Attachment 1

Final Status Survey Final Report Volume 6, Chapter 1

Groundwater Overview, Revision 1
(HDP-RPT-FSS-501)

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Hematite Decommissioning Project

Final Status Survey Final Report Volume 6, Chapter 1

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LIST OF ACRONYMS AND SYMBOLS

CFR	Code of Federal Regulations
cm/sec	centimeter per second
COC	Constituent of Concern
DCGL	Derived Concentration Guideline Level
DP	Hematite Decommissioning Plan
EPA	U.S. Environmental Protection Agency
FSS	Final Status Survey
FSSFR	Final Status Survey Final Report
ft	feet
ft/yr	feet per year
HDP	Hematite Decommissioning Project
HP	Health Physics
HSU	Hydrostratigraphic Unit
IGMP	Interim Groundwater Monitoring Plan
LSA	Land Survey Area
µCi/L	microcuries per liter
µg/pCi	micrograms per picocurie
mrem/yr	millirem per year
msl	mean sea level
NRC	U.S. Nuclear Regulatory Commission
pCi/g	picocuries per gram
pCi/L	picocuries per liter
RASS	Remedial Action Support Survey
RAI	Request for Additional Information
RI	Remedial Investigation
ROC	Radionuclides of Concern
SAP	Sampling and Analysis Plan for Operable Unit 1
SOF	Sum of Fractions
Tc	Technetium
U	Uranium
VOC	Volatile Organic Carbons
WTS	Water Treatment System

1.0 INTRODUCTION

The purpose of this volume, Final Status Survey Final Report (FSSFR) Volume 6, Chapter 1, *Groundwater Overview,* is to provide a summary of the ground water monitoring program that was conducted for the Hematite Decommissioning Project (HDP). This summary describes the program objectives and regulatory basis for the monitoring, a summary of the data collected, and the analysis of the sample results. The monitoring results are used to demonstrate that Westinghouse Electric Company LLC (Westinghouse) has met its commitments to the U.S. Nuclear Regulatory Commission (NRC) in supporting the unrestricted release of the site at license termination in regard to groundwater.

The HDP FSSFR Volume 1, Chapter 1, *Final Status Survey Final Report Overview*, Westinghouse letter HEM-16-3, dated January 7, 2016) provides overview information in regards to the approval process and history of the HDP Decommissioning Plan (DP). Figure 1-1 is a photograph of the Hematite site circa 2006, indicating the location of Buildings 110, 115, 230, and 231, which are the buildings that will remain at license termination. Figure 1-2 shows the pre-demolition location of major structures onsite by building number.

The Hematite DP {ML092330123} and associated documents contain the requirements and commitments for groundwater sampling.

During the approval process for the DP, the NRC issued a Request for Additional Information (RAI) in letters dated October 14, 2010, NRC letter to Westinghouse, "Hematite Decommissioning Plan Review Requests for Additional Information for Decommissioning Plan Chapters 1, 4, 6 and 7," {ML102810455} and February 9, 2011, NRC letter to Westinghouse, "NRC Request for Additional Information from Westinghouse on Hematite Decommission Plan Chapter 3" {ML110210533}. Westinghouse responded to the NRC's requests for clarifying information regarding groundwater in the following responses:

- Westinghouse letter HEM-10-126, "Partial Responses to Requests for Additional Information on Decommissioning Plan Chapters 1, 4, 6 and 7," December 10, 2010 {ML103490102}.
- Westinghouse letter HEM-10-132, "Remaining Responses to Requests for Additional Information on Decommissioning Plan Chapters 1, 4, 6 and 7," December 21, 2010 {ML103560708}.
- Westinghouse letter HEM-11-25, "Response to Request for Additional Information on Decommissioning Plan Chapter 3, Site Description," March 10, 2011 {ML110730270}.
- Westinghouse letter HEM-11-96, "Final Supplemental Response to NRC Request for Additional Information on the Hematite Decommissioning Plan and Related Revision to a Pending License Amendment Request," July 5, 2011{ML111880290}.

In response to the NRC's RAIs, Westinghouse committed to make modifications to its groundwater monitoring program regarding well placements and post-remediation sampling. These commitments were captured by the NRC in the Safety Evaluation Report {ML112101630} that was issued in conjunction with the approval of the DP and associated documents.

FSSFR Volume 6, Chapter 1, provides an overview of the sampling programs and monitoring that were and continue to be implemented at the HDP, along with a description of the analytical results prior to remediation, during remediation, and post-remediation. The guidance contained in the following regulatory documents are used to manage the groundwater monitoring program and to demonstrate that the dose contribution from residual activity remaining in groundwater meets the dose criterion for license termination specified in 10 CFR 20.1402:

- DO-08-004, Hematite Decommissioning Plan,
- NUREG-1757, Volume 2, Consolidated NMSS Decommissioning Guidance - Characterization, Survey, and Determination of Radiological Criteria,
- 10 CSR 23-4, *Monitoring Well Construction Code*

The conduct of the groundwater monitoring program is directed through the implementation of the following HDP plan:

- EO-06-003, Interim Groundwater Monitoring Plan (Reference 8.1)

The conduct of groundwater monitoring activities is carried out through the implementation of the following HDP policies and procedures:

- HDP-PR-EM-011, Low Flow Well Sampling
- HDP-PR-EM-012, Water Quality Field Measurements
- HDP-PR-QA-006, Chain of Custody
- HDP-PO-QA-001, Project Quality Plan
- HDP-PO-FSS-700, Final Status Survey Program
- HDP-PR-FSS-720, Final Status Survey Data Integrity and Database Management
- HDP-PR-FSS-722, Final Status Survey Reporting

A revision history for the above policies and procedures is provided in Appendix A.

Information specific to each monitoring period is provided in the respective Volume 6 chapter as follows:

FSSFR Document	**Monitoring Period**
Volume 6, Chapter 2	Groundwater Monitoring Results During Remediation
Volume 6, Chapter 3	Post-remediation Groundwater Monitoring 1st Quarter Results
Volume 6, Chapter 4	Post-remediation Groundwater Monitoring 2nd Quarter Results
Volume 6, Chapter 5	Post-remediation Groundwater Monitoring 3rd Quarter Results
Volume 6, Chapter 6	Post-remediation Groundwater Monitoring 4th Quarter Results
Volume 6, Chapter 7	Post-remediation Groundwater Monitoring Summary

2.0 BACKGROUND

The objective of the decommissioning process is to ensure that any dose from residual radioactivity at License termination does not exceed the annual dose criterion for unrestricted use as specified in NRC Title 10 of the *Code of Federal Regulations* (10 CFR) Part 20, "Standards for Protection Against Radiation," Subpart E, "Radiological Criteria for License Termination," and that the levels of residual radioactivity are As Low As Reasonably Achievable (ALARA). The principal requirement is that the dose to future site occupants is shown to be less than 25 millirem/year. In order to meet the unrestricted release criteria of 10 CFR 20.1402, residual radioactivity in both soil and in groundwater sources of drinking water must be accounted for in Westinghouse's performance assessment of the Site. Westinghouse has accounted for this requirement through the excavation and removal of soils radiologically contaminated from former site operations, by removing the potential soil sources of radiological contamination to the groundwater, and by monitoring and evaluating the results of groundwater to verify that only very low, insignificant, concentrations of radionuclides of concern (ROC) are present that may contribute to future occupant dose.

The Westinghouse DP was approved by the NRC in Amendment 57 of Hematite License SNM-033 on October 13, 2011 {ML112101699 and ML112101640}. In conjunction with the issuance of Amendment 57 the NRC issued the Safety Evaluation Report (SER) {ML112101630) for Westinghouse Amendment Request for Approval of Hematite Decommissioning Plan and Associated Supporting Documents. Within the SER, the NRC outlined Westinghouse's additional commitments to protect the groundwater from future radioactive contamination. These commitments included:

1. Remove the 'leachate" impacted with radionuclides in the overburden clay. During soil excavation the contaminated "leachate" entering the excavation pit will be pumped to and treated for radionuclides by the Water Treatment System (WTS) prior to its release in accordance with the effluent discharge requirements.
2. Abandon selected wells that contain screens that cross both the silty clay overburden and the sand/gravel unit below. The cross communication resulted in the transport of contaminated water from the silty clay overburden to the sand/gravel unit. New monitoring wells will be installed in the sand/gravel unit in close proximity to the abandoned wells which will monitor for groundwater during and after site remediation. Figures 2-1 through 2-6 are an example of groundwater monitoring well abandonment.
3. Conduct borings in the close proximity to four specified wells and collect soil samples to the top of sand/gravel layer for radionuclide analysis. Further soil excavation will be conducted if spent limestone and soil above the release criteria are found below the initially proposed excavation depth.
4. Monitor groundwater post-remediation.

Each of these commitments is discussed in this overview document.

3.0 SUBSURFACE GEOLOGY AND GROUNDWATER

The current understanding of the site groundwater is described by the various water bearing zones (hydrostratigraphic units [HSU]) and their interactions. This understanding has been continuously refined since 2002, when studies of subsurface water at the HDP site began. Some early concepts about groundwater and interactions between the HSUs have given way to refined concepts as more data has been collected, more wells have been installed, and more analyses have occurred.

The subsurface geology at the site has a significant effect on the movement of groundwater, and subsequently the potential movement of radiological contaminates. The basic geology of the overburden and bedrock formations present at the site is described along with an explanation of how groundwater moves through these formations.

3.1 Overburden

The HDP is situated upon 20 to 35 feet (ft) of terrace/alluvial floodplain sediments overlying bedrock within the valley carved by Joachim Creek. Surface elevation within the Hematite Facility ranges from ~420 to ~440 ft mean sea level (msl). The terrace/alluvium overburden consists primarily of upper fine-grained silts and clay that overlie coarser-grained material (sands-gravels) near the bedrock surface.

The thickness of the coarse-grain sand/gravel unit is highly variable in this region. Boring logs from overburden boreholes conducted in support of the Remedial Investigation (RI) (Reference 8.2) to establish an understanding of the geology and hydrology of the site showed that the sand-gravel layer is relatively thin directly under the Facility (<1 to 2 ft), and thickens toward Joachim Creek (5 to 20 ft) as the overburden transitions from terrace deposits near the Hematite Facility to alluvial sediments near Joachim Creek.

The overburden is comprised of a predominantly clay/silty clay HSU (Silty Clay HSU) that acts as an aquitard overlying a more permeable sand and gravel HSU (Sand/Gravel HSU). Recharge to the clay aquitard occurs through the infiltration of precipitation and from bedrock formations that truncate the alluvial deposits north of the HDP. Discontinuous thin layers, lenses, inclusions, or seams of sand and silt transmit water laterally over limited distances within the silty clay HSU. Storage and evaporation ponds, burial pits, and trenches excavated into the silty clay overburden when the Hematite facility was operational provided additional reservoirs for liquid migration into the overburden. Precipitation and recharge interaction with the buried waste materials and contaminated soil prior to their removal, resulted in the generation of leachate that migrated downward through the silty clay aquitard, and potentially into the Sand/Gravel HSU.

3.2 Bedrock

The underlying bedrock formations in the area are the Jefferson City-Cotter and the Roubidoux Formations. Regionally, the Jefferson City-Cotter Formation consists predominantly of dolostone with small quantities of shale, chert, and sandstone. While the Roubidoux Formation is a loosely to well-cemented sandstone or a sandy to cherty dolostone containing several distinct sandstone bodies (Imes and Emmett 1994) (Reference 8.3), there is not a clear dividing line

between the Jefferson City-Cotter Bedrock HSU and the Roubidoux Bedrock HSU; instead, the transition uncertainty is referred to as the contact zone. The contact zone has lower transmissivity than the bedrock HSUs and therefore is not discussed as a separate HSU.

Groundwater flow in bedrock occurs predominantly through transmissive interbeds and secondary porosity features including fractures, joints, and bedding planes. The efficiency of the secondary porosity network is enhanced by chemical dissolution of the carbonate bedrock. Groundwater elevation maps for the Jefferson City-Cotter HSU indicate that groundwater flow in the upper bedrock aquifer is radial reflecting the surface topography surrounding the site area with an area of groundwater convergence located southeast of the Hematite Facility. Groundwater flow in the Roubidoux formation is generally to the north-northeast toward the Mississippi River valley.

Based on the various studies and the current knowledge of the Hematite site, the subsurface geology has been divided into four distinct HSUs for the purposes of discussion and data compilation. The following summaries of the HSUs are based on the SAIC Report "Supplemental Analysis of Hydrogeologic Conditions in Overburden at Westinghouse Hematite Facility, Hematite, Missouri," Revision 0, 2009 (Reference 8.4) and SAIC Report "Radionuclide Activity in Bedrock Groundwater at Westinghouse Hematite Facility, Hematite, Missouri," Revision 0, 2009 (Reference 8.5).

- The Silty Clay Aquitard HSU nominally extends 24 feet below the surface. The thickness ranges from 4 to 38 feet, and is typically thicker near the Site buildings and thinner near Joachim Creek. General lateral flow in the Silty Clay Aquitard HSU has not been evident, but there may be local lateral movement if heterogeneities are encountered in the clay layers. The calculated vertical hydraulic gradient through the clay is downward-directed. The mean hydraulic conductivity (2.85 x E-5 centimeters per second [cm/sec]) indicates limited water flow through the silty clay. Based on a conceptual model of vertical seepage in the silty clay layer with localized conduit flow along vertical wellbores that cross connect the silty clay layer and the underlying sand/gravel layer, it is theorized that the vertical migration of radiological contamination is being attenuated by the silty clay layer.
- The Sand/Gravel HSU nominally extends 2 feet below the Silty Clay Aquitard HSU. The thickness ranges from 0 to 20 feet, and is typically thicker near Joachim Creek and thinner near the Site buildings. Lateral flow in the Sand/Gravel HSU is to the southeast towards Joachim Creek under a prevailing hydraulic gradient of approximately 0.0109 feet/foot. The estimated velocity of flow is 20 to 300 feet per year (ft/yr).
- The Jefferson City-Cotter Bedrock HSU nominally extends 50 feet below the Sand/Gravel HSU. The lateral flow in the Jefferson City-Cotter Bedrock HSU is easterly under a mean hydraulic connectivity of 1.29E-3 cm/sec.
- The Roubidoux Bedrock HSU is below the Jefferson City-Cotter Bedrock HSU. Lateral flow in the Roubidoux Bedrock HSU is northeasterly under a mean hydraulic connectivity of 7.55E-5 cm/sec.

4.0 CHARACTERIZATION OF GROUNDWATER

4.1 HSUs Viability as Sources of Drinking Water

Each of the four HSUs (Silty Clay Aquitard, Sand/Gravel, Jefferson City-Cotter Bedrock, and Jefferson City-Cotter Bedrock) has been analyzed to determine whether they are a viable source for drinking water or irrigation water (Reference 8.4).

- The Silty Clay Aquitard HSU is not viable as a sustainable water supply for the purposes of drinking water, irrigation, or industrial use based on its mean hydraulic conductivity (2.85E-5 cm/sec), its low mean matrix permeability (3.48E-8 cm/sec), and its apparent lack of internal interconnected flow pathways. The State of Missouri Well Construction Code (10 CSR 23-3) for the Hematite location requires "No less than twenty feet of casing shall be set above the screened or perforated interval of the well". This restriction would preclude development of a water supply for domestic or irrigation purposes from the Silty Clay Aquitard HSU (unless the State of Missouri approved a variance to its regulations).
- The Sand/Gravel HSU underlying the immediate facility area has insufficient quantities of shallow water to sustain feasible and economic production based on its limited extent and thickness. However, while the sand and gravel deposits are an effective underdrain for the Silty Clay Aquitard HSU, and could provide a viable water resource south of the Site buildings, due to the presence of volatile organics exceeding drinking water standards, the Sand/Gravel HSU is currently restricted for use (through deed restrictions) as a source of potable water.
- The Jefferson City-Cotter Bedrock HSU is a viable water supply.
- The Roubidoux Bedrock HSU is a viable water supply.

The report, "Supplemental Analysis of Hydrogeologic Conditions in Overburden at the Westinghouse Hematite Facility", (Reference 8.4) summarizes the rationale and data supporting the separation of data from the aquitard HSU, hybrid wells, and sand/gravel wells. The summary draws from previous site characterization studies conducted by Gateway Environmental Associates, Inc. (References 8.6 and 8.7), Leggette, Brashears, and Graham (References 8.8, 8.9 and 8.10), GEO Consultants, LLC and Science Applications International Corporation (SAIC) (References 8.11 and 8.12), and quarterly monitoring results (Reference 8.13). The characterization data compiled from these studies includes well and boring data, groundwater elevation measurements, groundwater radiological analyses, laboratory geotechnical testing, and field hydrogeologic testing.

The report showed that Tc-99 and uranium isotopes were the most widely detected radionuclides in water underlying the facility and were predominantly found in the vicinity of the Evaporation Ponds/Leach Field; an area on the northeast side of the Process Building; and the limestone storage/Deul's Mountain area (see Figure 4-1). The majority of radionuclide activity was identified in leachate water sampled from the wells screened in the silty clay aquitard HSU near facility areas. Very limited contamination was identified in the groundwater from wells monitoring the sand and gravel aquifer.

The predominant radiological constituents detected at the Site were closely associated with the source areas within the footprint of the Hematite Facility. Technetium-99 and uranium measurements in leachate from overburden wells screened in the silty clay HSU indicated activity centered at the northeastern corner of the Evaporation Pond area and extending toward the eastern side of the Process Building. Technetium-99 measurements in groundwater from overburden wells monitoring the sand and gravel aquifer indicated only isolated, low-level detections in the aquifer. Uranium activity in the sand and gravel aquifer was determined to be indistinguishable from background.

