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Characterization of Vadose Zone Sediment: Borehole 299-E33-45 Near BX-102 in the B-BX-BY Waste Management Area

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Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

This report was revised in September 2008 to remove acid-extractable sodium data from Table 4.22. The data was removed due to potential contamination introduced during the acid extraction process. The remaining text is unchanged from the original report issued in 2002.

The overall goal of the Tank Farm Vadose Zone Project, led by CH2M HILL Hanford Group, Inc., is to define risks from past and future single-shell tank farm activities. To meet this goal, CH2M HILL Hanford Group, Inc., asked scientists from Pacific Northwest National Laboratory to perform detailed analyses on vadose zone sediments from within Waste Management Area B-BX-BY. This report is the first in a series of four reports to present the results of these analyses. Specifically, this report contains all the geologic, geochemical, and selected physical characterization data collected on vadose zone sediment recovered from borehole 299-E33-45 installed northeast of tank BX-102.

This report also presents interpretation of the data in the context of the sediment lithologies, the vertical extent of contamination, the migration potential of the contaminants, and the likely source of the contamination in the vadose zone, perched water and groundwater east of the BX tank farm. The information presented in this report supports the Waste Management Area B-BX-BY field investigation report prepared by CH2M HILL Hanford Group, Inc.(a)

Overall, the analyses identified common ion exchange and heterogeneous (solid phase-liquid solute) precipitation reactions as two mechanisms that influence the distribution of contaminants within that portion of the vadose zone affected by tank liquor. Significant indications of caustic alteration of the sediment mineralogy or porosity were not observed, but slightly elevated pH values between the depths of 79 to 141 ft below ground surface (bgs) were observed. X-ray diffraction measurements indicate no evidence of mineral alteration or precipitation resulting from the interaction of the tank liquor with the sediment. However, no samples were studied by scanning electron microscopy, a more sensitive technique for searching for faint evidence of caustic attack.

The analyses do not firmly suggest that the source of the contamination in the groundwater east of the BX tank farm is the 1951 overfill event at tank BX-102. However, evidence is convincing that the fluids from the overfill event are present in the vadose zone sediments at borehole 299-E33-45 to a depth of 170 ft bgs.

The near horizontally bedded, northeasterly dipping sediment likely caused horizontal flow of the migrating contaminants. At borehole 299-E33-45, there are several fine-grained lenses within the Hanford H2 unit at 74.5, 120, and 167 ft bgs that likely cause some horizontal spreading of percolating fluids. The 21-ft thick Plio-Pleistocene fine-grained silt/clay unit is also an important horizontal flow conduit as evidenced by the perched water zone between 227 and 232 ft bgs.

The following are the key findings of the detailed characterization of the borehole 299-E33-45 vadose zone sediments. The porewater electrical conductivity shows a two-lobed elevated plume. The shallower lobe, between 24.08 and 36.58 meters (79 and 120 feet) bgs, resides within the middle sand sequence in the Hanford H2 unit. The shallow lobe appears to pond on top of the fine-grained paleosol at 120 ft bgs. The more concentrated lobe resides between 45.72 and 52.73 m (150 and 173 ft) bgs with the most

(a) Knepp AJ. 2002a. Field Investigation Report for Waste Management Area B-BX-BY. RPP-10098, CH2M HILL Hanford Group, Inc., Richland, Washington.

concentrated fluid between 150 and 160 ft bgs (within the Hanford H2 unit) perhaps ponding on the fine-grained wet zone (i.e., 167 to 169.8 ft bgs) at the bottom of the Hanford H2 unit. Thus, the leading edge of the tank overfill plume appears to reside at about 170 ft bgs which is well above the water table at 255 ft bgs.

High nitrate concentrations in borehole 299-E33-45 sediment start at the contact between the Hanford H1 and H2 units at 34 feet bgs and extend down into the fine-grained Plio-Pleistocene mud unit (PPlz) and perhaps extend all the way to the water table at 77.7 m (255 ft) bgs. The bulk of the water-extractable nitrate is bounded between two thin fine-grained lenses in the H2 middle sand sequence unit. The upper boundary is the fine-grained lens at 120 ft bgs and lower boundary is the fine-grained 2.5 ft-thick lens that forms the bottom of the Hanford H2 unit at 167 to 170 ft bgs. Nitrate concentrations reach 6150 mg/L or ~0.1M at 47.6 m (156.2 ft) bgs. However, there also appears to be somewhat elevated nitrate throughout the Hanford H3 unit at a fairly constant porewater concentration of 600 ± 200 mg/L. The nitrate in the PPlz unit porewater is slightly higher than the nitrate in the H3 unit. There is a decrease in porewater nitrate in the Plio-Pleistocene gravelly unit (PPlg) down to the capillary fringe zone where nitrate increases to values similar to those found in the groundwater. The nitrate data suggest that the BX-102 overfill fluids might have reached the groundwater. However, an alternate source of nitrate within and below the PPlz could be the nearby cribs and trenches after allowing horizontal transport within the perched water zone.

The significantly elevated uranium-238 concentrations first appear at 73.4 ft bgs in the Hanford H2 unit sediment just above the first thin lens (one-ft thick at 74.5 ft bgs). From about 90 ft to ~111 ft bgs, there is little indication that significantly elevated concentrations of uranium are present. Between 111 and 120 ft bgs, the uranium content in the sediment averages about 100 ppm. In the thin lens at 120 ft bgs, which may be a paleosol, the uranium concentration is very high (i.e., up to 1,649 ppm in the finest grained material from this sleeve). Below 120 ft bgs down to 145 ft bgs, the uranium content in the sediment is quite high (reaching values between 200 and 500 ppm). Between 145 and 167.2 ft bgs, in the lower portion of the H2 middle sand sequence, there are slightly elevated uranium concentrations (between 50 and 200 ppm). Within the fine-grained lens between 167.2 and 169.8 ft bgs, the uranium concentration increases again to values between 200 and 400 ppm. Below in the H3 lower sand sequence and the Plio-Pleistocene sediments, there is no significant indication of elevated uranium in the sediments. The in situ Kd values for uranium are distinctly higher in the PPlz and PPlg strata suggesting that no Hanford processing derived uranium is present (the high Kd values indicate the presence of only natural uranium that is much less water soluble in these deep vadose zone sediments).

The other major contaminant in the tank overfill fluid is technetium-99. Elevated concentrations of technetium-99 are found in the vadose zone between 120 and 167 ft bgs (within the middle sand sequence of H2). There appears to be a second less concentrated plume of technetium-99 within the contact between the H3 unit and the PPlz unit (i.e., 220 to 235 ft bgs). Both the acid extractable and water extractable data support this conclusion, however, the water extractable data are of higher quality. There is very good agreement between the technetium-99 concentrations found in the actual porewater and the dilution corrected sediment-water extracts in all regions and lithologies. Further, the technetium-99 concentration in the perched water also agrees with the nearby dilution corrected water extracts. There are obvious elevated concentrations of technetium-99 in the PPlz but not the PPlg unit down to the water table. It is also possible that the technetium-99 in the perched water and groundwater in the vicinity of borehole 299-E33-45 did not come from the overfilling of tank BX-102.

The water extractable cations suggest that an ion-exchange process dominates the major constituent porewater-sediment interactions in the borehole where tank fluid passed by or currently exists. The leading edge of the tank leak plume is enriched in alkaline earth cations that were displaced from the native sediment exchange sites. The interaction of the uranium present in the 1951 tank overfill fluids with the vadose zone sediments appears to include a combination of surface adsorption and discrete solid phase precipitation-dissolution with the precipitated uranium dominating. More mechanistic experiments are discussed in the Science and Technology Project contributions found in Appendix D of the Waste Management Area B-BX-BY field investigation report(a).

Based on a comparison of the depth of penetration of various contaminants and the percentages that are water leachable, it can be stated that uranium migrates slower than technetium-99 and nitrate. The technetium-99 desorption Kd data are consistently near zero, meaning that the technetium-99 is not interacting with the sediment. Despite the findings that only ten to thirty percent of the uranium is water leachable in 1:1 water extracts over a few days, the uranium desorption Kd values are still <3 mL/g in the entire zone where the bulk of the tank fluid currently resides.

In summary, the moisture content, pH, electrical conductivity, and the sodium, tritium, and uranium profiles do not suggest that the leading edge of the plume has penetrated below 170 ft bgs. In general, the majority of the ratios of constituents found in the porewater in the Hanford formation sediments are closer to those from the 1951 metals waste solution that escaped tank BX-102 during a cascading accident than to the other possible source, the 1970s BX-101 junction box leaks. The profiles (but not the ratios to other contaminants) of two constituents considered to be mobile, technetium-99 and nitrate, suggest that the leading edge of the plume may have penetrated all the way to groundwater. However, the ratios also suggest there may be other sources of these two mobile contaminants in the deep vadose zone. The perched water is a likely driving force to move fluids from other sources into the borehole environs. The technetium-99 to nitrate ratio for the perched water at 227 ft bgs is ~1.8 pCi/mg and for the groundwater at 258.7 ft bgs is 43 pCi/mg. This suggests that there may be a source of water, containing nitrate but not technetium, which is feeding the perched water zone. But this unknown water source has not changed the ratio in the surrounding sediments nor diluted the groundwater that is found only 21 ft deeper. The deep vadose, perched water, and groundwater data at borehole 299-E33-45 do not present a clear picture on what might be occurring in the Plio-Pleistocene unit.

Another unresolved issue is the depth of penetration of uranium and the 1951 tank overfill fluids. Based on the total uranium content in the vadose zone sediments, it is not considered that Hanford derived uranium has penetrated below the fine-grained lens separating the Hanford formation H2 unit from the H3 unit (~170 ft bgs). However, the in situ uranium Kd data suggest that Hanford derived uranium might have penetrated the entire Hanford formation down to the Plio-Pleistocene mud unit at ~220 ft bgs.

Acronyms and Abbreviations

ASA	American Society of Agronomy
ASTM	American Society for Testing and Materials
bgs	below ground surface
EC	electrical conductivity
EPA	Environmental Protection Agency (United States federal government regulatory organization)
FIR	Field Investigation Report
g	gravitational constant (980 cm^2/s)
GEA	gamma energy analysis
GPS	global positioning system
HCl	hydrochloric acid
HPGe	High-Purity Germanium
IC	ion chromatography
ICP	inductively coupled plasma (also called inductively coupled plasma – optical emission spectroscopy
ICP-MS	inductively coupled plasma mass spectrometer
ICP-OES	inductively coupled plasma – optical emission spectroscopy
Kd	distribution coefficient or sorption partition coefficient in units of mL/g
KUT	potassium, uranium, and thorium
MSL	mean sea level
PNNL	Pacific Northwest National Laboratory
PPlc	Plio-Pleistocene caliche layer
PPlg	Plio-Pleistocene gravelly sand or sandy gravel unit
PPlz	Plio-Pleistocene mud unit
QA	quality assurance
QC	quality control
RCRA	*Resource Conservation and Recovery Act*
REDOX	Reduction Oxidation Process (the second fuel reprocessing process used at the Hanford Site to extract plutonium)
SEM	scanning electron microscope
TEM	transmission electron microscopy
UFA	unsaturated flow apparatus (ultracentrifuge for squeezing porewater out of sediment)
UV	ultraviolet
WMA	Waste Management Area
XRD	X-ray diffraction
XRF	x-ray fluorescence (a technique to measure total element mass in solids)

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1.0 Introduction

The overall goals of the of the Tank Farm Vadose Zone Project, led by CH2M HILL Hanford Group, Inc., are: 1) to define risks from past and future single-shell tank farm activities, 2) to identify and evaluate the efficacy of interim measures, and 3) to aid via collection of geotechnical information and data, the future decisions that must be made by the Department of Energy regarding the near-term operations, future waste retrieval, and final closure activities for the single-shell tank Waste Management Areas (WMA). For a more complete discussion of the goals of the Tank Farm Vadose Zone Project, see the overall work plan, *Phase 1 RCRA Facility Investigation/Corrective Measures Study Work Plan for the Single-Shell Tank Waste Management Areas* (DOE 1999). Specific details on the rationale for activities performed at WMA B-BX-BY are found in CH2M HILL (2000). To meet these goals, CH2M HILL Hanford Group, Inc., asked scientists from Pacific Northwest National Laboratory (PNNL) to perform detailed analyses of vadose zone sediment, both uncontaminated and contaminated, from within WMA B-BX-BY.

Specifically, this report contains all the geologic, geochemical, and selected physical characterization data collected on vadose zone sediment recovered from borehole 299-E33-45 northeast of tank BX-102. Also provided is interpretation of the data in the context of determining the appropriate lithologic model, the vertical extent of contamination, the migration potential of the contaminants that still reside in the vadose zone, and the correspondence of the contaminant distribution in the borehole sediment to groundwater plumes in the aquifer proximate and down gradient from the BX tank farm.

This report is one in a series of four reports to present recent data collected on vadose zone sediments, both uncontaminated and contaminated, from within WMA B-BX-BY. Two other PNNL reports discuss the characterization of: 1) uncontaminated sediment from a *Resource Conservation and Recovery Act* (RCRA) borehole (299-E33-338) (Lindenmeier et al. 2002a), to provide a baseline against information from contaminated sediment; and 2) contaminated sediment obtained from borehole 299-E33-46 northeast of tank B-110, which has been decommissioned (Serne et al. 2002e). A fourth report presents characterization data collected on vadose zone sediments obtained from two nearby inactive liquid waste disposal facilities **(**Lindenmeier et al. 2002b. The four documents contain preliminary interpretations to identify the distribution of key contaminants within the vadose zone and to determine what their future migration potential could be. Key information was incorporated in Appendix B of the WMA B-BX-BY field investigation report (FIR) (Knepp 2002a).

This document describes the characterization data collected and interpretations assembled by the Applied Geology and Geochemistry Group within the PNNL Environmental Technology Division. The main objective for placing the 299-E33-45 borehole at the location ~70 ft northeast from the BX-102 tank wall was to investigate the vertical extent of uranium and other mobile contaminants at a spot known to contain high uranium contents based on spectral gamma logging. The borehole was driven to groundwater in order to track other mobile contaminants that cannot be tracked with gamma logging such as technetium-99 and nitrate.

This report is divided into sections that describe the geology, geochemical characterization methods employed, geochemical results, and contaminant migration potential, as well as summary and conclusions, references, and four appendices with additional details and sediment photographs.

2.0 Geology

The geology of the vadose zone underlying the 241-BX tank farm forms the framework through which contaminants move, and provides the basis with which to interpret and extrapolate the physical and geochemical properties that control the migration and distribution of contaminants. Of particular interest are the interrelationships between the coarser and finer-grained facies, and the degree of contrast in their physical and geochemical properties.

This section presents the geologic setting of the tank farm followed by brief discussions on the drilling, sampling, and geophysical logging of well 299-E33-45, the laboratory methodologies used to extract, sub-sample, and visually describe the vadose zone materials, and finally, a description of the sediments penetrated by this borehole.

2.1 Geologic Setting of the 241-BX Tank Farm

The 241-BX tank farm was constructed in 1953 and 1954 within Pleistocene Hanford formation and Holocene eolian deposits that overlie a portion of the northern flank of the Cold Creek flood bar (Wood et al. 2000). The geology beneath the 241-BX tank farm has been the subject of numerous reports, including Lindsey et al. (2001), Wood et al. (2000), Narbutovskih (1998), Caggiano (1996), and Price and Fecht (1976). The major stratigraphic units beneath the tank farm include (in descending order); the Hanford formation, a unit of uncertain origin described here as the Hanford formation/ Plio-Pleistocene unit, and the Columbia River Basalt Group (Figure 2.1). The upper 12.5 m (40 ft) of the Hanford formation was removed during construction of the tank farm and the stockpiled sediments later used as backfill around the underground storage tanks. However, borehole 299-E33-45 is on the eastern edge of the tank farm excavation such that only 3 m (9 ft) of backfill is present.

The stratigraphic terminology used in this report is summarized in Table 2.1. The general stratigraphic interpretation presented here is consistent with that provided by Wood et al. (2000).

2.2 Drilling and Sampling of Well 299-E33-45

Well 299-E33-45 was installed and samples collected between November 13, 2000 and January 25, 2001. This borehole was installed approximately 21 m (70 ft) from the edge of tank 241-BX-102 at about the 4 o'clock position (Reynolds 2001) (Figure 2.2). Global Positioning System (GPS) readings place the well at N137350.6, E573693.1, with an elevation of 200.2 m (656.7 ft).

The borehole was installed in three stages using drive-barrel drilling methods. A different casing size was used during each drilling stage, advancing the casing like a telescope until a total depth of 80 m (260 ft) was reached (Reynolds 2001). A geologic log was compiled in the field, based on observations made on cuttings retrieved from the drive barrel and observations made during retrieval and packaging of the split-spoon liners (Reynolds 2001). Penetration resistance (i.e., blow counts) and percent core recovered from each core run, were also recorded (Reynolds 2001).

A perched water zone was encountered near the end of the second stage of drilling, at a depth of 69.2 m (227.1 ft) within a silty-to-clayey silt zone. Thus, a bentonite seal was installed at a depth of 71.7 to 72.8 m (235.1 to 238.7 ft) before downsizing the casing and initiating the third stage of drilling (Reynolds 2001). Groundwater was reached at a depth of 77.7 m (255 ft), and a section of stainless steel screen installed to complete the borehole as a groundwater monitoring well.

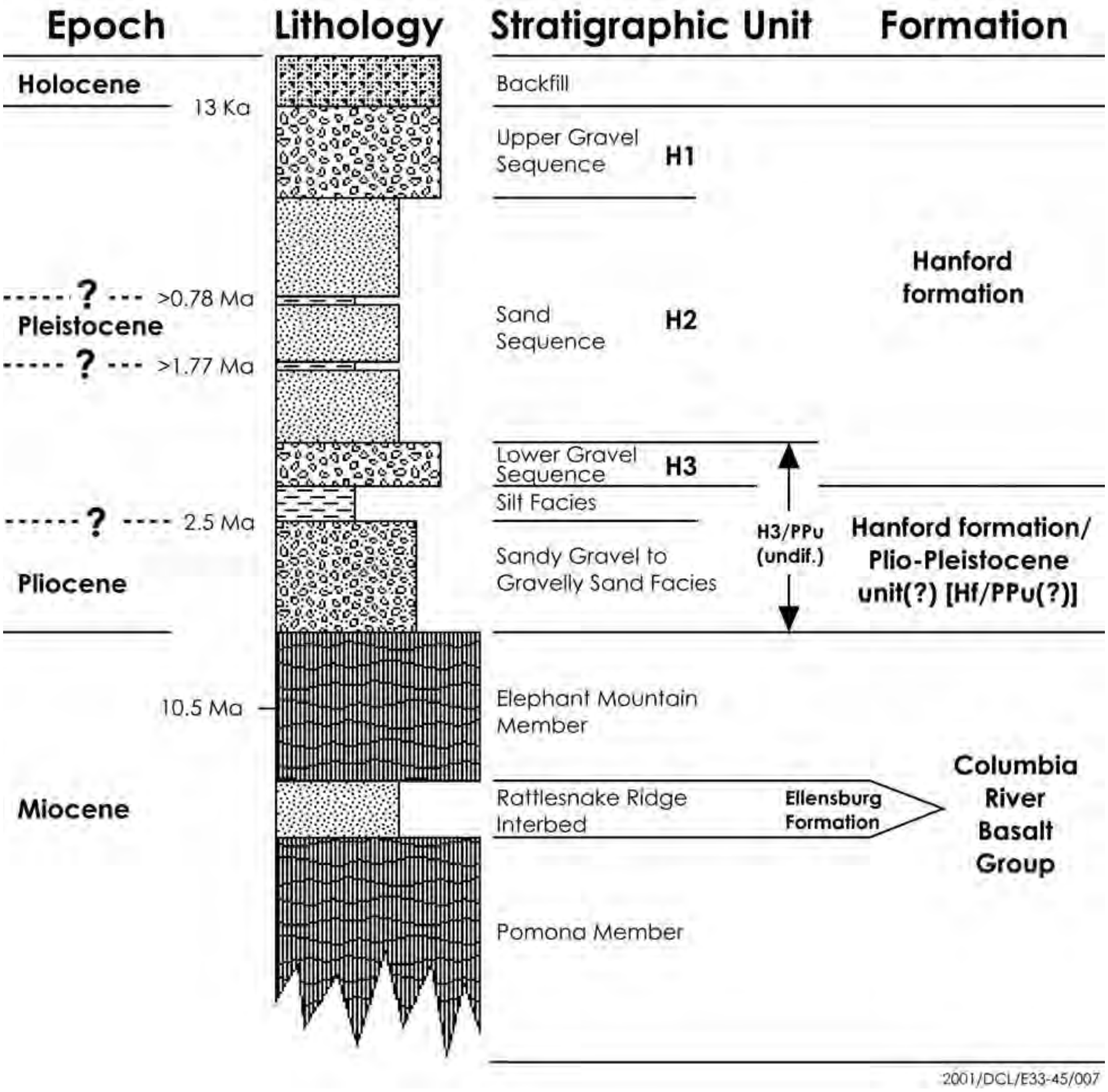

Figure 2.1. Generalized, Composite Stratigraphy for the Late Cenozoic Sediments Overlying the Columbia River Basalt Group Beneath the 241-B and 241-BX Tank Farms (Modified After Wood et al. 2000)

