser grained sequences commonly contain highly variable amounts of granule- to pebble-sized gravel (2-30 mm) consisting of well-rounded to subangular clasts of igneous and metamorphic derivation. Finer grained sand sequences typically possess low-angle cross laminae and climbing ripple laminae defined by thin partings of silt and clay. Large carbonized wood fragments (up to 30 mm) and smaller macerated carbonaceous matter are other common features. Brownish silts and clays predominate in the upper seven to ten feet of most borings. Typically, they show a high degree of interbedding defined by thin laminae and the proportion of each sediment type varies greatly in a given vertical sequence. The silts and clays tend to dissipate down-section over a gradational boundary as ever-increasing proportions of fine sand constitute the predominant sediment type.

Despite the lack of lateral continuity of the various sediment types, a distinct “fining upward” pattern of sedimentation was recognized in most borings. In general, sequences of coarse-grained sand are overlain by very fine- to fine-grained sand, which in turn, are overlain by very fine-grained sand interbedded with silt and clay, followed by interbedded silt, silty clay, and clay. This style of vertical sequencing denotes a gradual reduction in the “energy” of the depositional environment (i.e. sediment-load carrying capacity of the transporting medium) and is characteristic of alluvial sediments deposited in a fluvial setting.

The vertical sequencing observed in the borings has been characterized for the purposes of this report into five principal depositional units, or facies. Each facies reflects a major component of a fluvial environmental setting and has been used to assist in the development of a better understanding of the sedimentological history of the site. These five facies, which are interrelated and commonly transitional with one another, are termed in rough ascending order: channel deposits; channel margin/splay deposits; flood plain/levee deposits, and; flood basin deposits. The remaining facies, backswamp/cut-off deposits, occur at variable depths typically at the expense of the four other facies environments identified in this report.

The facies identification maps presented as Figures 9 through 11, demonstrate the progressive changes with time in the depositional setting of the site. Initially, channel deposits predominate (Figure 9). Channel margin/splay and flood plain/levee deposits are shown in association with the main channel areas. Backswamp/cut-off deposits have a more limited extent and most do not appear to measure more than two to three acres in size. Flood basin deposits are absent. Through time, there is considerable development of the flood plain/levee facies, at the expense of both the channel and channel margin/splay facies (Figure 10). Channel deposits have largely disappeared, and in their place a narrow, northward trending channel or creek has developed. Backswamp/cut-off deposits continue to be randomly distributed throughout the area. More recent deposits consist almost exclusively of a combination of flood basin and flood plain/levee sediments (Figure 11). Channel sands have completely disappeared. Isolated backswamp/cut-off deposits remain common, but a large expanse measuring approximately 40 to 50 acres in size has also developed in the east-central part of the site.

Cross-sectional data reveal the irregular distribution of the various facies comprising the fluvial deposits (Figures 12 to 17). Flood plain deposits are widespread and appear to constitute the uppermost sediments throughout the site. Underlying flood plain/levee deposits are also extensively developed, but vary more in thickness, usually as a result of the development of backswamp/cut-off deposits. They extend below the limits of investigation in places. Backswamp/cut-off deposits are found at virtually all levels of investigation and are more or less discontinuous across the site boundaries. Channel deposits reside at deeper depths and are relatively widespread. They constitute the lowermost deposits identified in most borings. Finer grained sequences interpreted as channel margin/splay deposits commonly occur above and along the flanks of the channel deposits.

6.3 Hydrology

The 100 piezometers installed at this site within the alluvial aquifer permit an accurate characterization to be made of uppermost groundwater flow behavior at the proposed UWL site. The water table generally occurred at depths less than ten feet below ground surface. In some places, rising groundwater levels resulted in the water table surface extending slightly above ground surface (Table 3, June 8, 2010 data for P-102, P-155, P-165, P-167, and P-177). Regardless, groundwater levels were relatively uniform across the site during a given monitoring event. The maximum variability recorded was during the month of December 2009 (3.94 feet) and the minimum variability recorded was during the month of October 2010 (0.78 feet). From month-to-month, variability within a given piezometer was greatest in those located closest to the Missouri River, in the northwestern part of the site (Table 3). It was least variable in those piezometers farthest from the Missouri River, in the southeastern part of the site,. Depositional controls on the depth to water table appear to be negligible. Comparable depths to groundwater were found regardless if a piezometer was screened across predominantly sand, silt, or clay intervals representing the channel, channel margin/splay, flood plain/levee, or backswamp/cut-off deposits as defined in this report.

Groundwater flow direction varied across the site during the 12-month investigation (Figures 18 to 29). From December 2009 through February 2010, groundwater movement was northward or northwestward, toward the Missouri River (Figures 18 to 20). During the next six months (March to August 2010), groundwater movement generally was eastward (Figures 21 to 26). In September and October 2010, groundwater resumed a more northerly flow direction (Figures 27 and 28) and in November 2010 it shifted back to the northwest, similar to the December 2009 measurements. The piezometers located in the northwestern part of the site appear most sensitive to the changes in groundwater flow direction, which is reflected by an increased groundwater gradient in that area on many of the water table surface maps presented in this report.

Despite the northwestward steepening, the most obvious characteristic of the water table is its flat surface. The differences between monthly maximum and minimum groundwater elevations as derived from monthly measurements were less than four feet and generally were less than two feet (Table 3). Such subtle variation roughly equates to an overall hydraulic gradient of one and one-half to three ft/mi. Calculated hydraulic gradients ranged from 1.990×10^{-6} ft/ft to 6.161×10^{-5} ft/ft (0.011 to 0.33 ft/mi) for lower end values and from 3.517×10^{-3} ft/ft to 5.534×10^{-4} ft/ft (3 to 18 ft/mi) for upper end values. Except for the northwestern part of the site, the lower end values are believed to be more representative of overall site conditions. The shallow gradient of the water table surface is the reason why Figures 18 through 29 were developed using a 0.5-ft contour interval. Otherwise, subtleties in groundwater configuration from month to month could be overlooked.

Comparison of precipitation data to piezometric data (Figure 30) shows some apparent measurable influence, particularly in the northwestern part of the site, but it is believed that changes in Missouri River elevation are a greater influence on the local water table (Figure 31). In particular, comparison of groundwater levels in the northwestern and southeastern parts of the site support the observation that changes in groundwater flow direction occur when river levels attain an elevation of between 461 and 463 feet.

Aquifer test results demonstrate that calculated hydraulic conductivities for the fluvial sediments range from 9.47×10^{-2} to 2.15×10^{-2} ft/min (Tables 6 and 7). The 25 calculated test results yield a geometric mean hydraulic conductivity value of 4.51×10^{-2} ft/min. These results fall within the range of hydraulic conductivity values typically ascribed to coarse and medium sand deposits (Todd, 1980, p.71). In general, there is a tendency toward higher hydraulic conductivity values where at least part of the screened interval intersects with relatively coarse-grained sands interpreted as channel deposits. The data also suggest a lack of geographic trends for the development of preferential areas of increased groundwater movement. Rather, the patterning appears random, with piezometers showing relatively high calculated hydraulic conductivity values interspersed with piezometers showing relatively low calculated hydraulic conductivity values throughout the site (Figures 9 to 11).

As shown in Table 8, calculated groundwater velocity values show considerable variation and range from extremes of 0.1 to 584 ft/yr. This wide range is dependent on the variables used in the calculation, particularly the hydraulic gradient values generated by Surfer® and the choice of effective porosity values. If only the low ranges in hydraulic gradient (i.e. 6.161×10^{-5} to 1.990×10^{-6} ft/ft) are considered, which generally are believed to be more representative of the overall water table surface, then perhaps a more realistic appraisal are the groundwater velocities that range between 0.1 and 10 ft/yr. Higher velocities would be expected in the northwestern part of the site, where the groundwater contours, as shown on Figures 18 through 29, generally steepen as the Missouri River is approached.

7.0 Conclusions

The data presented in this report reveal that the unconsolidated alluvial deposits underlying the proposed Ameren Missouri Labadie Utility Waste Disposal Area consist of a complex, heterogeneous mixture of gravel, sand, silt, and clay related to migratory patterns of the ancestral Missouri River. The complex interbedding negates attempts to reliably trace discrete, easily identifiable units from place to place across proposed site boundaries. However, observations of vertical sequencing and knowledge of the behavior of fluvial sedimentation permit the division of geologic sediments encountered into five principal depositional sequences, or facies. These facies, termed channel, channel margin/splay, flood plain/levee, flood basin, and backswamp/cut-off deposits, each record a subtle but distinct chapter in the depositional history of the site and permit a clearer understanding of both the geologic setting and its relationship to the hydraulic behavior of groundwater contained in the shallow alluvial aquifer that underlies the site.

Drill data demonstrate that relatively "clean", coarse-grained sands interpreted as channel deposits, are the most commonly encountered facies at the base of most borings. Sequences identified as representing flood plain/levee, backswamp/cut-off, and channel margin/splay deposits were also noted at or near total depth, including several of the deeper borings. The presence of these relatively fine-grained sediments suggests that a widespread erosional event, such as those produced by the steady progression of a large river channel with consequent scouring and filling by relatively coarse-grained sediments, did not occur throughout the proposed UWL site. Rather, the available evidence suggests that the site reflects the development of distributaries subordinate to the main river channel (if any existed) and that intermittent shifts in the position of these distributaries led to the creation of interceding areas favorable for the accumulation of finer grained sediments variously interpreted here as channel margin/splay, flood plain/levee, and backswamp/cut-off depositional environments.

The variable direction of groundwater movement at this site appears intrinsically related to Missouri River elevation. When river elevations are relatively high, it apparently acts as a recharge source to the alluvial aquifer and groundwater movement is generally toward the east and southeast. Conversely, when river elevations are relatively low, the local water table appears to "unwater" toward the river and groundwater movement is generally toward the north and northwest. Based on the data contained in this report, this change in flow direction occurs when the Missouri River reaches an elevation between 461 and 463 feet. Comparison of the river gauge data acquired during the 12-month monitoring period to gauge data for the preceding ten years suggests that river levels were unseasonably high in 2010, relative to the years 2000-2009. Thus, "unwatering" of the local water table toward the Missouri River may be more prevalent than what is suggested by the current data. Regardless, groundwater movement throughout much of the site is along a shallow hydraulic gradient. Calculated groundwater velocities believed to be representative of this shallow gradient range from 0.1 to 10 ft/yr, but could be as high as 584 ft/yr. Higher velocities to the northwest are suggested, where groundwater contours generally steepen and hydraulic gradient increases.

As described in 10 CSR 80-2.015, a UWL site is suitable for the development of a solid waste disposal area, if: no Holocene epoch geologic faults exist within the proposed UWL boundary; groundwater can be effectively monitored due to the lack of karst terrane conditions; or no subsurface voids or conditions exist that present a significant potential for catastrophic collapse. Based on the results of the field work and analysis presented in this report, these three items are addressed below:

1. Holocene-age (i.e. active) faults, as defined by regulation, do not occur within the site nor are they known to exist within one-quarter mile of the proposed UWL boundary.

2. The data presented documents the presence of a continuous water table surface contained within the alluvial aquifer underlying the proposed UWL site. This uppermost aquifer readily yielded water to each piezometer, indicating sufficient quantities of groundwater can be obtained throughout the site for the purposes of routine detection sampling and analysis. This report did not identify locations that can be consistently described as hydraulically upgradient or hydraulically downgradient of proposed disposal area limits. An intra-well approach to groundwater sampling and analysis obviates the need for such comparisons, which is intrinsic to an inter-well sampling methodology. For these reasons, it is concluded that the groundwater contained within the alluvial aquifer can be effectively monitored and should therefore be considered as the long-term monitoring horizon for this proposed UWL site.

3. Subsurface voids or conditions that present a significant potential for catastrophic collapse do not occur within the site nor are they known to exist within one-quarter mile of the proposed UWL boundary.

Therefore, it is concluded that the Labadie site is suitable for development of a Utility Waste Disposal Area.

8.0 Conceptual Groundwater Monitoring Network

A conceptual groundwater monitoring network for the proposed UWL is presented in Figure 33. The concept was developed based on the conclusions of this report and data acquired during this investigation, specifically overall groundwater flow direction(s), hydraulic gradients, and groundwater fluctuations recorded in the 100 on-site piezometers during the last 12 months. This network is only conceptual; it provides only a generalized model of a possible groundwater monitoring system. A more detailed plan with the number of wells and well locations will be provided in the construction permit application.