4.2 IGMP Results During Remediation

Remediation of the HDP began in the spring of 2012. Sampling conducted during this timeframe began under the IGMP Revision 3 document. Impending remedial activities within the Central Tract area necessitated the abandonment of one monitoring well in May, 2013. An eroding bank at Joachim Creek required the abandonment and relocation of three (3) monitoring wells. A Revision 4 of the IGMP was necessary to remove the previously abandoned wells (GW-T, BR-03-OB, BR-03-JC, and BR-03-RB) and include the newly installed wells (BR-03R-OB, BR-03R-JC, and BR-03R-RB). The revision also added quality assurance requirements to supplement the contents of the Hematite Project Quality Plan. Revision 5 of the IGMP was required to remove the wells that were abandoned in November, 2013 and January, 2014, and to add a new well that was installed in January, 2014.

Ongoing remedial activities within the Central Tract area necessitated the abandonment of six monitoring wells (Fringe Well GW-AA and Source Wells GW-D, GW-S, GW-U and GW-Z and Remaining Site Well WS-07). The wells were abandoned in November, 2013, and January, 2014. One new plume well (GW-JJ) was installed in January, 2014. In addition, the functional grouping for Well PZ-02 was changed from a Remaining Site Well to a Group III Plume Well.

Throughout the remediation, the results of the IGMP sampling were documented in annual IGMP Reports. Each year, the reports would evaluate the Tc-99 and Uranium data based on the HSU being sampled. The reports included summary tables containing the number of samples collected, the number of detections, number of detects for each isotope, the minimum and maximum concentration detected, the well from which the sample with the maximum concentration was collected, and the quarterly event of collection. Table 4-1, Summary of Annual IGMP Sampling, is a compilation of the annual summary tables from the start of remediation in 2012, to the end of 2015.

Included in these tables is a comparison of the results to the MCLs for drinking water. Concentrations of Tc-99 in groundwater have been below the EPA drinking water maximum contaminant level (MCL) of 900 pCi/L. 900 pCi/L MCL for Tc-99 is equivalent to the 4 mrem/year National Primary Drinking Water Standard for beta particles and photon emitters. The uranium detected in groundwater has been below 20 microcuries per liter (μCi/L) for total uranium compounds.

Full results of radiological monitoring during remediation, including results and trending graphs are included in FSSFR Volume 6, Chapter 2.

4.3 Leachate versus Groundwater in Overburden

Based on 10 CFR 20.1402 and 10 CFR 40, the term "groundwater" is applied to sources of subsurface waters that are sources of drinking water or aquifers that are capable of yielding a significant amount of groundwater to wells or springs. Based on these regulatory descriptions of groundwater, the water in the Sand/Gravel HSU, Jefferson City-Cotter Bedrock HSU, and Roubidoux Bedrock HSU is groundwater. The term "leachate" is used for describing the water within the pore space of the Silty Clay Aquitard HSU and is used to describe wells that are or were, in the case of abandoned wells, screened only in the Silty Clay Aquitard HSU, which is a non-potable source of water.

The distinction between leachate, which is water contained within the pore space of the silty clay aquitard, and groundwater, which is within the lower Sand/Gravel HSU, was important in assessing the extent of remedial actions necessary to address groundwater contamination and for post-remediation groundwater monitoring. While initial groundwater monitoring at the Site concluded there was no radiological contamination in "groundwater" (Reference 8.2), some subsequent sampling results indicated there could be Tc-99 in the Sand/Gravel HSU. This uncertainty was eventually determined to be the result of the installation of wells with screens that crossed over between the silty clay aquitard and the Sand/Gravel HSU (hybrid wells). Contamination from a water sample collected from a hybrid well ending in the Sand/Gravel HSU was in all probability pulling the contamination from the silty clay aquitard. This was based on the fact that nearby non-hybrid wells pulling water from only the Sand/Gravel HSU were not showing similar levels of contamination. Since it could not be determined with certainty from which HSU a contaminant originated when obtained from a hybrid well, these wells were eventually abandoned.

Due to the installation of the well screens of the hybrid monitoring wells intercepting both the silty-clay and the sand/gravel zone, these wells may serve to provide a pathway for limited downward migration of contaminants to the sand/gravel zone. Therefore, these hybrid wells have been abandoned to reduce the potential for enhanced downward migration of radionuclides to the sand/gravel and for subsequent lateral migration in this zone. Wells that were not abandoned in 2011, were subsequently abandoned during the remediation of the adjacent areas between 2013, and 2015.

4.4 Paired Well Analysis

To further demonstrate the distinction between the leachate and groundwater, eleven additional wells were installed in the Sand/Gravel HSU in September, 2011. All but two of these new wells were located next to existing wells that had screens penetrating the silty clay only (leachate wells) or penetrating both the silty-clay and sand/gravel (hybrid wells). The new wells were all constructed with the screen solely within the Sand/Gravel HSU in order to draw only groundwater into the well.

Wells GW-U and GW-Z were installed in close proximity to the designated pair well rather than adjacent to it due to safety and decommissioning process reasons. Well GW-U which is paired with well EP-20 was installed in its location to best align with EP-20 but to avoid locating it where it would receive interference from the Evaporation Ponds and the berm surrounding the Ponds, the natural gas pipeline, and the site fence. Well GW-Z which is paired with well WS-13

was installed to best align with WS-13 but be at a location to minimize the possibility that it would be destroyed or removed during Process Building demolition. Figure 5-2, *Locations of Groundwater Monitoring Wells*, shows the locations of the leachate/hybrid wells and the wells installed in 2011 that were used in the analysis.

In general, for these paired and proximity wells in which radionuclides were detected, the hybrid and leachate wells exhibited radioactivity higher than the wells with screens installed completely within the sand/gravel. Based on the analytical results and the proximity of the paired wells, the elevated radioactivity in the hybrid and leachate wells is attributed to contaminated water in the overlying silty-clay formation. Construction data for the wells installed in 2009, as well as the associated "paired" wells, are included in Table 4-2 *Paired Wells Description* and Figures 4-3a, 4-3b, and 4-3c, *Cross-sections of Paired Wells.*

Groundwater samples were collected from the eleven new wells screened in the sand/gravel zone and the nine paired hybrid or leachate wells during five quarterly sampling events occurring from the 3rd Quarter 2009 (3Q09), through the 3rd Quarter 2010 (3Q10). The radiological monitoring results for the nine new wells that have been paired with hybrid or leachate wells are summarized in Table 4-3, *Groundwater Radiological Results.* The data collected from the wells is described based on well pairing and radionuclide in the following sections.

4.4.1 Technetium 99 Data

Samples collected from well pairs GW-S/BD-14 and GW-W/NB-81 were non-detects (less than the MDC) for Tc-99. Samples collected from well pairs GW-D/WS-17B, GW-T/DM-02, GW-U/EP-20, and GW-V/NB-31 indicated Tc-99 in the hybrid and leachate wells that was several orders of magnitude higher than the paired wells screened in only the sand/gravel zone. The finding of higher activity in the hybrid and leachate wells as compared to the sand/gravel wells suggests that the silty-clay and sand/gravel zones are hydraulically separate. It also suggests that the migration of Tc-99 to the sand/gravel zone may have been enhanced by the construction of the hybrid wells intercepting both zones.

Samples from well pair GW-D/WS-17B indicated Tc-99 in the leachate well that was higher than the paired well screened in the sand/gravel zone. The Tc-99 in sand/gravel well GW-D ranged from less than MDC (MDC of 2.6 pCi/L) to 3 pCi/L, while the Tc-99 in leachate well WS-17B ranged from 1,390 to 2,500 pCi/L. This set of wells (GW-D/WS-17B) is located near the rail spur southeast of Building 256 (Process Building Warehouse) in an area where subsurface soils were removed during decommissioning activities.

Samples from well pair GW-T/DM-02 indicated Tc-99 in the hybrid well that was higher than the paired well screened in the sand/gravel zone. The Tc-99 in sand/gravel well GW-T ranged from less than the MDC (MDC of 2.5 pCi/L) to 4.3 pCi/L, while the Tc-99 in hybrid well DM-02 ranged from 157 to 414 pCi/L. An increase in Tc-99 was observed in well DM-02 between the sampling periods 2Q10, and 3Q10, but the 3Q10 concentration was consistent with the Tc-99 levels observed in this well in 2008 (542 to 546 pCi/L). This set of wells (GW-T/DM-02) is located east of Building 256 in an area where subsurface soils were removed during decommissioning activities.

Samples from well pair GW-U/EP-20 indicated Tc-99 in the leachate well that was higher than the paired well screened in the sand/gravel zone. The Tc-99 in sand/gravel well GW-U ranged from less than the MDC (MDC of 2.3 pCi/L) to 3.1 pCi/L, while the Tc-99 in leachate well EP-20 ranged from 735 to 985 pCi/L. This set of wells (GW-U/EP-20) is located near the Evaporation Ponds and the natural gas pipeline in an area where subsurface soils were removed during decommissioning activities.

Samples from well pair GW-V/NB-31 indicated Tc-99 in the hybrid well that was higher than the paired well screened in the sand/gravel zone. The Tc-99 in sand/gravel well GW-V ranged from 3.2 to 7.1 pCi/L, while the Tc-99 in hybrid well NB-31 ranged from 65.9 to 231 pCi/L. This set of wells is located on the south side of the rail line that runs parallel to the south fence line of the Central Tract. The location of these paired wells is outside the Central Tract in an area where soil removal was not conducted. During the installation of monitoring well NB-31 in June 2004, soil samples were collected from the borehole and analyzed for radiological parameters including Tc-99. The soil samples were collected from 5, 15, 27, and 32 feet below ground surface. The Tc-99 results for these samples were less than the MDC (MDC ranged from 0.78 to 0.83 picocuries per gram [pCi/g]). During the installation of monitoring well GW-V in September 2009, soil samples were collected from the borehole at 26 and 32 feet below ground surface. The Tc-99 for the sample collected at 26 feet below ground surface was 1.09 pCi/g (MDC of 0.52 pCi/g). The Tc-99 for the sample collected from 32 feet below ground surface was less than the MDC (0.51 pCi/g). Without a source of Tc-99 within the silty-clay overburden at these paired wells, a series of interconnected sand lenses from the Central Tract area is suggested to exist in the silty-clay overburden. A review of the boring logs for wells within this area was reviewed to determine if any sandy or gravely layers of lenses were noted. The boring logs did not clearly define any such layers.

Well pair GW-Y/NB-33 indicated Tc-99 that was slightly higher in the well screened in the sand/gravel (GW-Y) as compared to the hybrid well (NB-33). However the Tc-99 in well GW-Y is only slightly above the MDC (1.9 to 3.6 pCi/L), while well NB-33 exhibited Tc-99 that was consistently below the corresponding MDC (non-detect). In addition, all of the Tc-99 positive results for well GW-Y were within the range of error of the MDC. This suggests that the detections may be false positives, or if not, they are well below any regulatory release criteria. This set of wells is located on the south side of the rail line that runs parallel to the south fence line of the Central Tract.

The Tc-99 results for wells GW-AA and GW-BB (not paired with hybrid or leachate wells) were also less than the MDC (1.6 pCi/L), except for an isolated detection of 1.7 pCi/L in GW-AA during the third quarter 2010, monitoring event.

An exception to the general condition that only trace amounts of Tc-99 radioactivity have been observed in some of the sand/gravel wells are the data obtained from well pair GW-X/PL-06. At this location the concentration of Tc-99 in the silty-clay and the sand/gravel layer are nearly equivalent, and range from 96 to 170 pCi/L. This well pair is located near Building 231 (Warehouse) and the natural gas pipeline. This well pair is also located in the thickest layer of sand and gravel identified within the fenced portion of the facility. Due to the thickness of the sand at this location, seasonal variation of the potentiometric surface can cause the sand to be

unsaturated and allow water containing Tc-99 in the overlying clay to drain into the sand/gravel zone.

Samples collected from the wells with screens installed in the sand/gravel zone exhibited Tc-99 (0 to 157 pCi/L) below 4 mrem/yr (900 pCi/L), which is the National Primary Drinking Water Standard for beta particles and photon emitters.

4.4.2 Isotopic Uranium Data

The uranium isotope radioactivity in the samples from well pairs GW-D/WS-17B, GW-U/EP-20, GW-V/NB-31, GW-W/NB-81, GW-X/PL-06, and GW-Y/NB-33 were found to be indistinguishable from background. The Background Threshold Value for total uranium is discussed in the response to RAI HDP-4-14. Samples collected from well pairs GW-S/BD-14, GW-T/DM-02, and GW-Z/WS-13 exhibited uranium isotope radioactivity that was significantly higher in the hybrid or leachate wells as compared to the sand/gravel wells.

Samples from well pair GW-S/BD-14 indicated total uranium in the hybrid well that was higher than the paired well screened in the sand/gravel zone. The total uranium in sand/gravel well GW-S ranged from 0.07 to 0.5 pCi/L, while the total uranium in hybrid well BD-14 ranged from 0.7 to 3.4 pCi/L. This set of wells (GW-S/BD-14) is located southeast of the Process Building in an area where subsurface soils were removed during the decommissioning activities.

Samples from well pair GW-T/DM-02 indicated total uranium in the hybrid well that was significantly higher than the paired well screened in the sand/gravel zone. The total uranium in sand/gravel well GW-T ranged from 0.1 to 0.2 pCi/L, while the total uranium in hybrid well DM-02 ranged from 158 to 201 pCi/L. This set of wells (GW-T/DM-02) is located east of Building 256 (Process Building) in an area where subsurface soils were removed during the decommissioning activities.

Samples from the proximity well pair GW-Z/WS-13 indicated total uranium in the leachate well that was significantly higher than the paired well screened in the sand/gravel zone. The total uranium in sand/gravel well GW-Z ranged from less than MDC (0.078 pCi/L) to 0.3 pCi/L, while the total uranium in leachate well WS-13 ranged from 52 to 58 pCi/L. This set of wells (GW-Z/WS-13) is located near the Process Building in an area where subsurface soils were removed during the decommissioning activities.

Total uranium in groundwater samples from the well pairs was compared to the National Primary Drinking Water Standard for uranium of 30 μg/L (20 pCi/L, based on a conservative conversion factor of 1.5 micrograms per picocurie [μg/pCi] for natural uranium). One of the hybrid wells (DM-02) and one of the leachate wells (WS-13) exhibited total uranium above 20 pCi/L. Total uranium in DM-02 ranged from 158 to 201 pCi/L and in WS-13 ranged from 52 to 58 pCi/L. Groundwater samples collected from the corresponding sand/gravel paired wells (GW-T and GW-Z) exhibited uranium activities comparable to the MDC and orders of magnitude less than the Drinking Water Standard.

The difference in contaminant concentrations within wells screened adjacent to each other demonstrates the difference between the leachate, water contained within the pore space of the

silty clay aquitard which is percolating downward, and the sand/gravel aquifer, which is the groundwater that is migrating laterally beneath the site.

4.5 Decommissioning Group

The NRC has outlined in Volume 1, Revision 2 of NUREG-1757 a roadmap for the decommissioning of nuclear facilities, with the goal of ensuring that when completed, a decommissioning will comply with NRC requirements for License termination. This roadmap categorizes decommissioning sites into one of seven Groups "based on the amount of residual radioactivity, the location of that material, and the complexity of the activities needed to decommission the site." Among these seven groups, a Group 4 decommissioning presumes there is no groundwater contamination while a Group 5 decommissioning presumes ground water contamination exists. Both Groups require the licensee to demonstrate that the site meets unrestricted use levels derived from site-specific dose modeling, meaning both Groups would require the inclusion of a dose from the ground water pathway when conducting the site-specific dose modeling to demonstrate the site could be released for unrestricted use. The Hematite site presented an interesting dilemma, "There was radiological contamination in the water within the clay aquitard; however, was the water within the aquitard sufficient to support a potable water pathway in the dose assessment scenario?" If it could, then the Hematite decommissioning should be categorized as a Group 5.

Westinghouse stated in Section 1.3 of the DP that the groundwater was not contaminated radiologically and proposed Hematite as a Group 4 site. The NRC staff questioned that categorization in RAI 1.3-Q1 {ML102810455}. Westinghouse provided a response on December 10, 2010 {ML103490102}. In its response, Westinghouse did not define the water in the silty clay overburden as groundwater. Additionally, Westinghouse took the position that the silty clay overburden would not provide sufficient yield to meet the aquifer definition given for a Group 5 decommissioning. As a result, Westinghouse concluded that the Hematite decommissioning should *not* be a Group 5 site.

In contrast to Westinghouse's conclusions, the NRC's regulations and guidance (10 CFR Part 40 Appendix A, 10 CFR 63.302, and NUREG-1757) consistently define groundwater as water that is below the land surface in a zone of saturation, and contained in pores or fractures in that saturated zone. Although the Hematite facility groundwater data indicates that the silty clay overburden is in a saturated condition, the hydraulic data also indicates that the unit will not provide a sufficient yield for domestic use. The uppermost aquifers at the Hematite facility are the sand/gravel and Jefferson City-Cotter bedrock hydrostratigraphic units. These units are interconnected hydraulically and behave as a single aquifer. The current levels of uranium and Tc-99 detected in the sand/gravel and the Jefferson City-Cotter units are significantly less than their respected US EPA MCLs {ML110250138}. The potential dose resulting from the current levels of radionuclides in these units is negligible.