Table 2.1. Stratigraphic Terminology Used in this Report for the Vadose Zone Beneath the BX Tank Farm (Taken from Wood et al. 2000)

Stratigraphic Symbol	Formation	Facies / Subunit	Description	Genesis
Holocene/Fill	NA	Backfill	Poorly sorted cobbles, pebbles, and coarse to medium sand with some silt derived from the Hanford formation (Price and Fecht 1976)	Anthropogenic
H1	Hanford formation	Unit H1	An upper gravel sequence consisting of high-energy, gravel-dominated facies interbedded with lenticular and discontinuous layers of sand-dominated facies. Equivalent to the upper gravel sequence discussed by Last et al. (1989) and Lindsey et al. (1992), to the H1 sequence discussed by Lindsey et al. (1994) and the Qfg documented by Reidel and Fecht (1994).	Cataclysmic Flood Deposits
H2		Unit H2	Sand sequence consisting predominantly of sand-dominated facies, with multiple graded beds of plane to forset-bedded sand or gravelly sand, which sometimes grade upward to silty sand or silt. Equivalent to the sandy sequence discussed in Last et al. (1989) and Lindsey et al. (1992), to the H2 sequence discussed by Lindsey et al. (1994) and to Qfs documented by Reidel and Fecht (1994).	
H3		Unit H3	Lower gravel sequence consisting predominantly of gravel-dominated facies with occasional interbedded lenticular and discontinuous sand-dominated facies. Equivalent to the lower gravel sequence discussed by Last et al. (1989) and Lindsey et al. (1992), to the H3 sequence discussed by Lindsey et al. (1994) and the Qfg documented by Reidel and Fecht (1994).	
Hf/Ppu and/or PPlz	Hanford formation / Plio-Pleistocene unit	Silt Facies	Silt sequence consisting of interstratified well sorted calcareous silt and fine sand. At least partially correlative with the "early Palouse soil" described by Tallman et al. (1979) and DOE (1988) and recently included with the Plio-Pleistocene unit (Lindsey et al. 1994, Slate 1996, 2000).	Fluvial overbank and/or Eolian Deposits (with some weakly developed paleosols)
Hf/Ppu and/or PPlg		Sandy Gravel to Gravelly Sand Facies	Sandy gravel to gravelly sand sequence consisting predominantly of unconsolidated basaltic sands and gravels.	Flood gravels and/or Pre-ice-age flood plane alluvium

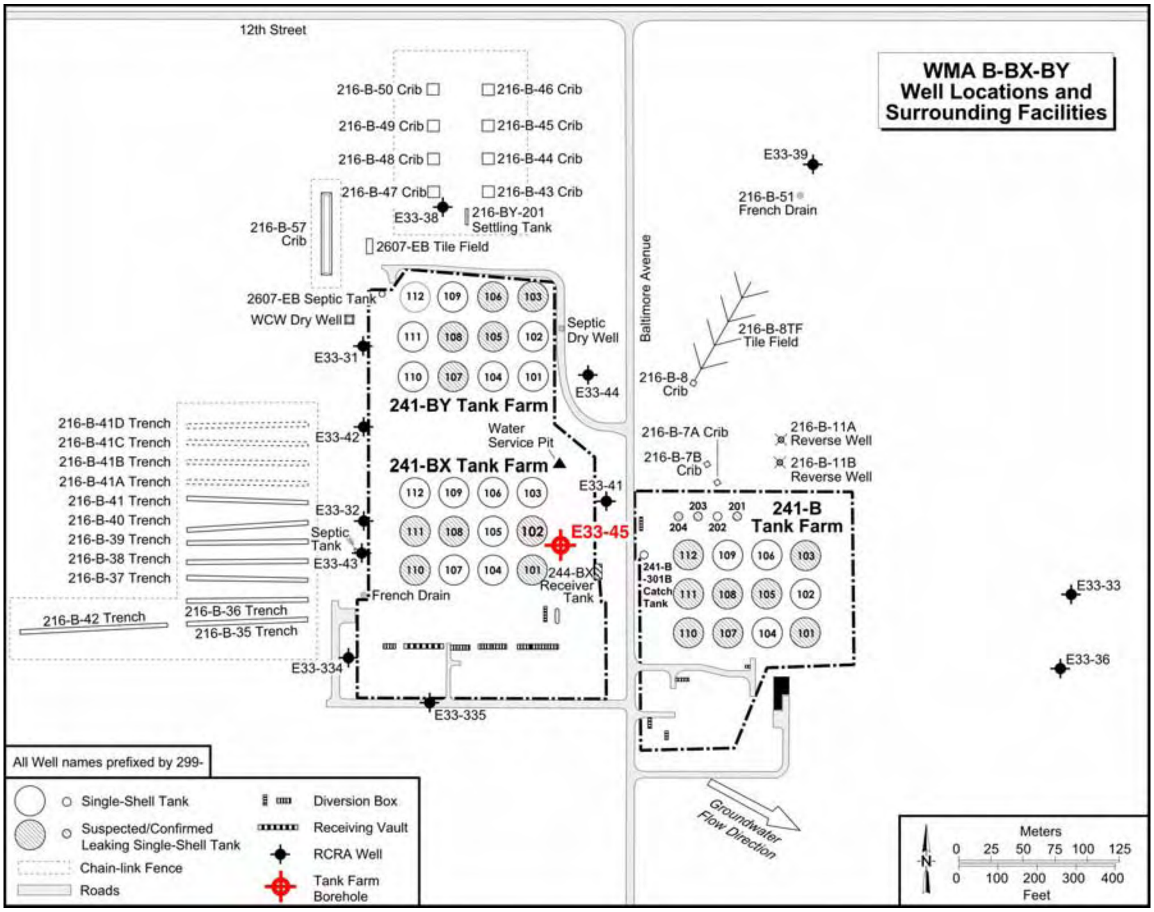

Figure 2.2. Location of Well 299-E33-45

Thirty-five split-spoon core samples were collected approximately every 3 m (10 ft) or at pre-selected locations where hydrogeologic contacts were anticipated. Grab samples were collected between these core sample intervals to yield near continuous samples to a depth of 77 m (254 ft). The split-spoon samples were taken ahead of the casing by driving a split-spoon sampler into the undisturbed formation below the casing. The location of each split-spoon sample is shown in Figure 2.3 along with stratigraphic interpretations. Table 2.2 provides estimated depth intervals for these samples.

Each of the thirty-five split-spoon samples was disassembled in the field and the sample liners recovered. Each sampler contained four 15-cm (6-in) long stainless steel liners. Upon recovery, each liner was immediately capped, and packaged for transport to the PNNL 3720 Laboratory for sample analysis. The lower most sample liner in the split-spoon was designated "A" and the upper most liner designated as "D". All split-spoon liners and grab samples were surrounded by cold packs to maintain sample temperature between 2 and 4 °C during transport to the laboratory. The shipping containers were sealed with custody tape and maintained under chain-of-custody protocols.

Ninety-six composite grab samples (including 2 surface samples and 4 duplicate samples) were collected by filling 1L glass jars with material composited from the core drive barrel, representing a roughly 60-cm (2-ft) interval of the borehole (Reynolds 2001). Additionally, 26 grab samples were taken from the shoe of the split-spoon samplers as they were disassembled in the field for recovery of the liners. All samples were tightly capped, and packaged for transport to the 3720 Laboratory for sample analysis. Table 2.3 provides estimated depth intervals for these composite and split-spoon-shoe grab samples.

Table 2.2. Depth of Split-Spoon Samples (2 pages)

Sample Number	Top Depth (ft)	Bottom Depth (ft)	Sampled Interval Thickness (ft)	Sample Type
S01014-1	9.39	10.89	1.50	Split-spoon Liners
S01014-6	19.09	21.09	2.00	Split-spoon Liners
S01014-11	30.19	32.09	1.90	Split-spoon Liners
S01014-16	40.29	42.29	2.00	Split-spoon Liners
S01014-21	49.89	51.89	2.00	Split-spoon Liners
S01014-27	61.24	63.24	2.00	Split-spoon Liners
S01014-32	69.49	71.49	2.00	Split-spoon Liners
S01014-33	71.64	73.64	2.00	Split-spoon Liners
S01014-34	73.90	75.90	2.00	Split-spoon Liners
S01014-35	76.44	78.44	2.00	Split-spoon Liners
S01014-36	77.59	79.59	2.00	Split-spoon Liners
S01014-40	86.90	88.90	2.00	Split-spoon Liners
S01014-44	98.34	100.34	2.00	Split-spoon Liners
S01014-49	109.39	111.39	2.00	Split-spoon Liners
S01014-53	117.29	119.29	2.00	Split-spoon Liners
S01014-54	119.14	121.14	2.00	Split-spoon Liners
S01014-61	129.20	131.20	2.00	Split-spoon Liners
S01014-67	139.50	141.50	2.00	Split-spoon Liners
S01014-72	149.80	151.80	2.00	Split-spoon Liners
S01014-78	159.10	161.10	2.00	Split-spoon Liners
S01014-82	166.90	168.90	2.00	Split-spoon Liners
S01014-83	169.30	171.30	2.00	Split-spoon Liners
S01014-84	171.60	173.60	2.00	Split-spoon Liners
S01014-88	179.90	181.90	2.00	Split-spoon Liners
S01014-93	188.90	190.90	2.00	Split-spoon Liners
S01014-99	199.60	201.60	2.00	Split-spoon Liners
S01014-104	209.67	211.67	2.00	Split-spoon Liners
S01014-110	217.70	219.70	2.00	Split-spoon Liners
S01014-111	220.00	222.00	2.00	Split-spoon Liners
S01014-112	221.90	223.90	2.00	Split-spoon Liners
S01014-116	229.70	231.70	2.00	Split-spoon Liners

Table 2.2. Depth of Split-Spoon Samples (2 pages)

Sample Number	Top Depth (ft)	Bottom Depth (ft)	Sampled Interval Thickness (ft)	Sample Type
S01014-122	240.14	242.14	2.00	Split-spoon Liners
S01014-124	243.50	245.50	2.00	Split-spoon Liners
S01014-128	250.50	252.00	1.50	Split-spoon Liners
S01014-129	251.90	253.90	2.00	Split-spoon Liners

Table 2.3. Depth of Composite and Split-Spoon Shoe Grab Samples (4 Pages)

Sample Number	Top Depth (ft)	Bottom Depth (ft)	Sampled Interval Thickness (ft)	Sample Type
S01015-01	0	1	1	Surface Grab
S01015-02	0	1	1	Surface Grab
S01014-02	11.74	13.50	1.76	Composite Grab
S01014-03	13.50	16.69	3.19	Composite Grab
S01014-04	16.69	18.24	1.55	Composite Grab
S01014-05	18.24	19.09	0.85	Composite Grab
S01014-06	21.09	21.59	0.50	Shoe
S01014-07	21.59	23.19	1.60	Composite Grab
S01014-08	23.19	25.69	2.50	Composite Grab
S01014-09	25.69	27.74	2.05	Composite Grab
S01014-10	27.74	30.19	2.45	Composite Grab
S01014-11	32.09	32.59	0.50	Split-spoon Shoe
S01014-12	32.59	34.87	2.28	Composite Grab
S01014-13	34.87	36.69	1.82	Composite Grab
S01014-14	36.69	38.70	2.01	Composite Grab
S01014-15	38.70	40.29	1.59	Composite Grab
S01014-16	42.29	42.59	0.30	Composite Grab
S01014-17	42.39	44.39	2.00	Composite Grab
S01014-18	44.39	46.49	2.10	Composite Grab
S01014-19	46.49	48.59	2.10	Composite Grab
S01014-20	48.59	49.89	1.30	Composite Grab
S01014-21	51.89	52.39	0.50	Composite Grab
S01014-22	52.39	54.59	2.20	Composite Grab
S01014-23	54.59	56.04	1.45	Composite Grab
S01014-24	56.04	58.14	2.10	Composite Grab
S01014-25	58.14	60.45	2.31	Composite Grab

Table 2.3. Depth of Composite and Split-Spoon Shoe Grab Samples (4 Pages)

Sample Number	Top Depth (ft)	Bottom Depth (ft)	Sampled Interval Thickness (ft)	Sample Type
S01014-26	60.45	61.24	0.79	Composite Grab
S01014-27	63.24	63.74	0.50	Composite Grab
S01014-28	63.74	64.09	0.35	Composite Grab
S01014-29	64.09	65.87	1.78	Composite Grab
S01014-30	65.87	68.24	2.37	Composite Grab
S01014-31	68.24	69.34	1.10	Composite Grab
S01014-32	71.49	71.99	0.50	Composite Grab
S01014-33	73.64	74.14	0.50	Composite Grab
S01014-34	75.90	76.40	0.50	Composite Grab
S01014-35	78.44	78.94	0.50	Composite Grab
S01014-37	81.59	83.39	1.80	Composite Grab
S01014-38	83.97	85.59	1.62	Composite Grab
S01014-39	85.59	86.90	1.31	Composite Grab
S01014-40	88.90	91.10	2.20	Composite Grab
S01014-41	91.74	93.69	1.95	Composite Grab
S01014-42	93.69	95.69	2.00	Composite Grab
S01014-43	95.69	98.34	2.65	Composite Grab
S01015-06	95.69	98.34	2.65	Grab - Duplicate
S01015-07	95.69	98.34	2.65	Grab - Duplicate
S01014-44	100.34	100.54	0.20	Composite Grab
S01014-45	100.54	102.99	2.45	Composite Grab
S01014-46	102.10	105.59	3.49	Composite Grab
S01014-47	105.59	107.44	1.85	Composite Grab
S01014-48	107.44	109.39	1.95	Composite Grab
S01014-49	111.39	111.59	0.20	Composite Grab
S01014-50	111.59	113.19	1.60	Composite Grab
S01014-51	113.19	114.19	1.00	Composite Grab
S01014-52	114.19	117.29	3.10	Composite Grab
S01014-53	119.29	119.49	0.20	Composite Grab
S0-014-54	121.14	121.34	0.20	Composite Grab
S01014-55	121.34	121.34	0.00	Grab – Previously Sampled Depth
S01014-56	121.34	123.29	1.95	Composite Grab
S01014-57	123.29	124.40	1.11	Composite Grab
S01014-58	124.40	126.60	2.20	Composite Grab

Table 2.3. Depth of Composite and Split-Spoon Shoe Grab Samples (4 Pages)

Sample Number	Top Depth (ft)	Bottom Depth (ft)	Sampled Interval Thickness (ft)	Sample Type
S01014-59	126.60	128.20	1.60	Composite Grab
S01014-60	128.20	129.10	0.90	Composite Grab
S01014-61	131.20	131.40	0.20	Composite Grab
S01014-62	131.40	133.30	1.90	Composite Grab
S01014-63	133.30	134.90	1.60	Composite Grab
S01014-64	134.90	136.10	1.20	Composite Grab
S01014-65	136.10	138.10	2.00	Composite Grab
S01014-66	138.10	139.80	1.70	Composite Grab
S01014-67	141.50	141.70	0.20	Composite Grab
S01014-68	141.70	143.40	1.70	Composite Grab
S01014-69	143.40	145.50	2.10	Composite Grab
S01014-70	145.50	147.70	2.20	Composite Grab
S01014-71	147.70	149.50	1.80	Composite Grab
S01014-72	151.80	152.00	0.20	Composite Grab
S01014-73	152.00	153.40	1.40	Composite Grab
S01014-74	153.40	154.70	1.30	Composite Grab
S01014-75	154.70	157.70	3.00	Composite Grab
S01014-76	157.70	159.10	1.40	Composite Grab
S01014-77	159.10	159.10	0.00	Composite Grab
S01014-79	161.30	162.90	1.60	Composite Grab
S01014-80	162.90	164.20	1.30	Composite Grab
S01014-81	164.20	166.90	2.70	Composite Grab
S01014-82	168.90	169.30	0.40	Composite Grab
S01014-83	171.30	171.50	0.20	Composite Grab
S01014-84	173.60	173.80	0.20	Composite Grab
S01014-85	173.80	175.60	1.80	Composite Grab
S01014-86	175.60	178.20	2.60	Composite Grab
S01014-87	178.20	180.20	2.00	Composite Grab
S01014-89	182.10	183.30	1.20	Composite Grab
S01014-90	183.30	185.50	2.20	Composite Grab
S01014-91	185.50	186.90	1.40	Composite Grab
S01014-92	186.90	189.90	3.00	Composite Grab
S01014-94	191.20	193.80	2.60	Composite Grab
S01014-95	193.80	195.30	1.50	Composite Grab
S01014-96	195.30	197.00	1.70	Composite Grab

Table 2.3. Depth of Composite and Split-Spoon Shoe Grab Samples (4 Pages)

Sample Number	Top Depth (ft)	Bottom Depth (ft)	Sampled Interval Thickness (ft)	Sample Type
S01014-97	197.00	198.00	1.00	Composite Grab
S01014-98	198.60	199.60	1.00	Composite Grab
S01014-99	201.60	201.90	0.30	Composite Grab
S01014-100	201.90	204.20	2.30	Composite Grab
S01014-101	204.20	206.20	2.00	Composite Grab
S01014-102	206.20	208.10	1.90	Composite Grab
S01014-103	208.10	209.67	1.57	Composite Grab
S01014-104	211.67	211.97	0.30	Composite Grab
S01014-105	211.97	213.60	1.63	Composite Grab
S01014-106	213.60	215.30	1.70	Composite Grab
S01014-107	215.30	216.40	1.10	Composite Grab
S01014-108	216.40	217.80	1.40	Composite Grab
S01014-109	216.40	217.80	1.40	Composite Grab
S01014-110	219.70	220.00	0.30	Composite Grab
S01014-111	222.00	222.20	0.20	Composite Grab
S01014-112	223.90	224.10	0.20	Composite Grab
S01014-113	224.10	226.00	1.90	Composite Grab
S01014-114	226.00	227.70	1.70	Composite Grab
S01014-115	227.70	228.70	1.00	Composite Grab
S01014-116	231.70	231.90	0.20	Composite Grab
S01014-119	231.90	234.20	2.30	Composite Grab
S01014-120	236.00	238.60	2.60	Composite Grab
S01014-121	238.60	240.34	1.74	Composite Grab
S01014-123	242.34	243.50	1.16	Composite Grab
S01014-125	245.70	246.50	0.80	Composite Grab
S01014-126	246.50	248.10	1.60	Composite Grab
S01014-127	248.10	250.10	2.00	Composite Grab
S01015-12	254.10	256.10	2.00	Composite Grab

2.3 Geophysical Logging

Geophysical logging was conducted at the end of each drilling stage prior to placement of the next downsized string of casing and then when the borehole had reached its final depth (Reynolds 2001). Geophysical logging was conducted using a neutron-moisture logging tool and a High-Purity Germanium (HPGe) spectral gamma logging tool. Detailed descriptions of the logging tools, data analysis, and general conclusions can be found in reports by Reynolds (2001) and Lindsey et al. (2001). A composite of the moisture and spectral gamma logs is shown in Figure 2.3.

The neutron-moisture log is generally used to depict the average volumetric moisture content within a 20 to 30 cm (8 to 12 in.) radius around the borehole. However, logging was completed with an uncalibrated neutron-moisture logging system, therefore, the results are reported as neutron count rate (Lindsey et al. 2001). An increase in count rate (and thus, a corresponding increase in moisture content) was noted at a depth of 51.8 m (170 ft) at the interface between a fine sand and silt unit overlying a sand and gravel unit (Lindsey et al. 2001). Another sharp increase in the neutron count rate occurs at a depth of 66.6 m (218.5 ft) at the contact with a silt-dominated unit. A third increase in the neutron count rate occurs between the depths of 71.6 m (235 ft) and 72.5 m (238 ft), where the bentonite seal was placed (Reynolds 2001). This likely reflects the high water content associated with the silt dominated unit, the perched water, and the bentonite seal. These neutron count rate changes correlate well with changes in the geologic materials (Section 2.4).

Three different HPGe spectral-gamma logging events were conducted to identify the specific gamma-emitting radionuclides in the formation surrounding the borehole (Reynolds 2001). A different logging event was conducted at the end of each drilling phase, through a single thickness of casing (with the exception of short overlaps between successive events) (Lindsey et al. 2001). Processing of the spectral gamma log data provided plots of total gamma, naturally occurring radionuclides, potassium, uranium, and thorium (KUT), cesium-137, uranium-235, and uranium-238 (Reynolds 2001; Lindsey et al. 2001).