The conceptual plan includes 33 groundwater monitoring wells along the perimeter, each within approximately 100 feet of the proposed waste disposal boundary. Two different well spacings are suggested: a 500-ft well spacing along the northwestern, northern, eastern, and southeastern margins of the site because of the slightly higher hydraulic gradients observed in the northwestern part of the site toward the Missouri River; and a 700-ft well spacing along the western and southwestern margins of the site, where upgradient or “side” gradient conditions prevail and hydraulic gradients were relatively flat. The groundwater monitoring plan will be refined during the construction permit application process, taking into account aspects of construction, as well as the possibility of interim wells around initial phases of disposal.

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TABLES

Detailed Site Investigation
Proposed Utility Waste Disposal Area
Ameren Missouri Labadie Power Plant
Franklin County, Missouri

Drilling Summary
Table 1

No.	Boring ID[1]	Boring Type[2]	Date Drilled	Total Depth (ft)[3]	Location Northing	Location Easting	Ground Surf. Elev. (feet)[4]	Remarks
1	1	P/D	3/14/07	91.5	996214.10	727590.30	470.70	Bedrock TD
2	2	P	3/12/07	30.0	993370.60	728605.50	466.40	
3	3	P	3/12/07	30.0	990178.70	728523.00	466.10	
4	4	B	3/9/07	25.0	995211.0	728668.0	467.0	
5	5	B	3/12/07	25.0	994284.0	726729.0	467.0	
6	6	B	3/12/07	20.0	992542.0	726673.0	467.0	
7	7	B/D	3/12/07	104.5	991914.0	728564.0	464.8	Bedrock TD
8	8	B	3/9/07	20.0	989801.0	726627.0	467.0	
9	9	P	10/20/09	36.5	996108.40	726981.78	469.90	
10	10	B	11/2/09	35.0	996103.24	727271.42	469.40	
11	11	C	10/28/09	34.9	996087.44	727863.35	468.60	
12	12	P	9/16/09	36.5	996215.71	728171.12	468.95	
13	13	B	11/2/09	50.0	996065.73	728454.79	468.40	
14	13a	C	10/28/09	41.8	996064.70	728453.55	468.10	CPT offset to confirm adjacent drill data
15	14	B	10/28/09	35.0	995811.17	726971.86	470.00	
16	15	P	9/17/09	36.5	995802.44	727271.36	469.35	
17	16	C	10/23/09	35.0	995796.01	727587.85	469.50	
18	17	P	9/16/09	36.5	995789.75	727851.61	469.30	
19	18	C	10/28/09	35.3	995781.84	728155.08	468.00	
20	19	P	10/16/09	36.5	995768.95	728438.40	467.90	
21	20	P	9/17/09	36.5	995510.59	726856.24	469.35	
22	21	C	10/23/09	35.0	995508.43	727263.08	469.10	
23	22	P	10/7/09	36.5	995503.30	727579.54	468.40	
24	23	C	10/28/09	35.4	995493.86	727854.19	468.50	
25	24	P	9/16/09	36.5	995476.21	728133.29	468.50	
26	25	C	10/28/09	35.4	995479.57	728426.49	467.00	
27	26	B	10/28/09	45.0	995220.60	726964.14	468.50	
28	27	P	9/17/09	36.5	995206.06	727247.55	469.07	
29	28	C	10/23/09	35.0	995191.80	727570.51	468.00	
30	29	P	9/15/09	36.5	995188.03	727844.69	467.73	
31	30	C	10/29/09	35.3	995181.54	728136.93	468.20	
32	31	P	10/12/09	36.5	994921.76	726950.89	467.67	
33	32	C	11/4/09	2.5	NA	NA	NA	failed test
34	32a	C	11/4/09	35.5	994919.82	727239.84	468.10	CPT offset to confirm adjacent drill data
35	33	P	9/14/09	36.5	994910.34	727559.71	468.44	
36	34	C	10/29/09	42.7	994906.91	727840.02	467.10	
37	35	P	9/15/09	36.5	994886.38	728125.58	467.61	
38	36	P	9/15/09	36.5	995058.28	728509.44	468.20	
39	37	C	10/22/09	40.5	994633.32	726940.78	466.80	
40	38	P	9/22/09	36.5	994618.74	727238.62	467.15	
41	39	C	10/23/09	35.0	994610.37	727532.49	467.00	
42	40	P	10/12/09	36.5	994582.15	727832.47	467.05	
43	41	C	10/23/09	35.0	994571.00	728120.73	467.00	
44	42	P	10/6/09	36.5	994538.42	728420.83	467.74	
45	43	P	9/17/09	36.5	994333.02	726945.21	466.07	
46	44	C	11/2/09	33.3	994339.91	727235.79	466.50	
47	45	P	9/18/09	36.5	994324.97	727532.26	467.12	
48	46	C	11/2/09	44.6	994335.16	727828.30	466.50	

Detailed Site Investigation
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Drilling Summary
Table 1

No.	Boring ID[1]	Boring Type[2]	Date Drilled	Total Depth (ft)[3]	Location Northing	Location Easting	Ground Surf. Elev. (feet)[4]	Remarks
49	46a	C	11/2/09	43.8	994335.46	727834.36	466.40	CPT offset to confirm adjacent drill data
50	47	P	9/18/09	36.5	994320.66	728124.52	467.10	
51	48	C	11/2/09	35.2	994317.23	728416.23	466.70	
52	49	P	10/14/09	36.5	994499.84	728938.97	467.58	
53	50	B	11/4/09	50.0	994279.71	729167.67	467.70	
54	50a	C	11/2/09	42.2	994279.51	729171.66	467.60	CPT offset to confirm adjacent drill data
55	51	P	10/14/09	36.5	994463.37	729490.00	466.25	
56	52	B	11/4/09	35.0	994257.04	729758.59	465.30	
57	53	P	10/15/09	36.5	994428.21	730049.96	466.46	
58	54	B	11/3/09	35.0	994252.30	730351.55	467.10	
59	55	P	10/14/09	36.5	994395.43	730584.11	467.33	
60	56	B	11/3/09	50.0	994240.10	730939.28	467.40	
61	57	P	10/15/09	36.5	994356.77	731212.53	465.99	
62	58	B	11/6/09	35.0	994038.11	726928.67	464.30	
63	59	P	9/21/09	36.5	994039.34	727225.40	465.36	
64	60	C	11/6/09	31.2	994027.11	727521.57	466.40	
65	61	P	10/26/09	36.5	994020.22	727813.31	465.92	
66	62	C	11/6/09	35.2	994016.40	728113.05	466.20	
67	63	P	9/21/09	36.5	994004.98	728407.71	466.20	
68	64	C	11/6/09	35.2	993995.34	728865.99	466.60	
69	65	P	10/13/09	36.5	993990.81	729165.61	468.06	
70	66	C	9/7/09	23.4	993980.14	729457.50	467.70	
71	66a	C	12/28/09	34.7	993983.55	729455.30	467.60	
72	67	P	10/13/09	36.5	993985.65	729758.28	465.52	
73	68	C	11/6/09	35.3	993969.55	730078.53	466.10	
74	69	P	10/13/09	36.5	993965.46	730346.87	465.05	
75	70	C	11/7/09	35.3	993949.84	730636.69	466.00	
76	71	P	10/21/09	36.5	993948.36	730927.90	467.42	
77	72	B	11/10/09	35.0	993933.70	731225.42	467.30	
78	73	P	11/6/09	36.5	993742.59	726924.60	467.06	
79	74	C	11/3/09	35.3	993741.15	727218.57	464.60	
80	75	P	9/28/09	36.5	993730.50	727511.13	466.12	
81	76	C	11/3/09	35.3	993720.40	727809.69	465.70	
82	77	P	9/28/09	36.5	993714.81	728102.38	465.41	
83	78	C	11/3/09	35.2	993707.27	728399.78	465.30	
84	79	P	10/28/09	36.5	993695.02	728850.48	467.01	
85	79a	C	11/5/09	35.3	993690.91	728845.97	466.70	CPT offset to confirm adjacent drill data
86	80	C	11/5/09	35.3	993682.86	729155.13	466.60	
87	81	P	10/28/09	36.5	993679.30	729444.97	467.64	
88	81a	C	11/5/09	35.2	993687.41	729445.36	467.30	CPT offset to confirm adjacent drill data
89	82	C	11/5/09	35.6	993677.60	729741.30	467.50	
90	83	P	11/10/09	36.5	993664.23	730089.18	464.74	
91	84	C	11/5/09	35.3	993657.32	730332.48	465.10	
92	85	P	11/10/09	36.5	993647.31	730619.20	464.41	
93	86	C	11/5/09	35.1	993650.66	730924.62	465.70	
94	87	P	10/26/09	36.5	993693.54	731420.88	466.69	
95	88	P	11/6/09	36.5	993401.94	727072.92	466.25	
96	89	C	11/3/09	35.3	993438.19	727504.02	465.10	

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Drilling Summary
Table 1

No.	Boring ID[1]	Boring Type[2]	Date Drilled	Total Depth (ft)[3]	Location Northing	Location Easting	Ground Surf. Elev. (feet)[4]	Remarks
97	90	P	9/28/09	36.5	993427.80	727804.04	465.38	
98	91	C	11/3/09	35.8	993413.86	728094.56	465.10	
99	92	C	11/3/09	23.3	993398.00	728843.81	465.60	
100	92	B	11/9/09	45.0	993398.38	728845.92	465.70	TB offset to confirm adjacent drill data
101	93	P	10/20/09	36.5	993388.35	729062.32	465.91	
102	94	C	11/4/09	35.4	993375.69	729434.37	466.50	
103	95	P	10/20/09	36.5	993368.45	729725.06	467.22	
104	96	C	11/4/09	33.1	993362.59	730021.06	467.90	
105	97	P	10/21/09	36.5	993349.44	730302.43	467.05	
106	98	C	11/4/09	35.4	993346.95	730622.85	465.20	
107	99	P	10/21/09	36.5	993336.45	730887.27	464.38	
108	100	B/D	11/4/09	107.7	993325.31	731204.95	465.70	Bedrock TD
109	100a	C	11/3/09	31.9	993325.31	731205.45	465.70	CPT offset to confirm adjacent drill data
110	101	B	11/7/09	50.0	993154.88	727200.58	466.00	
111	102	P	9/29/09	36.5	993140.49	727503.68	464.29	
112	103	C	11/9/09	35.1	993136.62	727785.53	464.50	
113	104	P	10/5/09	36.5	993125.75	728085.40	465.00	
114	105	C	11/9/09	35.5	993135.15	728390.05	464.70	
115	106	P	10/29/09	36.5	993103.56	728837.82	465.11	
116	106a	C	11/9/09	35.2	993109.35	728836.44	464.90	CPT offset to confirm adjacent drill data
117	107	C	11/9/09	22.9	993103.27	729135.70	465.00	
118	107a	C	11/9/09	35.3	993103.10	729146.13	464.90	CPT offset to confirm adjacent drill data
119	108	P	11/4/09	36.5	993084.09	729427.93	465.71	
120	109	C	11/9/09	35.4	993088.06	729726.68	466.30	
121	110	P	11/4/09	36.5	993066.85	730012.30	466.14	
122	111	C	11/9/09	34.9	993063.54	730316.44	466.30	
123	112	P	11/4/09	36.5	993051.48	730620.74	465.92	
124	113	C	11/10/09	35.2	993055.00	730901.31	463.50	
125	114	P	11/12/09	36.5	993026.22	731203.72	463.94	
126	115	B	11/7/09	45.0	992864.44	727489.17	465.30	
127	116	P	9/29/09	36.5	992841.30	727788.60	464.82	
128	117	C	11/11/09	35.2	992838.23	728076.07	465.30	
129	118	P	9/29/09	36.5	992825.03	728377.28	464.81	
130	119	C	11/10/09	35.0	992807.06	728831.40	465.10	
131	120	P	10/22/09	36.5	992787.68	729145.90	464.75	
132	121	C	11/10/09	35.1	992788.41	729418.06	464.10	
133	122	P	11/10/09	36.5	992758.84	729781.01	464.74	
134	123	C	11/10/09	35.3	992783.29	730008.50	464.90	
135	124	P	11/11/09	36.5	992775.57	730303.49	464.92	
136	125	C	11/10/09	35.6	992770.51	730600.29	466.00	
137	126	P	11/11/09	36.5	992667.51	730879.77	465.77	
138	127	B	11/10/09	35.0	992782.41	731193.33	463.40	
139	128	P	11/7/09	36.5	992561.87	727385.52	465.74	
140	129	C	11/11/09	35.2	992541.28	727767.11	464.10	
141	130	P	9/30/09	36.5	992537.68	728075.04	465.15	
142	131	C	11/11/09	35.2	992547.91	728365.33	465.00	
143	132	P	10/15/09	36.5	992536.17	728817.00	465.36	
144	133	C	11/11/09	35.1	992516.71	729146.50	464.60	