4.6 NRC Safety Evaluation Report for Westinghouse License SNM-33 Amendment 57

In October, 2011, the NRC completed the SER for the amendment request for approval of Hematite DP and the associated documents, including the RAIs. In this document, NRC acknowledged the study conducted in which Westinghouse installed eleven monitoring wells

screened solely in the sand/gravel unit in 2009, and that additional groundwater monitoring data were collected from these sand/gravel wells during 2009-2010. Based on its review, NRC stated:

> "*it is highly likely that the hybrid well screens may have facilitated the transport of water/sediment impacted with radionuclides from the silty clay overburden into the water sample during well purging and sampling,*"
>
> and,
>
> "*The uranium and Technetium-99 levels observed in the sand/gravel aquifer in the vicinity of the Hematite facility are significantly below the respected EPA Maximum Contaminant Levels (MCLs) of 30 µg/L (or 20 pCi/L) for uranium and 4 millirem/year(or 900 pCi/L) for beta/photon emissions (ML103560708). The extent of groundwater impacted with Technetium-99 above the background level (1.5 pCi/L) in the sand/gravel aquifer is approximately 700 ft beyond the railroad tracks into the Joachim Creek flood plain.*"
>
> Based on similar data of the bedrock HSUs, the NRC stated that:
>
> "*it was unlikely that site operations would have negatively impacted the bedrock aquifers as there are only minimal levels of uranium and Technetium-99 detected in the sand/gravel HSU located above the bedrock aquifers.*"
>
> The NRC concluded in the SER:
>
> "*Although the Hematite facility groundwater data indicates that the silty clay overburden is in a saturated condition, this hydraulic data also indicates that the unit will not provide a sufficient yield for domestic use. The upper most aquifer at the Hematite facility is the sand/gravel and Jefferson City-Cotter bedrock hydrostratigraphic units. These units are interconnected hydraulically and behave as a single aquifer. The current levels of uranium and Technetium-99 detected in the sand/gravel and the Jefferson City-Cotter units are significantly less than their respected US EPA maximum contaminant levels (MCLs). The potential dose resulting from the current levels of radionuclides in these units is negligible. Given the groundwater definition in the NRC regulations and NUREG-1757, staff does not believe that the Hematite site decommissioning is a Group 4 site. Despite this conclusion, staff believes WEC's proposed remedial action of removal of contaminated silty clay and treatment of impacted groundwater is acceptable as explained below and meets the Hematite facility's decommissioning goals.*"

4.7 Pre-remediation and Remediation Groundwater Monitoring Wells

Westinghouse committed that following the completion of site remediation, groundwater would be monitored to assure that the removal of the source term in the soil and buried debris areas of the site was effective in protecting groundwater sources in the Sand/Gravel, Jefferson City-Cotter, and Roubidoux HSUs.

To accomplish the monitoring, HDP utilized information from existing groundwater monitoring wells to develop the monitoring plan as discussed in the DP. In addition to the existing

groundwater monitoring wells, HDP installed additional groundwater monitoring wells during remediation to provided need groundwater data as remediation of the site progressed.

Figure 4-2, *Locations of Groundwater Monitoring Wells at the Start of Remediation and During Remediation,* provides the locations of these groundwater monitoring wells.

5.0 EXCAVATION OF OVERBURDEN CLAY

The radiological contamination in the overburden clay was the result of former operational activities at the Hematite site. Removal of this contaminated soil was a substantial portion of the remediation performed at the Hematite Decommissioning Project. The objective was to remove the contaminated soil that could act as a future source for potentially contaminating the drinking water aquifers. As this soil was excavated it was evaluated to determine whether it would be disposed off-site as radioactive waste or whether the residual soil contamination was low enough that it could remain on site. In conducting the radiological remediation of the HDP site, over 138,000 cubic yards of soil was excavated and shipped off-site for disposal. An overview of the remediation of site soil is addressed in FSSFR Volume 2, Chapter 1, *Reuse Soil and Off-site Borrow Material Overview* {ML16152A752}, and Volume 3, Chapter 1, *Land Survey Areas (LSA) Overview* {ML16027A303}.

The criteria used for remediation of the overburden were based on the soil since that was the source of radioactivity in the leachate. For soil, the estimate of areal and vertical extent of impacted overburden soil was provided in the Hematite Radiological Characterization Report (HRCR) {ML092870496}, and summarized in DP Chapter 4. Chapter 5 of the DP provided the basis for the release criteria for soil removal and DP Chapter 14 described the process for evaluating the adequacy of remediation, including a comparison to the release criteria defined in DP Chapter 5 (i.e., whether in soil or leachate), so meeting the derived concentration guideline level (DCGL) was protective of the ground water. The inputs to this evaluation included data obtained through radiological surveys and laboratory analysis of soil samples. Coincident with soil excavation, the portion of the leachate entrained in soil that exceeded the DCGLs was also removed. Similarly, a portion of the leachate was entrained in the soil samples analyzed by the laboratory, thereby accounting for that contribution to residual radioactivity. The RESRAD modeling described in DP Chapter 5 accounted for the residual radioactivity (i.e., whether in soil or leachate), so meeting the DCGLs was protective of the ground water. DP Chapter 7 addressed the ALARA aspects of the DCGLs.

Moisture that was entrained within the soil, which had the potential to be leachate, was removed with the excavated soil that was shipped off-site as waste. However, standing liquid remaining within the excavation (e.g., either draining from the contaminated soil during excavation, or from infiltration into the excavation) was pumped from the excavation and treated and/or sampled prior to its release in accordance with NRC and MDNR effluent discharge requirements. When a sample of the remaining, post-excavation soil was taken for analysis and comparison to the DCGLs, the sample included any Tc-99 that was in the pore space of the soil. Thus, the total amount of Tc-99 in the remaining soil, both on the soil itself and in liquid in the soil's pore space, was compared against the DCGL. Since radioactivity in both liquid and solid portions of the soil is sampled and accounted for, attempting to separately develop criteria for water in the

pore space would have amounted to double accounting of the same radioactivity. Relying on soil remediation to protect groundwater was justified by the silty clay soil having a high affinity for Tc-99. In effect, the silty clay soil was a "collection filter" for Tc-99, removing it from the water that moved vertically through the silty clay soil. Removing buried materials and soil that was acting as a "collection filter" removed a large portion of the source term.

6.0 GROUNDWATER MONITORING

The objective of groundwater monitoring is to demonstrate that the sum of the annual dose for all the radionuclides from groundwater does not exceed the Environmental Protection Agency (EPA) Maximum Contaminant Level (MCL) of 4 millirem per year (mrem/yr), and to demonstrate that the total dose from residual radioactivity from all sources (including groundwater) for a Land Survey Area survey unit does not exceed the unrestricted release dose criterion (25 mrem/yr) for license termination.

To demonstrate that this objective is achieved, Westinghouse committed to a groundwater sampling program in Revision 0 of the DP. This program was slightly modified in subsequent responses by Westinghouse in following up to Requests for Additional Information (RAI) by the NRC during its review of the DP.

6.1 Radionuclide Activity in Bedrock Groundwater

The SAIC Report "Radionuclide Activity in Bedrock Groundwater at Westinghouse Hematite Facility, Hematite, Missouri" (Reference 8.5) summarizes the historic groundwater samples from wells screened in the Jefferson City and Roubidoux HSUs. The report concluded that radionuclide activity in the bedrock groundwater underlying the Hematite Facility is generally below background levels with the exception of technetium-99 (Tc-99) activity reported in widely spaced bedrock wells PZ-03, BR-01-JC, BR-03-JC, and BR-08-JC (see Figure 5-2 for well locations). Two of the wells (BR-01-JC and PZ-03) were located on the facility area and the remaining wells (BR-03-JC, BR-08-JC) were located on the Joachim Creek floodplain south of the Hematite Facility. Gross-β activity in the wells BR-03-JC, BR-08-JC, and PZ-03 followed similar trends suggestive of background activity while gross-β activity fluctuated widely in well BR-01-JC between June and December 2007. After December 2007, gross-β activity in well BR-01-JC followed trends similar to the remaining bedrock wells. The source of the fluctuations in well BR-01-JC is not definitively known but may be related to the installation of dedicated sampling equipment in a 1" diameter well and subsequent equilibration of the well. Time series analysis of reported Tc-99 and gross-β activity in bedrock groundwater showed that the analytical results were oscillatory around zero activity and were not indicative of Tc-99 groundwater contamination or a developed Tc-99 plume affecting the bedrock groundwater.

Samples collected from the wells with screens installed in the bedrock HSUs exhibited Tc-99 below 4 mrem/yr (900 picocuries per liter [pCi/L]) and uranium activities comparable to the minimum detectable concentration (MDC) which is orders of magnitude less than the Drinking Water Standard. Therefore, there were no indications that the bedrock groundwater was negatively impacted by radiological contaminants at the site.

6.2 Interim Groundwater Monitoring Plan (IGMP) 2007- 2012 (Pre-Remediation)

The purpose of the IGMP (Reference 8.1), which has been implemented continuously from June 2007, to the present, is to provide continuing groundwater data for evaluation of potential temporal or seasonal changes in concentrations and migration pathways for constituents of concern (COC). Although the primary regulatory agency for the IGMP is the Missouri Department of Natural Resources (MDNR), and the focus is chemical contamination, radiological parameters, including gross alpha, gross beta, isotopic uranium and technetium-99, were analyzed as part of the program.

Throughout the implementation of the IGMP program, monitoring wells at the site have been sampled on a quarterly basis for chemical and radiological parameters. However, there have been changes made to the IGMP which were in the wells sampled. These changes have been the result of an increased understanding of the site groundwater, removal of wells based on control of vertical migration (hybrid wells), removal of wells due to remediation in the proximity, and the replacement and addition of new wells. Each of these changes is captured in the associated annual IGMP report. Data results for each well can be found in the annual IGMP reports and are not duplicated herein. A summary of the IGMP is provided below.

The original IGMP divided the existing monitoring well network at HDP into eight (8) well groupings based on the function of the wells for monitoring purposes.

- Group I Sentry Wells: assess the potential for off-site migration of volatile organic carbons (VOC) in the Roubidoux bedrock aquifer.

- Group II Water Level Wells: obtain routine water level measurements to assist in evaluating local groundwater flow.

- Groups III and IIIa Plume Wells: Group III and IIIa groundwater monitoring points assess potential changes in contaminant concentrations in the identified plume in the Jefferson City/Cotter Formation. Group III wells are situated to assess both radiological and VOC plume components. Group IIIa wells assess the VOC bedrock plume component relative to contamination in former private wells located to the southeast of Joachim Creek.

- Group IV Plume Fringe Wells: selected to evaluate potential temporal changes in contaminant concentrations at the edge of the overburden plume.

- Group V Source Wells: monitor groundwater in vicinity of facility sources.

- Group VI Additional Sampling Wells: wells requiring additional data prior to making a determination regarding inclusion into the IGMP or abandonment.

- Group VII: Current NRC license sampling wells.

The December 2010, Revision 1 to the IGMP was based on changes to the sampling requirements given the evolving nature of the site conditions (such as building demolition and

preparatory work for remediation), data generated from 12 quarters of groundwater monitoring obtained between June 2007, through March 2010, and the monitoring conducted in accordance with License SNM-00033 issued by NRC. Sentry Wells originally designated to be sampled for gross alpha and gross beta were revised in the plan to be sampled for isotopic uranium and technetium-99. This allow for isotope specific results for use in evaluating the potential presence of radiological contamination in the groundwater. This revision replaced the original IGMP and redefined the monitoring at the Site. In the revised IGMP, five categories of wells were defined for monitoring of radionuclides and VOCs in groundwater. The remaining Site wells were monitored for water elevation for mapping groundwater elevation. The IGMP Revision 1 functional groupings were:

- Group I Sentry Wells: This group of wells is positioned beyond the current boundary of identified contamination and is designed to detect expansion of the plume. The wells chosen as Group I wells have historically shown no contamination. These wells will monitor the overburden, the Jefferson City Formation, and the Roubidoux Formation.

- Group II Fringe Wells: located along the farthest extent of observed contamination. Fringe wells will monitor the overburden, the Jefferson City Formation, and the Roubidoux Formation.

- Group III Plume Wells: represent areas of known contamination. These wells will monitor the overburden, the Jefferson City Formation, and the Roubidoux Formation.

- Group IV Source Wells: This group of wells is located in areas suspected of being sources of groundwater impacts. This group of wells is comprised of overburden wells.

- Group V License Wells: This group includes the license-required groundwater monitoring wells and will be sampled in accordance with NRC license requirements.

Revision 2 of the IGMP was necessary to remove nine (9) wells that were abandoned in April 2011, (PL-06, NB-31, NB-33, NB-81, BD-14, DM-02, EP-20, WS-13, and WS-17B) from the list of monitoring wells to be sampled. These nine wells were hybrid or leachate wells and were part of the paired well analysis conducted in 2011. A sand/gravel well was placed adjacent to each of these well and both sets of wells were sampled prior to abandonment as discussed in Section 4.4 above. Revision 2 redefined the functional groupings to four categories of wells (Group I –Sentry Wells; Group II – Fringe Wells; Group III – Plume Wells; and Group IV-Source Wells) to be used for monitoring of radionuclides and VOCs in groundwater. Figures 4-1 through 4-6 are photographs showing the removal process of the wells abandoned in 2011. These wells were over cored to pull the pipe out being removed and the hole was backfilled with grout.

Revision 3 of the IGMP was necessary due to the impending remedial activities within the Central Tract area, which would have impacted the wells. This excavation within the Central Tract area necessitated the abandonment of sixteen (16) wells from the Source Area functional grouping (IV) for the monitoring period between January 2012, and December 2012. Monitoring wells BD-02, BD-03, BD-04, BD-06, BD-08, BD-13, BP-17, BP-20A, BP-20B, BP-21, BP-22A,

BP-22B, EP-14, EP-16, LF-09, and WS-16 were abandoned in accordance with MDNR requirements.

6.3 Post-Remediation Groundwater Sampling

6.3.1 Background

Section 14.5 of the DP, Revision 0, stated that groundwater sampling would be conducted during and following the completion of soil remediation. The goal of the post-remediation sampling was to identify adverse effects on water quality as a result of excavation, and to verify the absence of any significant amount of residual radioactivity in the groundwater that could be a part of a credible exposure scenario. It was expected that remediation would result in a reduction in the radioactivity levels in water within the overburden soil, and would not have an adverse impact on groundwater from a dose perspective. Monitoring of well water between the initial Remedial Investigation Sampling in 2004, and the submittal of the DP in 2009, indicated that radioactivity in the water beneath the site was primarily limited to the overburden soil in source areas, including the Burial Pit Area, the Evaporation Ponds, and in soil beneath the Process Building. This indicated that the impacted water was ingrained in the soil as leachate and not within the usable groundwater HSUs.

Radioactivity in the bedrock groundwater (drinking water) underlying the site was generally within the range of background with the potential exception of technicium-99 (Tc-99) concentrations at very low, insignificant levels (maximum bedrock groundwater detection was 49.9 pCi/l or 5.5% of the EPA Drinking Water Standard of 900 pCi/l which equates to a 4 mrem/year dose). The post-remediation sampling and analysis strategy was to focus on monitoring vertical seepage in the clay overburden and lateral migration in the sandy/gravelly deposits at the base of the clay overburden. The approach was based on site-specific hydrogeology, the pre-remediation groundwater contaminant distribution, and potential radionuclide transport pathway data as detailed in Chapter 3 of the DP.

6.3.2 Changes to the DP Post-Remediation Groundwater Sampling Based on RAIs

The NRC requested additional information regarding groundwater topics during its review of the DP. One concern, (HDP-3.7-Q4) (Reference 8.14), stated that the Post-Remediation Groundwater Wells lacked sufficient details and that the rationales for the proposed groundwater monitoring network were not discussed in the text. As a result, Westinghouse responded in Westinghouse letter HEM-11-25 (Reference 8.15), providing updated maps showing the existing monitoring wells in the central tract and the outlying areas. Consistent with the monitoring program for volatile organics (VOCs) in groundwater, the post-remediation sampling and analysis strategy for radionuclides was chosen to focus on monitoring lateral migration in the Sand/Gravel HSU at the base of the silty clay overburden and vertical seepage to the Jefferson City-Cotter and Roubidoux HSUs. The radionuclides of concern for ground water were total uranium (U-234, U-235, and U-238) and Tc-99, consistent with the radionuclides of concern applied during the site characterization. These radionuclides were monitored quarterly during site remediation through the IGMP.

The selection of existing wells and proposed new wells for post-remediation monitoring was based on the potential source regions (remediated areas) for uranium and/or Tc-99 contamination

in soil, the general direction of groundwater flow in the Sand/Gravel, Jefferson City-Cotter, and Roubidoux HSUs. Based on the knowledge gained during the remediation of impacted silty clay overburden, source regions were determined to be in the area where undocumented burials (trash that was radiologically released at the time) occurred, the area southeast of the former Process Building, the area beneath the former Process Building slabs, the Evaporation Ponds/Leach Field Area, and the Red Room Roof Burial Area.

Based on these areas of contamination, Westinghouse committed to monitor seven new wells and eight existing wells to verify that the post-remediation condition of the Sand/Gravel HSU groundwater met the requirements set forth for license termination. In addition, seven new wells and two existing wells were proposed for post-remediation monitoring of the Jefferson City HSU and four existing wells selected for post-remediation monitoring of the Roubidoux HSU. In general, the monitoring wells were located down gradient (i.e., southeast) of the related source area with a goal of intercepting contamination released from the source areas, if any.

The primary post-remediation well network was to be composed of 12 monitoring wells screened in the Sand/Gravel HSU, seven monitoring wells screened in the Jefferson City-Cotter HSU, and four monitoring wells screened in the Roubidoux HSU. The sampling strategy also included secondary wells to be sampled if results from the primary wells indicated contamination. The sampling strategy has been revised to include the primary and secondary wells in each round of quarterly sampling.