The total gamma and KUT data correlate well with changes in the geologic materials (Section 2.6). The KUT activities were reported to be generally typical for Hanford formation sediments and remained essentially featureless throughout the borehole with the exception of increased uranium concentrations in the second spectral-gamma logging event, and between depths of 65.5 to 71.6 m (215 to 235 ft). Lindsey et al. (2001) attributed the increased natural uranium concentrations during the second spectral-gamma logging event to the presence of radon-222 in the borehole. Lindsey et al. (2001) reported that potassium-40 concentrations increased from 15 pCi/g in the backfill to almost 20 pCi/g in the Hanford formation. Additionally, Lindsey et al. (2001) attributed increases in potassium, uranium, and thorium concentrations between the depths of 65.5 to 71.6 m (215 to 235 ft) to the presence of bentonite grout. However, this conflicts somewhat with the location of the bentonite seal as reported by Reynolds (2001) who stated that the bentonite seal was installed between the depths of 71.7 to 72.8 m (235.1 to 238.7 ft).

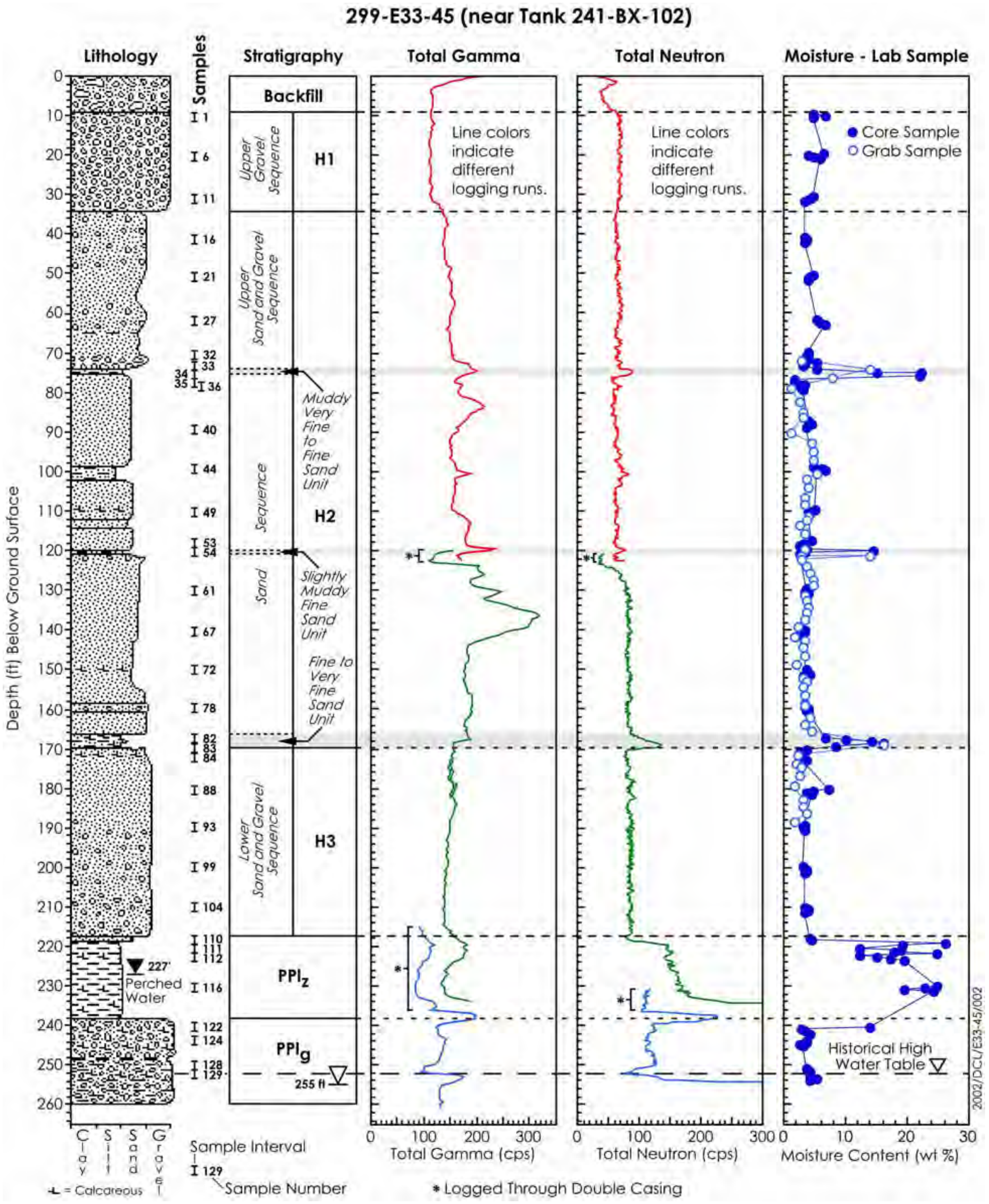

Figure 2.3. Generalized Borehole Log for Well 299-E33-45

Lindsey et al. (2001) reported that cesium-137 contamination was limited to the surface soils with a maximum concentration about 2.5 pCi/g. They found “processed” uranium (i.e., uranium from Hanford operations distinct from natural uranium) to occur in two distinct zones between the depths of 21.3 to 59.4 m (70 to 195 ft). Maximum concentrations of uranium-235 were slightly greater than 8 pCi/g, while uranium-238 concentrations were almost 250 pCi/g. Lindsey et al. (2001) suggest that diminishing and intermittent uranium-235 and uranium-238 occurrences below a depth of 51.8 m (170 ft) may be due to drag down during drilling. This information is correlated with radiochemical sample analyses as presented in Section 4.3.2.

2.4 Sample Handling

Once received by the laboratory, the sample liners and grab samples were stored in a refrigerator to maintain the sample temperatures between 2 and 4 °C. Soon after arrival at the laboratory, each split-spoon liner was taken to a fume hood, unpackaged, and the lower most (i.e., deepest depth) end cap removed. A small portion of the sample (approximately 1 cm) was scraped away and a sandwich of filter papers (for matric potential measurements) inserted into the sample. The scraped materials were then placed back over the filter papers such that the filter paper sandwich was surrounded by and in intimate contact with the soil. The end cap was re-installed, sealed with tape, and the sample returned to the refrigerated storage.

After refrigerator storage for between three to twelve weeks, each split-spoon liner was taken to a fume hood, where the end caps were removed, and the filter papers in each liner were removed for processing. Then the approximate amount of sample material retained in the liner (% recovery) was noted. The sample material was then removed from the liner and placed in a plastic tray container for sub-sampling, geologic description, and photography.

If coarse-grained, the materials were removed from the sample liners using a hammer to tap on the stainless steel liner to allow the materials to fall out into the plastic sample tray. Efforts were made to keep the sample materials as intact as possible. However, the unconsolidated friable nature of these coarse-grained materials generally made it impossible to preserve the internal sedimentary structures in these materials. Where deemed appropriate, the finer-grained materials were extruded from the stainless steel liners using a specially designed sample extruder (designed and fabricated by K. D. Reynolds, Duratek Federal Services) to try to preserve the sedimentary structures (Figure 2.4). These efforts were reasonably successful.

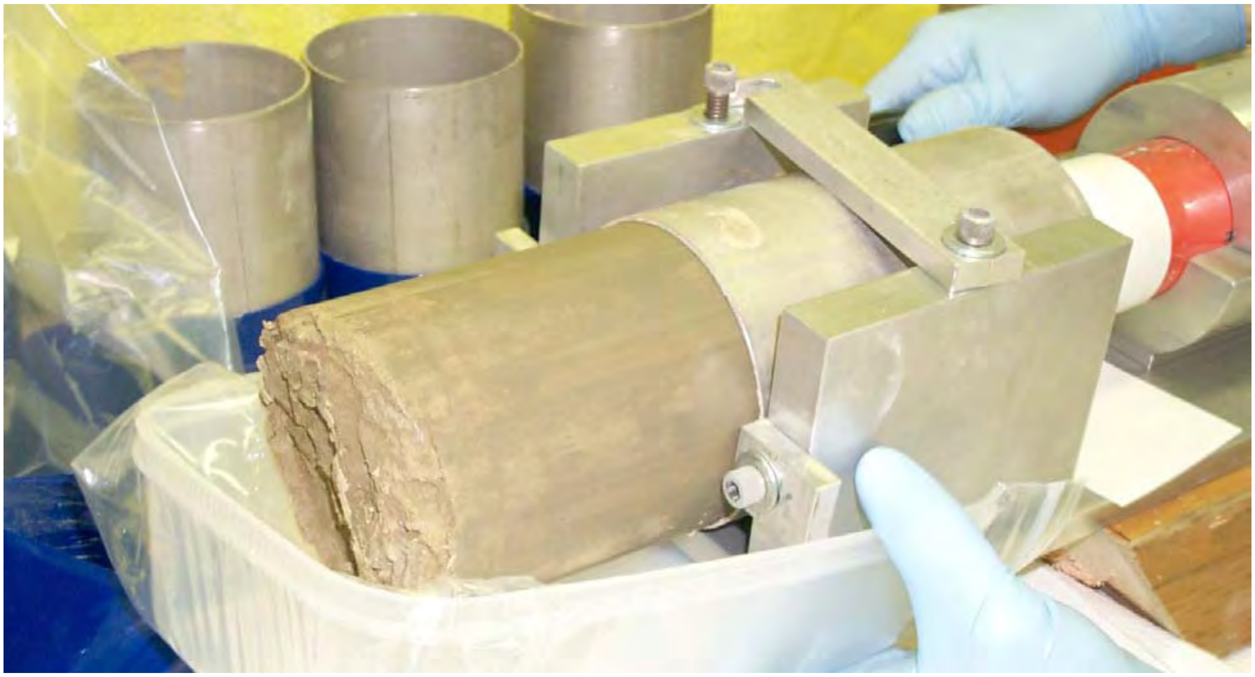

Figure 2.4. Extrusion of Sample S01014-111A

2.5 Sub-Sampling and Geologic Description

The sampled materials were quickly inspected and moisture samples and gamma energy analysis samples collected from discrete portions of each sample liner. The intent was to sample the finer grained and/or wetter materials in each liner. If there were distinct hydrogeologic units present, each was sampled separately. For all sub-sampling, the geologist tried to avoid slough and/or other unrepresentative portions. The remaining portions of the samples were then used for a brief visual geologic evaluation.

The visual geologic evaluation was conducted in accordance with procedures ASTM D 2488 (ASTM 1993) and PNL-MA-567-DO-1 (PNL 1990a). Throughout the sub-sampling and geologic evaluation activities, the laboratory geologist made continual visual observations regarding the sample structure, grain-size distribution (and sorting), grain-shape (e.g., roundness), color, moisture, consistency, cementation, hardness, and reaction to hydrochloric acid (an indicator of carbonate content). Particular attention was given to estimating visually the percentage (by weight) of gravel, sand, and mud (silt+clay), and to visually classify the samples based on the modified Folk (1968)/Wentworth (1922) classification scheme historically used at the Hanford Site and described by Fecht and Price (1977). This sediment classification scheme uses a ternary diagram to categorize the sediment into one of 19 classes based on the relative proportions of gravel, sand, and mud (silt+clay) (Figure 2.5). Geologic logs recording the visual observations made while opening, sub-sampling, and characterizing these liners, are provided in Appendix A. Photographs were also taken of each sample, and are included in Appendix B.

PARTICLE DESIGNATION			PARTICLE DIAM. (MM)
GRAVEL	BOULDER		>256
	COBBLE	LARGE	256-128
		SMALL	128-64
	PEBBLE	VERY COARSE	64 - 32
		COARSE	32 - 16
		MEDIUM	16 - 8
		FINE	8 - 4
		VERY FINE	4 - 2
SAND		VERY COARSE	2 - 1
		COARSE	1 - 1/2
		MEDIUM	1/2 - 1/4
		FINE	1/4 - 1/8
		VERY FINE	1/8 - 1/16
MUD		SILT & CLAY	<1/16

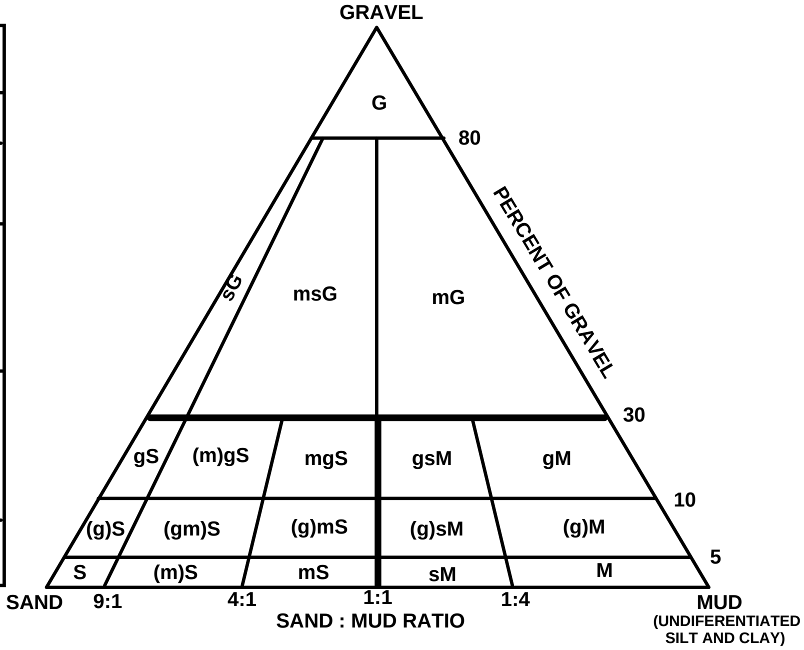

Figure 2.5. Sediment Classification Scheme (Modified after Folk 1968) and Grain Size Nomenclature (Modified after Wentworth 1922)

2.6 Geology of Well 299-E33-45

Figure 2.3 presents a generalized lithology/stratigraphy section for the borehole. The stratigraphy shown here is a synergistic interpretation of the field geologist's logs, geologic descriptions of the split-spoon sample materials, laboratory analyses, and geophysical logs. Three primary stratigraphic units were encountered by this borehole: 1) backfill materials, 2) the Hanford formation, and 3) the Plio-Pleistocene unit. A brief description of the sampled materials from each of these major stratigraphic units is presented below.

2.6.1 Backfill

A review of the well location, relative to the as-built drawing of the tank farm excavation (drawing number H-2-37989), suggests that the well is located on the eastern slope of the excavation, intersecting the native geologic materials at an elevation of about 197.2 m (647 ft), or approximately 3 m beneath the existing ground surface. This depth correlates nicely with a spike in the neutron moisture log. Thus, the backfill is believed to extend from the ground surface to a depth of approximately 3 m (~9 ft) where it contacts with the Hanford formation. Split-spoon samples were not collected from this interval; however, the borehole log described this material as non-cohesive, poorly sorted, sandy gravel with sub-angular to sub-rounded pebble to cobble. The color was described as dark grayish brown, with no-reaction to hydrochloric acid.

2.6.2 Hanford Formation

Wood et al. (2000) and Lindsey et al. (2001), describe cataclysmic flood deposits of the Hanford formation beneath the 241-BX tank farm as consisting of three informal units (i.e., H1, H2, and H3). However, the upper portion of the H1 unit was partially removed during excavation of this portion of the tank farm, and then later used as backfill around the tanks.

Based on the lithologies observed during drilling and in core samples from this well, the Hanford formation beneath the backfill can locally be subdivided into an upper gravel sequence, an upper sand and gravel sequence, a sand sequence, and a lower sand and gravel sequence. Distinctly finer (muddy/silty) facies are found within and bordering several sand sequences.

Hydrometer/sedimentation particle-size analyses from near by wells (albeit primarily from hard tool samples) suggest that the mud fraction of the Hanford formation is predominantly silt with a median silt to clay ratio of 3.5:1 (Appendix C). Thus, throughout the following discussion, the term "silt" is often used in lieu of the less descriptive term "mud". The gravel and sand dominated facies are associated with high to moderate energy deposition during flooding, while the mud (silt) layers probably represent remnants of slack-water sedimentation deposited towards the end of episodes of Ice-Age Flooding (Baker et al. 1991).

Consistent with Lindsey et al. (2001), the upper gravel dominated unit is referred to here as the Hanford H1 unit. The upper two sand sequences and intercalated mud units above a depth of 51.8 m (169.8 ft) have been assigned to the Hanford H2 unit, while those below this depth, but above a depth of 66.4 m (218 ft) are assigned to the Hanford H3 unit.

2.6.2.1 Hanford H1 Unit

Three split-spoon samples were collected from this interval. These materials were described as gravel to muddy sandy gravel, ranging from 50 to 90% gravel (Figure 2.6). The gravels were described as multi-lithologic but generally containing a high percentage of basalt. The gravel clasts were generally subrounded to well rounded up to 50 mm in diameter where not broken. The finer fraction was described as mostly very coarse to coarse sand with perhaps as much as 5 to 7% mud. The samples generally displayed no cementation or obvious sedimentary structure, and only weak to no reaction to hydrochloric acid (HCl). The general overall moist color ranged from olive brown to very dark grayish brown (2.5Y4/3 to 2.5Y3/2).

Figure 2.6. Example of the Gravel Dominated Hanford H1 Unit from Sample S01014-6A Collected at a Depth of 6.3 to 6.4 m (20.6 to 21.1 ft)

2.6.2.2 Hanford H2 Unit

Lindsey et al. (2001) assigned Hanford formation materials above a depth of 51.8 m (169.8 ft)[1] to the Hanford H2 unit. These materials can be further subdivided into two sand sequences and two distinct mud/silt units.

2.6.2.2.1 Upper Sand and Gravel Sequence

The uppermost sand sequence (Figure 2.7) extends from the base of the H1 unit to a depth of 22.7 m (74.5 ft) where it contacts with a thin muddy very fine to fine sand layer (Figure 2.8). Five split-spoon samples were collected within this uppermost sand sequence, a sixth split-spoon sample captured the contact with and the entire thickness of the muddy very fine to fine sand layer. The materials within this uppermost sand and gravel sequence were described as moderately sorted, mostly medium to very coarse sand, with some coarse to very coarse sand laminations, and occasional pebbles up to 10 mm in diameter (intermediate axis). Some thin strata with up to 5% gravel are also present, including gravels up to 55 mm in intermediate diameter. These materials are further described as un-cemented with weak to no reaction to hydrochloric acid (except for occasional caliche [$CaCO_3$ cemented] fragments). The moist color of these materials ranged from mostly dark grayish brown (2.5Y4/2) in the upper portion of the unit, to grayish brown (2.5Y5/2) near the bottom.

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[1] Lindsey et al. (2001), page 16 lists the depth of this change at 49.98 m (164 ft). However, their Figure 5 and Table 1 indicate the depth of change is more consistent with the depth reported here.

2.6.2.2.2 Muddy Very Fine to Fine Sand Unit

A muddy very fine to fine sand layer, approximately 30 cm (1 ft) thick, was encountered from a depth of 22.7 m (74.5 ft) to 23.0 m (75.5 ft). The entire thickness of this layer was captured within one split-spoon sample (S01014-34 liners C, B, and A as indicated on the right hand portion of Figure 2.8 and left hand portion of Figure 2.9. These materials were described as muddy very fine to fine sand with an estimated 30% mud (interpreted to be mostly silt). The materials were well stratified to laminated with one prominent coarse sand layer. The materials were described as moist to wet with a moist color of dark grayish brown (2.5Y4/2) to olive brown (2.5Y4/3), and weak to no reaction to hydrochloric acid.

2.6.2.2.3 Middle Sand Sequence

The middle sand sequence is an estimated 27.9 m (91.5 ft) thick extending from a depth of 23.0 m (75.5 ft) to 50.9 m (167 ft), where it overlies a thin (1 m thick) fine-grained sequence of very fine sand to muddy very fine sand. Eleven split-spoon samples were collected throughout this middle sand sequence. These materials were described as multilithologic and somewhat stratified ranging mostly from coarse to very coarse sand with some medium to very fine pebble (e.g., near the 23.5 m [77 ft] depth) Figure 2.10), to mostly coarse to medium sand (Figure 2.11). The color of the moist materials was generally described as grayish brown (2.5Y5/2) to dark grayish brown (2.5Y4/2).

Occasional thin strata up to 0.5 m (1.5 ft) thick of medium to fine sand were observed at the 30.5 m (100 ft), 36.6 m (120 ft), and 45.7 m (150 ft) depths. Four thin zones of moderate cementation and weak to strong reaction to HCl were observed at depths of 33.4 m (109.5 ft), 36.6 m (120 ft), 42.5 m (139.5 ft), and 45.7 m (150 ft). The thin fine-grained calic horizon at 36.6 m (120 ft) (Figure 2.12) may represent an old soil (paleosol) surface.