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Drilling Summary
Table 1

No.	Boring ID[1]	Boring Type[2]	Date Drilled	Total Depth (ft)[3]	Location Northing	Location Easting	Ground Surf. Elev. (feet)[4]	Remarks
145	134	P	11/10/09	36.5	992491.31	729438.21	464.10	
146	135	C	11/11/09	19.1	992494.22	729732.31	463.70	
147	135a	C	11/11/09	31.7	992494.17	729740.20	463.90	CPT offset to confirm adjacent drill data
148	136	P	11/11/09	36.5	992488.64	730004.49	463.71	
149	137	C	11/12/09	34.8	992490.70	730304.63	463.60	
150	138	P	11/12/09	36.5	992469.33	730675.26	464.10	
151	139	C	11/12/09	22.4	992467.71	730891.11	464.40	
152	139a	C	11/12/09	32.2	992473.22	730892.04	464.50	CPT offset to confirm adjacent drill data
153	140	P	10/27/09	36.5	992404.70	731394.93	465.72	
154	141	B	11/7/09	35.0	992258.30	727479.78	466.20	
155	142	P	11/6/09	36.5	992250.72	727764.69	464.83	
156	143	C	11/13/09	35.1	992247.00	728062.44	463.90	
157	144	P	9/30/09	36.5	992236.95	728361.22	464.56	
158	145	C	11/13/09	25.6	992222.70	728823.71	465.00	
159	145a	C	11/13/09	35.1	992218.35	728823.23	465.00	CPT offset to confirm adjacent drill data
160	146	P	11/9/09	36.5	992265.54	729102.62	464.80	
161	147	C	11/12/09	23.4	992208.03	729416.58	464.50	
162	147a	C	11/13/09	24.8	992202.60	729416.37	464.50	CPT offset to confirm adjacent drill data
163	148	P	11/9/09	36.5	992252.64	729630.10	463.86	
164	149	C	12/23/09	35.4	992190.52	730004.82	463.30	
165	150	P	11/14/09	36.5	992189.21	730256.27	463.22	
166	151	C	11/12/09	35.4	992180.61	730603.47	463.00	
167	152	P	11/12/09	36.5	992168.58	730889.93	463.55	
168	153	B	11/11/09	45.0	992163.20	731176.80	463.70	
169	154	B	11/9/09	40.0	991956.86	727759.71	465.10	
170	155	P	9/30/09	36.5	991943.98	728065.97	463.44	
171	156	P	11/9/09	36.5	991964.30	728791.30	464.89	
172	157	C	11/13/09	23.5	991919.96	729107.35	464.10	
173	157a	C	11/13/09	31.1	991925.41	726106.30	464.00	CPT offset to confirm adjacent drill data
174	158	P	11/13/09	36.5	991945.43	729368.05	464.72	
175	159	C	11/16/09	35.2	991906.89	729691.99	463.80	
176	160	P	12/11/09	36.5	991884.45	729979.25	463.70	
177	161	C	12/23/09	30.3	991888.46	730278.18	463.20	
178	162	P	12/10/09	36.5	991801.20	730561.78	463.28	
179	163	C	12/28/09	32.1	991897.76	730886.02	462.30	
180	164	P	12/4/09	36.5	991871.12	731169.33	463.42	
181	165	P	11/13/09	36.5	991660.67	727734.64	464.05	
182	166	C	12/22/09	35.6	991654.39	728048.68	464.20	
183	167	P	10/5/09	36.5	991646.82	728350.01	463.60	
184	168	C	11/16/09	34.0	991635.63	728804.08	464.00	
185	168a	C	11/16/09	33.0	991644.97	728805.72	464.20	CPT offset to confirm adjacent drill data
186	169	P	12/2/09	36.5	991653.97	729053.82	464.75	
187	170	C	11/16/09	35.3	991620.18	729392.25	464.00	
188	171	P	12/2/09	36.5	991629.80	729636.72	463.97	
189	172	C	12/23/09	35.1	991596.82	729981.26	463.20	
190	173	P	12/12/09	36.5	991592.90	730278.01	463.40	
191	174	C	12/23/09	33.1	991581.45	730570.70	463.50	
192	175	P	12/15/09	36.5	991556.51	730873.59	463.57	

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Table 1

No.	Boring ID[1]	Boring Type[2]	Date Drilled	Total Depth (ft)[3]	Location		Ground Surf. Elev. (feet)[4]	Remarks
					Northing	Easting		
193	176	B	1/19/10	50.0	991570.90	731163.53	462.70	
194	177	P	11/13/09	36.5	991336.76	728049.81	464.07	
195	178	C	12/22/09	35.0	991342.28	728334.65	463.90	
196	179	P	12/3/09	36.5	991350.86	728780.92	464.19	
197	180	C	12/22/09	35.1	991331.60	729095.02	464.30	
198	181	P	12/3/09	36.5	991334.49	729380.23	464.42	
199	182	C	12/22/09	35.5	991324.63	729674.16	464.50	
200	183	P	12/11/09	36.5	991309.56	729980.89	463.40	
201	184	C	12/24/09	35.2	991307.04	730272.57	463.20	
202	185	P	12/15/09	36.5	991289.70	730564.03	463.75	
203	186	C	12/23/09	35.1	991283.38	730857.67	463.40	
204	187	P	10/28/09	36.5	991308.51	731386.11	462.85	
205	188	B	11/9/09	35.0	991065.40	728033.59	464.90	
206	189	P	10/12/09	36.5	991059.00	728325.94	464.91	
207	190	C	12/22/09	35.3	991041.41	728854.90	463.20	
208	191	P	12/3/09	36.5	991032.57	729099.94	464.41	
209	192	C	12/22/09	35.3	991029.27	729372.42	464.30	
210	193	P	12/4/09	36.5	991026.43	729688.59	464.11	
211	194	C	12/24/09	35.3	991014.62	729967.60	463.20	
212	195	P	12/11/09	36.5	991065.81	730256.04	463.44	
213	196	C	12/24/09	35.1	990995.86	730560.69	463.50	
214	197	P	12/5/09	36.5	990891.95	730883.14	463.54	
215	198	C	12/22/09	35.0	990764.91	728321.53	463.70	
216	199	P	12/1/09	36.5	990738.72	728782.05	465.28	
217	200	B	1/18/10	60.0	990737.06	729073.29	464.80	
218	200a	C	12/21/09	65.1	990737.64	729076.02	464.80	CPT offset to confirm adjacent drill data
219	201	P	12/1/09	36.5	990567.70	729279.14	464.65	
220	202	B	1/18/10	35.0	990727.02	729660.51	463.80	
			Footage Totals	8047.2				

[1] See Figure 8 for boring locations.
[2] B = Temporary Boring; D = Deep Boring (to top of bedrock); P = Piezometer Boring; C = Cone Penetrometer Sounding.
[3] Estimated depths recorded in field notes, based on visual observations.
[4] Survey data completed by Kuhlmann design Group.
NA = Information not available.

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Piezometer Installation Summary
Table 2

No.	Piezometer ID	Date Drilled	Diameter (inches)[4]	Location[1] Northing	Location[1] Easting	Ground Surf.[1] Elev. (feet)	Top of Casing[1] Elev. (feet)	Base of Well Elev. (feet)	Total Depth (feet, btoc)[2]	Top of Screen Elev. (feet)[3]	Top Primary Filter Pack Elev. (feet)[3]
1	1	3/14/2007	2	996214.10	727590.30	470.70	473.92	441.97	31.95	451.97	NA
2	2	3/12/2007	2	993370.60	728605.50	466.40	469.59	438.09	31.50	448.09	NA
3	3	3/12/2007	2	990178.70	728523.00	466.10	469.85	437.75	32.10	447.75	NA
4	9	10/20/09	4	996108.40	726981.78	469.90	473.26	435.29	37.97	445.62	449.1
5	12	09/16/09	2	996215.71	728171.12	468.95	472.14	435.38	36.76	445.71	448.2
6	15	09/17/09	2	995802.44	727271.36	469.35	472.40	434.85	37.55	445.18	447.6
7	17	09/16/09	2	995789.75	727851.61	469.30	472.19	434.60	37.59	444.93	447.2
8	19	10/16/09	4	995768.95	728438.40	467.90	470.84	433.51	37.33	443.84	447.2
9	20	09/17/09	2	995510.59	726856.24	469.35	472.28	434.78	37.50	445.11	447.6
10	22	10/07/09	4	995503.30	727579.54	468.40	471.27	433.77	37.50	444.10	447.3
11	24	09/16/09	2	995476.21	728133.29	468.50	471.44	433.83	37.61	444.16	446.9
12	27	09/17/09	2	995206.06	727247.55	469.07	471.99	433.72	38.27	444.05	447.1
13	29	09/15/09	2	995188.03	727844.69	467.73	470.83	433.29	37.54	443.62	446.0
14	31	10/12/09	4	994921.76	726950.89	467.67	470.22	433.13	37.09	443.46	446.5
15	33	09/14/09	2	994910.34	727559.71	468.44	471.18	433.88	37.30	444.21	447.0
16	35	09/15/09	2	994886.38	728125.58	467.61	470.61	434.20	36.41	444.53	446.6
17	36	09/15/09	2	995058.28	728509.44	468.20	471.23	433.74	37.49	444.07	447.1
18	38	09/22/09	2	994618.74	727238.62	467.15	470.11	432.95	37.16	443.28	446.1
19	40	10/12/09	2	994582.15	727832.47	467.05	469.93	432.20	37.73	442.53	446.5
20	42	10/06/09	4	994538.42	728420.83	467.74	470.60	433.20	37.40	443.53	446.7
21	43	09/17/09	2	994333.02	726945.21	466.07	469.20	432.00	37.20	442.33	445.0
22	45	09/18/09	2	994324.97	727532.26	467.12	470.07	432.63	37.44	442.96	446.0
23	47	09/18/09	2	994320.66	728124.52	467.10	469.86	432.77	37.09	443.10	445.9
24	49	10/14/09	2	994499.84	728938.97	467.58	470.56	432.75	37.81	443.08	446.5
25	51	10/14/09	2	994463.37	729490.00	466.25	469.06	431.74	37.32	442.07	445.8
26	53	10/15/09	4	994428.21	730049.96	466.46	469.10	432.00	37.10	442.33	445.8
27	55	10/14/09	2	994395.43	730584.11	467.33	470.02	433.01	37.01	443.34	446.3
28	57	10/15/09	4	994356.77	731212.53	465.99	468.87	431.59	37.28	441.92	445.0

Detailed Site Investigation
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Piezometer Installation Summary
Table 2