As there are no previous sample analysis results with indication of radionuclide contamination in the groundwater within the Sand/Gravel, Jefferson City-Cotter, or the Roubidoux HSU exceeding MCLs or a dose limit of 4 mrem/year, the purpose of post-remediation sampling is to verify that remediation of the source area had not contributed radionuclide contamination to the groundwater. Therefore, the post-remediation groundwater monitoring is to be terminated after a year (4 quarters) of sampling if sample data indicates that there had been no deleterious effect to groundwater due to remediation.

6.3.3 Locations of Monitoring Wells

The new monitoring wells were installed, placing seven in the Sand/Gravel HSU and seven in the Jefferson City-Cotter HSU. Figure 4-4, *Post-Radiological Remediation Groundwater Monitoring Wells,* provides the locations of all the monitoring wells that are monitored for radiological purposes post-remediation. The new monitoring well construction information is provided in Table 4-5, *Post-Radiological Remediation Groundwater Monitoring Wells Construction Data.*

The post-remediation well network is composed of 18 monitoring wells screened in the sand/gravel HSU, eight wells screened in the Jefferson City-Cotter HSU, and five wells screened in the Roubidoux HSU. Monitoring wells GW-BB, GW-EE, GW-FF, GW-GG, GW-W, NB-71, and NB-10 are positioned down gradient (northeast, east, and southeast) of the former burial pits to assess ground water quality following removal of contaminated soil/materials from this area.

Monitoring wells GW-DD, GW-II, GW-JJ, and GW-V are positioned down gradient (southeast) of the Process Building to assess groundwater quality following building demolition and removal of contaminated soil from this area.

Monitoring wells GW-CC, GW-X, GW-Y, NB-34, NB-35 and PZ-02 are positioned down gradient (southeast) of the Evaporation Ponds and former Leach Field to assess groundwater quality following removal of contaminated soil from these areas.

Monitoring well GW-HH is positioned down gradient (southeast) of the Red Room Roof Burial Area and Cistern/Burn Pit to assess groundwater quality following removal of contaminated soil and materials from these areas.

Three new monitoring wells (BR-14-JC, BR-15-JC, and BR-18-JC) have been installed in the Jefferson City-Cotter HSU down gradient of the Burial Pit and Tc-99 source areas. The wells are placed at locations to the south and east of the Documented Burial Pit Area. These wells are located closer to the central tract than the previously sampled wells and are located in areas that, if contaminant migration is occurring, will identify the degradation of the water within the post-remediation monitoring timeframe.

Post-remediation monitoring of the Jefferson City-Cotter HSU in the vicinity of the former Process Building is accomplished by monitoring three newly installed monitoring wells (BR-13-JC, BR-16-JC, and BR-17-JC) within the source and down gradient of the areas beneath the former Process Buildings where the highest levels of contamination were removed. These wells will be used to evaluate the potential for contaminant migration from the overburden into the shallow bedrock.

Post-remediation monitoring of the Jefferson City-Cotter HSU in the vicinity of the former Evaporation Ponds is accomplished by monitoring of a newly installed monitoring well (BR-19-JC) at a location down gradient of the primary (deep) Evaporation Pond.

Post-remediation monitoring of the Roubidoux HSU will be conducted using the sentry wells designated as BR-03-RB, BR-04-RB, BR-08-RB, and BR-10-RB. In addition, a background well (WS-04), which is located off-site at the Hematite Post Office will be monitored.

This post-remediation monitoring will be performed at wells identified in Table 4-4, *Post-Radiological Remediation Groundwater Monitoring Wells*. In general, the monitoring wells shown on Figure 4-4, *Post-Radiological Remediation Groundwater Monitoring Wells*, are located down gradient of the related former source area with a goal of intercepting any potential residual contamination released from the source areas.

6.3.3 Frequency of Post-Remediation Monitoring, Sampling Method and Evaluation

As provided in the DP, following completion of site soil excavation and remediation, groundwater monitoring is performed quarterly. Westinghouse will maintain the quarterly sampling frequency. Post-remediation quarterly monitoring commenced in June, 2016.

The DP also stated that groundwater sampling would be conducted following site procedures using a low-flow technique that provided a representative sample while reducing investigation derived waste. Site procedures provide that for each monitoring well, unfiltered and filtered samples are collected and analyzed and turbidity is measured in the field on unfiltered groundwater. Samples are analyzed for gross alpha, gross beta, isotopic uranium, and Tc-99.

The DP states that "*monitoring would be discontinued when it could be determined that the radioactivity concentrations did not pose an unacceptable potential for dose.*" Therefore, at the completion of the fourth quarter of post-remediation monitoring, an evaluation of the

groundwater sample data will be performed to determine if the concentrations are stable, or are showing an increasing or decreasing trend as compared to historical data (2009 – 2015). The outcome of the evaluation will determine if it is appropriate to discontinue monitoring and the site is acceptable for unrestricted release, or if further monitoring and evaluation is necessary.

A Mann-Kendall analysis will be performed at the conclusion of quarterly sampling, using a minimum of four data points, on each of the wells to evaluate trends in sample results. For existing wells that have data prior to the completion of radiological remediation, the Mann-Kendall analysis will be performed throughout the groundwater demonstration period as well as at the conclusion of the four quarters of post radiological remediation monitoring. Groundwater elevation contour maps will be provided with the quarterly sampling data.

6.3.4 Groundwater Dose Determination

As described in Section 4.1 above, the Silty Clay Aquitard HSU and the Sand/Gravel HSU have been determined to not present themselves as sources of drinking water. As such, the radiological sample data from the Jefferson City-Cotter Bedrock HSU and the Roubidoux Bedrock HSU are used to determine the dose for comparison to the EPA drinking water maximum contaminant level (MCL) of 900 pCi/L and to calculate the groundwater dose contribution as it applies to the total dose calculation for a LSA survey unit.

For the determination of the groundwater dose contribution for Final Status Survey purposes, , the corresponding dose will be calculated using the Dose to Source Ratios (DSRs) listed in DP Chapter 5, Table 5-14 for positive sample results, above background, from samples collected in the bedrock aquifers for the highest sample value identified during the post-remediation monitoring period.

For the determination of the groundwater dose for comparison to the EPA drinking water MCL, , the corresponding dose will be calculated using the Dose to Source Ratios (DSRs) listed in DP Chapter 5, Table 5-14 for positive sample results, above background, from samples collected in the sand/gravel and bedrock aquifers.

The first quarter of post-remediation groundwater monitoring sampling was completed during June, 2016. The results of the first quarter post-remediation groundwater monitoring sample analyses showed that the radionuclides of concern were either not detected or detected at significantly low concentrations (fractions of the drinking water standards). The first quarter post-remediation sample data is consistent with the groundwater monitoring sample data both pre-remediation and during remediation. The first quarter sampling results are included in Table 5-6.

7.0 SUMMARY

The objective of the decommissioning process is to ensure that any dose from residual radioactivity at License termination does not exceed the annual dose criterion for unrestricted use as specified in 10 CFR Part 20 Subpart E. The principal requirement is that the dose to future site occupants is shown to be less than 25 millirem/year. In order to meet the unrestricted release criteria of §20.1402, residual radioactivity in soil and in groundwater sources of drinking water must be accounted for in Westinghouse's performance assessment of the Hematite Site. Westinghouse has accounted for this requirement through the excavation and removal of soils radiologically contaminated from former site operations, and by evaluating the results of groundwater to verify that only very low, insignificant concentrations of ROCs are present that can contribute to future occupant dose.

When the Westinghouse DP was approved by the NRC in Amendment 57 of Hematite License SNM-033, the NRC also issued concurrently an SER which specified Westinghouse's commitments to remove the radiologically contaminated soil and protect the groundwater from future radioactive contamination. These commitments have been addressed as follows:

1. Abandon selected hybrid wells identified with "leachate" impacted with radionuclides. These hybrid wells have well screens that cross both the silty clay overburden and the sand/gravel unit below. This cross communication has resulted in the transport of contaminated water from the silty clay overburden to the sand/gravel unit. The hybrid wells proposed for abandonment include PL-06, NB-33, EP-20, BD-14, WS-13, NB-31, NB-81, WS-17B, and DM-02. Most of these wells are located down gradient of the Process Building.

   This objective was completed by Westinghouse by the removal of the hybrid and leachate wells prior to and during remediation. There are currently no hybrid wells that are screened across both the silty clay aquitard and the sand gravel HSU.

2. Remove 'leachate" impacted with radionuclides in the overburden clay. As soil excavation proceeded, the contaminated "leachate" entering the excavation pit was pumped to and treated for radionuclides by the WTS prior to its release in accordance with the effluent discharge requirements.

   This objective was met through the excavation and off-site disposal of radiologically contaminated soil and debris from the HDP Site. Excavation in the identified areas removed the impacted silty clay overburden material, and thus the pore space water where the contamination was located. The excavated areas were surveyed to verify the radiologically contaminated soil had been removed and the areas were backfilled with reuse or non-impacted soil. Water that accumulated within the open excavations during remediation was collected and treated through the on-site WTS.

3. Conduct borings in the close proximity to hybrid wells BD-001, BD-02, BD-03, and BD-04 within the investigation area, and collect soil samples to the top of sand/gravel layer for radionuclide analysis. Further soil excavation will be conducted where spent limestone and soil above the DCGLs are found below the initially proposed excavation depth.

This objective was completed through the subsurface evaluation that was conducted within the former building slabs. This evaluation was described in the report, FSSFR Volume 3, Chapter 1 *Land Survey Areas (LSA) Overview.*

4. Monitor groundwater post-remediation. The Westinghouse monitoring strategy will focus on the potential migration of radionuclides (Uranium-234, Uranium-235, and Uranium-238 and Technetium-99) in the sand/gravel, the Jefferson City-Cotter, and Roubidoux units at locations down gradient of formerly identified source areas at the Site. Seven new wells will be installed in the sand/gravel unit and incorporated with seven other existing wells in the sand/gravel monitoring network. The proposed monitoring network for the Jefferson City-Cotter unit includes seven new wells and two existing wells. The Roubidoux unit monitoring network will retain the four existing monitoring wells. Monitoring of the wells will be quarterly.

   This objective will be met through the installation of monitoring wells as described in the DP and associated RAIs and reiterated within this document. Based on the data collected to date, there is no indication of radiological contamination within the groundwater HSUs either before or during the HDP remediation. Therefore, one round (one year) of groundwater sampling will be conducted to verify that the groundwater has not been negatively impacted through site remediation.

   The installation of the new monitoring wells was completed by March 31, 2016. Quarterly monitoring began once all the monitoring wells have been installed.

Following the conclusion of the post-remediation sampling period (March 31, 2017), Westinghouse will demonstrate that the sum of the annual dose for all the radionuclides from groundwater does not exceed the EPA MCL of 4 mrem/yr, and that the dose from residual radioactivity from all sources (including groundwater) does not exceed the annual dose criterion for license termination for unrestricted use such that the dose to future site occupants will be less than 25 mrem/yr.

8.0 REFERENCES

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8.3 Imes, J.L. and Emmett, L.F., "Geohydrology of the Ozark Plateaus Aquifer System in Parts of Missouri, Arkansas, Oklahoma, and Kansas," U. S. Geological Survey Professional Paper 1414-D, 1994.

8.4 EO-09-003, SAIC Report, "Supplemental Analysis of Hydrogeologic Conditions in Overburden at Westinghouse Hematite Facility, Hematite, Missouri," Revision 0, July 2009.

8.5 EO-09-002, SAIC Report, "Radionuclide Activity in Bedrock Groundwater at Westinghouse Hematite Facility, Hematite, Missouri," Revision 0, July 2009.

8.6 Gateway Environmental Associates (GEA), "Investigation to Determine the Source of Technetium-99 in Groundwater Monitoring Wells 17 and 17B," prepared for Combustion Engineering, Hematite, Missouri, September 1996.

8.7 GEA, "Exploratory Probe Hole Investigation for the Evaporation Ponds at the ABB Combustion Engineering Hematite Facility," letter report to Mr. Robert Sharkey, ABB Combustion Engineering, Inc., April 1997.

8.8 Leggette, Brashears, and Graham (LBG), "Hydrogeologic Investigation and Ground-Water, Soil and Stream Characterization," prepared for Combustion Engineering, Hematite, Missouri, March 1999.

8.9 LBG, "Interim Hydrogeologic Investigation to Support the Engineering Evaluation and Cost Analysis for the Response Action for Off-Site Groundwater Quality Impacts," prepared for Westinghouse Electric Company, Hematite, Missouri, November 2002.

8.10 LBG, "Site-Specific Soil Parameters Westinghouse Former Fuel Cycle Facility D&D Project," prepared for Westinghouse Electric Company, Hematite Facility, Festus, Missouri, September 15, 2003.

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8.13 SAIC, Electronic data tables for Quarterly Groundwater Monitoring of Radionuclides and Chemicals, data provided by SAIC-Hematite facility in Excel™ format, 2009.

8.14 NRC (J. J. Hayes) letter to Westinghouse (E. K. Hackmann), "NRC Request for Additional Information from Westinghouse on Hematite Decommission Plan Chapter 3," February 9, 2011. {ML110210533}

8.15 Westinghouse letter HEM-11-25, "Response to Request for Additional Information on Decommissioning Plan Chapter 3, Site Description," March 10, 2011. {ML110730270}

8.21 Westinghouse letter HEM-10-126, "Partial Responses to Requests for Additional Information on Decommissioning Plan Chapters 1, 4, 6 and 7," December 10, 2010. {ML103490102}

8.22 Westinghouse letter HEM-11-11, "Submittal of HDP-TBD-EHS-001 Subsurface Water," January 21, 2011. {ML110250138}

8.23 Westinghouse letter HEM-10-132, "Remaining Responses to Requests for Additional Information on Decommissioning Plan Chapters 1, 4, 6 and 7," December 21, 2010. {ML103560708}

8.24 Westinghouse letter HEM-11-96, "Final Supplemental Response to NRC Request for Additional Information on the Hematite Decommissioning Plan and Related Revision to a Pending License Amendment Request," July 5, 2011. {ML111880290}

Figure 1-1
Hematite Circa 2006
Showing Buildings 110, 115, 230 and 231, which are the only buildings that will remain at license termination.

Figure 1-2
Major Structures at Hematite

Figure 2-1
Groundwater Monitoring Well Prior to Abandonment (Removal)

Figure 2-2
Commencement of Coring of an Abandoned Groundwater Monitoring Well

Figure 2-3
Example of Over-boring an Abandoned Groundwater Monitoring Well.

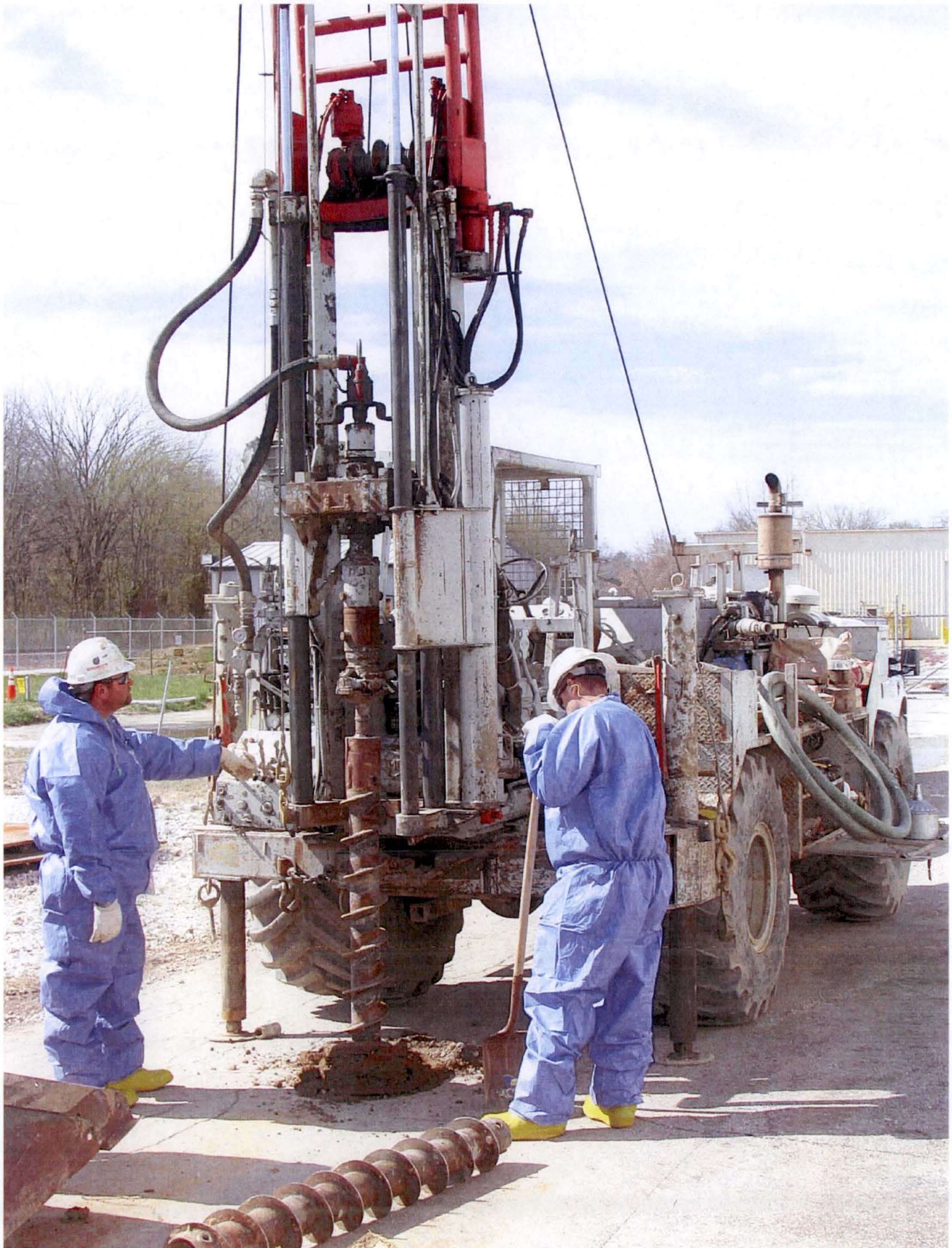

Figure 2-4
Example of Casing Removed from Abandoned Groundwater Monitoring Well

Figure 2-5
Example of Casing and Piping Removed from Abandoned Groundwater Monitoring Well