Figure 2.7. Example of the H2 Upper Sand Sequence in Sample S01014-16C, Collected at a Depth of 12.6-12.7m (41.3-41.8 ft)

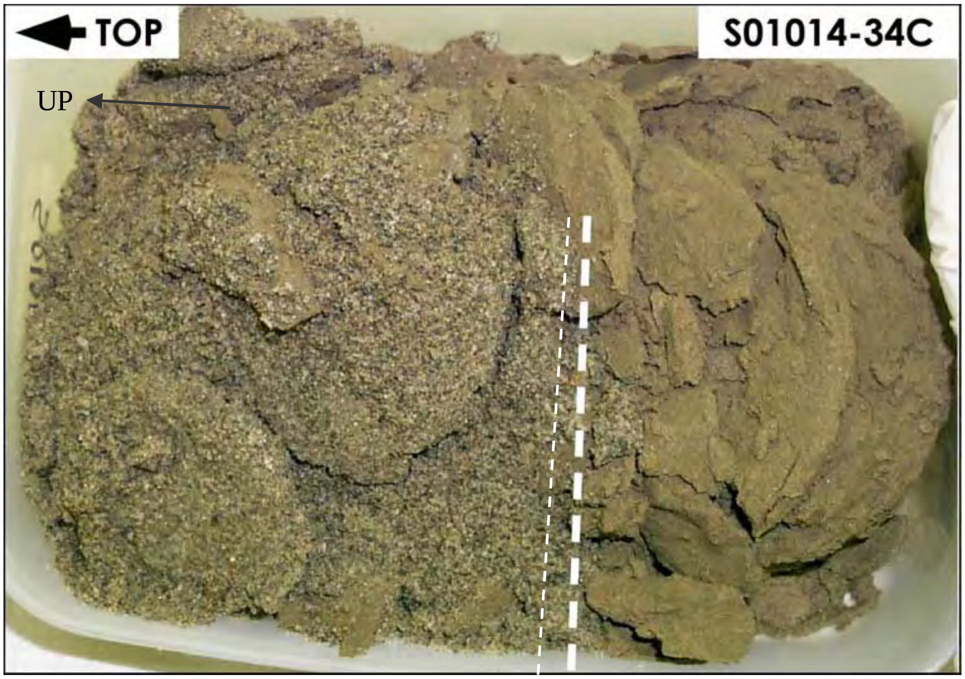

Figure 2.8. Contact Between H2 Upper Sand Squence and Underlying Muddy Very Fine to Fine Sand Layer, as Observed in Sample S01014-34C, Collected at a Depth of 22.7 to 22.8m (74.4 to 74.9 ft)

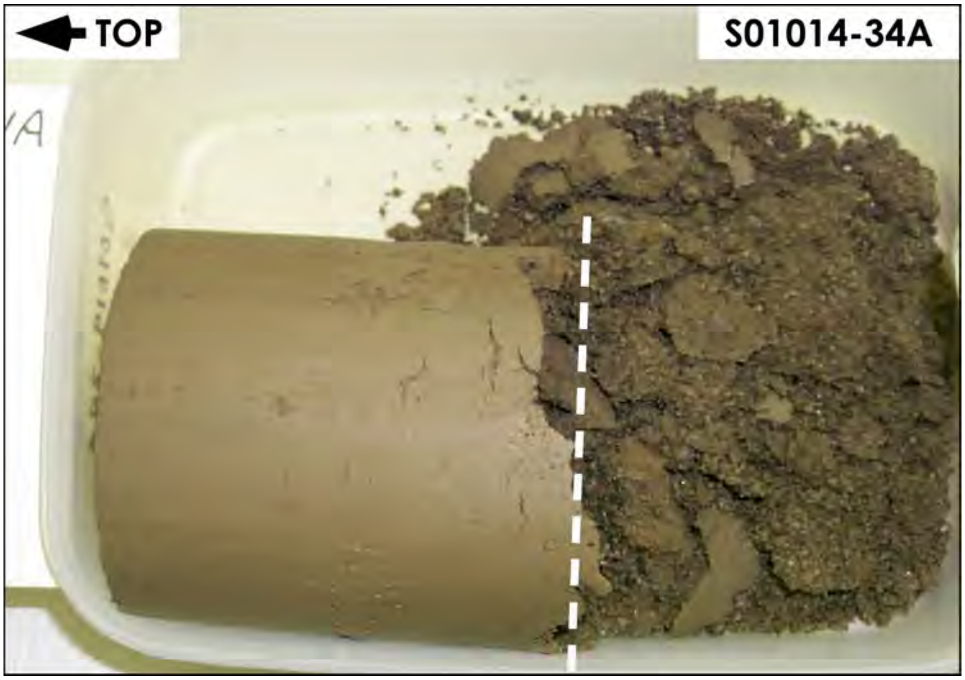

Figure 2.9. Lower Contact of the Muddy Very Fine to Fine Sand Layer in Sample S01014-34A at a Depth of 23 to 23.1 m (75.4 to 75.9 ft). Contact Occurs at the Break Between the Cohesive Muddy Sand on the Left, and the Loose Coarse Sand on the Right.

Figure 2.10. Coarse to Very Coarse Sand of the Middle Sand Sequence from Sample S-101014-35B at a Depth of 23.6 to 23.7 m (77.4 to 77.9 ft)

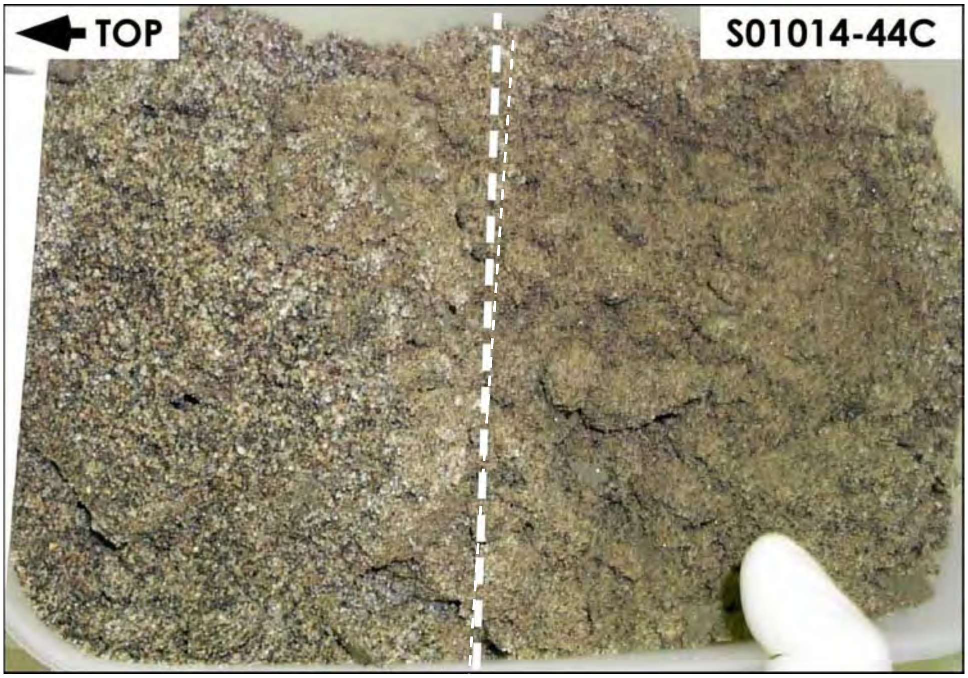

Figure 2.11. Contact Between Coarse Sand and Medium Sand Strata in the Middle Sand Sequence from Sample S-01014-44C at a Depth of 30.1 to 30.2 m (98.8 to 99.3 ft)

Figure 2.12. Thin Weak Paleosol(?) Observed in Sample S01014-54C at a Depth of 36.5 to 36.6 m (119.6 to 120.1 ft)

2.6.2.2.4 Fine to Very Fine Sand Unit

This fine-grained unit is approximately 0.8 m (2.6 ft) thick and is highly variable in texture. The top of the unit is characterized by a fairly sharp contact with the overlying medium sand at 51.0 m (167.2 ft). The upper 30 cm (12 in.) is weakly stratified to laminated mostly fine to very fine sand, with some slightly coarser (fine sand) stringers (left side of Figure 2.13 is the fine-very fine sand). These materials were described as weak to moderately cemented with weak to strong reaction to hydrochloric acid. This is believed to be a weakly developed paleosol that may correlate with the Matuyama-Olduvai paleomagnetic boundary (1.77 Ma) identified in well 299-E33-335 (Pluhar et al. 2000, 2002; Bjornstad et al. 2001). This material is underlain by a slightly coarser (medium) sand sequence that grades downward to fine sand. These materials are described as poorly sorted, laminated, and moderately cemented, with weak to strong reaction to hydrochloric acid (right side of Figure 2.14; left hand side of Figure 2.14 is medium sand), and visually contained more moisture compared to the finer sands above. The moist color was described as dark grayish brown (2.5Y4/2). These materials are in turn, underlain by a thin, 6 cm (2.5 in.) thick, silty very fine sand layer (right hand side of Figure 2.14). This layer is very compacted and moderately cemented and forms a very sharp contact with the underlying medium sand at 51.8 m (169.8 ft).

2.6.2.3 Hanford H3 Unit (Lower Sand Sequence)

The lower sand sequence is approximately 14.6 m (48 ft) thick extending from a depth of 51.8 m (169.8 ft) to 66.4 m (217.8 ft). Lindsey et al. (2001) assigned these materials to the Hanford H3 unit. This sand-dominated sequence consists predominantly of stratified coarse to medium sand with occasional pebbles up to 30 mm Figure 2.15). Some reverse graded (coarsening upward) beds on the order of 45 cm (18 in) thick, with up to 10% gravel (Figure 2.16), were observed near the middle of this sequence. The materials were further described as poorly sorted, with weak to no cementation near the top of the sequence and moderate to strong cementation near the bottom (Figure 2.17). Reactions to hydrochloric acid were primarily weak to none, except at the very top of the sequence where some reactions were described as weak to strong, suggesting the presence of some calcium carbonate ($CaCO_3$). The moist color of these materials was primarily described as dark grayish brown to grayish brown (2.5Y4/2 to 2.5Y5/2).

2.6.3 Hanford /Plio-Pleistocene/Ringold (?) Unit

Materials underlying the Hanford H3 unit correlate to those referred to as the Hanford formation/ Plio-Pleistocene Unit (?) (Hf/PPu(?) by Wood et al. (2000) and the Hanford/Plio-Pleistocene/Ringold(?) (H/PP/R[?]) unit by Lindsey et al. (2001). The origin of these deposits is in question. Wood et al. (2000) recognized two facies of the Hf/PPu(?) beneath the 241-B, 241-BX, and 241-BY tank farms: a fine-grained eolian/overbank silt and a sandy gravel to gravelly sand. The locally thick silt facies is generally believed to be a pre-ice age flood deposit potentially equivalent to the early "Palouse" soil (Tallman et al. 1979; DOE 1988), which is now believed to be part of the upper Plio-Pleistocene unit (Wood et al. 2000; Lindsey et al. 2001). Lindsey et al. (2001) suggests that the gravelly materials underlying this silt are consistent with the properties of Ringold gravels. However, Wood et al. (2000) indicate that where this silt layer is missing, the sandy gravel to gravelly sand facies cannot be distinguished from the overlying Hanford formation.

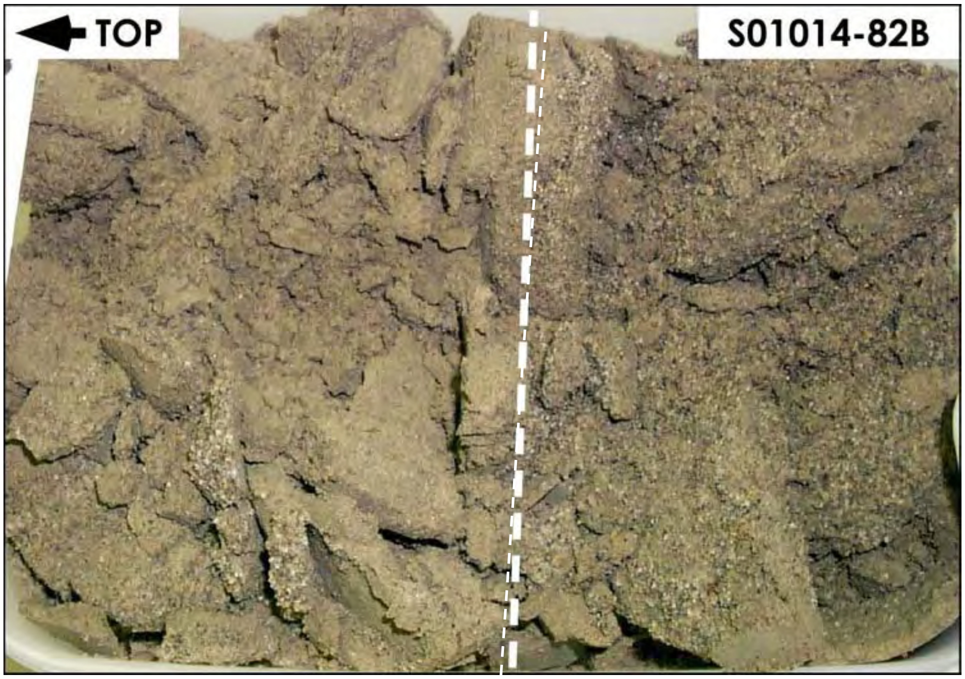

Figure 2.13. Fine to Very Fine Sand and Poorly Sorted Medium Sand Sequence Observed in Sample S01014-82B at a Depth of 51.2 to 51.3 m (167.9 to 168.4 ft)

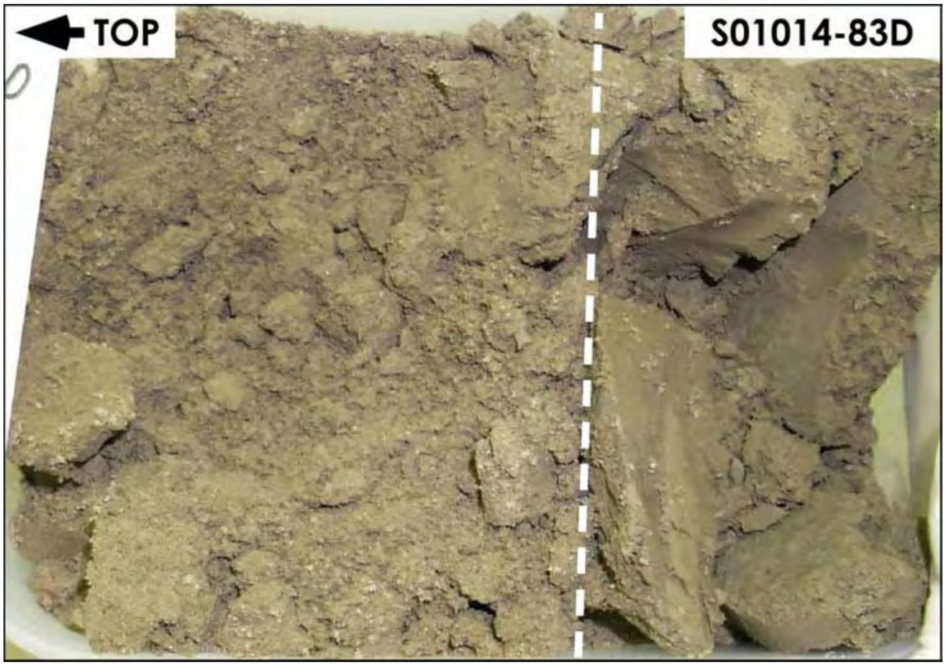

Figure 2.14. Poorly Sorted Medium Sand in Contact with the Silty Very Fine Sand Layer in Sample S01014-83D at a Depth of 51.6 to 51.7 m (169.3 to 169.8 ft)

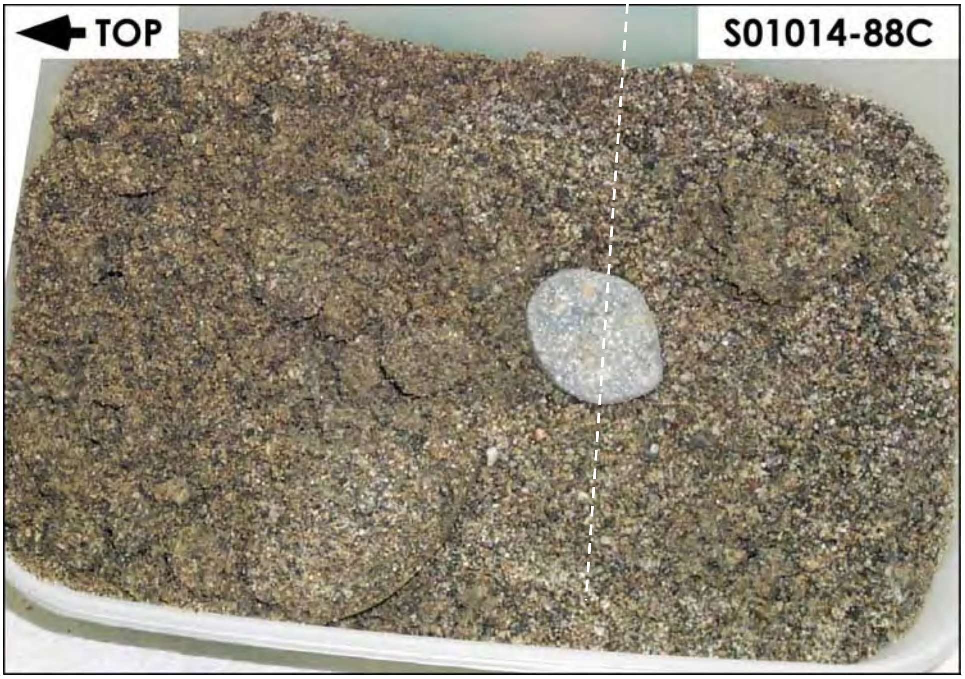

Figure 2.15. Coarse to Medium Sand of the Lower Sand Sequence Observed in Sample S01014-88C at a Depth of 55.0 to 55.1 m (180.4 to 180.9 ft)

Figure 2.16. Gravelly (Mostly Fine to Very Fine Pebble) Coarse to Medium Sand in Sample S01014-88A at a Depth of 55.3 to 55.4 m (181.4 to 181.9 ft)

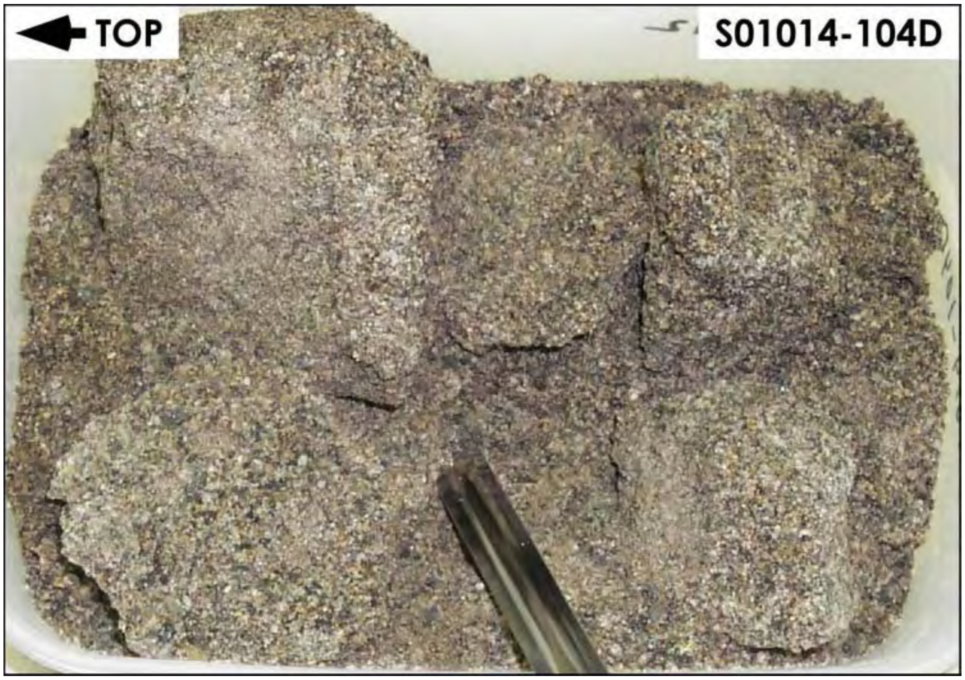

Figure 2.17. Moderate to Strongly Cemented Coarse to Medium Sand in Sample S01014-104D at a Depth of 63.9 to 64 m (209.7 to 209.2 ft)

2.6.3.1 Silt Facies

The silt facies encountered by well 299-E33-45 is an estimated 6.3 m (20.9 ft) thick, extending from a depth of 66.4 m (217.8 ft) to a depth of 72.7 m (238.7 ft). This unit is believed to be equivalent to the Plio-Pleistocene silt unit (PPlz) that overlies an extensive caliche layer (PPlc) beneath 200 West Area. These materials are characterized by stratified mud (silt) and sand deposits, with relatively thick beds (i.e., >45 cm [18 in.]) near the top and bottom of the unit, and relatively thin beds (ranging from 1 to 15 cm) in the middle of the unit. Contacts between the mud (silt) and sand deposits are relatively sharp (Figure 2.18).