No.	Piezometer ID	Date Drilled	Diameter (inches)[4]	Location[1] Northing	Easting	Ground Surf.[1] Elev. (feet)	Top of Casing[1] Elev. (feet)	Base of Well Elev. (feet)	Total Depth (feet, btoc)[2]	Top of Screen Elev. (feet)[3]	Top Primary Filter Pack Elev. (feet)[3]
29	59	09/21/09	2	994039.34	727225.40	465.36	467.94	430.57	37.37	440.90	443.7
30	61	10/26/09	4	994020.22	727813.31	465.92	468.87	431.34	37.53	441.67	444.9
31	63	09/21/09	2	994004.98	728407.71	466.20	469.10	431.81	37.29	442.14	444.7
32	65	10/13/09	2	993990.81	729165.61	468.06	471.31	433.67	37.64	444.00	446.9
33	67	10/13/09	2	993985.65	729758.28	465.52	468.28	431.13	37.15	441.46	444.8
34	69	10/13/09	2	993965.46	730346.87	465.05	467.73	430.19	37.54	440.52	443.9
35	71	10/21/09	2	993948.36	730927.90	467.42	470.70	433.08	37.62	443.41	446.3
36	73	11/06/09	4	993742.59	726924.60	467.06	469.94	433.10	36.84	443.43	446.1
37	75	09/28/09	2	993730.50	727511.13	466.12	468.75	431.52	37.23	441.85	444.9
38	77	09/28/09	2	993714.81	728102.38	465.41	468.05	430.60	37.45	440.93	444.0
39	79	10/28/09	2	993695.02	728850.48	467.01	469.84	432.24	37.60	442.57	445.7
40	81	10/28/09	4	993679.30	729444.97	467.64	470.31	432.88	37.43	443.21	446.4
41	83	11/10/09	2	993664.23	730089.18	464.74	467.55	430.41	37.14	440.74	443.7
42	85	11/10/09	4	993647.31	730619.20	464.41	466.75	430.04	36.71	440.37	443.6
43	87	10/26/09	2	993693.54	731420.88	466.69	469.64	433.47	36.17	443.80	447.1
44	88	11/06/09	2	993401.94	727072.92	466.25	469.13	432.12	37.01	442.45	445.0
45	90	09/28/09	2	993427.80	727804.04	465.38	468.10	431.09	37.01	441.42	444.9
46	93	10/20/09	2	993388.35	729062.32	465.91	468.82	431.92	36.90	442.25	445.2
47	95	10/20/09	2	993368.45	729725.06	467.22	469.92	432.80	37.12	443.13	446.1
48	97	10/21/09	2	993349.44	730302.43	467.05	469.67	432.82	36.85	443.15	446.2
49	99	10/21/09	2	993336.45	730887.27	464.38	467.21	430.66	36.55	440.99	444.2
50	102	09/29/09	2	993140.49	727503.68	464.29	467.27	431.40	35.87	441.73	445.1
51	104	10/05/09	4	993125.75	728085.40	465.00	467.78	430.44	37.34	440.77	444.0
52	106	10/29/09	2	993103.56	728837.82	465.11	468.10	430.32	37.78	440.65	443.7
53	108	11/04/09	2	993084.09	729427.93	465.71	468.55	431.10	37.45	441.43	444.5
54	110	11/04/09	2	993066.85	730012.30	466.14	468.99	431.98	37.01	442.31	445.4
55	112	11/04/09	2	993051.48	730620.74	465.92	468.92	432.22	36.70	442.55	445.2
56	114	11/12/09	4	993026.22	731203.72	463.94	466.78	429.24	37.54	439.57	442.5

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Piezometer Installation Summary
Table 2

No.	Piezometer ID	Date Drilled	Diameter (inches)[4]	Location[1] Northing	Easting	Ground Surf.[1] Elev. (feet)	Top of Casing[1] Elev. (feet)	Base of Well Elev. (feet)	Total Depth (feet, btoc)[2]	Top of Screen Elev. (feet)[3]	Top Primary Filter Pack Elev. (feet)[3]
57	116	09/29/09	2	992841.30	727788.60	464.82	467.55	430.07	37.48	440.40	443.6
58	118	09/29/09	2	992825.03	728377.28	464.81	467.70	429.74	37.96	440.07	443.3
59	120	10/22/09	4	992787.68	729145.90	464.75	467.65	430.26	37.39	440.59	443.9
60	122	11/10/09	2	992758.84	729781.01	464.74	467.71	430.27	37.44	440.60	444.1
61	124	11/11/09	2	992775.57	730303.49	464.92	467.99	430.26	37.73	440.59	443.6
62	126	11/11/09	4	992667.51	730879.77	465.77	468.83	431.96	36.87	442.29	445.9
63	128	11/07/09	4	992561.87	727385.52	465.74	468.60	431.21	37.39	441.54	444.6
64	130	09/30/09	2	992537.68	728075.04	465.15	468.13	430.78	37.35	441.11	444.7
65	132	10/15/09	2	992536.17	728817.00	465.36	468.47	430.76	37.71	441.09	444.5
66	134	11/10/09	2	992491.31	729438.21	464.10	466.82	429.20	37.62	439.53	444.1
67	136	11/11/09	4	992488.64	730004.49	463.71	466.73	429.10	37.63	439.43	442.2
68	138	11/12/09	2	992469.33	730675.26	464.10	466.99	429.94	37.05	440.27	443.2
69	140	10/27/09	2	992404.70	731394.93	465.72	468.57	431.41	37.16	441.74	444.8
70	142	11/06/09	2	992250.72	727764.69	464.83	467.66	430.10	37.56	440.43	443.1
71	144	09/30/09	4	992236.95	728361.22	464.56	467.74	430.22	37.52	440.55	443.3
72	146	11/09/09	2	992265.54	729102.62	464.80	467.48	430.20	37.28	440.53	445.9
73	148	11/09/09	2	992252.64	729630.10	463.86	466.84	429.42	37.42	439.75	442.7
74	150	11/14/09	2	992189.21	730256.27	463.22	465.91	428.29	37.62	438.62	441.4
75	152	11/12/09	2	992168.58	730889.93	463.55	466.31	429.17	37.14	439.50	442.5
76	155	09/30/09	2	991943.98	728065.97	463.44	466.27	428.94	37.33	439.27	442.3
77	156	11/09/09	2	991964.30	728791.30	464.89	467.60	430.36	37.24	440.69	443.7
78	158	11/13/09	2	991945.43	729368.05	464.72	467.63	429.99	37.64	440.32	443.5
79	160	12/11/09	2	991884.45	729979.25	463.70	466.42	428.52	37.90	438.85	442.1
80	162	12/10/09	4	991801.20	730561.78	463.28	465.98	428.27	37.71	438.60	441.6
81	164	12/04/09	4	991871.12	731169.33	463.42	465.83	428.57	37.26	438.90	442.1
82	165	11/13/09	4	991660.67	727734.64	464.05	466.80	429.50	37.30	439.83	443.1
83	167	10/05/09	2	991646.82	728350.01	463.60	466.56	429.46	37.10	439.79	442.7
84	169	12/02/09	4	991653.97	729053.82	464.75	467.42	429.49	37.93	439.82	443.0

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No.	Piezometer ID	Date Drilled	Diameter (inches)[4]	Location[1] Northing	Easting	Ground Surf.[1] Elev. (feet)	Top of Casing[1] Elev. (feet)	Base of Well Elev. (feet)	Total Depth (feet, btoc)[2]	Top of Screen Elev. (feet)[3]	Top Primary Filter Pack Elev. (feet)[3]
85	171	12/02/09	2	991629.80	729636.72	463.97	466.87	429.17	37.70	439.50	442.6
86	173	12/12/09	2	991592.90	730278.01	463.40	466.33	428.42	37.91	438.75	441.4
87	175	12/15/09	2	991556.51	730873.59	463.57	466.06	428.27	37.79	438.60	443.0
88	177	11/13/09	2	991336.76	728049.81	464.07	466.87	429.71	37.16	440.04	442.7
89	179	12/03/09	2	991350.86	728780.92	464.19	466.93	428.96	37.97	439.29	443.2
90	181	12/03/09	2	991334.49	729380.23	464.42	467.35	429.85	37.50	440.18	443.1
91	183	12/11/09	2	991309.56	729980.89	463.40	465.96	428.24	37.72	438.57	441.9
92	185[5]	12/15/09	2	991289.70	730564.03	463.75	466.26	428.29	37.97	438.62	441.8
93	187	10/28/09	2	991308.51	731386.11	462.85	465.67	429.25	36.42	439.58	442.6
94	189	10/12/09	2	991059.00	728325.94	464.91	467.93	430.82	37.11	441.15	444.7
95	191	12/03/09	2	991032.57	729099.94	464.41	467.10	429.42	37.68	439.75	443.0
96	193	12/04/09	4	991026.43	729688.59	464.11	467.00	429.81	37.19	440.14	443.3
97	195	12/11/09	2	991065.81	730256.04	463.44	466.07	427.93	38.14	438.26	441.4
98	197	12/05/09	4	990891.95	730883.14	463.54	466.10	428.98	37.12	439.31	442.5
99	199	12/01/09	4	990738.72	728782.05	465.28	468.13	430.41	37.72	440.74	443.7
100	201[5]	12/01/09	2	990567.70	729279.14	464.65	467.08	429.55	38.16	439.88	443.7

1. Survey data completed December 30, 2009 by Kuhlmann design Group, Inc. (KdG).
2. btoc = below top of casing.
3. Refer to construction details provided in Appendix 5.
4. Four-inch (4") piezometers used for aquifer testing.
5. Top of Casing Measurements for P-185 & P-201 adjusted due to post-survey modifications to the piezometers; P-185 (-0.175 ft), P-201 (-0.395 ft).

NA = Information not available.

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Monthly Groundwater Monitoring Data
Table 3