Figure 2-6
Example of Tremie Grouting Abandoned Monitoring Well to Prevent Cross Communication

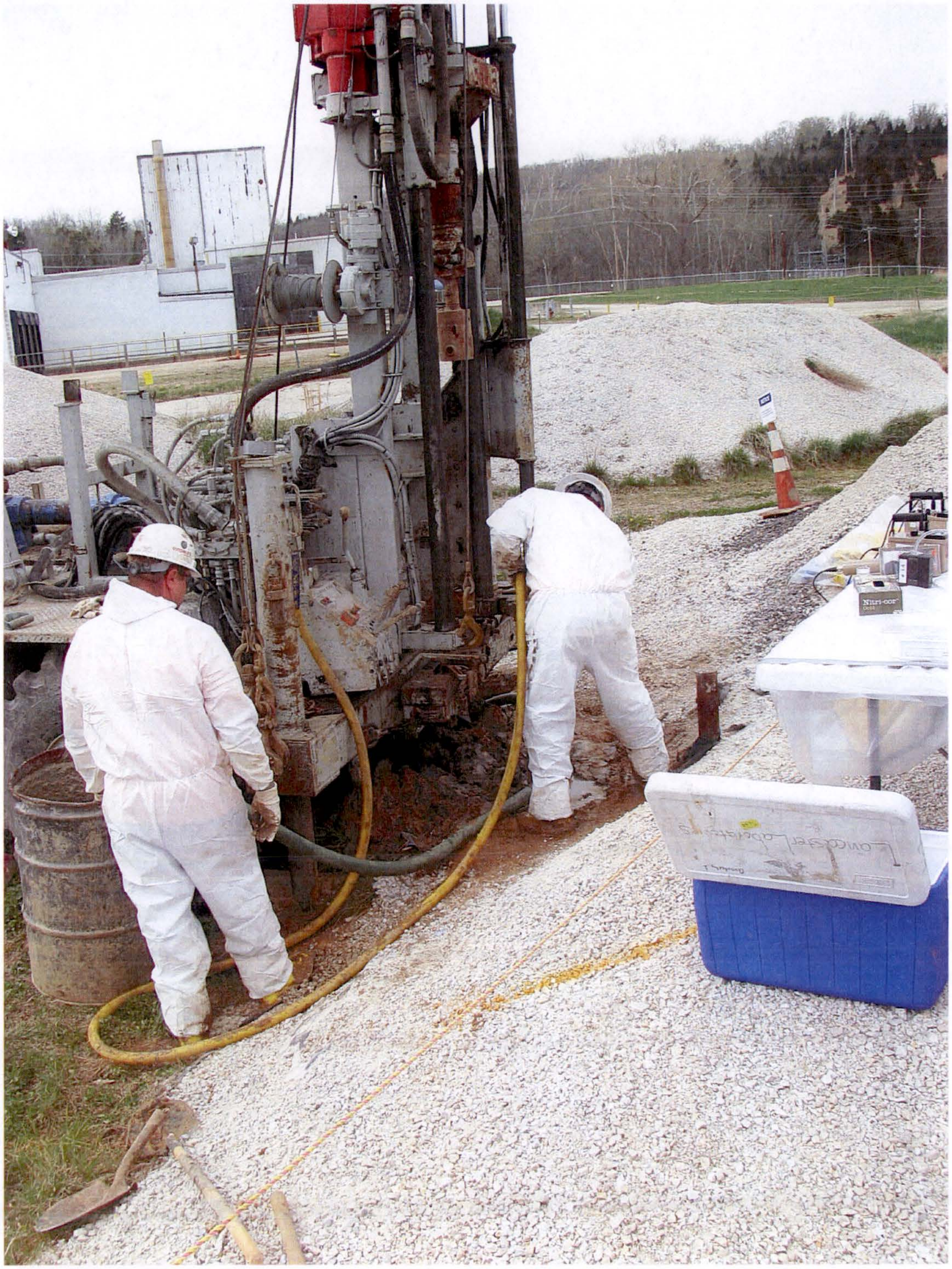

Figure 4-1
Limestone Fill Area and Deul's Mountain Locations

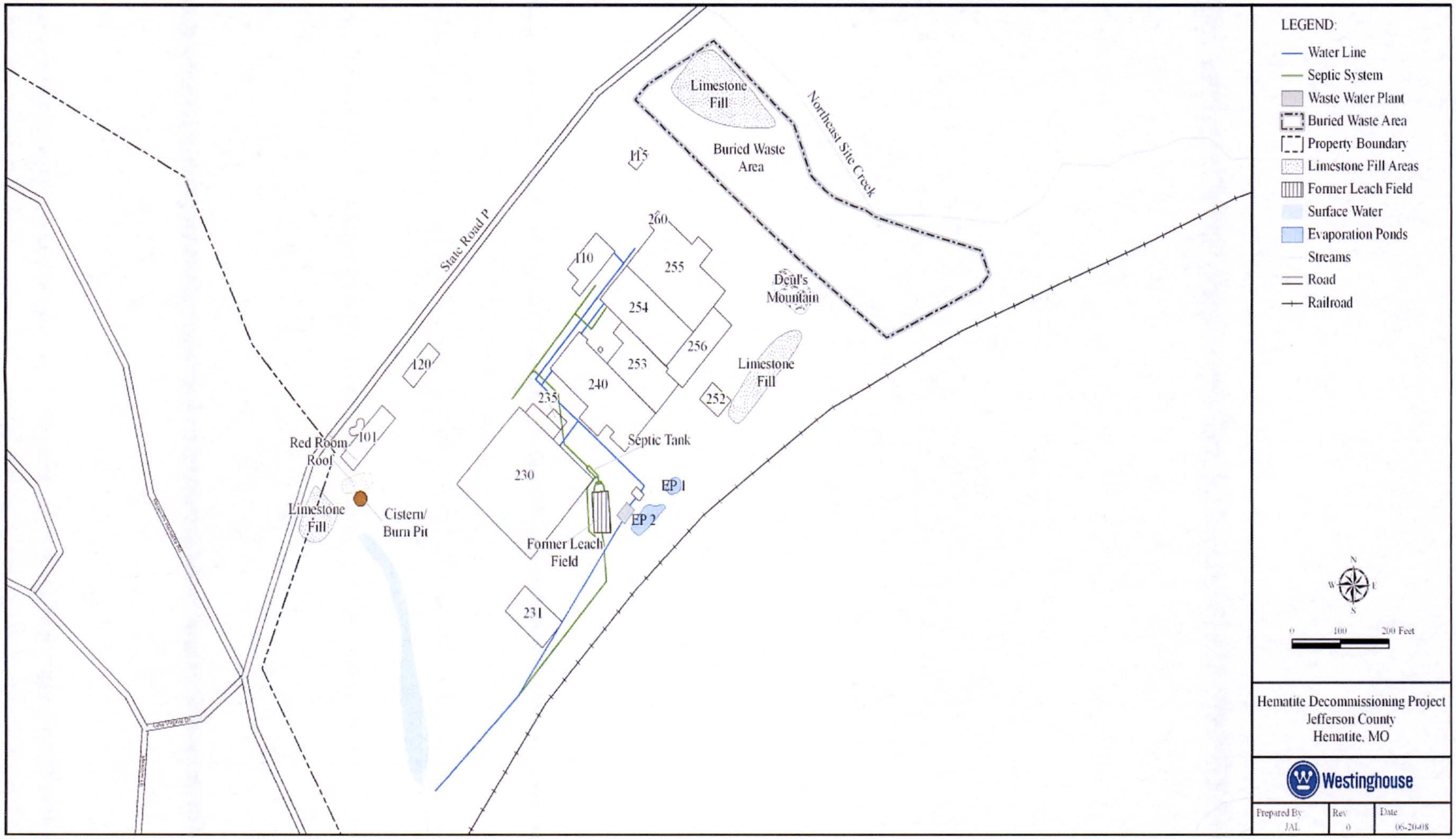

Figure 4-2
Locations of Groundwater Monitoring Wells at the Start of Remediation and During Remediation