Four split-spoon samples were collected from this unit. The upper beds (right hand portion of Figure 2.18) consist of massive (lacking internal laminations), well sorted, medium to fine sand grading to fine sand in places, with only minor amounts of mud (~5%). These deposits are moderate to uncemented with weak or no reaction to dilute hydrochloric acid. The moist color was described as grayish brown (2.5Y5/2) to dark grayish brown (2.5Y4/2). Sand beds in the middle and lower portion of this unit are described as muddy (silty) fine to very sand with weak to strong reaction to hydrochloric acid.

The mud (silt)-dominated beds (Figure 2.19) were described as hard, moderate to strongly cemented with a weak reaction to HCl. These materials are mostly silt, with some fine to very fine sand, and very little clay. There are some fine laminations and banding and/or mottling (color changes) present, due in part to the presence of iron-oxide staining. However, these beds are often described as massive and homogeneous. The overall moist color was described as dark grayish brown (2.5Y42).

The silt facies ranged from moist to dry, with the exception of a fully saturated zone between depths of 69.2 m (227.1 ft) and 70.7 m (231.9 ft). Water samples were collected from this perched water during drilling and from the groundwater zone after completion of drilling. The results from the perched water samples are described in Section 4.12 of this report.

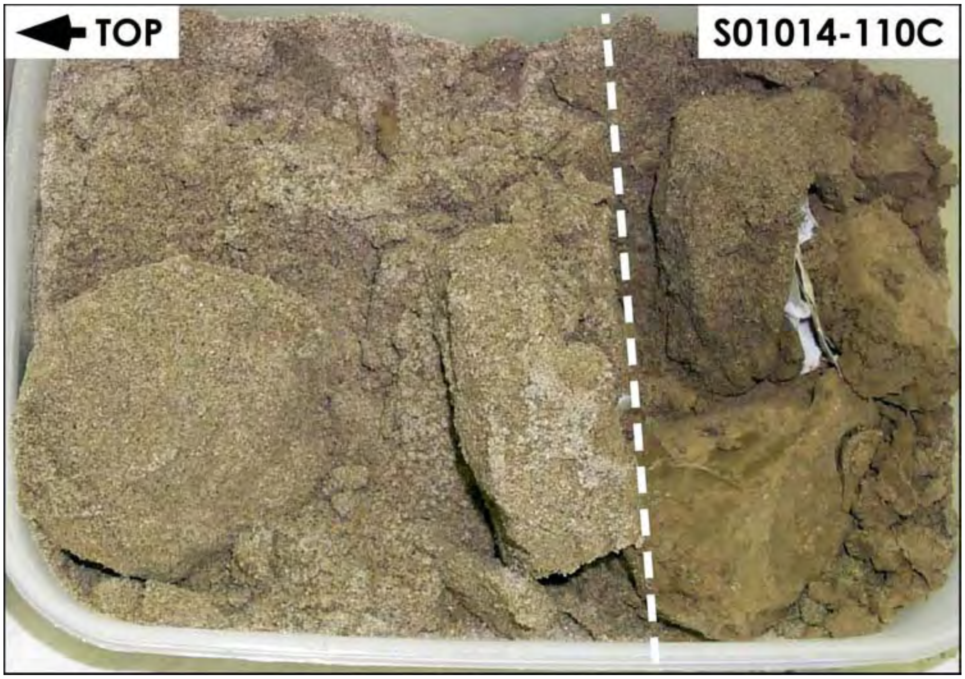

Figure 2.18. Contact Beneath Upper Sand and Lower Mud (Silt) Strata with in the Silt Facies of the H/PP/R (?) Unit in Sample S01014-110C at a Depth of 66.5 to 66.6 m (218.2 to 218.7 ft)

Figure 2.19. Mud (Silt) from the Silty Facies of the H/PP/R (?) Unit Encountered in Sample S01014-111A at a Depth of 67.5 to 67.6 m (221.5 to 222.0 ft)

2.6.3.2 Sandy Gravel to Gravelly Sand Facies

A sequence of sandy gravel to gravelly sand was encountered at a depth of 72.8 m (238.7 ft). This gravel rich facies continues to at least the bottom of the borehole at 79.55 m (261 ft) below ground surface (bgs). If the overlying silt facies is indeed equivalent to the upper Plio-Pleistocene unit, then this gravelly facies must be at least Plio-Pleistocene in age and cannot be correlative with the Hanford formation. Thus, these materials must either be equivalent to the pre-Missoula Gravels (Lindsey et al. 1994), or Ringold Formation gravel (Lindsey et al. 2001).

Four split-spoon samples contained these materials. These materials were described as muddy sandy gravel (Figure 2.20) to sandy gravel (Figure 2.21), consisting of an estimated 30 to 80% gravel, 15 to 65% sand, and up to 15% mud. The gravel clasts were described as a mixture of mostly quartzite, basalt, and some highly weathered friable granite. Where unbroken, the gravel clasts are subrounded to rounded and range up to at least 60 mm in diameter (intermediate axis). The matrix was described as ranging from mostly very fine sand to poorly sorted coarse to medium sand, with variable mud content. The moist color of the matrix was generally described as olive brown (2.5Y4/4) to grayish brown (2.5Y5/2), with some light gray (2.5Y7/2) to yellow (2.5Y7/6) coloration in places. These materials were further described as moderate to uncemented with strong to no reaction to dilute hydrochloric acid. Some caliche fragments were noted, exhibiting a strong reaction to hydrochloric acid.

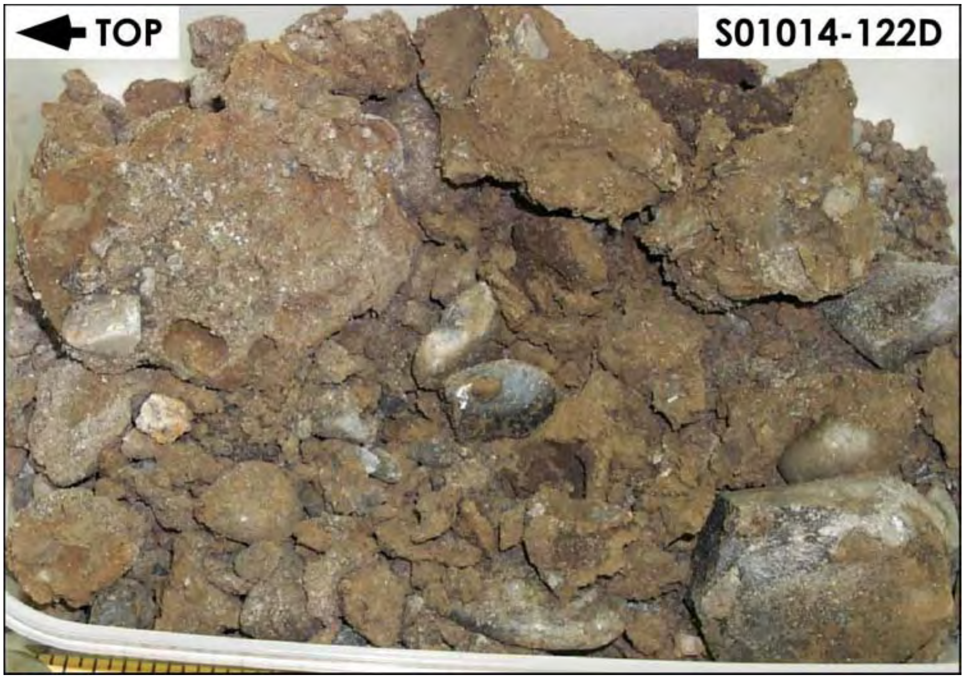

Figure 2.20. Muddy Sandy Gravel Encountered in Sample S01014-122 D at a Depth of 73.5 to 73.6 m (240.1 to 240.6 ft)

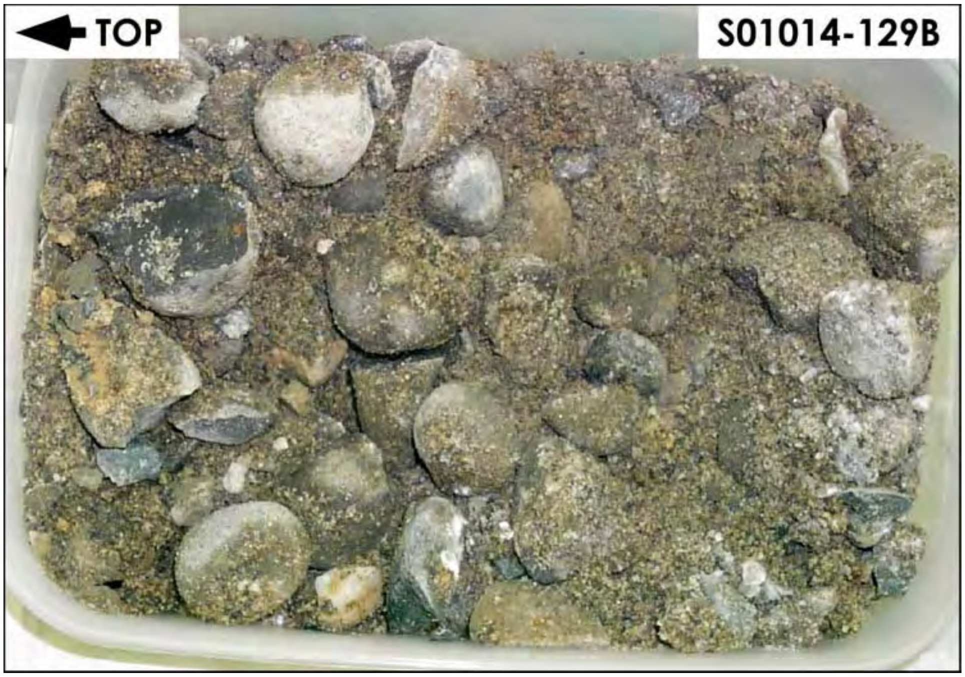

Figure 2.21. Sandy Gravel from Sample S01014-129B at a Depth of 77.1 to 77.2 m (252.9 to 253.4 ft)

2.7 Historic Groundwater Levels

Wood et al. (2000) reported that the discharge of large volumes of wastewater in the early 1950s raised the water table in the vicinity of the 241-BX tank farm to over 4.9 m (16 ft) above pre-Hanford conditions. They indicated that the groundwater reached a maximum elevation of approximately 124 m (407 ft) mean sea level (MSL) in the 1967 to 1968 time frame, with a secondary maximum, just below this in the 1986 to 1989 time frame. Water levels have declined approximately 7 to 8 ft since 1989 at a rate of approximately 20 cm/yr (0.7 ft/yr).

Given a surface elevation about 201 m (659.7 ft) MSL, the maximum water table is estimated to have reached a depth of about 77 m (253 ft). The geologists logs made during the drilling of borehole 299-E33-45 indicate that the groundwater table was encountered at a depth of 77.7 m (255 ft). This suggests that the groundwater level has either dropped less than a meter (2 to 3 ft) or that the groundwater table may have actually reached a depth as high as 75 m (246 ft) during the two high water eras (i.e., 1967 to 1968 and 1986 to 1989).

If the high water mark was at 246 ft bgs, then the observed perched water at 227 to 232 ft bgs is still much shallower and not likely a remnant “bath tub ring” from the historical high water level. Some other water source must have fed this perched zone. The depth of the current water table, historical high water, and the perched water are shown on Figure 2.3.

3.0 Geochemical Method and Materials

This chapter discusses the methods and philosophy used to determine which samples would be characterized and the parameters that would be measured.

3.1 Sample Inventory

Samples were identified using a project-specific prefix, in this case, S01014, followed by a specific sample identification suffix such as -01, for each split spoon. As noted in Section 2.2, the cores contained four sleeves identified by the letters A, B, C, and D, where the A sleeve was always in the position closest to the drive shoe.

3.2 Tiered Approach

During the investigations at WMA SX, significant changes in sediment type and contaminant concentrations were noted within a distance of a few inches within a given sleeve. It was concluded that a more methodical scoping approach would be necessary to provide the technical justification for selecting samples for detailed characterization as defined in the data quality objectives process (DOE 1999**)**. Subsequently, a tiered method was developed that considered depth, geology (e.g., lithology, grain-size composition, carbonate content), individual sleeve contaminant concentration (e.g., radionuclides, nitrate), moisture content, and overall sample quality. Inexpensive analyses and certain key parameters (i.e., moisture content, gamma energy analysis) were performed on sediment from each sleeve.

The objective of the tier 1 characterization was to quantify the extent of penetration of mobile contaminants into the vadose zone sediment. Only the sediment from the A Sleeve was analyzed for most constituents except moisture and gamma energy. Measurable or significant drag down effects for contaminants were not noted, perhaps because the borehole was installed 70 ft distant from the tank walls and the main contaminants (i.e., uranium-238 and technetium-99) are associated mainly with the porewater (technetium-99) or not exclusively concentrated on the sediment particles (uranium-238). Because drag down is dominated by highly contaminated sediment particles, the contaminants in this borehole had less chance of concentrating on particles.

Immediately following the geologic examination, the sleeve contents were sub-sampled for moisture content, gamma-emission radiocounting (for these samples, effectively, natural potassium-40, uranium-238, uranium-235, and natural thorium-232 were found), one-to-one water extracts (which provide soil pH, electrical conductivity, cation, and anion data), total carbon and inorganic carbon content, and 8 M nitric acid extracts (which provide a measure of the total leachable sediment content of contaminants). The remaining sediment from each sleeve was then sealed and placed in cold storage. Later, additional aliquots of selected sleeves or grab samples were removed to measure particle size distribution and mineralogy and to squeeze porewater.

3.3 Materials and Methods

During sub-sampling of the selected core liner and grab samples, every effort was made to minimize moisture loss and prevent cross contamination between samples. Depending on the sample matrix, very coarse pebble and larger material (i.e., >32 millimeter) was avoided during sub-sampling. Larger substrate was excluded to provide moisture contents representative of counting and 1:1 sediment-to-water extract samples. Results from sub-sample measurements should then take into consideration a possible bias toward higher concentrations for some analytes that would be considered associated with smaller sized sediment fractions. The sediment in the Plio-Pleistocene mud facies contained no large pebbles or cobbles.

Procedures ASTM D2488-93 (1993) and PNL-MA-567-DO-1 (PNL 1990a) were followed for visual descriptions and geologic description of all split-spoon samples. The sediment classification scheme used for geologic identification of the sediment types is based on the modified Folk/Wentworth classification scheme described earlier (Figure 2.5). However, the mineralogic and geochemical characterization relied on further separation of the mud into discrete silt and clay sizes.

At borehole 299-E33-45, three perched water samples and one groundwater sample were taken during the drilling process. These four water samples along with the cores and grab samples and ultracentrifuged porewaters (from the sediments) constitute the scope of the characterization activity.

3.3.1 Moisture Content

Gravimetric water contents of the sediment samples from each sleeve and selected grab samples were determined using PNNL procedure PNL-MA-567-DO-1 (PNL 1990a). This procedure is based on the American Society for Testing and Materials procedure *Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock* (ASTM D2216-98 1998). One representative sub-sample of at least 15 to 70 grams was taken from each sleeve and selected grab samples. Sediment samples were placed in tared containers, weighed, and dried in an oven at 105°C until constant weight was achieved, which took at least 24 hours. The containers then were removed from the oven, sealed, cooled, and weighed. At least two weighings, each after a 24-hour heating, were performed to ensure that all moisture was removed. All weighings were performed using a calibrated balance. A calibrated weight set was used to verify balance performance before weighing samples. The gravimetric water content was computed as percentage change in soil weight before and after oven drying.

3.3.2 1:1 Sediment-to-Water Extracts

The water-soluble inorganic constituents were determined using a 1:1 sediment-to-deionized-water extract method. This method was chosen because the sediment was too dry to easily extract vadose zone porewater. The extracts were prepared by adding an exact weight of deionized water to approximately 60 to 80 grams of sediment sub-sampled from each sleeve and selected grab samples. The weight of deionized water needed was calculated based on the weight of the field-moist samples and their previously determined moisture contents. The sum of the existing moisture (porewater) and the deionized water was fixed at the mass of the dry sediment. The appropriate amount of deionized water was added to screw cap jars containing the sediment samples. The jars were sealed and briefly shaken by hand, then placed on a mechanical orbital shaker for 1 hour. The samples were allowed to settle until the supernatant liquid was fairly clear. The supernatant was carefully decanted and separated into unfiltered aliquots for conductivity and pH determinations, and filtered aliquots (passed through 0.45 µm membranes) for anion, cation, carbon, and radionuclide analyses. More details can be found in Rhoades (1996) within *Methods of Soils Analysis Part* (ASA 1996).

3.3.2.1 pH and Conductivity

Two approximately 3-milliliter aliquots of the pH unfiltered 1:1 sediment-to-water extract supernatant were used for pH and conductivity measurements. The pHs for the extracts were measured with a solid-state pH electrode and a pH meter calibrated with buffers 4, 7, and 10. Conductivity was measured and compared to potassium chloride standards with a range of 0.001 M to 1.0 M.

3.3.2.2 Anions

The 1:1 sediment-to-water extracts were analyzed for anions using an ion chromatograph. Fluoride, acetate, formate, chloride, nitrite, bromide, nitrate, carbonate, phosphate, sulfate, and oxalate were separated on a Dionex AS17 column with a gradient elution of 1 mM to 35 mM sodium hydroxide and measured using a conductivity detector. This methodology is based on U.S. Environmental Protection Agency (EPA) Method 300.0A (EPA 1984) with the exception of using the gradient elution of sodium hydroxide.

3.3.2.3 Cations and Trace Metals

Major cation analysis was performed using an inductively coupled plasma (ICP-OES) unit using high-purity calibration standards to generate calibration curves and verify continuing calibration during the analysis run. Dilutions of 100x, 50x, 10x, and 5x were made of each sample for analysis to investigate and correct for matrix interferences. Details are found in EPA Method 6010B (EPA 2000b). The second instrument used to analyze trace metals, including technetium-99 and uranium-238, was an inductively coupled plasma mass spectrometer (ICP-MS) using the PNNL-AGG-415 method (PNNL 1998). This method is quite similar to EPA Method 6020 (EPA 2000c).

3.3.2.4 Alkalinity and Carbon

The alkalinity and inorganic/organic carbon content of several of the 1:1 sediment-to-water extracts were measured using standard titration with acid and a carbon analyzer respectively. The alkalinity procedure is equivalent to the U.S. Geological Survey Method Field Manual (USGS 2001). Inorganic and organic carbon in the water extracts were determined using a carbon analyzer and ASTM Method D4129-88 (1988), "Standard Test Method for Total and Organic Carbon in Water by High Temperature Oxidation and by Coulometric Detection."

3.3.2.5 Cyanide Analysis

Total cyanide concentration in selected sediments and the perched and groundwater was determined by micro distillation and colorimetric analysis by ultraviolet (UV) spectrophotometer. This was performed on ~1-g aliquots of some of the vadose sediment samples, the perched water, and groundwater samples. The analysis was performed according to Lachat Instruments QuikChem Method 10-204-00-1-X (MICRODIST Cyanide Method) (Lachat Instruments 2000), which has interim approval from EPA Region 10.

3.3.3 Porewater, Perched and Groundwater Composition

Fourteen samples (i.e., 27A, 33A, 34C, 34A, 44B, 55, 61A, 61B, 63, 64, 82C, 110B, 112B, and 116C) were packed in drainable cells that were inserted into an ultracentrifuge. The samples were centrifuged for up to 8 hours at several thousand times the gravitational constant (g) to squeeze the porewater out of the sediment. The three perched water samples and one groundwater sample were also characterized for pH, electrical conductivity, cation, trace metals, and anions using the same techniques as used for the 1:1 sediment-to-water extracts.

3.3.4 Radioanalytical Analysis

3.3.4.1 Gamma Energy Analysis

Gamma energy analysis (GEA) was performed on sediment from all core sleeves and some of the grab samples. All samples for gamma energy analysis were analyzed using 60%-efficient intrinsic germanium gamma detectors. All germanium counters were efficiency calibrated for distinct geometries using mixed gamma standards traceable to the National Institute of Standards and Technology. In the first GEA counting campaign, field-moist samples were placed in 150–cm^3 counting containers and analyzed for 100 minutes in a fixed geometry. All spectra were background subtracted. Spectral analysis was conducted using libraries containing most mixed fission products, activation products, and natural decay products. Control samples were run throughout the analysis to ensure correct operation of the detectors. The controls contained isotopes with photo peaks spanning the full detector range and were monitored for peak position, counting rate, and full-width half-maximum. Details are found in *Gamma Energy Analysis Operation and Instrument Verification using Genie Support Software* (PNNL 1997).