Piez.	Date	Location		Ground	Top Casing	DATE OF MEASUREMENT																								Maximum
						December 21, 2009		January 25, 2010		February 16, 2010		March 16, 2010		April 13, 2010		May 11, 2010		June 8, 2010		July 7, 2010		August 5, 2010		September 8, 2010		October 7, 2010		November 4, 2010		Variability
ID	Drilled	Northing	Easting	Elev. (ft)	Elev. (ft)	Depth (ft)[1]	Elev. (ft)	Depth (ft)[1]	Elev. (ft)	Depth (ft)[1]	Elev. (ft)	Depth (ft)[1]	Elev. (ft)	Depth (ft)[1]	Elev. (ft)	Depth (ft)[1]	Elev. (ft)	Depth (ft)[1]	Elev. (ft)	Depth (ft)[1]	Elev. (ft)	Depth (ft)[1]	Elev. (ft)	Depth (ft)[1]	Elev. (ft)	Depth (ft)[1]	Elev. (ft)	Depth (ft)[1]	Elev. (ft)	(ft)
1	3/14/2007	996170	727590	470.7	473.92	16.42	457.50	15.72	458.20	15.40	458.52	12.00	461.92	10.67	463.25	12.06	461.86	9.49	464.43	9.46	464.46	10.95	462.97	13.74	460.18	11.73	462.19	15.31	458.61	6.96
2	3/12/2007	993371	728606	466.4	469.59	10.70	458.89	10.18	459.41	10.26	459.33	8.97	460.62	6.50	463.09	7.51	462.08	5.61	463.98	5.80	463.79	6.82	462.77	9.00	460.59	7.20	462.39	10.29	459.30	5.09
3	3/12/2007	990179	728523	466.1	469.85	9.67	460.18	8.77	461.08	9.46	460.39	8.69	461.16	6.52	463.33	7.29	462.56	5.91	463.94	6.35	463.50	6.98	462.87	8.63	461.22	6.98	462.87	9.85	460.00	3.94
9	10/20/09	996108.40	726981.78	469.90	473.26	16.83	456.43	14.44	458.82	15.34	457.92	11.14	462.12	10.00	463.26	11.64	461.62	8.69	464.57	8.66	464.60	10.30	462.96	13.46	459.80	11.28	461.98	15.15	458.11	8.17
12	09/16/09	996215.71	728171.12	468.95	472.14	14.33	457.81	14.20	457.94	13.44	458.70	11.94	460.20	8.99	463.15	10.39	461.75	7.95	464.19	7.95	464.19	9.36	462.78	12.05	460.09	9.99	462.15	13.43	458.71	6.38
15	09/17/09	995802.44	727271.36	469.35	472.40	15.23	457.17	13.77	458.63	14.02	458.38	11.12	461.28	9.08	463.32	10.64	461.76	7.91	464.49	7.99	464.41	9.35	463.05	12.37	460.03	10.25	462.15	13.94	458.46	7.32
17	09/16/09	995789.75	727851.61	469.30	472.19	14.38	457.81	13.86	458.33	13.49	458.70	11.67	460.52	8.96	463.23	10.35	461.84	8.03	464.16	7.96	464.23	9.30	462.89	11.98	460.21	9.96	462.23	13.44	458.75	6.42
19	10/16/09	995768.95	728438.40	467.90	470.84	12.44	458.40	12.75	458.09	11.88	458.96	11.03	459.81	7.73	463.11	8.99	461.85	6.75	464.09	6.81	464.03	8.07	462.77	10.60	460.24	8.56	462.28	11.85	458.99	6.00
20	09/17/09	995510.59	726856.24	469.35	472.28	15.26	457.02	13.34	458.94	13.95	458.33	10.74	461.54	8.89	463.39	10.47	461.81	7.62	464.66	7.79	464.49	9.22	463.06	12.22	460.06	10.09	462.19	13.85	458.43	7.64
22	10/07/09	995503.30	727579.54	468.40	471.27	13.57	457.70	12.68	458.59	12.63	458.64	10.47	460.80	8.01	463.26	9.44	461.83	6.87	464.40	6.75	464.52	8.36	462.91	11.16	460.11	9.02	462.25	12.52	458.75	6.82
24	09/16/09	995476.21	728133.29	468.50	471.44	13.17	458.27	13.10	458.34	12.50	458.94	11.22	460.22	8.27	463.17	9.58	461.86	7.28	464.16	7.33	464.11	8.60	462.84	11.13	460.31	9.11	462.33	12.48	458.96	5.89
27	09/17/09	995206.06	727247.55	469.07	471.99	14.36	457.63	13.08	458.91	13.31	458.68	10.88	461.11	8.60	463.39	10.07	461.92	7.43	464.56	7.66	464.33	8.95	463.04	11.81	460.18	9.67	462.32	13.30	458.69	6.93
29	09/15/09	995188.03	727844.69	467.73	470.83	12.74	458.09	12.07	458.76	11.95	458.88	10.17	460.66	7.62	463.21	8.91	461.92	6.50	464.33	6.69	464.14	7.93	462.90	10.54	460.29	8.53	462.30	11.92	458.91	6.24
31	10/12/09	994921.76	726950.89	467.67	470.22	12.57	457.65	11.11	459.11	11.43	458.79	9.00	461.22	6.78	463.44	8.26	461.96	5.65	464.57	5.84	464.38	7.15	463.07	9.95	460.27	7.84	462.38	11.45	458.77	6.92
33	09/14/09	994910.34	727559.71	468.44	471.18	13.16	458.02	12.10	459.08	12.29	458.89	10.31	460.87	7.90	463.28	9.22	461.96	6.79	464.39	6.71	464.47	8.20	462.98	10.84	460.34	8.80	462.38	12.27	458.91	6.45
35	09/15/09	994886.38	728125.58	467.61	470.61	12.16	458.45	11.76	458.85	11.58	459.03	10.21	460.40	5.53[3]	465.08	8.72	461.89	6.46	464.15	6.68	463.93	7.83	462.78	10.29	460.32	8.32	462.29	11.61	459.00	5.70
36	09/15/09	995058.28	728509.44	468.20	471.23	12.49	458.74	12.64	458.59	12.07	459.16	11.20	460.03	8.14	463.09	9.28	461.95	7.11	464.12	7.33	463.90	8.47	462.76	10.83	460.40	8.86	462.37	12.06	459.17	5.53
38	09/22/09	994618.74	727238.62	467.15	470.11	12.11	458.00	10.84	459.27	11.22	458.89	9.20	460.91	6.83	463.28	8.21	461.90	5.79	464.32	5.99	464.12	7.17	462.94	9.82	460.29	7.79	462.32	11.22	458.89	6.32
40	10/12/09	994582.15	727832.47	467.05	469.93	11.60	458.33	10.69	459.24	10.90	459.03	9.27	460.66	6.79	463.14	8.02	461.91	5.85	464.08	5.98	463.95	7.11	462.82	9.59	460.34	7.65	462.28	10.92	459.01	5.75
42	10/06/09	994538.42	728420.83	467.74	470.60	11.93	458.67	11.61	458.99	11.41	459.19	10.36	460.24	7.52	463.08	8.65	461.95	6.62	463.98	6.76	463.84	7.85	462.75	10.23	460.37	8.27	462.33	11.39	459.21	5.31
43	09/17/09	994333.02	726945.21	466.07	469.20	11.07	458.13	10.03	459.17	10.10	459.10	7.94	461.26	5.76	463.44	7.12	462.08	4.59	464.61	4.88	464.32	6.09	463.11	8.70	460.50	6.79	462.41	10.16	459.04	6.48
45	09/18/09	994324.97	727532.26	467.12	470.07	11.78	458.29	10.77	459.30	11.01	459.06	9.22	460.85	6.84	463.23	8.12	461.95	5.79	464.28	6.06	464.01	7.19	462.88	9.66	460.41	7.77	462.30	11.09	458.98	5.99
47	09/18/09	994320.66	728124.52	467.10	469.86	11.36	458.50	10.63	459.23	10.77	459.09	9.26	460.60	6.79	463.07	7.96	461.90	5.75	464.11	5.98	463.88	7.12	462.74	9.49	460.37	7.64	462.22	10.82	459.04	5.61
49	10/14/09	994499.84	728938.97	467.58	470.56	11.61	458.95	11.54	459.02	11.32	459.24	10.48	460.08	7.50	463.06	8.60	461.96	6.67	463.89	6.82	463.74	7.90	462.66	10.11	460.45	8.19	462.37	11.21	459.35	4.94
51	10/14/09	994463.37	729490.00	466.25	469.06	9.98	459.08	10.08	458.98	9.83	459.23	9.17	459.89	6.18	462.88	7.13	461.93	5.29	463.77	5.47	463.59	6.52	462.54	8.64	460.42	6.76	462.30	9.67	459.39	4.79
53	10/15/09	994428.21	730049.96	466.46	469.10	9.87	459.23	10.23	458.87	9.87	459.23	9.46	459.64	6.38	462.72	7.29	461.81	5.49	463.61	5.69	463.41	6.70	462.40	8.71	460.39	6.90	462.20	9.71	459.39	4.74
55	10/14/09	994395.43	730584.11	467.33	470.02	10.60	459.42	11.23	458.79	10.82	459.20	10.63	459.39	7.44	462.58	8.26	461.76	6.60	463.42	6.79	463.23	7.72	462.30	9.61	460.41	7.90	462.12	10.59	459.43	4.63
57	10/15/09	994356.77	731212.53	465.99	468.87	9.35	459.52	10.03	458.84	9.68	459.19	9.58	459.29	6.47	462.40	7.22	461.65	5.66	463.21	5.86	463.01	6.77	462.10	8.54	460.33	6.89	461.98	9.46	459.41	4.37
59	09/21/09	994039.34	727225.40	465.36	467.94	9.63	458.31	8.69	459.25	8.00[3]	459.94	6.88	461.06	4.65	463.29	5.92	462.02	3.50	464.44	3.88	464.06	4.95	462.99	7.48	460.46	5.61	462.33	8.91	459.03	6.13
61	10/26/09	994020.22	727813.31	465.92	468.87	10.42	458.45	9.50	459.37	9.71	459.16	8.02	460.85	5.68	463.19	6.85	462.02	4.63	464.24	4.82	464.05	5.98	462.89	8.36	460.51	7.64[3]	461.23	9.75	459.12	5.79
63	09/21/09	994004.98	728407.71	466.20	469.10	10.44	458.66	9.86	459.24	9.91	459.19	8.58	460.52	6.08	463.02	7.18	461.92	5.04	464.06	5.32	463.78	6.40	462.70	8.69	460.41	6.87	462.23	9.96	459.14	5.40
65	10/13/09	993990.81	729165.61	468.06	471.31	12.34	458.97	12.14	459.17	12.10	459.21	11.08	460.23	8.31	463.00	9.34	461.97	7.47	463.84	7.68	463.63	8.70	462.61	10.83	460.48	9.03	462.28	12.01	459.30	4.87
67	10/13/09	993985.65	729758.28	465.52	468.28	9.11	459.17	9.18	459.10	9.10	459.18	8.35	459.93	5.47	462.81	6.40	461.88	4.63	463.65	4.86	463.42	5.83	462.45	7.85	460.43	6.10	462.18	8.94	459.34	4.55
69	10/13/09	993965.46	730346.87	465.05	467.73	8.36	459.37	8.71	459.02	8.52	459.21	8.13	459.60	5.12	462.61	5.98	461.75	4.32	463.41	4.54	463.19	5.50	462.23	7.37	460.36	5.68	462.05	8.41	459.32	4.39
71	10/21/09	993948.36	730927.90	467.42	470.70	11.12	459.58	11.73	458.97	11.42	459.28	11.20	459.50	8.16	462.54	8.93	461.77	7.35	463.35	7.62	463.08	8.53	462.17	10.27	460.43	8.64	462.06	11.24	459.46	4.38
73	11/06/09	993742.59	726924.60	467.06	469.94	11.47	458.47	11.05	458.89	10.63	459.31	8.88	461.06	6.51	463.43	7.78	462.16	5.43	464.51	5.63	464.31	6.81	463.13	9.36	460.58	7.50	462.44	10.81	459.13	6.04
75	09/28/09	993730.50	727511.13	466.12	468.75	10.36	458.39	9.38	459.37	9.61	459.14	7.78	460.97	5.50	463.25	6.76	461.99	4.46	464.29	4.78	463.97	5.84	462.91	8.27	460.48	6.45	462.30	9.76	458.99	5.90
77	09/28/09	993714.81	728102.38	465.41	468.05	9.48	458.57	8.68	459.37	8.90	459.15	7.38	460.67	5.00	463.05	6.13	461.92	3.96	464.09	4.27	463.78	5.31	462.74	7.64	460.41	5.82	462.23	8.97	459.08	5.52
79	10/28/09	993695.02	728850.48	467.01	469.84	10.96	458.88	10.53	459.31	10.63	459.21	9.42	460.42	6.80	463.04	7.81	462.03	5.95	463.89	6.15	463.69	7.17	462.67	9.34	460.50	7.54	462.30	10.56	459.28	5.01
81	10/28/09	993679.30	729444.97	467.64	470.31	11.23	459.08	11.08	459.23	11.07	459.24	10.12	460.19	7.35	462.96	8.32	461.99	6.57	463.74	6.79	463.52	7.76	462.55	9.81	460.50	8.04	462.27	10.96	459.35	4.66
83	11/10/09	993664.23	730089.18	464.74	467.55	8.23	459.32	8.35	459.20	6.23[3]	461.32	7.65	459.90	4.76	462.79	5.63	461.92	3.96	463.59	4.21	463.34	5.15	462.40	7.05	460.50	5.33	462.22	8.10	459.45	4.39
85	11/10/09	993647.31	730619.20	464.41	466.75	7.24	459.51	7.64	459.11	7.47	459.28	7.10	459.65	4.13	462.62	4.94	461.81	3.35	463.40	3.60	463.15	4.51	462.24	6.31	460.44	4.64	462.11	7.28	459.47	4.29
87	10/26/09	993693.54	731420.88	466.69	469.64	9.99	459.65	10.56	459.08	10.37	459.27	10.26	459.38	7.31	462.33	8.03	461.61	6.57	463.07	6.83	462.81	7.67	461.97	9.36	460.28	7.74	461.90	10.21	459.43	3.99
88	11/06/09	993401.94	727072.92	466.25	469.13	10.60	458.53	10.09	459.04	9.84	459.29	8.12	461.01	5.81	463.32	6.75	462.38	4.74	464.39	4.95	464.18	6.12	463.01	8.61	460.52	6.80	462.33	10.06	459.07	5.86
90	09/28/09	993427.80	727804.04	465.38	468.10	9.60	458.50	8.68	459.42	8.88	459.22	7.16	460.94	4.89	463.21	6.04	462.06	3.81	464.29	4.15	463.95	5.19	462.91	7.56	460.54	5.75	462.35	8.92	459.18	5.79
93	10/20/09	993388.35	729062.32	465.91	468.82	9.80	459.02	9.45	459.37	9.50	459.32	8.52	460.30	5.89	462.93	6.85	461.97	5.06	463.76	5.26	463.56	6.24	462.58	8.34	460.48	6.58	462.24	9.54	459.28	4.74
95	10/20/09	993368.45	729725.06	467.22	469.92	10.67	459.25	10.62	459.30	10.55	459.37	9.82	460.10	7.10	462.82	7.99	461.93	6.30	463.62	6.52	463.40	7.45	462.47	9.40	460.52	7.69	462.23	10.55	459.37	4.37
97	10/21/09	993349.44	730302.43	467.05	469.67	10.24	459.43	10.41	459.26	10.34	459.33	9.85	459.82	6.98	462.69	7.81	461.86	6.27	463.40	6.46	463.21	7.36	462.31	9.20	460.47	7.51	462.16	10.25	459.42	4.14
99	10/21/09	993336.45	730887.27	464.38	467.21	7.60	459.61	7.98	459.23	7.87	459.34	7.61	459.60	4.70	462.51	5.45	461.76	4.00	463.21	4.22	462.99	5.10	462.11	6.82	460.39	5.17	462.04	7.74	459.47	3.98
102	09/29/09	993140.49	727503.68	464.29	467.27	8.75	458.52	7.86	459.41	8.03	459.24	6.10	461.17	3.97	463.30	5.16	462.11	2.85	464.42	3.19	464.08	4.28	462.99	6.69	460.58	4.87	462.40	8.09	459.18	5.90
104	10/05/09	993125.75	728085.40	465.00	467.78	9.08	458.70	8.37	459.41	8.57	459.21	7.04	460.74	4.71	463.07	5.81	461.97	3.65	464.13	3.97	463.81	5.00	462.78	7.29	460.49	5.52	462.26	8.63	459.15	5.43
106	10/29/09	993103.56	728837.82	465.11	468.10	9.09	459.01	8.59	459.51	8.78	459.32	7.70	460.40	5.12	462.98	6.11	461.99	4.32	463.78	4.52	463.58	5.48	462.62	7.60	460.50	5.85	462.25	8.82	459.28	4.77
108	11/04/09	993084.09	729427.93	465.71	468.55	9.33	459.22	9.04	459.51	9.19	459.36	8.40	460.15	5.72	462.83	6.61	461.94	4.94	463.61	5.16	463.39	5.67	462.88	8.08	460.47	6.35	462.20	9.24	459.31	4.39
110	11/04/09	993066.85	730012.30	466.14	468.99	9.60	459.39	9.54	459.45	9.64	459.35	9.00	459.99	6.26	462.73	7.10	461.89	5.53	463.46	5.72	463.27	6.63	462.36	8.52	460.47	6.83	462.16	9.61	459.38	4.11
112	11/04/09	993051.48	730620.74	465.92	468.92	9.33	459.59	9.47	459.45	9.58	459.34	9.23	459.69	6.40	462.52	7.20	461.72	5.73	463.19	5.94	462.98	6.79	462.13	8.54	460.38	6.91	462.01	9.53	459.39	3.85
114	11/12/09	993026.22	731203.72	463.94	466.78	7.10	459.68	7.35	459.43	7.43	459.35	7.20	459.58	4.35	462.43	5.05	461.73	3.71	463.07	3.93	462.85	4.72	462.06	6.37	460.41	4.77	462.01	7.27	459.51	3.72
116	09/29/09	992841.30	727788.60	464.82	467.55	8.86	458.69	8.00	459.55	8.24	459.31	6.49	461.06	4.27	463.28	5.41	462.14	3.23	464.32	3.65	463.90	4.58	462.97	6.91	460.64	5.12	462.43	8.26	459.29	5.63
118	09/29/09	992825.03	728377.28	464.81	467.70	8.81	458.89	8.18	459.52	8.41	459.29	7.11	460.59	4.71	462.99	5.73	461.97	3.82	463.88	4.09	463.61	5.00	462.70	7.20	460.50	5.45	462.25	8.49	459.21	4.99
120	10/22/09	992787.68	729145.90	464.75	467.65	8.52	459.13	8.10	459.55	8.24	459.41	7.28	460.37	4.70	462.95	5.66	461.99	3.86	463.79	4.32	463.33	5.05	462.60	7.08	460.57	5.36	462.29	8.28	459.37	4.66