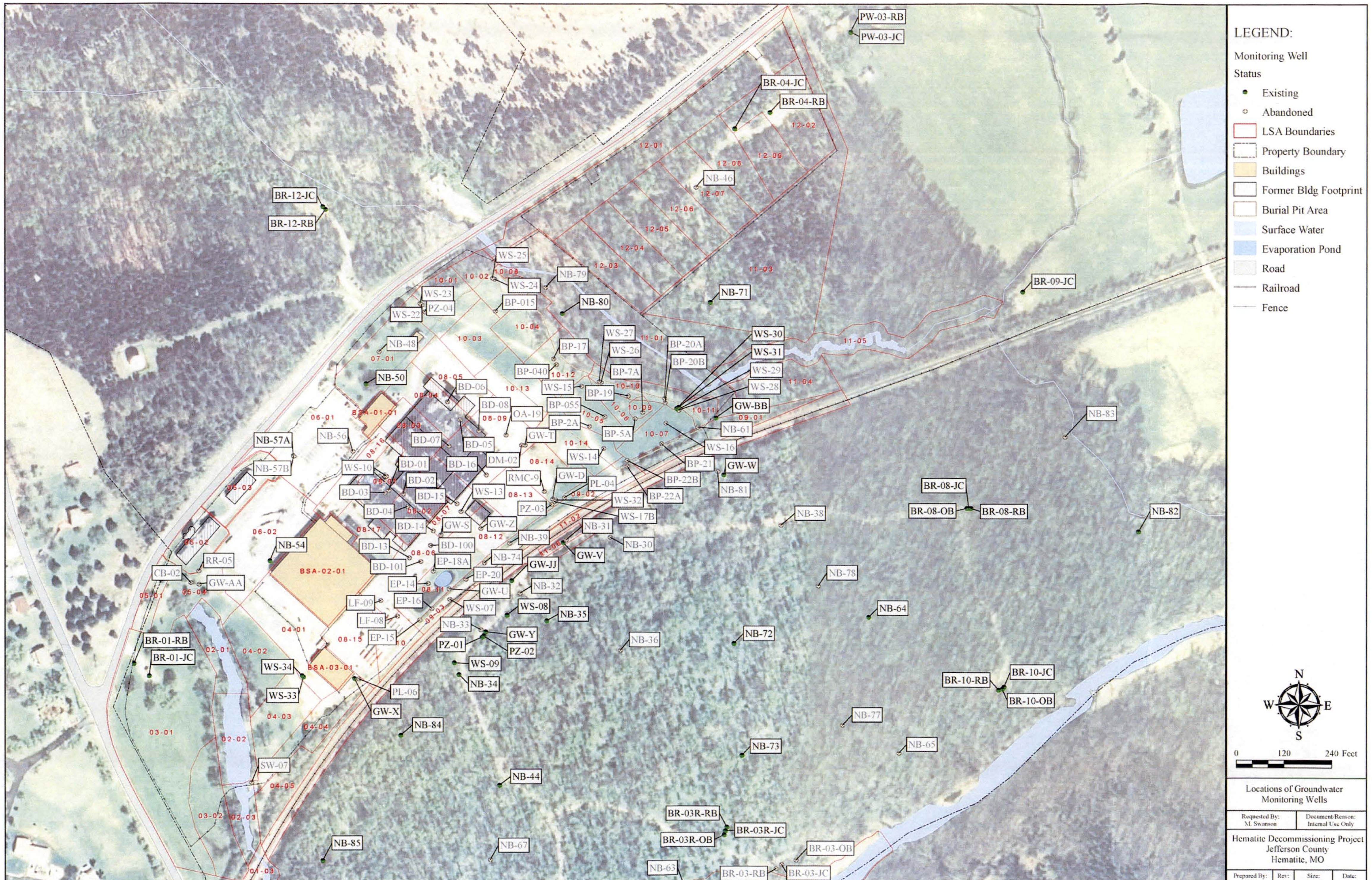

Figure 4-3a
Cross-Section of Paired Well

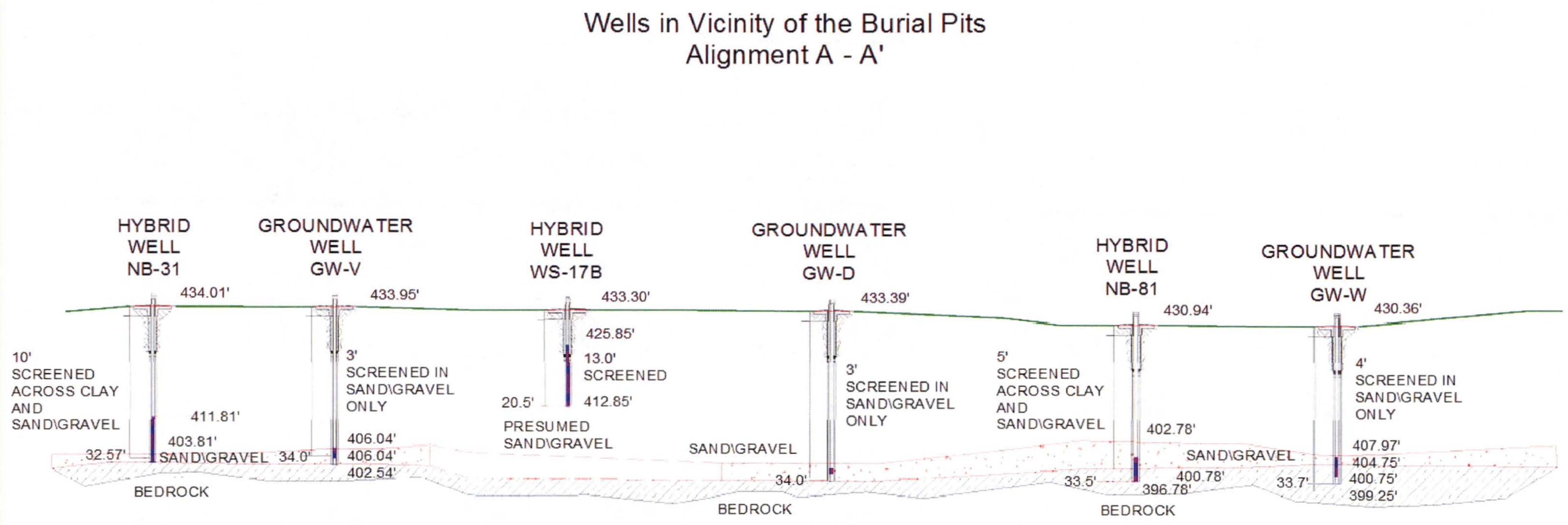

Figure 4-3b
Cross-Section of Paired Well

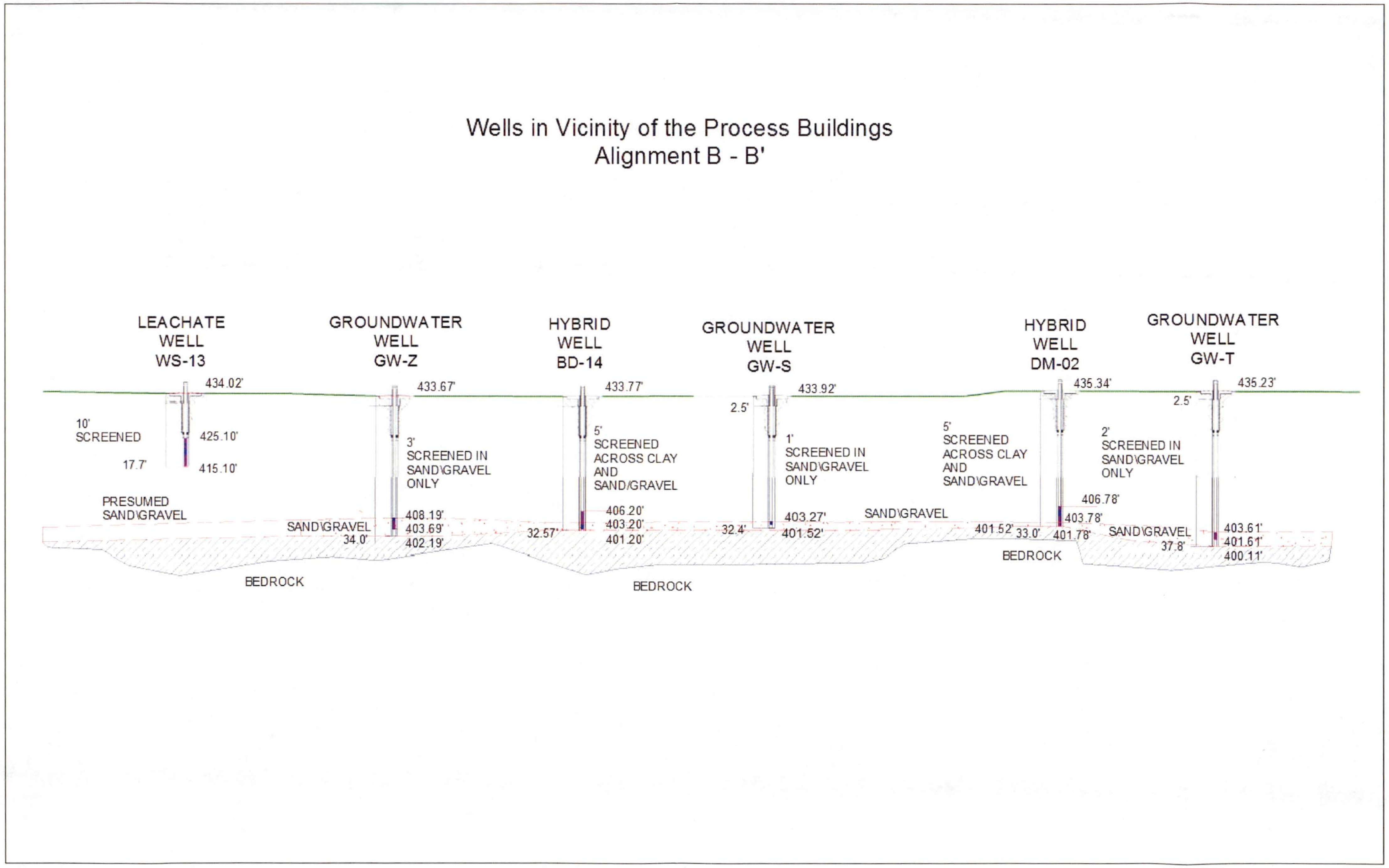

Figure 4-3c
Cross-Section of Paired Well

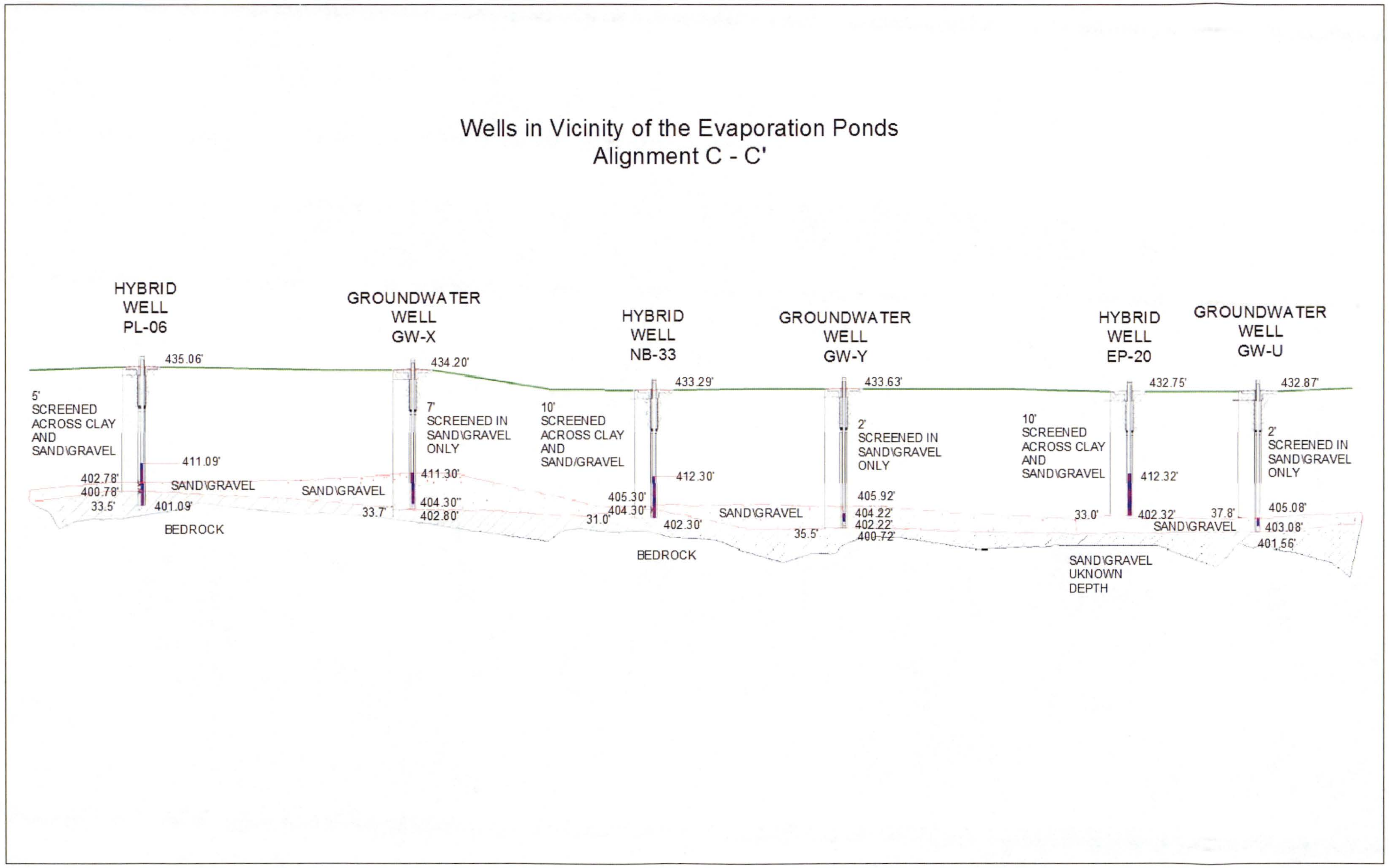

Figure 4-4
Post-remediation Groundwater Monitoring Wells

Table 4-1
Summary of Annual IGMP Sampling

Constituent	Units	Number of Analyses	Number of Detects	Minimum Detected Concentration	Maximum Detected Concentration	MCL (pCi/L)	Number of Analyses > MCL	Maximum Location	Maximum Quarter
2012 Silty Clay Overburden HSU									
Technetium-99	pCi/L	27	2	2.3 ±1.1	3.7 ±1.2	900	0	NB-35	3Q12
Uranium-234	pCi/L	27	13	0.078 ±0.059	2.3 ±0.36	20	0	NB-35	4Q12
Uranium-235/236	pCi/L	27	4	0.036 ±0.041	0.119 ±0.076	20	0	OB-01	2Q12
Uranium-238	pCi/L	27	16	0.029 ±0.033	1.71 ±0.3	20	0	NB-85	4Q12
2013 Silty Clay Overburden HSU									
Technetium-99	pCi/L	27	2	2.3 ±1.1	3.7 ±1.2	900	0	NB-35	3Q13
Uranium-234	pCi/L	27	13	0.078 ±0.059	2.3 ±0.36	20*	0	NB-35	4Q13
Uranium-235/236	pCi/L	27	4	0.036 ±0.041	0.119 ±0.076	20*	0	OB-01	2Q13
Uranium-238	pCi/L	27	16	0.029 ±0.033	1.71 ±0.3	20*	0	NB-85	4Q13
2014 Silty Clay Overburden HSU									
Technetium-99	pCi/L	30	5	5.010±1.5	7.98±1.62	900	0	NB-34	3Q2014
Uranium-234	pCi/L	30	20	0.0433±0.321	1.84±0.233	20*	0	OB-01	2Q2014
Uranium-235/236	pCi/L	30	2	0.059±0.045	0.092±0.07	20*	0	OB-01	4Q2014
Uranium-238	pCi/L	30	22	0.0188±0.0218	1.27±0.181	20*	0	OB-01	2Q2014
2015 Silty Clay Overburden HSU									
Technetium-99	pCi/L	22	7	2.46±1.3	6.48±1.59	900	0	NB-34	1Q2015
Uranium-234	pCi/L	22	13	0.0588±0.052	1.31±0.222	20*	0	OB-01	2Q2015
Uranium-235/236	pCi/L	22	3	0,0223±0.0223	0.0953±0.105	20*	0	NB-85	2Q2015
Uranium-238	pCi/L	22	14	0.0141±0.0016	0.953±0.213	20*	0	OB-01	1Q2015

HSU = Hydrostratigraphic unit.
MCL = Maximum contaminant level.
NA = Not applicable.
*Isotopic Evaluation Level since MCL is 20 μg/L for total uranium.

Table 4-1
Summary of Annual IGMP Sampling

Constituent	Units	Number of Analyses	Number of Detects	Minimum Detected Concentration	Maximum Detected Concentration	MCL (pCi/L)	Number of Analyses > MCL	Maximum Location	Maximum Quarter
2012 Sand Gravel Overburden HSU									
Technetium-99	pCi/L	88	32	1.68 ±0.98	149 ±15	900	0	GW-X	4Q12
Uranium-234	pCi/L	85	52	0.029 ±0.034	1.48 ±0.28	20	0	BR06-OB	4Q12
Uranium-235/236	pCi/L	85	8	0.035 ±0.04	0.078 ±0.064	20	0	BR06-OB	2Q12
Uranium-238	pCi/L	85	42	0.026 ±0.0261	0.69 ±0.22	20	0	BR10-OB	1Q12/2Q12
2013 Sand Gravel Overburden HSU									
Technetium-99	pCi/L	82	27	1.67 ±0.98	111 ±11.2	900	0	GW-X	2Q13/3Q13
Uranium-234	pCi/L	82	49	0.028 ±0.033	5.26 ±1.27	20*	0	BR-06-OB	2Q13
Uranium-235/236	pCi/L	82	11	0.033 ±0.038	0.307 ±0.381	20*	0	BD-100	2Q13
Uranium-238	pCi/L	82	46	0.028 ±0.032	1.14 ±0.47	20*	0	BR-06-OB	2Q13
2014 Sand Gravel Overburden HSU									
Technetium-99	pCi/L	62	23	2.41±1.27	120±12	900	0	GW-X	4Q2014
Uranium-234	pCi/L	60	37	0.0394±0.0396	2.27±0.308	20*	0	BR-06-OB	1Q2014
Uranium-235/236	pCi/L	60	12	0.025±0.0251	0.147±0.07	20*	0	BR-06-OB	1Q2014
Uranium-238	pCi/L	60	37	0.0313±0.0281	0.751±0.19	20*	0	BR-06-OB	4Q2014
2015 Sand Gravel Overburden HSU									
Technetium-99	pCi/L	41	18	2.24±1.38	94.8±9.6	900	0	GW-X	1Q2015
Uranium-234	pCi/L	41	23	0,0301±0,0247	2.4±0.372	20*	0	BR-06-OB	1Q2015
Uranium-235/236	pCi/L	41	4	0.0528±0.053	0.12±0.12	20*	0	BR-10-OB	1Q2015
Uranium-238	pCi/L	41	20	0.0295±0.0342	0.758±0.19	20*	0	BR-06-OB	1Q2015

HSU = Hydrostratigraphic unit.
MCL = Maximum contaminant level.
NA = Not applicable.
*Isotopic Evaluation Level since MCL is 20 µg/L for total uranium.

Table 4-1
Summary of Annual IGMP Sampling

Constituent	Units	Number of Analyses	Number of Detects	Minimum Detected Concentration	Maximum Detected Concentration	MCL (pCi/L)	Number of Analyses > MCL	Maximum Location	Maximum Quarter
2012 Jefferson City HSU									
Technetium-99	pCi/L	73	0	ND	ND	900	0	NA	NA
Uranium-234	pCi/L	73	73	0.34 ±0.12	4.84 ±0.6	20	0	PW-19-JC	3Q12
Uranium-235/236	pCi/L	73	16	0.033 ±0.038	0.079 ±0.064	20	0	PW-19-JC	2Q12
Uranium-238	pCi/L	73	71	0.075 ±0.057	0.74 ±0.19	20	0	PW-06-JC	1Q12,2Q12
2013 Jefferson City HSU									
Technetium-99	pCi/L	71	3	2.32 ±1.34	3.16 ±1.39	900	0	BR-08-JC	4Q13
Uranium-234	pCi/L	71	68	0.39 ±0.13	5.14 ±0.82	20*	0	BR-07-JC	3Q13
Uranium-235/236	pCi/L	71	14	0.035 ±0.041	0.26 ±0.25	20*	0	BR-03-JC	2Q13
Uranium-238	pCi/L	71	65	0.070 ±0.057	0.64 ±0.18	20*	0	PW-06-JC	4Q13
2014 Jefferson City HSU									
Technetium-99	pCi/L	66	0	ND	ND	900	0	NA	NA
Uranium-234	pCi/L	66	66	0.313±0.117	4.78±0.601	20*	0	PW-19-JC	2Q2014
Uranium-235/236	pCi/L	66	19	0.0204±0.02	0.0695±0.062	20*	0	BR-07-JC	4Q2014
Uranium-238	pCi/L	66	64	0.0679±0.035	0.706±0.182	20*	0	PW-06-JC	2Q2014
2015 Jefferson City HSU									
Technetium-99	pCi/L	34	0	ND	ND	900	0	NA	NA
Uranium-234	pCi/L	34	34	0.418±0.242	4.5±0.518	20*	0	PW-19-JC	2Q2015
Uranium-235/236	pCi/L	34	10	0.0251±0.0225	0.0859±0.058	20*	0	BR-07-JC	2Q2015
Uranium-238	pCi/L	34	31	0.01±0.0709	0.592±0.121	20*	0	BR-03R-JC	2Q2015

HSU = Hydrostratigraphic unit.
MCL = Maximum contaminant level.
NA = Not applicable.
*Isotopic Evaluation Level since MCL is 20 µg/L for total uranium.

Table 4-1
Summary of Annual IGMP Sampling

Constituent	Units	Number of Analyses	Number of Detects	Minimum Detected Concentration	Maximum Detected Concentration	MCL (pCi/L)	Number of Analyses > MCL	Maximum Location	Maximum Quarter
2012 Roubidoux Formation HSU									
Technetium-99	pCi/L	64	0	ND	ND	900	0	NA	NA
Uranium-234	pCi/L	64	64	1.81 ±0.31	6.93 ±0.81	20	0	BR-06-RB	1Q12
Uranium-235/236	pCi/L	64	10	0.036 ±0.042	0.081 ±0.061	20	0	BR-01-RB	2Q12
Uranium-238	pCi/L	64	63	0.083 ±0.075	0.85 ±0.19	20	0	BR-01-RB	4Q12
2013 Roubidoux Formation HSU									
Technetium-99	pCi/L	58	0	ND	ND	900	0	NA	NA
Uranium-234	pCi/L	58	57	0.127 ±0.077	6.6 ±0.7	20*	0	BR-06-RB	4Q13
Uranium-235/236	pCi/L	58	5	0.053 ±0.053	0.073 ±0.060	20*	0	PW-19-RB	1Q13
Uranium-238	pCi/L	58	55	0.066 ±0.054	0.82 ±0.2	20*	0	BR-01-RB	1Q13
2014 Roubidoux Formation HSU									
Technetium-99	pCi/L	58	0	ND	ND	900	0	NA	NA
Uranium-234	pCi/L	58	58	1.85±0.289	7.02±0.812	20*	0	BR-06-RB	4Q2014
Uranium-235/236	pCi/L	58	16	0.0153±0.0177	0.0827±0.068	20*	0	BR-06-RB	4Q2014
Uranium-238	pCi/L	58	58	0.123±0.0593	0.852±0.198	20*	0	BR-01-RB	3Q2014
2015 Roubidoux Formation HSU									
Technetium-99	pCi/L	30	0	ND	ND	900	0	NA	NA
Uranium-234	pCi/L	30	30	1.79±0.241	6.61±0.779	20*	0	BR-06-RB	1Q2015
Uranium-235/236	pCi/L	30	13	0.0341±0.0342	0.0787±0.053	20*	0	PW-16-RB	2Q2015
Uranium-238	pCi/L	30	30	0.075±0.0603	0.87±0.173	20*	0	BR-01-RB	2Q2015

HSU = Hydrostratigraphic unit.
MCL = Maximum contaminant level.
NA = Not applicable.
*Isotopic Evaluation Level since MCL is 20 µg/L for total uranium.