A second campaign of GEA counting was performed on larger volumes (i.e., 400 cm^3) of field-moist sediment for selected samples for 16 hours (960 minutes) each in order to better search for low activity antimony-125 and europium-152 activities. The same detectors and quality assurance / quality control (QA/QC) protocols were followed. Minimum detectable amounts for antimony-125 were reduced from 0.35 to 0.64 pCi/g to 0.04 pCi/g by using larger volume samples and longer count times.

3.3.4.2 Tritium Content in 1:1 Sediment to Water Extracts, Perched Water, and Groundwater

The tritium content of selected sediment samples was determined directly on the water extracts, perched water, and groundwater by liquid scintillation using PNNL-AGG-002 (PNNL 2000).

3.3.5 Carbon Content of Sediment

The carbon content of borehole sediment samples was determined using ASTM Method D4129-88, *Standard Methods for Total and Organic Carbon in Water Oxidation by High Temperature Oxidation and by Coulometric Detection* (ASTM 1988). Total carbon in all samples was determined using a Coulometrics, Inc. Model 5051 Carbon Dioxide Coulometer with combustion at approximately 980°C. Ultrapure oxygen was used to sweep the combustion products through a barium chromate catalyst tube for conversion to carbon dioxide. Evolved carbon dioxide was quantified through coulometric titration following absorption in a solution containing ethanolamine. Equipment output reported carbon content values in micrograms per sample. Soil samples for determining total carbon content were placed into pre-combusted, tared platinum combustion boats and weighed on a four-place analytical balance. After the combustion boats were placed into the furnace introduction tube, a 1-minute waiting period was allowed so that the ultrapure oxygen carrier gas could remove any carbon dioxide introduced to the system from the atmosphere during sample placement. After this system sparge, the sample was moved into the combustion furnace and titration begun. Sample titration readings were performed at 3 minutes after combustion began and again once stability was reached, usually within the next 2 minutes. The system background was determined by performing the entire process using an empty, pre-combusted platinum boat. Adequate system performance was confirmed by analyzing for known quantities of a calcium carbonate standard.

Inorganic carbon contents for borehole sediment samples were determined using a Coulometrics, Inc., Model 5051 Carbon Dioxide Coulometer. Soil samples were weighed on a four-place analytical balance, and then placed into acid-treated glass tubes. Following placement of sample tubes into the system, a 1-minute waiting period allowed the ultrapure oxygen carrier gas to remove any carbon dioxide introduced to the system from the atmosphere. Inorganic carbon was released through acid-assisted evolution (50% hydrochloric acid) with heating to 200°C. Samples were completely covered by the acid to allow full reaction to occur. Ultrapure oxygen gas swept the resultant carbon dioxide through the equipment to determine inorganic carbon content by coulometric titration. Sample titration readings were performed 5 minutes following acid addition and again once stability was reached, usually within 10 minutes. Known quantities of calcium carbonate standards were analyzed to verify that the equipment was operating properly. Background values were determined. Inorganic carbon content was determined through calculations performed using the microgram per-sample output data and sample weights. Organic carbon was calculated by subtracting inorganic carbon from total carbon and using the remainder.

3.3.6 8 M Nitric Acid Extract

Approximately 20 grams of oven-dried sediment was contacted with 8 M nitric acid at a ratio of ~5 parts acid to 1 part sediment. The slurries were heated to ~80°C for several hours and then the fluid was separated by centrifugation and filtration through 0.2 µm membranes. The acid extracts were analyzed for major cations and trace metals using ICP and ICP-MS techniques, respectively. The acid digestion procedure is based on EPA SW-846 Method 3050B (EPA 2000a).

3.3.7 Elemental Analysis

The elemental composition of the bulk sediment and clay fractions was determined by a combination of energy and wavelength dispersive x-ray fluorescence using methods developed at PNNL. Samples analyzed by the energy dispersive x-ray fluorescence method follow the KLM Analytical (KLM) Procedure XRF-01, which utilizes a KEVEX 0810A commercial x-ray fluorescence excitation and detection subsystem. Sample preparation involved grinding and mixing the sample in a Coors high-density alumina (Al_2O_3) mortar and pestle. Six hundred milligrams of the mixed sample were further ground to ~300 mesh size, placed between two sheets of stretched Parafilm, and loaded into the Kevel 0810A x-ray fluorescence unit. Acquisition times ranged between 600 and 3,000 seconds, depending on the targets (i.e., iron, gadolinium, silver, zirconium). Forty-one elements (i.e., aluminum, antimony, arsenic, barium, bromine, cadmium, calcium, cerium, cesium, chlorine, chromium, copper, gallium, indium, iodine, iron, lanthanum, lead, manganese, molybdenum, nickel, niobium, palladium, phosphorous, potassium, rhodium, rubidium, ruthenium, selenium, silicon, silver, strontium, sulfur, tellurium, thorium, tin, titanium, uranium, vanadium, yttrium, and zinc) were analyzed on each sample and the spectrum interpretation was by the backscatter fundamental parameter approach (described in KLM XRF-01, pages 2 and 3). Sample analysis by the wavelength method was accomplished using a Siemens Spectra 3000 instrument, equipped with both a flow counter detector to detect soft radiation of the low Z elements and a scintillation counter detector for the harder radiation of the higher Z elements. Bulk solid samples were prepared by taking 180 to 1,500 milligrams of ~300 mesh ground sample and pressing it into a 3.2-centimeter diameter pellet, using a 27,000-kilogram laboratory press. Standard addition and similar matrix methods were used to generate calibration curves for sodium and magnesium, which were then used to process the data. Additional discussion of x-ray fluorescence techniques for quantitative analysis of sediment are found in Chapter 7, “Elemental Analysis by X-Ray Fluorescence Spectroscopy” of ASA (1996), part 3, pages 161 through 223 and in the Siemens Spectra 3000 Reference Manual.

3.3.8 Particle Size Distribution

The wet sieving/hydrometer method was used to determine the particle size distribution. The technique is described in ASA (1986a), Part 1, Method 15-5, “Hydrometer Method,” and concentrated on quantifying the silt and clay distribution. The silt and clay separates were saved for mineralogical analyses. Samples from the borehole that were used for the hydrometer method were never air or oven dried to minimize the effects of particle aggregation that can affect the separation of clay grains from the coarser material.

3.3.9 Particle Density

The particle density of bulk grains was determined using pychnometers as described in ASA (1986b) Part 1, Method 14-3, “Pychnometer Method,” and oven-dried material. The particle density is needed to determine the particle size when using the hydrometer method.

3.3.10 Mineralogy

The mineralogy of the bulk sample and silt- and clay-size fractions of selected sediment samples were determined by x-ray diffraction techniques. Bulk sediment samples were dispersed by transferring 100 grams of sediment into a 1-liter bottle and mixing with 1 liter of 0.001 M solution of sodium hexametaphosphate. The suspensions were allowed to shake over night to ensure complete dispersion. The sand fraction was separated from the dispersed sample by wet sieving through a #230 sieve. The silt fractions were separated from the clay fractions by using Stoke's settling law described in Jackson (1969). The lower limit of the silt fraction was taken at 2 microns. Sand and silt fractions were oven dried at 110°C and prepared for x-ray diffraction and x-ray fluorescence analysis.

Each clay suspension (in the sodium hexametaphosphate dispersing solution) was concentrated to an approximate volume of 10 milliliters by adding a few drops of 10N magnesium chloride to the dispersing solution. Concentrations of the clay in the concentrated suspensions were determined by drying known volumes and weighing the dried sediment. The density of the slurry was calculated from the volume pipetted and the final weight of dried sediment. Volumes of slurry equaling 250 milligrams of clay were transferred into centrifuge tubes and treated to remove carbonates following the procedure described by Jackson (1969). The carbonate free clay was then saturated with either magnesium (Mg^{2+}) or potassium (K^{+}) cations. Clay samples were prepared using the Drever (1973) method and placed onto an aluminum slide for x-ray diffraction analysis. Due to the tendency of the clay film to peel and curl, the magnesium (Mg^{2+})-saturated specimens were solvated with a few drops of a 10% solution of ethylene glycol in ethanol and placed into a desiccator containing excess ethylene glycol for a minimum of 24 hours. Potassium-saturated slides were air dried and analyzed, then heated to 575 °C and reanalyzed.

All samples were analyzed on a Scintag x-ray diffraction unit equipped with a Pelter thermoelectrically cooled detector and a copper x-ray tube. Slides of preferentially oriented clay were scanned from 2 to 45 degrees 2θ, and randomly oriented powder mounts were scanned from 2 to 75 degrees 2θ. The bulk samples were prepared by crushing approximately 0.5 gram of sample to a fine powder that was then packed into a small circular holder. After air-drying approximately 0.5 gram of the clay slurry, a random mount was prepared and analyzed from 2 to 75 degrees 2θ.

Semiquantification of mineral phases by x-ray diffraction was performed according to Brindley and Brown (1980). The relationship of intensity and mass absorption to the weight fraction of an unknown phase is expressed as:

$$I/I_p=\mu_p/\mu \text{ (wf)}$$

where:

I	is the intensity of the unknown phase
I_p	is the intensity of the pure phase
μ_p	is the mass absorption of the pure phase
μ	is the average mass absorption of the unknown mixture
wf	is the weight fraction of the unknown.

Pure mineral phases of illite, smectite, kaolinite, and chlorite were obtained from the Clay Mineral Society source clays repository (operated from the University of Missouri in Columbia), and analyzed under the same conditions as the sediment samples. Quartz, feldspars, and calcite standards were purchased from the Excalibur Mineral Company (Peekskill, New York), ground, and analyzed on the diffractometer to obtain intensities for pure nonclay phases.

The mass attenuation coefficients of selected samples were measured according to Brindley and Brown (1980). Ground bulk powders and air-dried clays were packed into a 2.39-centimeter (0.94-inch) thick circular holder with no backing. The holder was placed in front of the detector and positioned to allow the x-ray beam, diffracted from pure quartz, to pass through the sample and into the detector. The scan was analyzed from 26 to 27 degrees 2θ. The mass attenuation coefficients were measured directly using the following equation:

$$\mu= (1/\rho x)\ln(I_o/I_x)$$

where:

$1/\rho x$ is the mass per unit area as the sample is prepared

I_o is the intensity of the incident beam

I_x is the intensity of the transmitted beam through sample thickness x.

In addition to x-ray diffraction, transmission electron microscopy (TEM) characterization of selected samples was conducted on a JEOL 1200X electron microscope equipped with a Links detector system. Samples were prepared for TEM by transferring a small aliquot of dilute clay slurry onto a formvar carbon-coated 3-millimeter copper support grid. The clay solution contained 0.15% tert-butylamine to reduce the surface tension of water.

Structural formulas were derived from data collected from the TEM analysis. On average, an energy dispersive x-ray spectra was collected from a minimum of five particles from the same mineral phase common to the sample. The x-ray spectra were collected and processed using the Cliff-Lorimer Ratio Thin Section method and then converted to a structural formula based on half-unit cell ($O_{10}(OH)_2$) by the method described in Moore and Reynolds (1997) and Newman (1987).

3.3.11 Water Potential (Suction) Measurements

Suction measurements were made on most of the core liners and grab samples from the borehole using the filter paper method described in PNL-MA-567-SFA-2 (PNL 1990b). This method relies on the use of a sandwich of three filter papers that rapidly equilibrates with the moisture in the sediment sample. The middle filter paper does not contact sediment that might stick to the paper and bias the mass measurements. At equilibrium, the matric suction in the filter paper is the same as the matric suction of the sediment sample. The dry filter paper sandwiches were placed in the airtight liners or grab sample jars while still filled with the sediment for at least 3 to 12 weeks to allow sufficient time for the matric suction in the sediment to equilibrate with the matric suction in the filter paper. The mass of the moist middle filter paper that had no direct contact with the sediment was subsequently determined, and the suction of the sediment was determined from a calibration relationship between filter paper water content and matric suction.

The relationships used for converting the water content of filter paper to matric suction for Whatman catalog number 42 filter paper have been determined by Deka et al. (1995) and can be expressed as:

$$Sm = 10^{(5.144 - 6.699\,w)}/10 \text{ for } w < 0.5$$

$$Sm = 10^{(2.383 - 1.309\,w)}/10 \text{ for } w > 0.5$$

where:

Sm is the matric suction (m) and
w is the gravimetric water content (g/g).

One hundred eighty-eight samples from borehole 299-E33-45 were analyzed for water content and soil matric suction. The samples covered the entire borehole profile from 9.6 to 253.6 ft bgs (2.93 to 77.3 m).

3.3.12 Uranium Desorption Experiment

Batch leach tests were performed on three sediment samples (i.e., 54A, 61A, and 67A) with high uranium radioactivity from borehole 299-E33-45. Duplicate batch reactors were prepared using 50 grams of sediment that was previously separated and analyzed via GEA (Section 3.3.4.1). Each batch reactor, including an experimental blank, received a simulated vadose zone porewater solution (approximately 26 meq/L total ionic strength; see Table 3.1) in a 1:3 solid to solution ratio. The simulated porewater was prepared based on dilution corrected 1:1 water extracts for the sediment samples just shallower than sample 54A, which is from the Hanford H2 middle sand sequence near 121 ft bgs. This simulated porewater composition should represent the fluid that would interact with the contaminated sediments if natural recharge was causing drainage through the vadose zone at the borehole location. The reactors were shaken gently (i.e., approximately 100 rpm), and small volumes (i.e., 10 mL) of solution were taken at the following time intervals: 4 hours, 24 hours, 48 hours, 72 hours, 7 days, 10 days, 16 days, 21 days, and 28 days. Sampling was conducted after 20 minutes of centrifugation (~2500 rpm); the sample was collected from the top half of the supernatant. Samples were filtered through 0.2 μm Nalgene syringe filters and analyzed for pH and electrical conductivity (EC) (Section 3.3.2.1), and uranium-238 via ICP-MS (Section 3.3.2.3). Ten mL of fresh simulated porewater was added to replace that withdrawn such that the solid to solution ratio was maintained for each contact period at ~1:3 g per mL.

After the 28 days of contact, the remaining porewater was removed and replaced with a 20 mM $NaHCO_3$ solution (pH 8). The same 1:3 solid to solution ratio was maintained. The batch reactors were shaken gently and 10 mL aliquots of solution were collected at 7 and 39 days additional contact (i.e., total contact of 35 and 67 days). Sampling was conducted in the same manner described above and samples were once again analyzed for pH, EC, and dissolved uranium-238. For this 0.02 M bicarbonate solution portion of the test, the ten mL removed after the first sampling was not replaced.

A third and final leaching step involved replacing the remaining 20 mM bicarbonate solution in the replicate batch reactors with either a 0.5 M sodium carbonate/bicarbonate solution (pH 10) or a 3.13 M citric acid solution (pH 1.4). One of each of the replicate containers was contacted with the sodium carbonate solution and the other was contacted with the citric acid solution. The solid to solution ratio was maintained at ~1:4 g per mL for this phase of the experiment. The reactors were shaken gently and sampled after three days of additional contact time. The total elapsed time from the start of the test was 70 days. The subsequent supernatant filtrates were analyzed for pH and dissolved uranium-238.

The percentage of uranium desorbed/dissolved versus time, resultant electrical conductivity, and pH for each contaminated sediment sample for each solution were plotted. Desorption Kd values were also calculated for each test during the leaching with simulated porewater and the 0.02 M sodium bicarbonate solution.

Table 3.1. Chemical Composition of Simulated Vadose Zone Porewater Solution

Constituent	Units	Value	Molarity	meq/L
Na	mg/L	378	1.64E-02	16.4
K	mg/L	30.8	7.90E-04	0.79
Ca	mg/L	45	1.13E-03	2.25
Mg	mg/L	82.6	3.40E-03	6.8
C	mg/L	28.4	1.64E-02	16.4
Cl	mg/L	13.8	3.90E-04	0.39
F	mg/L	7.6	4.00E-04	0.4
SO_4	mg/L	327	3.40E-03	6.8
NO_3	mg/L	135	2.25E-03	2.25
Σ Cations	meq/L			26.24
Σ Anions	meq/L			26.24

4.0 Results and Discussion

This section presents the geochemical and physical characterization data collected on sediment from borehole 299-E33-45. The tier 1 phase emphasized tests that were inexpensive or that were key to determining the vertical distribution of mobile contaminants. Information on the borehole sediment presented in this section includes moisture content, pH, and electrical conductivity of 1:1 sediment to water extracts, and measurements of major cations, anions, trace metals, and radionuclides in both the sediment and 1:1 sediment to water extracts. A gamma energy analysis on the sediments was also performed to define the uranium plume caused by the BX-102 tank overfill event in 1951. The particle size, mineralogy, cyanide, and tritium content of selected samples were measured in the tier 2 phase to aid in selecting contacts between major geologic units and to attempt to better define the vertical extent of the BX-102 tank overfill event. Geochemical and mineralogic changes caused by interaction with the caustic fluids lost from tank BX-102 were also identified. Finally, some batch desorption tests were performed on selected uranium-laden samples to help interpret its fate.

4.1 Moisture Content

The moisture content of the sediment from the sleeves and grab samples is listed in Table 4.1 and presented as a graph in Figure 2.3. Figure 2.3 shows both the field volumetric moisture obtained via neutron logging and the gravimetric moisture content of small aliquots of sediment taken during the geologic description activities. The moisture content profile correlates with the lithology described in Section 2.6 and shown in Figure 2.3. The first region with elevated moisture is the thin mud lens at 74.5 to 75.5 ft bgs (22.86 m) within the Hanford H2 unit. There is one other elevated moisture content at a thin stringer of fine-grained material at 120 ft bgs also within the Hanford H2 unit. However, laboratory gravimetric data did not indicate much sign of elevated moisture in one other thin fine-grained lens at 100 ft bgs. There is a very subtle indication in the field neutron log that this layer at 100 ft bgs is slightly wetter than sediment above and below.

At the bottom of the Hanford H2 unit at 167 to 169.8 ft (50.9 to 51.8 m) bgs is a moist, ~3 ft thick lens of fine-grained material with moisture contents of 16% by weight. Within the Hanford H3 unit there is a slightly moist lens at 180 ft (54.9 m) bgs with a moisture content of 7.3 wt% compared to values of 3 to 4 wt% nearby. The Plio-Pleistocene mud unit (PPlz) lithology between 217.8 and 238.7 ft bgs is the wettest material in the borehole with moisture contents ranging from 12 to 26 wt%. The gravels below this PPlz silt are relatively dry down to the water table that currently is found at 255 ft bgs (77.2 m).

Perched water was observed at 227 to 233 ft (69.2 to 71.0 m) bgs during the drilling of the borehole and two water samples were sent to the PNNL laboratory. Further, one water sample from the aquifer was taken and sent to both PNNL and the contract laboratory for the Sitewide Groundwater Monitoring Project for analysis. The chemical composition data from both perched water and groundwater samples are described along with the data from the unsaturated flow apparatus (UFA) extracted porewaters and dilution corrected 1:1 sediment to water extracts in the sections that follow.

The laboratory-generated data show gravimetric moisture content as wt% and the field data are related to volumetric water content (vol%). If the field tool had been calibrated accurately and the vadose zone bulk density profiles were known, the field data could be converted to gravimetric data by dividing by the bulk density. To meet the data needs, the two logs were merely qualitatively compared to see if the moisture peaks corresponded depthwise.