Detailed Site Investigation
Proposed Utility Waste Disposal Area
Ameren Missouri Labadie Power Plant
Franklin County, Missouri

Monthly Groundwater Monitoring Data
Table 3

Piez. ID	Date Drilled	Location Northing	Location Easting	Ground Elev. (ft)	Top Casing Elev. (ft)	December 21, 2009 Depth (ft)[1]	December 21, 2009 Elev. (ft)	January 25, 2010 Depth (ft)[1]	January 25, 2010 Elev. (ft)	February 16, 2010 Depth (ft)[1]	February 16, 2010 Elev. (ft)	March 16, 2010 Depth (ft)[1]	March 16, 2010 Elev. (ft)	April 13, 2010 Depth (ft)[1]	April 13, 2010 Elev. (ft)	May 11, 2010 Depth (ft)[1]	May 11, 2010 Elev. (ft)	June 8, 2010 Depth (ft)[1]	June 8, 2010 Elev. (ft)	July 7, 2010 Depth (ft)[1]	July 7, 2010 Elev. (ft)	August 5, 2010 Depth (ft)[1]	August 5, 2010 Elev. (ft)	September 8, 2010 Depth (ft)[1]	September 8, 2010 Elev. (ft)	October 7, 2010 Depth (ft)[1]	October 7, 2010 Elev. (ft)	November 4, 2010 Depth (ft)[1]	November 4, 2010 Elev. (ft)	Maximum Variability (ft)
122	11/10/09	992758.84	729781.01	464.74	467.71	8.40	459.31	8.16	459.55	8.30	459.41	7.61	460.10	4.95	462.76	5.81	461.90	4.04	463.67	4.44	463.27	5.29	462.42	7.22	460.49	5.51	462.20	8.34	459.37	4.36
124	11/11/09	992775.57	730303.49	464.92	467.99	8.51	459.48	8.50	459.49	8.65	459.34	8.07	459.92	5.37	462.62	6.16	461.83	4.60	463.39	4.90	463.09	5.72	462.27	7.55	460.44	5.88	462.11	8.59	459.40	4.05
126	11/11/09	992667.51	730879.77	465.77	468.83	9.12	459.71	9.24	459.59	9.40	459.43	9.05	459.78	6.33	462.50	7.05	461.78	5.70	463.13	5.91	462.92	6.67	462.16	8.39	460.44	6.78	462.05	9.33	459.50	3.70
128	11/07/09	992561.87	727385.52	465.74	468.60	9.91	458.69	9.03	459.57	9.22	459.38	7.39	461.21	5.21	463.39	6.38	462.22	4.20	464.40	4.43	464.17	5.51	463.09	7.91	460.69	6.11	462.49	9.33	459.27	5.71
130	09/30/09	992537.68	728075.04	465.15	468.13	9.26	458.87	8.51	459.62	8.72	459.41	7.23	460.90	4.93	463.20	5.99	462.14	4.04	464.09	4.28	463.85	5.23	462.90	7.46	460.67	5.70	462.43	8.81	459.32	5.22
132	10/15/09	992536.17	728817.00	465.36	468.47	9.35	459.12	8.86	459.61	9.10	459.37	9.00[3]	459.47	5.51	462.96	6.50	461.97	4.66	463.81	4.94	463.53	5.88	462.59	7.94	460.53	6.20	462.27	9.20	459.27	4.69
134	11/10/09	992491.31	729438.21	464.10	466.82	7.51	459.31	7.20	459.62	7.35	459.47	6.52	460.30	3.94	462.88	4.83	461.99	3.13	463.69	3.41	463.41	4.28	462.54	6.26	460.56	4.55	462.27	7.42	459.40	4.38
136	11/11/09	992488.64	730004.49	463.71	466.73	7.20	459.53	7.06	459.67	7.28	459.45	6.65	460.08	4.00	462.73	4.75	461.98	3.25	463.48	3.53	463.20	4.31	462.42	6.18	460.55	4.56	462.17	7.25	459.48	4.03
138	11/12/09	992469.33	730675.26	464.10	466.99	7.23	459.76	7.28	459.71	7.51	459.48	7.09	459.90	4.42	462.57	5.11	461.88	3.70	463.29	4.01	462.98	4.74	462.25	6.49	460.50	4.84	462.15	7.45	459.54	3.81
140	10/27/09	992404.70	731394.93	465.72	468.57	8.69	459.88	8.82	459.75	9.04	459.53	8.95	459.62	6.33	462.24	6.92	461.65	5.67	462.90	5.98	462.59	6.61	461.96	8.22	460.35	6.65	461.92	9.07	459.50	3.40
142	11/06/09	992250.72	727764.69	464.83	467.66	8.79	458.87	7.90	459.76	8.20	459.46	6.58	461.08	4.39	463.27	5.48	462.18	3.46	464.20	3.63	464.03	4.70	462.96	6.99	460.67	5.20	462.46	8.38	459.28	5.33
144	09/30/09	992236.95	728361.22	464.56	467.74	8.65	459.09	8.00	459.74	8.24	459.50	7.00	460.74	4.63	463.11	5.61	462.13	3.83	463.91	4.00	463.74	4.93	462.81	7.05	460.69	5.30	462.44	8.34	459.40	4.82
146	11/09/09	992265.54	729102.62	464.80	467.48	8.20	459.28	7.77	459.71	8.02	459.46	7.09	460.39	4.55	462.93	5.51	461.97	3.79	463.69	4.07	463.41	4.92	462.56	6.92	460.56	5.21	462.27	8.13	459.35	4.41
148	11/09/09	992252.64	729630.10	463.86	466.84	7.40	459.44	7.10	459.74	7.30	459.54	6.51	460.33	3.96	462.88	4.82	462.02	3.21	463.63	3.51	463.33	4.26	462.58	6.22	460.62	4.52	462.32	7.36	459.48	4.19
150	11/14/09	992189.21	730256.27	463.22	465.91	6.17	459.74	6.01	459.90	6.34	459.57	5.85	460.06	3.18	462.73	3.94	461.97	2.50	463.41	2.81	463.10	3.51	462.40	5.32	460.59	3.62	462.29	6.36	459.55	3.86
152	11/12/09	992168.58	730889.93	463.55	466.31	6.32	459.99	6.29	460.02	6.68	459.63	6.45	459.86	3.89	462.42	4.43	461.88	3.18	463.13	3.55	462.76	4.14	462.17	5.81	460.50	4.17	462.14	6.70	459.61	3.52
155	09/30/09	991943.98	728065.97	463.44	466.27	7.20	459.07	6.36	459.91	6.76	459.51	5.34	460.93	3.12	463.15	4.14	462.13	2.30	463.97	2.46	463.81	3.42	462.85	5.59	460.68	3.83	462.44	6.93	459.34	4.90
156	11/09/09	991964.30	728791.30	464.89	467.60	8.30	459.30	7.75	459.85	8.03	459.57	7.00	460.60	4.55	463.05	5.48	462.12	3.88	463.72	4.07	463.53	4.88	462.72	6.91	460.69	5.20	462.40	8.16	459.44	4.42
158	11/13/09	991945.43	729368.05	464.72	467.63	8.13	459.50	7.76	459.87	8.04	459.59	7.27	460.36	4.74	462.89	5.57	462.06	4.12	463.51	4.27	463.36	5.06	462.57	6.98	460.65	5.30	462.33	8.16	459.47	4.04
160	12/11/09	991884.45	729979.25	463.70	466.42	6.67	459.75	6.33	460.09	6.78	459.64	6.30	460.12	3.68	462.74	4.35	462.07	NM[2]	NM[2]	3.31	463.11	3.90	462.52	5.77	460.65	4.02	462.40	6.82	459.60	3.51
162	12/10/09	991801.20	730561.78	463.28	465.98	6.00	459.98	5.79	460.19	6.72[3]	459.26	6.00	459.98	3.48	462.50	4.00	461.98	2.91	463.07	3.15	462.83	3.67	462.31	5.73	460.25	3.73	462.25	6.30	459.68	3.39
164	12/04/09	991871.12	731169.33	463.42	465.83	5.80	460.03	5.63	460.20	6.13	459.70	5.62	460.21	3.50	462.33	3.97	461.86	2.97	462.86	3.17	462.66	3.67	462.16	5.33	460.50	3.73	462.10	6.16	459.67	3.19
165	11/13/09	991660.67	727734.64	464.05	466.80	7.73	459.07	6.74	460.06	7.14	459.66	5.49	461.31	3.36	463.44	4.42	462.38	2.47	464.33	2.76	464.04	3.66	463.14	5.90	460.90	4.14	462.66	7.30	459.50	5.26
167	10/05/09	991646.82	728350.01	463.60	466.56	7.23	459.33	6.48	460.08	6.92	459.64	5.77	460.79	3.48	463.08	4.40	462.16	2.74	463.82	2.93	463.63	3.77	462.79	5.82	460.74	4.11	462.45	7.13	459.43	4.49
169	12/02/09	991653.97	729053.82	464.75	467.42	7.92	459.50	7.36	460.06	7.13[3]	460.29	6.93	460.49	4.46	462.96	5.28	462.14	3.80	463.62	3.97	463.45	4.76	462.66	6.69	460.73	5.00	462.42	7.92	459.50	4.12
171	12/02/09	991629.80	729636.72	463.97	466.87	7.09	459.78	6.72	460.15	7.15	459.72	6.63	460.24	4.10	462.77	4.80	462.07	3.49	463.38	3.62	463.25	4.36	462.51	6.17	460.70	4.50	462.37	7.30	459.57	3.81
173	12/12/09	991592.90	730278.01	463.40	466.33	6.35	459.98	6.01	460.32	6.59	459.74	6.31	460.02	3.71	462.62	4.30	462.03	3.18	463.15	3.41	462.92	3.94	462.39	5.71	460.62	4.02	462.31	6.66	459.67	3.48
175	12/15/09	991556.51	730873.59	463.57	466.06	5.98	460.08	5.79	460.27	6.32	459.74	6.13	459.93	3.64	462.42	4.12	461.94	3.08	462.98	3.32	462.74	3.83	462.23	5.49	460.57	3.97	462.09	6.36	459.70	3.28
177	11/13/09	991336.76	728049.81	464.07	466.87	7.47	459.40	6.59	460.28	7.04	459.83	5.74	461.13	3.53	463.34	4.47	462.40	2.77	464.10	2.95	463.92	3.83	463.04	5.91	460.96	4.19	462.68	7.27	459.60	4.70
179	12/03/09	991350.86	728780.92	464.19	466.93	7.37	459.56	6.69	460.24	7.14	459.79	6.24	460.69	3.89	463.04	4.74	462.19	3.24	463.69	3.43	463.50	4.17	462.76	6.13	460.80	4.45	462.48	7.39	459.54	4.15
181	12/03/09	991334.49	729380.23	464.42	467.35	7.61	459.74	7.09	460.26	7.52	459.83	6.87	460.48	4.44	462.91	5.18	462.17	3.80	463.55	4.03	463.32	4.71	462.64	6.56	460.79	4.89	462.46	7.73	459.62	3.93
183	12/11/09	991309.56	729980.89	463.40	465.96	5.86	460.10	5.44	460.52	6.15	459.81	5.76	460.20	3.28	462.68	3.92	462.04	2.81	463.15	2.98	462.98	3.49	462.47	5.19	460.77	3.52	462.44	6.22	459.74	3.41
185	12/15/09	991289.70	730564.03	463.75	466.26	6.17	460.09	5.83	460.43	6.46	459.80	6.25	460.01	3.77	462.49	4.26	462.00	3.18	463.08	3.47	462.79	3.95	462.31	5.65	460.61	3.98	462.28	6.54	459.72	3.36
187	10/28/09	991308.51	731386.11	462.85	465.67	5.46	460.21	5.30	460.37	5.91	459.76	5.83	459.84	3.43	462.24	3.81	461.86	2.85	462.82	3.15	462.52	3.58	462.09	5.13	460.54	3.56	462.11	5.91	459.76	3.06
189	10/12/09	991059.00	728325.94	464.91	467.93	8.37	459.56	7.57	460.36	8.11	459.82	7.02	460.91	4.77	463.16	5.66	462.27	4.07	463.86	4.32	463.61	5.07	462.86	7.05	460.88	5.36	462.57	8.35	459.58	4.30
191	12/03/09	991032.57	729099.94	464.41	467.10	7.37	459.73	6.71	460.39	7.25	459.85	6.45	460.65	4.10	463.00	4.89	462.21	3.46	463.64	3.72	463.38	4.37	462.73	6.26	460.84	4.59	462.51	7.49	459.61	4.03
193	12/04/09	991026.43	729688.59	464.11	467.00	6.93	460.07	6.44	460.56	7.05	459.95	6.58	460.42	4.16	462.84	4.82	462.18	3.64	463.36	3.87	463.13	4.41	462.59	6.14	460.86	4.51	462.49	7.24	459.76	3.60
195	12/11/09	991065.81	730256.04	463.44	466.07	5.91	460.16	5.49	460.58	6.19	459.88	5.91	460.16	3.46	462.61	3.97	462.10	2.90	463.17	3.20	462.87	3.65	462.42	5.35	460.72	3.69	462.38	6.29	459.78	3.39
197	12/05/09	990891.95	730883.14	463.54	466.10	5.73	460.37	5.33	460.77	6.23	459.87	6.04	460.06	3.69	462.41	4.05	462.05	3.12	462.98	3.53	462.57	3.56	462.54	5.51	460.59	3.87	462.23	6.29	459.81	3.17
199	12/01/09	990738.72	728782.05	465.28	468.13	8.39	459.74	7.65	460.48	8.18	459.95	7.29	460.84	4.98	463.15	5.82	462.31	4.34	463.79	4.60	463.53	5.29	462.84	7.17	460.96	5.49	462.64	8.41	459.72	4.07
201	12/01/09	990567.70	729279.14	464.65	467.08	7.12	459.96	6.46	460.62	7.06	460.02	6.36	460.72	4.02	463.06	4.80	462.28	3.47	463.61	3.69	463.39	4.32	462.76	6.11	460.97	4.44	462.64	7.26	459.82	3.79
					Monthly Variability (ft)		3.94		3.14		2.47		2.83		1.20		0.95		1.84		2.08		1.18		1.42		0.78		1.89	