Table 4-2

Paired Wells Description

Well ID	Surface Elev.	Top of Casing Elev. (Surveyed)	Bottom Elev.	Well Depth bgs (ft)	Screen Length (ft)	Screened Material	Paired Well
BD-14	433.770	433.480	401.199	32.0	5.0	Hybrid	GW-S
DM-02	435.340	437.256	401.783	33.0	5.0	Hybrid	GW-T
EP-20	432.750	434.550	402.323	30.0	10.0	Leachate	GW-U
GW-AA	431.215	433.655	403.755	30.0	1.0	Sand	N/A
GW-BB	427.877	430.267	400.867	29.5	3.0	Sand	N/A
GW-D	433.391	435.911	399.711	36.3	1.0	Sand	WS-17B
GW-S	433.917	436.427	404.527	32.0	1.0	Sand	BD-14
GW-T	435.231	437.811	400.111	37.8	2.0	Sand	DM-02
GW-U	432.869	435.479	401.579	34.0	2.0	Sand	EP-20
GW-V	433.95	436.440	402.540	34.0	3.0	Sand	NB-31
GW-W	430.361	432.851	399.251	33.7	4.0	Sand	NB-81
GW-X	434.195	436.695	402.795	34.0	7.0	Sand	PL-06
GW-Y	433.628	436.118	400.718	35.5	2.0	Sand	NB-33
GW-Z	433.672	436.092	402.192	34.0	3.0	Sand	WS-13
NB-31	434.010	435.770	401.812	32.0	10.0	Hybrid	GW-V
NB-33	433.297	435.300	402.298	31.0	10.0	Hybrid	GW-Y
NB-81	430.640	432.600	396.777	33.5	5.0	Hybrid	GW-W
PL-06	435.085	436.033	401.085	34.0	10.0	Hybrid	GW-X
WS-13	434.020	435.800	415.100	17.7	10.0	Leachate	GW-Z
WS-17B	433.304	435.392	412.850	20.5	13.0	Leachate	GW-D

Table 4-3
Groundwater Radiological Results

Well ID	Paired Wells	Screened Zone	Technetium-99 (pCi/L)															Total Uranium (pCi/L)														
			3Q09			4Q09			1Q10			2Q10			3Q10			3Q09			4Q09			1Q10			2Q10			3Q10		
			Result	MDC	Error	Result	MDC	Error	Result	MDC	Error	Result	MDC	Error	Result	MDC	Error	Result	MDC[1]	Error[2]	Result	MDC[1]	Error[2]	Result	MDC[1]	Error[2]	Result	MDC[1]	Error[2]	Result	MDC[1]	Error[2]
GW-AA	N/A	Sand/ Gravel	-0.4	2	1.2	-0.6	2.5	1.5	0.01	2	1.2	0.26	1.6	0.95	1.7	1.6	1	1.7	0.1	0.56	0.22	0.08	0.14	0.2	0.1	0.17	0.23	0.02	0.14	0.39	0.07	0.29
GW-BB	N/A	Sand/ Gravel	-1.4	2.5	1.4	-0.3	2.1	1.2	-1.8	2.1	1.2	-0.5	1.5	0.87	0.5	3	1.8	0.09	0.11	0.15	0.02	0.07	0.07	0	0.09	0.09	0.1	0.06	0.12	0	0.1	0.06
GW-D	WS-17B	Sand/ Gravel	0.2	2.6	1.5	2.2	1.8	1.2	2.8	1.6	1.1	2.37	1.5	1	3	1.7	1.1	0.17	0.09	0.15	0.04	0.1	0.09	0.04	0.08	0.08	0.01	0.08	0.08	0.06	0.1	0.14
WS-17B	GW-D	Leachate	2500	5	210	2320	4	200	1670	3	140	1580	3	130	1390	3	120	0.16	0.09	0.16	0.06	0.06	0.11	0.26	0.11	0.22	0.19	0.06	0.16	0.15	0.08	0.16
GW-S	BD-14	Sand/ Gravel	0.2	2.1	1.2	1.2	1.8	1.1	0.6	1.7	1	1.6	1.6	1	1.13	1.6	0.98	0.51	0.09	0.31	0.14	0.07	0.12	0.22	0.07	0.21	0.07	0.06	0.1	0.1	0.12	0.15
BD-14	GW-S	Hybrid	-0.1	2.2	1.3	0.7	3.6	2.2	0.09	1.6	0.96	1.3	1.6	1	1.5	1.7	1.1	1.56	0.1	0.51	0.7	0.2	0.43	3.79	0.13	0.79	2.63	0.08	0.58	3.44	0.08	0.74
GW-T	DM-02	Sand/ Gravel	1	2.5	1.5	2.9	1.9	1.3	4.3	1.6	1.2	2.38	1.5	0.99	3.9	1.8	1.2	0.18	0.09	0.17	0.21	0.08	0.17	0.22	0.11	0.16	0.23	0.09	0.19	0.1	0.12	0.16
DM-02	GW-T	Hybrid	293	2	25	166	2	14	157	2	14	162	2	14	414	3	36	158	0.1	14.2	196	0.3	17.9	201	0.2	18.9	202	0.2	17.9	192	0.09	8.65
GW-U	EP-20	Sand/ Gravel	1.4	2.3	1.4	2.4	1.8	1.2	2.1	1.6	1	2.5	1.7	1.1	3.1	1.5	1	1.05	0.1	0.37	0.86	0.02	0.27	0.09	0.11	0.17	0.85	0.09	0.32	1.23	0.1	0.5
EP-20	GW-U	Leachate	985	3	84	952	3	81	868	2	74	776	2	66	735	2	63	0.17	0.09	0.15	0.29	0.09	0.19	0.19	0.09	0.2	0.13	0.07	0.14	0.23	0.05	0.11
GW-V	NB-31	Sand/ Gravel	5.6	2.2	1.5	4.7	1.7	1.2	3.2	1.7	1.1	4.6	1.5	1.1	7.1	1.7	1.4	0.07	0.12	0.14	0.05	0.09	0.09	0.07	0.08	0.12	0.05	0.12	0.12	0.03	0.11	0.11
NB-31	GW-V	Hybrid	231	2	20	97.8	1.9	8.7	65.9	1.6	6	75	1.5	6.8	107	1.5	9.5	0.31	0.1	0.22	0.18	0.08	0.14	0.22	0.1	0.2	0.31	0.13	0.27	0.3	0.15	0.3
GW-W	NB-81	Sand/ Gravel	-0.4	2.2	1.3	1	2.3	1.4	-1	1.8	1.1	1.6	1.6	1	-0.5	2.6	1.5	0.12	0.12	0.17	0.12	0.07	0.11	0.06	0.11	0.15	0.03	0.03	0.07	0.02	0.08	0.07
NB-81	GW-W	Hybrid	-1.2	2.6	1.5	-0.3	1.9	1.1	-1.6	2.1	1.2	0.33	1.5	0.91	0.7	3	1.8	0.15	0.09	0.14	0.04	0.07	0.08	0.02	0.05	0.06	0.02	0.07	0.07	0.03	0.1	0.11
GW-X	PL-06	Sand/ Gravel	152	2	13	157	2	14	96	1.9	8.6	130	2	11	97.9	1.5	8.7	0.04	0.11	0.12	0.02	0.09	0.09	0.06	0.06	0.1	0.03	0.05	0.07	0.04	0.09	0.09
PL-06	GW-X	Hybrid	168	2	15	121	2	11	170	2	15	151	2	13	150	2	13	0.07	0.12	0.14	0.16	0.09	0.15	2.94	0.17	0.85	0.13	0.08	0.13	0.12	0.09	0.14
GW-Y	NB-33	Sand/ Gravel	3.5	2.1	1.4	3	1.9	1.3	1.9	1.8	1.2	2.5	1.7	1.1	3.6	2.8	1.8	0.83	0.12	0.43	1.04	0.13	0.33	0.85	0.16	0.41	0.63	0.07	0.28	0.61	0.11	0.35
NB-33	GW-Y	Hybrid	0.04	2.1	1.2	0.3	1.8	1.1	-0.1	1.5	0.88	0.8	1.7	1	0.1	2.8	1.7	0.18	0.07	0.14	0.16	0.09	0.14	0.15	0.1	0.19	0.11	0.12	0.18	0.16	0.1	0.16
GW-Z[3]	WS-13	Sand/ Gravel	0.7	2.1	1.3	0.7	1.9	1.2	0.4	1.7	1	2.1	1.8	1.1	2.5	1.5	1	0.3	0.05	0.18	0.18	0.02	0.13	0.18	0.11	0.17	0.06	0.08	0.12	0.18	0.12	0.22
WS-13	GW-Z[3]	Leachate	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	52.2	0.2	5.62	58.5	0.1	5.85	—	—	—

[1] MDC value for total uranium is set equal to U-234 MDC value.
[2] Error value for total uranium is calculated from the square root of the sum of the squares for U233/234, U235/236, and U238 error values.
[3] Proximity Well

Table 4-3
Groundwater Radiological Results

Well ID	Paired Wells	Screened Zone	Uranium-233/234 (pCi/L)															Uranium-235/236 (pCi/L)														
			3Q09			4Q09			1Q10			2Q10			3Q10			3Q09			4Q09			1Q10			2Q10			3Q10		
			Result	MDC	Error	Result	MDC	Error	Result	MDC	Error	Result	MDC	Error	Result	MDC	Error	Result	MDC	Error	Result	MDC	Error	Result	MDC	Error	Result	MDC	Error	Result	MDC	Error
GW-AA	N/A	Sand/ Gravel	1.26	0.1	0.31	0.17	0.08	0.08	0.14	0.1	0.09	0.2	0.02	0.09	0.25	0.07	0.16	0.12	0.09	0.1	-0	0.06	0.01	-0	0.09	0.02	0	0.03	0.01	-0	0.13	0.01
GW-BB	N/A	Sand/ Gravel	0.06	0.11	0.07	0.02	0.07	0.04	-0	0.09	0.04	0.09	0.06	0.07	-0	0.1	0.02	0.01	0.08	0.04	-0	0.08	0.01	-0	0.09	0.03	0	0.04	0.02	-0	0.1	0.01
GW-D	WS-17B	Sand/ Gravel	0.06	0.09	0.07	-0	0.1	0.03	0.04	0.08	0.06	0	0.08	0.03	0.04	0.1	0.06	0.01	0.04	0.03	-0	0.08	0.02	-0	0.09	0.01	0.01	0.06	0.03	-0	0.1	0.04
WS-17B	GW-D	Leachate	0.08	0.09	0.07	0.03	0.06	0.04	0.22	0.11	0.13	0.12	0.06	0.07	0.12	0.08	0.09	0.03	0.04	0.04	0	0.08	0.03	0.01	0.11	0.04	0.01	0.04	0.03	-0	0.11	0.02
GW-S	BD-14	Sand/ Gravel	0.41	0.09	0.18	0.11	0.07	0.07	0.13	0.07	0.09	0.04	0.06	0.05	0.05	0.12	0.07	0.02	0.07	0.05	0.01	0.03	0.02	0.02	0.09	0.04	0	0.03	0.02	-0	0.09	0.01
BD-14	GW-S	Hybrid	1.23	0.1	0.31	0.45	0.2	0.21	3.21	0.13	0.52	2.06	0.08	0.35	2.97	0.08	0.5	0.04	0.09	0.06	0.09	0.1	0.1	0.1	0.11	0.09	0.11	0.07	0.08	0.08	0.05	0.08
GW-T	DM-02	Sand/ Gravel	0.15	0.09	0.09	0.13	0.08	0.08	0.2	0.11	0.12	0.14	0.09	0.09	0.08	0.12	0.09	0	0.09	0.03	0.02	0.06	0.03	-0	0.09	0.01	0.04	0.04	0.05	-0	0.12	0.02
DM-02	GW-T	Hybrid	130	0.1	11	162	0.3	14	167	0.2	15	165	0.2	14	159	0.09	6.9	5.95	0.06	0.9	7.3	0.1	1.1	6.5	0.1	1.1	8.1	0.1	1.1	6.34	0.1	0.45
GW-U	EP-20	Sand/ Gravel	0.57	0.1	0.17	0.5	0.02	0.13	0.05	0.11	0.07	0.52	0.09	0.16	0.67	0.1	0.23	0.04	0.07	0.05	0.03	0.03	0.03	0.01	0.11	0.05	0.02	0.07	0.04	0.04	0.11	0.07
EP-20	GW-U	Leachate	0.13	0.09	0.09	0.26	0.09	0.12	0.15	0.09	0.11	0.08	0.07	0.07	0.11	0.05	0.04	-0	0.09	0.01	0.01	0.04	0.03	0.02	0.11	0.05	0.01	0.07	0.03	0.04	0.1	0.03
GW-V	NB-31	Sand/ Gravel	0.03	0.12	0.07	0.05	0.09	0.06	0.04	0.08	0.06	-0	0.12	0.04	0.01	0.11	0.04	-0	0.11	0.02	0	0.04	0.02	0	0.05	0.02	-0	0.1	0.01	0	0.07	0.02
NB-31	GW-V	Hybrid	0.2	0.1	0.12	0.1	0.08	0.07	0.16	0.1	0.1	0.13	0.13	0.11	0.22	0.15	0.15	-0	0.09	0.01	-0	0.06	0.01	0.01	0.1	0.04	0.02	0.1	0.05	0.02	0.13	0.06
GW-W	NB-81	Sand/ Gravel	0.04	0.12	0.07	0.09	0.07	0.06	0.01	0.11	0.06	0	0.03	0.01	-0	0.08	0.01	0.03	0.09	0.05	0.02	0.03	0.03	-0	0.11	0.04	0	0.04	0.02	-0	0.1	0.01
NB-81	GW-W	Hybrid	0.09	0.09	0.07	0.03	0.07	0.04	0.02	0.05	0.03	0.01	0.07	0.03	0.02	0.1	0.05	-0	0.07	0.01	0	0.03	0.02	0	0.03	0.02	0	0.04	0.02	0.01	0.13	0.05
GW-X	PL-06	Sand/ Gravel	0.04	0.11	0.06	0.01	0.09	0.04	0.05	0.06	0.05	0.02	0.05	0.03	0.02	0.09	0.04	-0	0.1	0.01	-0	0.08	0.01	0.01	0.07	0.03	0	0.03	0.02	-0	0.11	0.01
PL-06	GW-X	Hybrid	0.01	0.12	0.04	0.13	0.09	0.08	1.63	0.17	0.4	0.08	0.08	0.07	0.11	0.09	0.09	-0	0.11	0.01	0	0.04	0.02	0.09	0.14	0.11	0	0.04	0.02	0	0.06	0.02
GW-Y	NB-33	Sand/ Gravel	0.43	0.12	0.19	0.63	0.13	0.17	0.5	0.16	0.2	0.36	0.07	0.14	0.36	0.11	0.16	0.05	0.07	0.07	0.03	0.06	0.04	0.06	0.09	0.07	0.01	0.07	0.03	0.05	0.11	0.07
NB-33	GW-Y	Hybrid	0.14	0.07	0.08	0.09	0.09	0.07	0.06	0.1	0.07	0.08	0.12	0.09	0.13	0.1	0.1	-0	0.07	0.01	0	0.03	0.02	0.02	0.1	0.05	0.02	0.06	0.04	-0	0.08	0.01
GW-Z[1]	WS-13	Sand/ Gravel	0.18	0.05	0.09	0.15	0.02	0.07	0.14	0.11	0.1	0.04	0.08	0.05	0.05	0.12	0.08	0.01	0.04	0.03	0.01	0.03	0.02	-0	0.11	0.01	-0	0.1	0.03	0.02	0.1	0.05
WS-13	GW-Z[1]	Leachate	—	—	—	—	—	—	48.8	0.2	4.7	54.6	0.1	5	—	—	—	—	—	—	—	—	—	1.7	0.15	0.48	2.38	0.12	0.5	—	—	—

[1] Proximity Well

Table 4-3
Groundwater Radiological Results

Well ID	Paired Wells	Screened Zone	Uranium-238 (pCi/L)														
			3Q09			4Q09			1Q10			2Q10			3Q10		
			Result	MDC	Error	Result	MDC	Error	Result	MDC	Error	Result	MDC	Error	Result	MDC	Error
GW-AA	N/A	Sand/ Gravel	0.32	0.09	0.15	0.05	0.06	0.05	0.06	0.07	0.06	0.03	0.05	0.04	0.14	0.1	0.12
GW-BB	N/A	Sand/ Gravel	0.01	0.08	0.04	-0	0.07	0.01	-0	0.09	0.02	0.02	0.06	0.03	-0	0.1	0.03
GW-D	WS-17B	Sand/ Gravel	0.09	0.03	0.06	0.04	0.07	0.05	-0	0.08	0.01	0	0.06	0.02	0.02	0.08	0.04
WS-17B	GW-D	Leachate	0.06	0.03	0.05	0.03	0.07	0.04	0.03	0.08	0.05	0.06	0.08	0.06	0.04	0.09	0.06
GW-S	BD-14	Sand/ Gravel	0.07	0.09	0.08	0.01	0.06	0.03	0.08	0.04	0.07	0.03	0.03	0.04	0.05	0.1	0.07
BD-14	GW-S	Hybrid	0.29	0.08	0.14	0.16	0.11	0.12	0.48	0.11	0.18	0.46	0.06	0.15	0.39	0.07	0.16
GW-T	DM-02	Sand/ Gravel	0.03	0.06	0.04	0.07	0.08	0.06	0.02	0.04	0.03	0.05	0.08	0.06	0.02	0.11	0.05
DM-02	GW-T	Hybrid	22.4	0.09	2.3	26.4	0.2	2.8	27.6	0.07	2.8	28.4	0.1	2.8	26.6	0.1	1.3
GW-U	EP-20	Sand/ Gravel	0.44	0.03	0.15	0.33	0.04	0.11	0.03	0.09	0.05	0.31	0.07	0.12	0.52	0.1	0.2
EP-20	GW-U	Leachate	0.04	0.07	0.05	0.02	0.08	0.04	0.02	0.05	0.04	0.03	0.03	0.04	0.08	0.08	0.04
GW-V	NB-31	Sand/ Gravel	0.04	0.08	0.06	-0	0.07	0.01	0.03	0.04	0.05	0.05	0.08	0.06	0.02	0.09	0.04
NB-31	GW-V	Hybrid	0.11	0.08	0.09	0.08	0.05	0.06	0.05	0.09	0.06	0.16	0.1	0.11	0.06	0.13	0.08
GW-W	NB-81	Sand/ Gravel	0.05	0.08	0.06	0.01	0.05	0.02	0.05	0.09	0.06	0.03	0.05	0.04	0.02	0.09	0.05
NB-81	GW-W	Hybrid	0.06	0.03	0.05	0.01	0.03	0.02	0	0.03	0.01	0.01	0.05	0.02	-0	0.09	0.01
GW-X	PL-06	Sand/ Gravel	-0	0.13	0.04	0.01	0.07	0.03	0.01	0.03	0.02	0.02	0.05	0.03	0.02	0.06	0.04
PL-06	GW-X	Hybrid	0.07	0.1	0.08	0.03	0.07	0.05	1.22	0.14	0.34	0.05	0.06	0.05	0.02	0.04	0.03
GW-Y	NB-33	Sand/ Gravel	0.35	0.11	0.17	0.38	0.07	0.12	0.29	0.1	0.14	0.26	0.03	0.11	0.2	0.11	0.12
NB-33	GW-Y	Hybrid	0.04	0.06	0.05	0.07	0.06	0.06	0.07	0.05	0.07	0.02	0.11	0.05	0.03	0.09	0.05
GW-Z[1]	WS-13	Sand/ Gravel	0.1	0.05	0.07	0.02	0.06	0.04	0.04	0.09	0.06	0.02	0.06	0.04	0.11	0.12	0.1
WS-13	GW-Z[1]	Leachate	—	—	—	—	—	—	1.74	0.14	0.44	1.47	0.12	0.35	—	—	—