Table 4.1. Moisture Content of Sediment from Borehole 299-E33-45 (3 Pages)

Lithologic Unit	Sample Number	Mid Depth (Vertical ft)[(a)]	% Moisture	Lithologic Unit	Sample Number	Mid Depth (Vertical ft)[(a)]	% Moisture
H1	01C	9.64	4.84	H2-ms	64	135.5	3.58
H1	01B	10.14	6.59	H2-ms	65	137.1	3.36
H1	01A	10.64	4.75	H2-ms	66	138.95	2.19
H1	06D	19.34	6.47	H2-ms	67D	139.75	3.48
H1	06C	19.84	3.83	H2-ms	67C	140.25	3.50
H1	06B	20.34	4.79	H2-ms	67B	140.75	2.91
H1	06A	20.84	5.75	H2-ms	67A	141.25	2.60
H1	11D	30.39	4.77	H2-ms	67	141.6	1.59
H1	11C	30.84	4.34	H2-ms	68	142.55	3.43
H1	11B	31.34	4.03	H2-ms	69	144.45	3.01
H1	11A	31.84	3.30	H2-ms	70	146.6	3.23
H2-us	16D	40.54	3.46	H2-ms	71	148.6	1.85
H2-us	16C	41.04	3.54	H2-ms	72D	150.05	3.59
H2-us	16B	41.54	3.66	H2-ms	72C	150.55	3.70
H2-us	16A	42.04	3.43	H2-ms	72B	151.05	4.10
H2-us	21D	50.14	4.81	H2-ms	72A	151.55	3.02
H2-us	21C	50.64	4.32	H2-ms	72	151.9	2.97
H2-us	21B	51.14	4.04	H2-ms	73	152.7	3.51
H2-us	21A	51.64	3.79	H2-ms	74	154.05	3.08
H2-us	27D	61.49	5.35	H2-ms	75	156.2	3.40
H2-us	27C	61.99	5.62	H2-ms	76	158.4	3.34
H2-us	27B	62.49	5.98	H2-ms	77	159.1	3.42
H2-us	27A	62.99	6.80	H2-ms	78D	159.35	3.45
H2-us	32D	69.74	3.82	H2-ms	78C	159.85	3.82
H2-us	32C	70.24	3.82	H2-ms	78B	160.35	3.60
H2-us	32B	70.74	3.73	H2-ms	78A	160.85	3.80
H2-us	32A	71.24	3.88	H2-ms	79	162.1	4.15
H2-us	32	71.74	2.87	H2-ms	80	163.55	3.32
H2-us	33D	71.89	3.71	H2-ms	81	165.55	4.50
H2-us	33C	72.39	5.42	H2-ms	82D	167.15	6.77
H2-us	33B	72.89	3.24	***	82C	167.65	9.91
H2-us	33A	73.39	3.18	***	82B	168.15	14.19
H2-us	33	73.89	14.03	***	82A	168.65	16.22
H2-us	34D	74.15	5.24	***	82	169.1	16.20

Table 4.1. Moisture Content of Sediment from Borehole 299-E33-45 (3 Pages)

Lithologic Unit	Sample Number	Mid Depth (Vertical ft)(a)	% Moisture	Lithologic Unit	Sample Number	Mid Depth (Vertical ft)(a)	% Moisture
*	34C	74.9	15.13	***	83D	169.55	8.47
*	34B	75.15	22.36	H3	83C	170.05	3.66
*	34A	75.65	21.93	H3	83B	170.55	2.48
H2-ms	34	76.15	7.73	H3	83A	171.05	2.84
H2-ms	35D	76.69	1.83	H3	83	171.4	2.12
H2-ms	35C	77.19	1.75	H3	84D	171.85	3.22
H2-ms	35B	77.69	1.82	H3	84C	172.35	2.84
H2-ms	35A	78.19	2.44	H3	84B	172.85	3.53
H2-ms	35	78.69	1.25	H3	84A	173.35	3.19
H2-ms	36D	77.84	3.27	H3	84	173.7	2.08
H2-ms	36C	78.34	2.73	H3	85	174.7	2.67
H2-ms	36B	78.84	2.77	H3	86	176.9	2.54
H2-ms	36A	79.34	3.10	H3	87	179.2	1.81
H2-ms	37	82.49	2.53	H3	88D	180.15	7.33
H2-ms	38	84.78	3.15	H3	88C	180.65	4.64
H2-ms	39	86.245	3.09	H3	88B	181.15	3.60
H2-ms	40D	87.15	3.92	H3	88A	181.65	4.59
H2-ms	40C	87.65	4.25	H3	89	182.7	2.95
H2-ms	40B	88.15	4.53	H3	90	184.4	3.13
H2-ms	40A	88.65	3.62	H3	91	186.2	3.56
H2-ms	40	90	1.22	H3	92	188.4	1.73
H2-ms	41	92.715	4.55	H3	93D	189.15	3.39
H2-ms	42	94.69	4.75	H3	93C	189.65	3.00
H2-ms	43	97.015	4.70	H3	93B	190.15	3.41
H2-ms	44D	98.59	4.61	H3	93A	190.65	3.37
H2-ms	44C	99.09	6.09	H3	99D	199.85	3.17
H2-ms	44B	99.59	6.79	H3	99C	200.35	3.65
H2-ms	44A	100.09	5.25	H3	99B	200.85	3.77
H2-ms	44	100.44	5.43	H3	99A	201.35	3.25
H2-ms	45	101.765	3.64	H3	104D	209.92	3.49
H2-ms	46	103.845	3.82	H3	104C	210.42	3.99
H2-ms	47	106.515	3.41	H3	104B	210.92	3.86
H2-ms	48	108.415	3.35	H3	104A	211.42	3.39
H2-ms	49D	109.64	5.10	H3	110D	217.95	4.22
H2-ms	49C	110.14	3.87	PPlz	110C	218.45	4.35
H2-ms	49B	110.64	4.09	PPlz	110B	218.95	26.27
H2-ms	49A	111.14	3.87	PPlz	110A	219.45	19.28
H2-ms	49	111.49	3.80	PPlz	111D	220.25	12.27
H2-ms	50	112.39	3.73	PPlz	111C	220.75	18.97
H2-ms	51	113.69	2.53	PPlz	111B	221.25	17.81

Table 4.1. Moisture Content of Sediment from Borehole 299-E33-45 (3 Pages)

Lithologic Unit	Sample Number	Mid Depth (Vertical ft)[(a)]	% Moisture	Lithologic Unit	Sample Number	Mid Depth (Vertical ft)[(a)]	% Moisture
H2-ms	52	115.74	3.45	PPlz	111A	221.75	24.79
H2-ms	53D	117.54	4.46	PPlz	112D	222.15	12.20
H2-ms	53C	118.04	3.13	PPlz	112C	222.65	14.99
H2-ms	53B	118.54	2.42	PPlz	112B	223.15	17.35
H2-ms	53A	119.04	3.18	PPlz	112A	223.65	19.37
H2-ms	53	119.39	3.49	PPlz	116D	229.95	24.86
H2-ms	54D	119.39	3.62	PPlz	116C	230.45	22.77
**	54C	120.14	14.59	PPlz	116B	230.95	19.59
H2-ms	54B	120.39	3.50	PPlz	116A	231.45	24.18
H2-ms	54A	120.89	2.56	PPlg	122D	240.39	13.97
H2-ms	54	121.24	2.84	PPlg	122C	240.89	2.75
H2-ms	55	121.34	13.83	PPlg	122B	241.39	3.37
H2-ms	56	122.315	2.85	PPlg	122A	241.89	4.14
H2-ms	57	123.845	3.67	PPlg	124D	243.75	3.61
H2-ms	58	125.5	4.13	PPlg	124C	244.25	3.58
H2-ms	59	127.4	4.62	PPlg	124B	244.75	2.65
H2-ms	60	128.65	4.71	PPlg	124A	245.25	3.04
H2-ms	61D	129.45	3.61	PPlg	128C	250.75	3.59
H2-ms	61C	129.95	3.90	PPlg	128B	251.25	3.83
H2-ms	61B	130.45	3.40	PPlg	128A	251.75	4.27
H2-ms	61A	130.95	3.86	PPlg	129D	252.15	4.28
H2-ms	61	131.3	3.48	PPlg	129C	252.65	4.24
H2-ms	62	132.35	3.52	PPlg	129B	253.15	5.19
H2-ms	63	134.1	4.02	PPlg	129A	253.65	4.32

(a) Multiply by 0.3048 to convert to meters
H1 = Hanford H1 unit-coarse sand
H2-us = Hanford H2 unit-upper sand sequence
H2-ms = Hanford H2 unit-middle sand sequence
H3 = Hanford H3 unit-lower sand sequence
PPlz = Plio-Pleistocene mud unit
PPlg = Plio-Pleistocene gravelly unit
*, **, *** = Various thin fine-grained lenses in the Hanford sand units

4.2 1:1 Sediment-to-Water Extracts

The main objective for placing the 299-E33-45 borehole at the location ~70 ft from the tank wall was to investigate the vertical extent of uranium and other mobile contaminants at a spot known to contain high uranium contents. In the 1970s, the operating contractor had placed several monitoring drywells to the east of tanks BX-101 and BX-102 to track what they had assumed was a recent leak event from tank BX-102. Details are discussed in the WMA B-BX-BY FIR in Section 3.2.1 (Knepp 2002a). Recent gamma spectral analyses in these dry monitoring boreholes were used to locate the new borehole (i.e., 299-E33-45) in the middle of the uranium plume. The borehole was extended to groundwater in order to track other mobile contaminants that cannot be tracked with gamma logging such as technetium-99 and nitrate. In addition to determining the vertical extent of uranium so that comparisons could be made to distributions in the vertical dry boreholes surrounding the tanks, there was interest in determining whether the mobile contaminants that have reached the groundwater proximate to BX tank farm could be traced all the way to the bottom of the borehole. The most economical method of determining the distribution of the mobile contaminants in the vadose zone sediment is to use water extracts of the sediments because most of the sediment is too dry to readily extract native porewater. The following sections discuss the results of the analyses done on 1:1 sediment to water extracts.

4.2.1 pH and Electrical Conductivity

The pH and electrical conductivity (EC) for the water extracts are shown in Table 4.2 and Figure 4.1. The electrical conductivity has been corrected for the dilution with deionized water, but the pH is plotted as measured in the 1:1 sediment to water extracts.

The pH profile shows that between 100 and 150 feet (30.48 and 45.72 m) bgs (in the Hanford formation H2 middle sand sequence), there are elevated values suggesting the presence of caustic waste interaction. One sample above this interval, sample 36A at 79 ft bgs, also had a water extract pH of 9.38, which also suggests some interaction with caustic waste. The sample 36A water extract also contains high electrical conductivity suggesting that this depth has been influenced by the tank solution. Perhaps the sediment at 79 ft bgs represents a zone with higher horizontal permeability than the sediments between 80 and 100 ft bgs. If the tank solutions were flowing mainly horizontally through the various strata at the borehole location, then the vertical coring would show such an irregular vertical profile for contaminants.

The elevated pH zone values range from 8.2 to 9.55 between the depths of 100 to 150 ft bgs. The sediment at depth 120 ft bgs has been described as a possible paleosol so that the drop in pH to ~8.2 may reflect past soil forming processes. Because so many chemical reactions can affect the pH, it is not possible to determine whether the post overfill tank fluid has traveled mainly in a vertical direction since the overfill event or continued to spread horizontally resulting in a complicated vertical profile at this borehole.

The porewater electrical conductivity (calculated by multiplying the 1:1 sediment to water extract electrical conductivity by the dilution factor) shows a two-lobed elevated plume. The shallower lobe between 24.08 and 36.58 m (79 and 120 ft) bgs resides within the middle sand sequence in Hanford H2 unit. The plume appears to pond on top of the fine-grained paleosol at 120 ft bgs. The more concentrated lobe resides between 45.72 and 52.73 m (150 to 173 ft) bgs with the most concentrated fluid between 150 and 160 ft bgs (within the Hanford H2 unit) and perhaps ponding on the fine-grained wet zone (167 to 169.8 ft bgs) at the bottom of Hanford H2 unit. Some elevated electrical conductivity is found in the top three feet of the Hanford H3 unit, which is, perhaps, evidence of slow diffusion across the lithologic contact or perhaps indicative of the calcareous nature of this contact that may represent a much older surficial sediment that was exposed to rain fall and evapotranspiration in the past. In Table 4.2, the values deemed to be elevated from interactions with tank fluids are shown in red type.

Table 4.2. Water Extract pH and Electrical Conductivity Values (2 Pages)

Sample Identification	Mid Depth (ft)(a)	Dilution Factor	1:1 pH	1:1 EC mS/cm	Pore EC mS/cm
Hanford H1 coarse sand					
01A	10.64	21.09	7.61	0.240	5.06
06A	20.84	17.43	7.53	0.171	2.98
11A	31.84	30.27	7.11	0.127	3.84
Hanford H2 upper sand sequence					
16A	42.04	29.2	7.21	0.133	3.88
21A	51.64	26.38	7.34	0.125	3.3
27A	62.99	14.72	6.93	0.215	3.16
32A	71.24	25.83	7.22	0.243	6.28
33A	73.39	31.48	7.37	0.245	7.71
H2 muddy very fine sand lens					
34A	75.65	4.91	7.55	0.458	2.25
34A-Dup	75.65	4.56	7.56	0.480	2.19
H2 middle sand sequence					
35A	78.19	40.97	7.78	0.160	6.56
36A	79.34	32.28	9.38	0.447	14.43
40A	88.65	27.63	7.68	0.158	4.37
44A	100.09	19.04	9.1	0.489	9.31
49A	111.14	25.85	9.51	0.710	18.35
53A	119.04	31.4	8.88	0.344	10.8
H2 muddy very fine sand lens					
54C	120.14	7.02	8.93	1.519	10.66
54C-Dup	120.14	9.27	8.24	1.213	11.24
54A	120.89	39.38	9.55	0.742	29.22
H2 middle sand sequence (continued)					
54	121.24	36.16	9.51	0.738	26.68
55	121.34	6.77	8.4	1.486	10.06
56	122.32	33.95	8.48	0.612	20.78
61A	130.95	25.93	9.5	0.822	21.31
67A	141.25	38.52	9	0.477	18.37
72C	150.55	28.44	7.39	1.567	44.56
72A	151.55	33.05	7.55	1.692	55.91
73	152.7	30.98	7.35	1.593	49.36
75	156.2	33.88	7.36	2.267	76.81
77	159.1	28.82	7.35	1.638	47.2

Table 4.2. Water Extract pH and Electrical Conductivity Values (2 Pages)

Sample Identification	Mid Depth (ft)[(a)]	Dilution Factor	1:1 pH	1:1 EC mS/cm	Pore EC mS/cm
78C	159.85	27.04	7.3	1.906	51.55
78A	160.85	26.29	7.39	1.737	45.67
81	165.55	21.84	7.45	0.261	5.7
H2 – fine-very fine sand lens					
82A	168.65	6.17	7.34	0.737	4.55
82A-Dup	168.65	6.17	7.32	0.806	4.97
82	169.1	5.78	7.33	0.775	4.48
83D	169.55	12.01	7.81	1.626	19.53
Hanford H3 Lower sand unit					
83A	171.05	35.27	7.3	0.168	5.93
84A	173.35	31.43	7.38	0.613	19.27
88A	181.65	21.76	7.58	0.240	5.22
93A	190.65	29.65	7.41	0.182	5.4
99A	201.35	30.75	7.35	0.201	6.18
104A	211.42	29.56	7.38	0.195	5.76
110D	217.95	34.26	7.37	0.210	7.19
PPlz Mud unit					
110A	219.45	5.32	7.56	0.932	4.96
111A	221.75	4.03	7.59	1.201	4.84
112A	223.65	5.31	7.58	0.800	4.25
116A	231.45	4.13	7.62	1.029	4.25
116A-Dup	231.45	4.14	7.52	1.034	4.28
PPlg Gravelly unit					
122A	241.89	24.16	7.49	0.204	4.93
124A	245.25	33.06	7.46	0.174	5.75
128A	251.75	23.88	7.49	0.206	4.92
129A	253.65	23.18	7.45	0.179	4.15

(a) Each sample was about 10 in. long, the mid point is used for plotting. Multiply by 0.3048 to convert to meters.

EC = Electrical conductivity

Values in red type indicate elevated values from caustic tank liquor

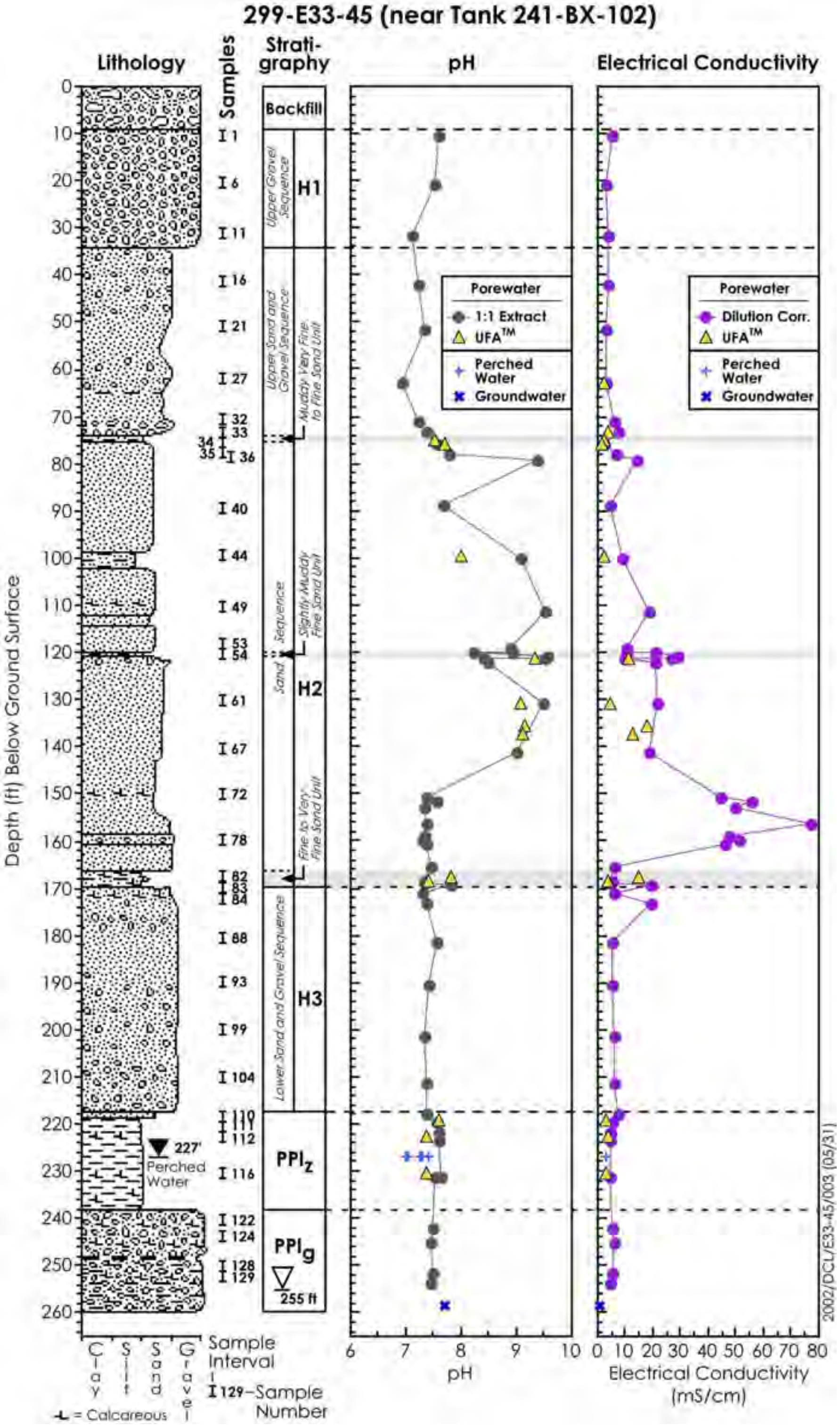

Figure 4.1. pH and Electrical Conductivity for Calculated (from sediment-to-water extracts) and Actual Porewaters for Borehole 299-E33-45 Sediment

The fourteen porewaters that were extracted from the sediment using an ultracentrifuge are compared with equivalent dilution-corrected 1:1 water extracts from the same depths in Table 4.3 and Figure 4.1. The UFA squeezings were performed on eleven samples from the H2 unit and three samples from the PPlz unit below the zone where the water extracts suggest that there is evidence of elevated electrical conductivity. The actual porewater electrical conductivity is somewhat lower than the dilution-corrected 1:1 sediment to water extracts but agreement on all but the samples at 100 and 130.7 ft bgs is acceptable. The dilution corrected porewater EC is significantly greater than the actual porewaters for these two depths. Between 131 and 160 ft bgs where the highest electrical conductivities are found, the UFA squeezed porewater and the calculated porewaters have similar EC values suggesting that high salt fluids truly are present.

When the actual porewater values are lower than the calculated porewaters, the water extraction process likely dissolves some solutes from the sediment. For studies at WMA S-SX, similar results were found where uncontaminated and slightly contaminated sediments showed lower electrical conductivity values than the dilution-corrected 1:1 sediment to water extracts because the 1:1 sediment to water extracts often dissolve material not present in the vadose zone porewater (Serne et al. 2002a, b). But for very highly contaminated sediments with large concentrations of sodium nitrate, the EC values for dilution corrected 1:1 sediment to water extracts were quite similar to the actual EC from UFA-squeezed porewaters (Serne et al. 2002c, d). Because the porewaters near BX-102 are not as dominated with sodium nitrate waste liquors, it is believed that the 1:1 sediment to water extracts will always slightly over-predict the actual porewater EC and thus chemical composition of the porewater.