Note: High and low piezometer elevation values for each month are shaded.

1. Depth measurements are in feet below top of casing (btoc).
2. NM = Well could not be accessed. No measurement.
3. Suspected measurement error. Value not considered in report.

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Supplemental Groundwater Monitoring Data[1]
Table 4

			DATE OF MEASUREMENT									
Piez.	Ground	Top Casing	April 28, 2010		April 30, 2010		May 3, 2010	May 18, 2010		June 15, 2010	June 21, 2010	June 23, 2010
ID	Elev. (ft)	Elev. (ft)	Depth (ft)[2]	Elev. (ft)	Depth (ft)[2]	Elev. (ft)	Elev. (ft)	Depth (ft)[2]	Elev. (ft)	Elev. (ft)	Elev. (ft)	Elev. (ft)
1	470.7	473.92	10.42	463.50	10.08	463.84	463.07	5.66	468.26	466.87	467.31	467.10
2	466.4	469.59	6.65	462.94	6.20	463.39	462.90	3.82	465.77	465.35	465.34	465.22
3	466.1	469.85	6.49	463.36	6.25	463.60	463.28	5.09	464.76	464.77	464.50	464.30
9	469.90	473.26	8.84	464.42	8.85	464.41	463.19	4.39	468.87	467.49	467.94	467.60
12	468.95	472.14	9.00	463.14	8.53	463.61	462.96	4.36	467.78	466.49	466.81	466.64
22	468.40	471.27	8.07	463.20	7.52	463.75	463.04	3.74	467.53	466.43	466.62	466.48
38	467.15	470.11	6.94	463.17	6.33	463.78	463.13	3.16	466.95	466.15	466.23	466.11
42	467.74	470.60	7.89	462.71	7.53	463.07	462.87	4.23	466.37	465.61	465.60	465.49
53	466.46	469.10	6.86	462.24	6.36	462.74	462.53	3.55	465.55	464.94	464.88	464.78
57	465.99	468.87	7.05	461.82	6.53	462.34	462.19	3.88	464.99	464.36	464.27	464.22
87	466.69	469.64	7.85	461.79	7.51	462.13	462.09	5.15	464.49	464.2	463.95	463.88
118	464.81	467.70	4.77	462.93	4.38	463.32	462.81	2.39	465.31	465.06	465.04	464.94
128	465.74	468.60	4.99	463.61	4.65	463.95	463.25	2.67	465.93	465.73	465.69	465.63
140	465.72	468.57	6.66	461.91	6.45	462.12	462.09	4.79	463.78	463.75	463.52	463.44
167	463.60	466.56	3.54	463.02	3.21	463.35	462.97	1.92	464.64	464.66	464.56	464.49
187	462.85	465.67	3.52	462.15	3.45	462.22	462.25	2.21	463.46	463.64	463.35	463.30
199	465.28	468.13	5.08	463.05	4.80	463.33	463.00	3.65	464.48	464.65	464.38	464.27

1. Supplemental data provided by Reitz & Jens, Inc.

2. Depth measurements unavailable for May 3, June 15, June 21, and June 23, 2010 events.

Note: Depth measurements are in feet below top of casing (btoc).

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Precipitation Summary[1]
Table 5

Year	2009				2010										
Month[2]	September	October	November	December	January	February	March	April	May	June	July	August	September	October	November[3]
Day	ppt (in.)	ppt (in.)	ppt (in.)	ppt (in.)	ppt (in.)	ppt (in.)	ppt (in.)	ppt (in.)	ppt (in.)	ppt (in.)	ppt (in.)	ppt (in.)	ppt (in.)	ppt (in.)	ppt (in.)
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.70	0.00	0.00	Tr	0.00	0.00
2	0.00	1.55	0.00	0.00	Tr	0.00	0.00	0.00	0.13	0.18	0.00	0.00	0.22	0.00	0.00
3	0.00	0.03	0.00	0.13	0.00	0.00	0.00	0.70	Tr	0.65	0.00	0.00	1.15	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
5	0.30	0.00	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.00	0.00	0.48	0.00	0.00	0.00
6	0.70	0.05	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.42	0.55	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.91	0.00	0.00	0.00	Tr	0.00	0.00	0.00	0.00	0.50	0.00	0.03	0.00	0.00
9	0.00	3.20	0.00	0.70	0.00	0.01	0.14	0.00	0.00	0.30	1.60	0.00	0.00	0.00	0.00
10	0.00	0.20	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	1.60	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.35	0.00	0.00	0.00	0.60	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.35	0.00	0.10	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	1.20	0.00	0.00	0.24	0.00	0.10	0.20	0.00	0.00	0.00	0.00	0.00
14	0.00	1.25	0.00	0.00	0.00	0.02	0.16	0.00	0.40	0.00	0.00	0.60	0.00	0.00	0.00
15	0.00	0.50	0.00	0.00	0.00	0.14	0.16	0.00	0.80	0.32	0.00	0.00	0.05	0.00	0.00
16	0.00	0.10	0.80	0.00	0.00	0.06	0.00	0.00	0.00	0.55	0.00	0.00	0.30	0.00	0.00
17	0.00	Tr	0.90	0.00	0.00	0.00	0.00	0.10	0.38	0.80	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.75	0.00	0.00	0.00	0.00	0.00	Tr	0.70	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.03	0.25	0.00	0.00	0.00	0.00	0.00	0.20	0.42	0.00	2.10	0.00	0.00
20	0.65	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.50	0.00	0.26	0.60	0.43	0.00	0.00
21	0.12	0.00	0.00	0.00	0.01	0.20	0.08	0.00	0.45	0.00	0.50	2.10	0.00	0.00	0.00
22	0.95	0.00	0.00	0.00	0.51	0.80	0.24	0.00	0.02	0.00	0.10	Tr	0.06	0.00	0.00
23	Tr	2.00	0.00	0.55	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00
24	0.14	0.00	0.00	0.15	1.15	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.28	0.00	0.00
25	0.22	0.00	0.28	1.20	0.10	0.00	0.18	0.75	0.00	0.00	0.30	0.00	0.00	0.25	0.00
26	0.00	0.70	0.00	0.00	0.04	0.00	0.75	0.42	0.00	0.00	0.00	0.00	0.04	0.2	0.00
27	0.30	0.24	0.00	0.02	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	Tr	0.00
28	0.02	0.70	0.00	0.01	Tr	0.00	0.20	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.06	0.00	0.00	0.00		0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	2.80	0.00	0.05	0.22		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31		0.25		0.00	0.00		0.00		0.00		1.05	0.00		0.00	
Totals	**3.82**	**15.09**	**2.76**	**4.26**	**2.47**	**2.19**	**3.05**	**2.54**	**4.92**	**5.60**	**4.83**	**3.78**	**6.94**	**0.45**	**0.00**

1. Precipitation data obtained from Labadie Power Plant recording station.
2. Snowfall during the months of December, January, and February converted to melt water equivalent using chart provided by NOAA at www.ncdc.noaa.gov/oa/climate/conversion/newsnowfall.html.
3. November precipitation data only extends through the date of final water level monitoring event conducted on November 4, 2010.