[1] Proximity Well

Table 4-4
Post-Radiological Remediation Groundwater Monitoring Wells

Well ID No.	HSU	Post-Remediation Protocol			Existing or New
		Purpose	Parameters	Sample Frequency	
GW-BB	Sand/Gravel	Burial Pit	Tc-99, Isotopic U	Quarterly	Existing
GW-EE	Sand/Gravel	Burial Pit	Tc-99, Isotopic U	Quarterly	New
GW-FF	Sand/Gravel	Burial Pit	Tc-99, Isotopic U	Quarterly	New
GW-GG	Sand/Gravel	Burial Pit	Tc-99, Isotopic U	Quarterly	New
GW-W	Sand/Gravel	Burial Pit	Tc-99, Isotopic U	Quarterly	Existing
NB-71	Sand/Gravel	Burial Pit	Tc-99, Isotopic U	Quarterly	Existing
NB-80	Sand/Gravel	Burial Pit	Tc-99, Isotopic U	Quarterly	Existing
GW-V	Sand/Gravel	Former Building Slabs	Tc-99, Isotopic U	Quarterly	Existing
GW-DD	Sand/Gravel	Former Building Slabs	Tc-99, Isotopic U	Quarterly	New
GW-II	Sand/Gravel	Former Building Slabs	Tc-99, Isotopic U	Quarterly	New
GW-JJ	Sand/Gravel	Former Building Slabs	Tc-99, Isotopic U	Quarterly	Existing
GW-CC	Sand/Gravel	Evaporation Pond	Tc-99, Isotopic U	Quarterly	New
GW-X	Sand/Gravel	Evaporation Pond	Tc-99, Isotopic U	Quarterly	Existing
GW-Y	Sand/Gravel	Evaporation Pond	Tc-99, Isotopic U	Quarterly	Existing
NB-34	Sand/Gravel	Evaporation Pond	Tc-99, Isotopic U	Quarterly	Existing
NB-35	Sand/Gravel	Evaporation Pond	Tc-99, Isotopic U	Quarterly	Existing
PZ-02	Sand/Gravel	Evaporation Pond	Tc-99, Isotopic U	Quarterly	Existing
GW-HH	Sand/Gravel	Red Room Rood Burial Area	Tc-99, Isotopic U	Quarterly	New
BR-04-JC	Jefferson City Cotter	Burial Pit	Tc-99, Isotopic U	Quarterly	Existing
BR-13-JC	Jefferson City Cotter	Former Building Slabs	Tc-99, Isotopic U	Quarterly	New
BR-14-JC	Jefferson City Cotter	Burial Pit	Tc-99, Isotopic U	Quarterly	New
BR-15-JC	Jefferson City Cotter	Burial Pit	Tc-99, Isotopic U	Quarterly	New
BR-16-JC	Jefferson City Cotter	Former Building Slabs	Tc-99, Isotopic U	Quarterly	New
BR-17-JC	Jefferson City Cotter	Former Building Slabs	Tc-99, Isotopic U	Quarterly	New
BR-18-JC	Jefferson City Cotter	Burial Pit	Tc-99, Isotopic U	Quarterly	New
BR-19-JC	Jefferson City Cotter	Evaporation Pond	Tc-99, Isotopic U	Quarterly	New
BR-04-RB	Roubidoux	Deep Bedrock	Tc-99, Isotopic U	Quarterly	Existing

Table 4-4
Post-Radiological Remediation Groundwater Monitoring Wells

Well ID No.	HSU	Post-Remediation Protocol			Existing or New
		Purpose	Parameters	Sample Frequency	
BR-08-RB	Roubidoux	Deep Bedrock	Tc-99, Isotopic U	Quarterly	Existing
BR-10-RB	Roubidoux	Deep Bedrock	Tc-99, Isotopic U	Quarterly	Existing
BR-03R-RB	Roubidoux	Deep Bedrock	Tc-99, Isotopic U	Quarterly	Existing
WS-04	Roubidoux	Deep Bedrock	Tc-99, Isotopic U	Quarterly	Existing

Table 4-5
Post-Radiological Remediation Groundwater Monitoring Wells Construction Data

Well ID	Screened Formation	Installation Date	Ground Surface Elevation	TOC Elevation	Boring Depth	Boring Bottom Elevation	Well Depth (bgs)	Well Bottom Elevation	Depth Top Screen	Depth Bottom Screen	Screen Length
BR-13-JC	JC	5/9/2016	434.039	436.864	110	324.039	110	324.039	95	110	15
BR-14-JC	JC	5/13/2016	429.929	432.924	109	320.929	109	320.929	94	109	15
BR-15-JC	JC	5/22/2016	425.688	428.359	84.5	341.188	84.5	341.188	69.5	84.5	15
BR-16-JC	JC	6/2/2016	435.431	438.33	89.5	345.931	89.5	345.931	69.5	89.5	20
BR-17-JC	JC	6/3/2016	435.049	437.954	84.5	350.549	84.5	350.549	69.5	84.5	15
BR-18-JC	JC	5/20/2016	427.517	430.156	84.5	343.017	85.5	343.017	69.5	84.5	15
BR-19-JC	JC	5/10/2016	432.855	435.667	109	323.855	109	323.855	94	109	15
GW-CC	Sand/Gravel	6/8/16	432.814	435.5140	35.5	397.314	35.5	397.314	32.5	35.5	3.0
GW-DD	Sand/Gravel	5/25/16	434.628	437.5360	37.0	397.628	37.0	397.628	35	37	2.0
GW-EE	Sand/Gravel	4/21/16	431.718	434.6250	34.0	397.718	34.0	397.718	31	34	3.0
GW-FF	Sand/Gravel	4/20/16	427.502	430.5070	29.0	398.502	29.0	398.502	26	29	3.0
GW-GG	Sand/Gravel	4/19/16	430.085	433.0300	30.0	400.085	30.0	400.085	29	30	1.0
GW-HH	Sand/Gravel	6/6/16	431.045	434.1870	29.5	401.545	29.5	401.545	28.5	29.5	1.0
GW-II	Sand/Gravel	5/24/16	435.406	438.6660	35.0	400.406	35.0	400.406	33	35	2.0

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HDP Procedure Revision History

HDP-PR-EM-011
Low Flow Well Sampling

Revision Number	Effective Date	Summary of the Revision
0	02/18/2009	Initial issuance of the procedure.
1	12/4/2009	This procedure revision contained significant editorial, clarification and formatting enhancements. The revision incorporated the necessary IGMP requirements as well as tracking and trending requirements. Modified the investigation threshold to align with License SNM-33.
2	10/27/2011	Deleted references to retired procedures. Added references for statistical methods. Clarified use of the Mann-Kendall statistical analysis. Added references and associated actions with the implementation of the Water Treatment System.
3	11/11/2011	Added information and requirements for locking of well caps. Clarified minimum practical flow rate requirement.
4	03/14/2012	Added clarifications and information related to corrective actions generated by identification of an unlocked well cap. Enhanced description of steps taken when sampling. Editorial changes related to organization changes.

HDP-PR-EM-012
Water Quality Field Measurements

Revision Number	Effective Date	Summary of the Revision
0	01/26/2009	Initial issuance of the procedure.
1	12/4/2009	Editorial changes related to organization changes. Formatting enhancements. Add the use of Alconox® for decontamination.
2	10/27/2011	Editorial changes.
3	03/12/2012	Clarified responsibilities of Environmental Manager. Added statement to Table 1 indicated that Alconox® is used for decontamination. Added instrument calibration records as forms.

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HDP Procedure Revision History

HDP-PO-FSS-700
Final Status Survey Program

Revision Number	Effective Date	Summary of the Revision
0	01/16/2012	Initial issuance of the policy. Implements the requirements of the Final Status Survey plan contained within the DP.
1	12/04/2012	Updated policy to include soil sampling requirements during the abandonment of hybrid wells, per Section 14.4.3.4.2 of the DP.
2	01/31/2013	Updated Section 13, Final Status Survey Reporting to reflect the changes of Section 14.6 in the DP.
3	11/26/2014	Revision included clarifications and enhancements.
4	02/19/2015	Added information regarding scan MDCs and revised wording to be consistent with Westinghouse letter HEM-11-56.
5	10/28/2015	Changed policy to Westinghouse Proprietary Class 2. No technical changes.
6	04/07/2016	The revision incorporates a new section 15 "SURVEILLANCE FOLLOWING FSS" as a component of a corrective action to a Notice of Violation. Clarifications have been made to section 9.7 regarding isolation and control.

HDP-PR-FSS-720
Final Status Survey Data Integrity and Database Management

Revision Number	Effective Date	Summary of the Revision
0	01/16/2012	Initial issuance of the procedure.
1	11/26/2015	Revised section for Data Download to update the process for downloading data to a FSS computer that is password protected, inclusion of a section to review and store GWS data, addition of new Data Download Report Form and changed back up of FSS data from being backed up as part of the routine site media backup process to being backed up on a password protected external hard drive and included a minimum frequency of weekly for hard drive backup.
2	10/28/2015	Changed procedure to Westinghouse Proprietary Class 2. No technical changes.

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HDP Procedure Revision History

HDP-PR-FSS-722 Final Status Survey Reporting		
Revision Number	Effective Date	Summary of the Revision
0	01/16/2012	Initial issuance of the procedure.
1	02/06/2013	Updated the procedure to reflect changes in section 14.6 of the DP.
2	02/10/2014	Administrative format changes. No technical changes.
3	11/26/2015	Administrative format changes. No technical changes.
4	10/28/2015	Changed procedure to Westinghouse Proprietary Class 2. No technical changes.

HDP-PO-QA-001 Project Quality Plan		
Revision Number	**Effective Date**	**Summary of the Revision**
0	04/27/2010	Initial issuance of the policy.
1	11/29/2012	Added use of on-going Self Assessments in lieu of scheduled self-assessments as identified in CAPs commitment. Editorial changes related to organization changes. 006Removal of Appendix B, *Procedure Implementation Matrix* as all applicable HDP policies and procedures have been reformatted and implemented. Minor administrative changes including editorial changes and typographical corrections.

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HDP Procedure Revision History

HDP-PR-QA-006 Chain of Custody		
Revision Number	**Effective Date**	**Summary of the Revision**
0	04/29/2010	Initial issuance of the procedure.
1	02/07/2011	Added allowance to write sample information directly on the sample bottle for flexibility of completion of requirement. Added exception to assignment of unique sample number to each sample to provide for routine, location-specific samples. Removed documentation storage requirements as the storage of samples occurs at the laboratory and not locally, therefore documentation of storage cannot be maintained. Clarified process of where the original chain of custody is placed. Clarified how the laboratory/end user returns the chain of custody form(s) to HDP. Added specification that the procedure is applicable to samples that are intended for off-site analysis.
2	02/29/2012	Westinghouse document proprietary classification change. No technical changes made.
3	12/19/2012	Minor clarification changes.
4	11/18/2015	Changed procedure to Westinghouse Proprietary Class 2. No technical changes.

Attachment 2

Pre-Audit Submittal Table for Final Status Survey Final Report Volume 6,

2 Total Pages

Westinghouse Electric Company LLC, Hematite Decommissioning Project

Docket No. 070-00036

Pre-Submittal Audit Table for Final Status Survey Final Report Volume 6, Chapter 1 – Groundwater Overview
(License No. SNM-00033, Docket No. 070-00036)

The purpose of the pre-submittal audit is to provide general guidance on the content that is expected in the Final Status Survey Report (FSSR) according to NUREG 1757, Vol 2, Rev 1. The table is used to facilitate discussions on the structure and content of draft reports and to help ensure that the final report will contain the relevant information the staff will need to carry out its review. Note that review of a draft report does not constitute final acceptance or approval of the final FSSR and there may be additional changes necessary during the staff's review of the final report.

NRC ID	Issue/Paragraph	Discussion Points	Westinghouse Response	Resolution
None	Entire Report	N/A	The review of FSSFR Volume 6, Chapter 1 and the discussion points provided by the NRC result in revision 1 to FSSFR Volume 6 Chapter 1. As such, Westinghouse has utilized the opportunity to re-sequence the discussion sections contained within the document to better reflect the timeline of activities regarding groundwater and groundwater monitoring. Westinghouse has also updated the appropriate discussion points for those actions that were noted to be accomplished in the future which have now been completed since the time FSSFR Volume 6, Chapter 1, Revision 0 was submitted for review.	N/A
1	Section 5.7	Sec. 5.7 states that a positive detection (concentration above the MDA +Error) in the primary post-remediation wells will initiate groundwater monitoring in the secondary wells. This is not acceptable. Westinghouse's rational was that if a positive detection is not found in the primary monitoring wells, which are located closer to the source area(s) than the secondary monitoring wells, there should be no contamination in the secondary monitoring wells. This argument may be not valid due to, for example preferential groundwater flow, and the primary monitoring wells not being in the dominant down-gradient direction as a result of change in hydraulic conditions. The primary and secondary monitoring wells in the post-remediation network as approved in the DP should be monitored.	The Decommission Plan Section 14.5.2 states: Following completion of soil remediation, groundwater monitoring will begin at a quarterly frequency. An evaluation of the groundwater results will be performed to determine if the concentrations are stable, or are showing an increasing or decreasing trend. Monitoring will be discontinued when it can be determined that the radioactivity concentrations do not pose an unacceptable potential for dose utilizing the methods described in Chapter 5. In Response to Request for Additional Information on Decommissioning Plan Chapter 3 (HEM-11-25), dated March 10, 2011, Westinghouse introduced the concept of primary and secondary wells for post-remediation monitoring. As is the current strategy, Westinghouse intended to use wells that were proximal to the source areas as primary wells and, if these wells indicated contamination, Westinghouse would sample secondary wells that were located further down-gradient. Many of these secondary wells exist now and have been sampled throughout the remediation of the site. The RAI response #5 stated that seven new wells and eight existing wells were proposed for the post-remediation monitoring well network in the Sand/Gravel HSU, seven new wells and two existing wells were proposed for the post-remediation monitoring of the Jefferson City HSU, and that four existing wells were selected for post remediation monitoring of the Roubidoux HSU. The wells listed contained both primary and secondary monitoring wells. The current post-remediation monitoring strategy is consistent with this RAI response and seven sand/gravel HSU and seven Jefferson City HSU wells were installed during April and May 2016. In addition, the strategy is to sample 18 sand/gravel HSU monitoring wells, eight	Previous Section 5.7 has been revised and re-sequenced and is now provided in Section 6.3.2. Previous Table 5-4 has been revised and is now Table 4-4. The groundwater wells in Table 4-4 will be sampled on a quarterly basis, therefore, the designation of primary or secondary is not used. The text and tables have also been updated to indicate the source area that the wells are intended to monitor.

The purpose of the pre-submittal audit is to provide general guidance on the content that is expected in the Final Status Survey Report (FSSR) according to NUREG 1757, Vol 2, Rev 1. The table is used to facilitate discussions on the structure and content of draft reports and to help ensure that the final report will contain the relevant information the staff will need to carry out its review. Note that review of a draft report does not constitute final acceptance or approval of the final FSSR and there may be additional changes necessary during the staff's review of the final report.

			Jefferson City HSU wells, and 5 Roubidoux HSU wells as primary wells. Commitments made in HEM-11-25 were accepted in HEM-11-96 and incorporated into the Site License.	
2	Section 5.7	Sec. 5.7 indicates a Mann-Kendall analysis would be performed to evaluate trends in sample results. The data requirements for this trend analysis to be valid is more than one year's (4 quarters) monitoring. This contradicts the proposed 4 rounds (year) of sampling.	Westinghouse concurs that the statement contained within Section 5.7 is not clear. The text, "A Mann-Kendall analysis would be performed quarterly on each of the wells to evaluate trends in sample results." implies that Westinghouse intends to do an analysis with less than four data points. The intent is to collect the four quarters of data and then conduct the analysis. Four data points has been determined to be the minimum amount of data necessary to apply the Mann-Kendall Test to identify statistically significant concentration trends, as described in, *Mann-Kendall Test for Analysis of Groundwater Contaminant Plume Stability and Evaluation of Sampling Frequency for Long-Term Monitoring*, presented at the 2013 Waste Management Conference in Phoenix, Arizona, Walker and Harrison, (Feb. 2013)	The statement which is now in Section 6.3.3 has been revised to state: "A Mann-Kendall analysis will be performed at the conclusion of quarterly sampling, using a minimum of four data points, on each of the wells to evaluate trends in sample results. For existing wells that have data prior to the completion of radiological remediation, the Mann-Kendall analysis will be performed throughout the groundwater demonstration period as well as at the conclusion of the four quarters of post radiological remediation monitoring."
3		Quarterly groundwater elevation contour maps should be constructed for the sand/gravel-Jefferson City-Cotter aquifer, and Roubidoux aquifer based on the water level measurements obtained during sampling. This information will be used to evaluate the potential changes in flow direction in both aquifers, and provide confidence that the contaminant plume(s) are being effectively monitored by the monitoring network. This information also provides updated data in determining the monitoring wells to be installed.	Westinghouse concurs that groundwater elevation contour maps should be constructed for each of the water bearing zones. Westinghouse currently completes these as part of the Interim Groundwater Monitoring Program and intends to continue creating these maps during the post-remediation monitoring period.	Quarterly groundwater elevation contour maps will be included in the final submittal of the FSSR Volume 6, Chapter 7, Post-remediation Groundwater Monitoring Summary.