Detailed Site Investigation
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Aquifer Test Data Summary
Table 6

Piezometer ID	Date Drilled	Total Depth (BTOC)	Csg Dia. (in)	Screen Slot Size (inches)	Screen Interval Elev. (feet)	Filter Sand Hgt (feet)	Aquifer Test Date	Initial SWL (BTOC)	Pump Rate[1] (gpm)	Maximum Drawdown (feet)	Time to Recover 90% (sec)	Hydraulic Conductivity (K) (ft/min)	Geologic Monitoring Horizon[2]	Principal Sediment	Mean Grain Size[3] dia. (mm)	Mean Grain Size[3] Class.
P-9	10/20/09	37.97	4	0.02	445.62-435.29	15.5	12/14/09	15.60	10.0	0.41	5.0	0.0556	Flood Plain-Channel	Fine-Coarse Sand	0.1764-0.4000	F_l to M_u
P-19	10/16/09	37.33	4	0.01	443.84-433.51	14.9	12/14/09	11.43	10.0	0.52	5.5	0.0464	Flood Plain-Channel	Fine-Gravelly Sand	0.2098-0.9836	F_u to C_u
P-22	10/07/09	37.50	4	0.02	444.10-430.77	13.5	12/14/09	12.36	10.0	0.34	5.0	0.0632	Flood Plain-Channel	Fine-Coarse Sand	0.2016-0.5093	F_u to C_l
P-31	10/12/09	37.09	4	0.01	443.46-433.13	15.0	12/14/09	11.23	10.0	0.59	7.0	0.0448	Backswamp-Channel Margin	Silty Sand-Coarse Sand	0.1342-0.4940	F_l to M_u
P-42	10/06/09	37.40	4	0.02	443.53-433.20	14.8	12/14/09	10.52	10.0	0.76	7.5	0.0456	Channel	Coarse Sand	0.4056-0.5032	M_u to C_l
P-53	10/15/09	37.10	4	0.01	442.33-432.00	15.0	10/29/09	7.57	16.0	2.51	15.5	0.0244	Backswamp-Floodplain	Silty Sand-Medium Sand	0.2205-0.2971	F_u to M_l
P-57	10/15/09	37.28	4	0.01	441.92-431.59	15.4	10/29/09	7.71	16.0	0.95	8.5	0.0474	Channel	Medium-Coarse Sand	0.4654-0.7467	M_u to C_l
P-61	10/26/09	37.53	4	0.02	441.67-431.34	14.7	12/15/09	9.43	9.8	0.49	6.0	0.0570	Channel Margin-Channel	Medium-Coarse Sand	0.2905-0.7553	M_l to C_u
P-73	11/05/09	36.84	4	0.02	443.43-433.10	14.7	12/15/09	10.62	9.8	0.42	4.0	0.0947	Flood Plain-Channel	Fine-Coarse Sand	0.2148-0.3655	F_u to M_l
P-81	10/28/09	37.43	4	0.02	443.21-432.88	14.8	12/15/09	10.27	17.5	0.63	6.0	0.0718	Flood Plain-Channel	Medium Sand	0.3711-0.6661	M_l to C_u
P-85	11/10/09	36.71	4	0.01	440.37-430.04	15.3	12/14/09	5.95	10.7	0.36	5.0	0.0774	Flood Plain-Channel	Very Fine Sand-Sandy Gravel	0.1998-0.2701	F_u to M_l
P-104	10/05/09	37.34	4	0.02	440.77-430.44	15.0	12/14/09	7.62	10.0	0.86	9.0	0.0427	Flood Plain	Very Fine-Fine Sand	0.1451-0.2279	F_l to F_u
P-114	11/12/09	37.54	4	0.01	439.57-429.24	14.7	12/14/09	5.64	10.0	0.55	7.0	0.0572	Channel	Gravelly Sand	0.2822-0.6890	M_l to C_l
P-120	10/22/09	37.39	4	0.02	440.59-430.26	15.2	12/14/09	6.94	10.0	0.50	6.5	0.0559	Flood Plain-Channel Margin	Fine-Coarse Sand	0.1690-0.2918	F_l to M_l
P-126	11/11/09	36.87	4	0.01	442.29-431.96	15.2	12/14/09	7.62	10.0	1.23	12.0	0.0335	Flood Plain-Channel Margin	Very Fine-Medium Sand	0.1318-0.1817	F_l
P-128	11/07/09	37.39	4	0.02	441.54-431.21	15.2	12/15/09	8.96	10.0	0.73	8.0	0.0447	Channel Margin-Channel	Medium Sand	0.2075-0.3569	F_u to M_l
P-136	11/11/09	37.63	4	0.01	439.43-429.10	14.7	12/15/09	6.12	17.5	2.58	20.0	0.0223	Backswamp-Channel	Medium Sand	0.2163-0.4684	F_u to M_u
P-144	09/30/09	37.52	4	0.02	440.55-430.22	14.7	12/14/09	7.02	10.7	0.78	8.0	0.0424	Backswamp-Channel	Fine-Coarse Sand	0.1178-0.5233	VF_u to C_l
P-162	12/10/09	37.71	4	0.01	438.60-428.27	15.1	12/16/09	5.03	17.5	1.46	10.5	0.0371	Flood Plain-Channel	Very Fine-Gravelly Sand	0.1685-0.2298	F_l
P-164	12/04/09	37.26	4	0.02	438.90-428.57	15.5	12/16/09	4.87	17.5	0.39	4.0	0.0820	Backswamp-Channel	Very Fine-Gravelly Sand	0.1126-0.9842	VF_u to C_u
P-165	11/13/09	37.30	4	0.02	439.83-429.50	15.1	12/15/09	6.60	10.0	0.39	4.0	0.0725	Channel	Coarse-Gravelly Sand	0.5684-0.6033	C_l
P-169	12/02/09	37.93	4	0.01	439.82-429.49	15.5	12/16/09	7.03	17.5	2.10	16.5	0.0215	Flood Plain	Very Fine-Fine Sand	0.1990-0.2151	F_u
P-193	12/04/09	37.19	4	0.02	440.14-429.81	15.5	12/16/09	6.01	17.5	1.98	12.0	0.0259	Backswamp-Channel Margin	Very Fine-Medium Sand	0.1875-0.2585	F_u to M_l
P-197	12/05/09	37.12	4	0.02	439.31-428.98	15.4	12/16/09	4.85	17.5	2.14	14.5	0.0215	Flood Plain-Channel Margin	Fine-Medium Sand	0.2005-0.2448	F_u
P-199	12/01/09	37.72	4	0.01	440.74-430.41	15.1	12/16/09	7.40	17.5	1.08	7.5	0.0385	Backswamp-Channel	Very Fine-Coarse Sand	0.1830-0.3506	F_l to M_l
											Mean Value[4]	4.512E-02				

1. Pump rate sustained for @5 minutes (see also Appendix 9).
2. Terminology explained in Section 5.1 of Report.
3. Sieve analysis performed by Reitz & Jens, Inc. See Appendix 2 for additional data.
4. Geometric Mean.

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Aquifer Test Calculations
Table 7

Piezometer ID	Effective Radius of Wellbore[1] r_w (feet)	Water Column Hgt[2] l (feet)	Distance from SWL to Top Well Screen d (feet)	Effective Radius of Well Casing[3] r_c (feet)	Radius of Influence R (feet)	Time Lag t_L (sec)	Calculated Hydraulic Conductivity[4] K (ft/sec)	K (ft/min)	K (cm/sec)
P-9	0.427	22.37	12.04	0.165	3.0	2.8	9.264E-04	5.558E-02	2.824E-02
P-19	0.427	25.90	15.57	0.165	3.1	3.4	7.737E-04	4.642E-02	2.358E-02
P-22	0.427	25.14	14.81	0.165	3.1	2.5	1.054E-03	6.324E-02	3.213E-02
P-31	0.427	25.86	15.53	0.165	3.1	3.5	7.470E-04	4.482E-02	2.277E-02
P-42	0.427	26.88	16.55	0.165	3.1	3.5	7.601E-04	4.561E-02	2.317E-02
P-53	0.427	29.53	19.20	0.165	3.2	6.6	4.073E-04	2.444E-02	1.242E-02
P-57	0.427	29.57	19.24	0.165	3.2	3.4	7.895E-04	4.737E-02	2.406E-02
P-61	0.427	28.10	17.77	0.165	3.2	2.8	9.491E-04	5.695E-02	2.893E-02
P-73	0.427	26.22	15.89	0.165	3.1	1.7	1.578E-03	9.470E-02	4.811E-02
P-81	0.427	27.16	16.83	0.165	3.2	2.2	1.197E-03	7.184E-02	3.650E-02
P-85	0.427	30.76	20.43	0.165	3.3	2.1	1.291E-03	7.744E-02	3.934E-02
P-104	0.427	29.72	19.39	0.165	3.2	3.8	7.121E-04	4.273E-02	2.171E-02
P-114	0.427	31.90	21.57	0.165	3.3	2.8	9.540E-04	5.724E-02	2.908E-02
P-120	0.427	30.45	20.12	0.165	3.3	2.9	9.308E-04	5.585E-02	2.837E-02
P-126	0.427	29.25	18.92	0.165	3.2	4.8	5.585E-04	3.351E-02	1.702E-02
P-128	0.427	28.43	18.10	0.165	3.2	3.6	7.451E-04	4.470E-02	2.271E-02
P-136	0.427	31.51	21.18	0.165	3.3	7.3	3.717E-04	2.230E-02	1.133E-02
P-144	0.427	30.50	20.17	0.165	3.3	3.8	7.074E-04	4.244E-02	2.156E-02
P-162	0.427	32.68	22.35	0.165	3.3	4.4	6.187E-04	3.712E-02	1.886E-02
P-164	0.427	32.39	22.06	0.165	3.3	2.0	1.367E-03	8.201E-02	4.166E-02
P-165	0.427	30.70	20.37	0.165	3.3	2.2	1.209E-03	7.254E-02	3.685E-02
P-169	0.427	30.90	20.57	0.165	3.3	7.5	3.582E-04	2.149E-02	1.092E-02
P-193	0.427	31.18	20.85	0.165	3.3	6.2	4.318E-04	2.591E-02	1.316E-02
P-197	0.427	32.27	21.94	0.165	3.3	7.6	3.582E-04	2.149E-02	1.092E-02
P-199	0.427	30.32	19.99	0.165	3.3	4.2	6.424E-04	3.854E-02	1.958E-02
							Mean Value[5]	**4.512E-02**	**2.292E-02**

1. All piezometers installed with 10-1/4" od HSA's.
2. Based on measurements made at time of testing.
3. All piezometers installed using nominal 4-inch Sch 40 PVC.
4. Calculated Values Based on the Formula for Unconfined Aquifers - Partial Penetration, $r_c^2 * \ln(R/r_w)/2(l-d) * t_L$. Assumptions made in calculation include:
   - a) Aquifer is bounded below by an aquiclude.
   - b) Saturated thickness = 90 feet.
   - c) All layers are horizontal & extend infinitely in the radial direction.
   - d) Initial SWL is horizontal and extends infinitely in the radial direction.
   - e) Aquifer is homogenous and isotropic.
   - f) Groundwater density and viscosity are constant.
   - g) Groundwater flow can be described by Darcy's Law.
   - h) Head losses are negligible.
   - i) The aquifer is incompressible.
   - j) Buildup of water table is small compared to saturated thickness.
5. Geometric Mean

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Calculated Groundwater Velocities for Alluvial Aquifer
Table 8

Hydraulic Conductivity (K)	Overall Site $K_{avg} = 4.512 \times 10^{-2}$ ft/min											
	Low Range of Hydraulic Gradient Values[1]						High Range of Hydraulic Gradient Values[1]					
Hydraulic Gradient (*i*)	i_{min} = 0.00000199 ft/ft			i_{max} = 0.00006161 ft/ft			i_{min} = 0.0005534 ft/ft			i_{max} = 0.003517 ft/ft		
Effective Porosity (n)	0.30	0.35	0.40	0.30	0.35	0.40	0.30	0.35	0.40	0.30	0.35	0.40
Velocity (=Ki/n) (ft/yr)	0.2	0.1	0.1	5	4	4	44	37	33	278	238	209
Hydraulic Conductivity (K)	Max Value K = 9.470×10^{-2} ft/min											
Hydraulic Gradient (*i*)	i_{min} = 0.00000199 ft/ft			i_{max} = 0.00006161 ft/ft			i_{min} = 0.0005534 ft/ft			i_{max} = 0.003517 ft/ft		
Effective Porosity (n)	0.30	0.35	0.40	0.30	0.35	0.40	0.30	0.35	0.40	0.30	0.35	0.40
Velocity (=Ki/n) (ft/yr)	0.3	0.3	0.2	10	9	8	92	79	69	584	500	438
Hydraulic Conductivity (K)	Min Value K = 2.149×10^{-2} ft/min											
Hydraulic Gradient (*i*)	i_{min} = 0.00000199 ft/ft			i_{max} = 0.00006161 ft/ft			i_{min} = 0.0005534 ft/ft			i_{max} = 0.003517 ft/ft		
Effective Porosity (n)	0.30	0.35	0.40	0.30	0.35	0.40	0.30	0.35	0.40	0.30	0.35	0.40
Velocity (=Ki/n) (ft/yr)	0.1	0.1	0.1	2	2	2	21	18	16	132	114	99

1. Denotes extremes in hydraulic gradient values as calculated by Surfer software (see note 6 on Figures 18-29).