Table 4.3. Comparison of Actual Porewater pH and Electrical Conductivity with Dilution-Corrected 1:1Water Extract Values (2 Pages)

Sample Identification	Depth (ft)[(a)]	Dilution Factor	pH	1:1 EC mS/cm	Pore EC mS/cm
Hanford H2 upper sand sequence					
27A	62.99	14.72	6.93	0.215	3.16
27A-UFA		1	NA[(b)]	—	2.55
33A	73.39	31.48	7.37	0.245	7.71
33A-UFA		1	NA	—	3.77
H2 muddy very fine sand lens					
34C-UFA	74.9	1	7.54	—	2.09
34A	75.65	4.91	7.55	0.458	2.25
34A-dup[(c)]		4.56	7.56	0.480	2.19
34A-UFA		1	7.72	—	1.64
H2 middle sand sequence					
44B-UFA	99.59	1	8.02	—	2.19
44A	100.09	19.04	9.10	0.489	9.31
H2 muddy very fine sand lens					
54A	120.89	14.98	9.55	1.951	29.22

Table 4.3. Comparison of Actual Porewater pH and Electrical Conductivity with Dilution-Corrected 1:1Water Extract Values (2 Pages)

Sample Identification	Depth (ft)[(a)]	Dilution Factor	pH	1:1 EC mS/cm	Pore EC mS/cm
H2 middle sand sequence (continued)					
54	121.24	39.38	9.51	0.678	26.68
55	121.34	6.77	8.40	1.486	10.06
55-UFA		1	9.35	—	11.19
56	122.32	33.95	8.48	0.612	20.78
61AB-UFA	130.7	1	9.06	—	4.86
61A	130.95	25.93	9.50	0.822	21.31
64-UFA	135.5	1	9.16	—	17.76
65-UFA	137.1	1	9.11	—	12.99
67A	141.25	38.52	9.00	0.477	18.37
Fine-very fine sand lens					
82C-UFA	167.65	1	7.81	—	14.88
82A	168.65	6.17	7.34	0.737	4.55
82A-dup		6.17	7.32	0.806	4.97
82A-UFA		1	7.4	—	3.53
PPlz Mud Unit					
110B-UFA	218.95	1	7.59	—	3.39
110A	219.45	5.32	7.56	0.932	4.96
112B-UFA	222.65	1	7.39	—	3.5
112A	223.65	5.31	7.58	0.800	4.25
116C-UFA	230.45	1	7.39	—	2.76
116A	231.45	4.13	7.62	1.029	4.25
116A-dup		4.14	7.52	1.034	4.28

(a) Core mid point used. Multiply by 0.3048 to convert to meters
(b) NA = not analyzed; lack of sample
(c) dup = duplicate sample was separately water extracted
EC = Electrical conductivity
UFA represents the actual porewater obtained by ultracentrifugation
— Indicates not applicable (no dilution or deionized water is present)
Values in blue type indicate actual porewater value is lower than corrected water extract value
Values in red type indicate values are higher than natural conditions (i.e., contamination is present)

4.2.2 Water Extract and Porewater Compositions

The 1:1 sediment-to-water extracts and the calculated porewater anion composition are shown in Table 4.4 and Figure 4.2a and Figure 4.2b. Water extracts are currently not available for comparable uncontaminated sediments proximate to BX tank farm so it is not possible to state conclusively which water extracts contain tank fluid. However, based on the shallowest sediments studied at borehole 299-E33-45, it would appear that there is nitrate contamination starting at the contact between the Hanford H1 and H2 units at 34 ft bgs and extending down into the sediment of the fine-grained PPLz all the way to the water table at 77.7 m (255 feet) bgs. The majority of the nitrate contamination resides between 35.1 and 51.8 m (115 and 170 ft) bgs with values reaching as high as 6.15 g/L or ~0.1M at 47.6 m (156.2 ft) bgs. The bulk of the water-extractable nitrate is bounded between two thin fine-grained lenses in the H2 middle sand sequence unit. The upper boundary is the fine-grained lens at 120 ft bgs and the lower boundary is the fine-grained, 2.5-ft thick lens that forms the bottom of the H2 unit at 167 to 170 ft bgs. There also appears to be somewhat elevated nitrate throughout the Hanford H3 unit at a fairly constant porewater concentration of 600 ± 200 mg/L. The nitrate in the PPlz unit porewater is slightly higher than the nitrate in the H3 unit. There is a decrease in porewater nitrate in the Plio-Pleistocene gravelly sand unit (PPlg) down to the capillary fringe zone where nitrate increases to values similar to that in the groundwater.

The bicarbonate concentration in the porewaters also is elevated in the H2 middle sand sequence between 75 and 167 ft bgs; both above and within the same zone with the largest nitrate concentrations. The largest calculated porewater bicarbonate concentration occurs in the suspected paleosol at 120 ft bgs. However, based on the UFA squeezings, the dilution-corrected 1:1 sediment to water extract bicarbonate values may be biased high because of dissolution of carbonate bearing solids. The porewater bicarbonate concentration varies between 0.1 and 0.21 M between 110 to 130 ft bgs around this potential paleosol at 120 ft bgs.

The porewater sulfate concentrations appear to be slightly elevated over most of the vertical profile but the most significant concentrations are found in a narrow zone within the middle sand sequence of the H2 unit between 140 and 166 ft bgs. No UFA squeezings were obtained from sediments from this narrow zone. However, where UFA squeezings were obtained from other zones with slightly elevated sulfate, there is good agreement with dilution-corrected 1:1 sediment to water extracts. There is a significant source of sulfate from use of sulfuric acid to keep the uranium (VI) soluble in the metals solution prior to the bismuth phosphate precipitation step to isolate plutonium. Most of the sulfate ends up in the uranium-rich metals waste solution that was neutralized with sodium hydroxide and carbonate prior to disposal in the BX single-shell tanks. Therefore, elevated levels of sulfate would indicate BX-102 tank overfill fluids from the early 1950s could be present in the sediments. The very high sulfate concentrations between 140 and 166 ft bgs suggest such is the case.

The porewater chloride concentrations appear slightly elevated between 70 and 255 ft bgs (i.e., the water table) compared to uncontaminated sediments from the 200 West Area. As mentioned previously, baseline uncontaminated sediment water extracts are not available yet for 200 East Area sediments. It will not be possible to evaluate further until data is available for comparable uncontaminated sediments from borehole 299-E33-338. The chloride vertical distribution is not similar to any of the other anions. In the Hanford formation, the UFA squeezings and chloride values from the dilution-corrected 1:1 sediment to water extracts agree nicely but in the PPlz unit, the dilution-corrected extract chloride values are larger than the UFA squeezings. The uranium metals waste that was neutralized with sodium hydroxide and sodium carbonate prior to disposal to BX tanks in the early 1950s did not contain substantial amounts of chloride. Thus, the observed chloride profile may reflect natural conditions.

Figure 4.2b shows the distribution of three minor anions. The fluoride porewater distribution differs from all the other anions because it shows significant concentrations in the shallow Hanford H2 upper sand sequence. There may be Hanford processing-induced excess fluoride in the H2 and H3 units whereas the PPlz mud stratum has very low fluoride concentrations. Similar to the nitrate and sulfate, the greatest concentrations of fluoride are found in the H2 middle sand sequence between 120 and 167 ft bgs.

The phosphate porewater distribution in the vadose zone sediment at borehole 299-E33-45 shows elevated concentrations between ~80 and 130 ft (24.4 to 39.6 m) bgs within the H2 middle sand sequence, in the paleosol at 120 ft bgs, and just below the paleosol to 130 ft bgs. Phosphate was a major component in the acidic waste stream from the bismuth phosphate precipitation process. Even after neutralization with sodium hydroxide and sodium carbonate, soluble phosphate was present. Generally, soluble phosphate levels in natural sediments at Hanford are quite low because of precipitation of highly insoluble apatite minerals. The elevated water soluble phosphate values between 80 and 130 ft bgs likely are a marker for BX-102 tank overfill liquids. The nitrite porewater distribution shows four elevated values at depths that do not correlate with any lithologic contacts and analytical vagaries are suspected as the likely cause for these seemingly high values.

Unlike the porewater data from the SX tank farm studies, the anion data for borehole 299-E33-45 sediments are not as clearly interpretable. Perhaps the more dilute waste type, (i.e., carbonate neutralized bismuth phosphate) as opposed to the highly nitrate dominated Reduction Oxidation Process (REDOX) waste stream at SX tank farm, is clouding the ability to define the vertical extent of the BX-102 overfill leak. In addition, borehole 299-E33-45 is ~70 ft away from the side of tank BX-102 and perhaps the bulk of the fluid that percolated to the borehole region came horizontally as opposed to vertically. The bulk of the nitrate appears to reside in the lower portion of the Hanford H2 middle sand sequence between 121 and 169 ft bgs but there is elevated nitrate all the way to the water table at 255 ft bgs. The bulk of the sulfate also resides in the lower portion of the H2 middle sand sequence and may also reach the water table at elevated concentrations. The phosphate profile seems to be shallower in the vadose zone and there is no indication that it extends beyond the Hanford H2 middle sand sequence.

Table 4.5 shows the comparison of the calculated porewater anion composition (from the sediment to water extracts) with the actual porewater anion composition. The comparison is hampered by the fact that porewater concentrations can vary significantly in samples that are within centimeters of each other, especially around the contacts between the thin fine-grained lenses and the thicker sand strata. There are 5 data sets where both 1:1 sediment to water extracts and UFA squeezings on the same liner (6-in long cores) are available. These data sets are highlighted in green in Table 4.5. In general, the dilution corrected 1:1 water extract anion concentrations are similar to the actual porewater anion concentrations that were obtained by ultracentrifugation (from UFA squeezings) for sulfate, chloride, and nitrate. For fluoride, nitrite, and phosphate, the dilution corrected 1:1 water extracts over-estimate the concentrations that were measured in the actual porewater. The bicarbonate comparisons are inconclusive, but at WMA S-SX, the dilution corrected 1:1 water extracts over-estimated the actual porewater alkalinity.

The actual porewater concentrations (from UFA squeezings) are plotted with the dilution corrected 1:1 water extracts in the figures shown in this section. There are plausible explanations for the dilution-corrected water extracts (i.e., calculated porewaters) having higher concentrations, but a geochemical explanation for the observed opposite trend found for a few of the comparisons cannot be offered. The most likely explanation is analytical errors.

Table 4.6 shows the calculated concentrations of cations in the porewater from the vadose zone sediment at borehole 299-E33-45 obtained by dilution correction of the 1:1 sediment-to-water extracts. The distributions of several of the major cations versus depth are shown in Figure 4.3. The depth profiles for the divalent alkaline earth cations calcium, magnesium, and strontium and the monovalent alkali cation potassium show remarkable similarities. All show elevated concentrations in a relatively thin zone between 140 and 165 ft (42.7 to 50.3 m) bgs within the middle sand sequence of the Hanford H2 unit. The calcium, magnesium, and strontium porewater concentrations between 78 and 140 ft (23.8 to 42.7 m) bgs appear to be lower than in the sediments directly above these depths suggesting that they have been replaced by some other cation. Barium differs from the other divalent cations and is present at low concentrations perhaps reflecting only natural amounts that are present and that are not impacted by tank fluids. The porewater sodium depth profile shows elevated concentrations from about 76 to 165 ft (23.2 to 50.3 m) bgs. The maximum sodium porewater concentration is about 0.5 M in the zone from 150 to 165 ft bgs. The maximum calcium, magnesium, strontium, and potassium porewater concentrations occur at about 156 ft bgs at levels of 0.057 M, 0.031 M, 1×10^{-4} M, and 0.013 M, respectively. The depleted zone between 78 and 140 feet for the common divalent cations is caused by sodium in the tank fluids exchanging most of the ion exchangeable divalent cations and pushing them either deeper in the profile or further away from the leak if the tank overfill fluid was mainly migrating horizontally.

Table 4.4. Anion Content of Water Extracts of Borehole BX-102 Sediment (3 Pages)

Identification	Depth Vertical ft[(a)]	Dilution Factor	1:1 Extracts in mg/L							Dilution Corrected Porewater mg/L						
			NO3	F-	NO2	Cl	SO4	PO4	HCO3	NO3	F-	NO2	Cl	SO4	PO4	HCO3
Hanford H1 coarse sand																
01A	10.64	21.09	1.1	1.2	<0.1	1.2	20.8	0.35	105.7	22	24.3	2.1	24	439	7	2229
01A-Dup	10.64	21.09	1	1.1	<0.1	1.1	20.8	0.38	N/A	22	23	2.1	24	438	8	NA
06A	20.84	17.43	1.4	0.9	<0.1	0.7	10	<0.5	76.2	24	16	1.7	12	174	<9	1328
11A	31.84	30.27	1.9	0.4	<0.1	0.6	10.2	<0.5	47.6	58	11.5	3	18	308	<15	1441
Hanford H2 upper sand sequence																
16A	42.04	29.2	4.8	0.4	<0.1	0.7	11.7	<0.5	52.4	139	11.4	2.9	21	340	<15	1529
21A	51.64	26.38	5	0.4	<0.1	0.6	11.4	<0.5	46.0	133	10	2.6	15	301	<13	1213
27A	62.99	14.72	9.9	0.4	<0.1	0.9	24	<0.5	45.5	146	5.2	1.5	13	352	<7	670
32A	71.24	25.83	11.3	0.3	<0.1	2.1	55.3	<0.5	39.2	291	7.5	2.6	53	1429	<13	1012
33A	73.39	31.48	7.8	0.1	<0.1	1.9	62.3	<0.5	40.2	245	2.5	3.2	59	1962	<16	1267
H2 muddy very fine sand lens																
34A	75.65	4.91	25.8	0.1	<0.1	32.4	85.5	1.07	68.2	127	0.4	0.5	159	420	5	335
34A-Dup	75.65	4.56	27.6	0.1	<0.1	34	91.4	0.07	68.4	126	0.3	0.5	155	417	0	312
H2 middle sand sequence																
35A	78.19	40.97	1.5	0.3	<1	2.2	12.5	1.01	64.8	59	12.3	41	91	513	41	2654
36A	79.34	32.28	1.9	0.1	<1	1.9	11.9	2.95	161.1	62	3.9	32.3	62	383	95	5200
40A	88.65	27.63	3.6	0.1	<0.1	1.3	7.4	1.97	66.6	98	3.6	2.8	35	205	54	1840
44A	100.09	19.04	9.6	0.5	<0.1	6.9	16.8	6.05	189.0	182	9.1	1.9	130	319	115	3598
49A	111.14	25.85	10.1	0.6	<0.1	0.7	11.9	12.34	263.8	260	15	2.6	19	309	319	6818
53A	119.04	31.4	33.8	0.6	<0.1	0.7	15	<0.5	131.1	1062	17.9	3.1	22	470	<16	4115
H2 muddy very fine sand lens																
54C Fine	120.14	7.02	173.7	0	0.02	4.7	121.3	148.561	513.5	1219	0.3	0.1	33	852	1043	3605
54C DUP Fine	120.14	9.27	96	0	0.36	2.8	64.7	126.351	408.0	890	0.3	3.3	26	600	1172	3782
54C Upper	120.14	14.98	85.8	0.4	0.04	2.6	52.8	3.498	226.0	1286	6.2	0.6	39	791	52	3385
54A	120.89	39.38	32	0.5	<0.1	0.9	21.8	52.18	209.4	1259	18.5	3.9	35	858	2055	8247

Table 4.4. Anion Content of Water Extracts of Borehole BX-102 Sediment (3 Pages)

Identification	Depth Vertical ft[(a)]	Dilution Factor	1:1 Extracts in mg/L							Dilution Corrected Porewater mg/L						
			NO3	F-	NO2	Cl	SO4	PO4	HCO3	NO3	F-	NO2	Cl	SO4	PO4	HCO3
H2 middle sand sequence (continued)																
54	121.24	36.16	22	0.1	<0.01	0.8	18.8	40.297	290.8	796	3.9	<0.26	30	679	1457	10516
55	121.34	6.77	201.5	0.1	0.01	5.6	127.1	172.616	530.6	1364	0.4	0.1	38	860	1169	3592
56	122.32	33.95	12.9	0.1	0.01	0.5	9.6	10.997	381.0	438	4.7	0.4	18	327	373	12936
61A	130.95	25.93	43	1.1	0.12	1.1	32.9	15.09	263.3	1115	29	3.1	29	852	391	6827
67A	141.25	38.52	62	1.4	<0.1	1.4	46.2	<0.5	122.3	2390	55.1	3.9	55	1779	<19	4712
72C	150.55	28.44	15	0.4	0.05	0.5	1413	0.063	86.1	426	11.9	1.3	14	40183	2	2449
72A	151.55	33.05	97.4	0.2	<1	4.2	701.9	<0.5	34.3	3217	6	33.1	138	23196	<17	1132
73	152.7	30.98	74	0.6	0.17	2.6	767.3	<0.014	77.9	2292	17.7	5.2	81	23775	<0.43	2412
75	156.2	33.88	181.6	0.5	0.1	6.3	896.6	<0.014	N/A	6155	18.2	3.5	214	30379	<0.47	N/A
77	159.1	28.82	45.6	0.5	0.03	1.8	692.1	<0.014	81.6	1314	14.5	0.8	51	19946	<0.40	2352
78C	159.85	27.04	41.9	0.5	0.12	1.8	612.2	<0.014	N/A	1134	12.7	3.1	48	16556	<0.38	N/A
78A	160.85	26.29	100.1	0.4	<0.5	3.1	732.3	<2.5	33.5	2632	9.5	13.2	82	19253	<66	881
81	165.55	21.84	66.2	0.5	0.18	2.7	19.5	<0.014	111.5	1447	11.1	3.8	59	425	<0.31	2436
H2 – fine-very fine sand lens																
82A	168.65	6.17	204.6	0.3	<1	17.9	111.1	<0.5	35.8	1262	1.9	6.2	110	685	<3	221
82A-Dup	168.65	6.17	228.6	0.3	<1	20.7	124.1	<0.5	33.1	1410	1.9	6.2	128	765	<3	204
82	169.1	5.78	209.9	0.5	0.04	23	112.5	<0.014	74.6	1295	2.8	0.2	142	694	<0.09	431
83D	169.55	12.01	249.4	0.6	0.5	11.4	492.3	1.91	150.2	2995	7.3	6	136	5911	23	1804
Hanford H3 Lower sand unit																
83A	171.05	35.27	15.5	0.4	<0.1	2	19.7	<0.5	39.2	546	12.3	3.5	70	693	<18	1384
84A	173.35	31.43	13.2	0.4	<0.1	1.9	20	<0.5	38.4	416	11.6	3.1	60	630	<16	1208
88A	181.65	21.76	21.9	0.5	<0.1	5.3	29	<0.5	68.2	477	10.5	2.2	114	631	<11	1483
93A	190.65	29.65	20.1	0.3	0.17	2.9	22.8	<0.5	37.9	595	9.5	5	87	677	<15	1123
99A	201.35	30.75	25.2	0.3	<0.1	4.3	29.1	<0.5	32.7	774	10.5	3.1	133	893	<15	1005
104A	211.42	29.56	27.2	0.4	<0.1	4.8	24.1	<0.5	35.3	803	10.3	3	143	712	<15	1042

Table 4.4. Anion Content of Water Extracts of Borehole BX-102 Sediment (3 Pages)

Identification	Depth Vertical ft[(a)]	Dilution Factor	1:1 Extracts in mg/L							Dilution Corrected Porewater mg/L						
			NO3	F-	NO2	Cl	SO4	PO4	HCO3	NO3	F-	NO2	Cl	SO4	PO4	HCO3
110D	217.95	34.26	23.6	0.3	0.06	4.8	31	0.038	36.3	810	10.5	2	164	1062	1	1245
PPlz Mud unit																
110A	219.45	5.32	186	0.3	<1	21.7	206.9	<0.5	58.5	989	1.7	5.3	116	1100	<3	311
111A	221.75	4.03	323.6	0.3	<1	30.4	227.5	<0.5	55.8	1305	1.3	4	123	918	<2	225
112A	223.65	5.31	213.4	0.3	<1	22.2	108.9	<0.5	51.0	1134	1.4	5.3	118	579	<3	271
116A	231.45	4.13	331.4	0.5	<1	24.3	145.8	<0.5	42.9	1370	2	4.1	100	603	<2	177
116A-Dup	231.45	4.14	322.8	0.5	<1	24	147.4	<0.5	45.2	1335	2	4.1	99	610	<2	187
PPlg Gravelly unit																
122A	241.89	24.16	20.2	0.4	<0.1	1.8	25.4	<0.5	51.7	487	9.4	2.4	44	614	<12	1248
124A	245.25	33.06	3.2	0.4	<0.1	1	32.5	<0.5	41.0	106	13.9	3.3	34	1075	<16	1355
128A	251.75	23.88	27.3	0.4	<0.1	2.7	27.4	<0.5	41.2	652	8.8	2.4	65	654	<11	983
129A	253.65	23.18	34.3	0.3	<1	196	299	<0.5	49.5	794	6.7	23.2	4545	6932	<11	1148

(a) Multiply by 0.3048 to convert ft bgs to m bgs

NA = not analyzed

Red type = Sample 129A sulfate value is likely erroneous. See discussion on page 4.26 of comparison of ICP sulfur data with IC sulfate data.

Pink shading indicates zones of obvious contamination.

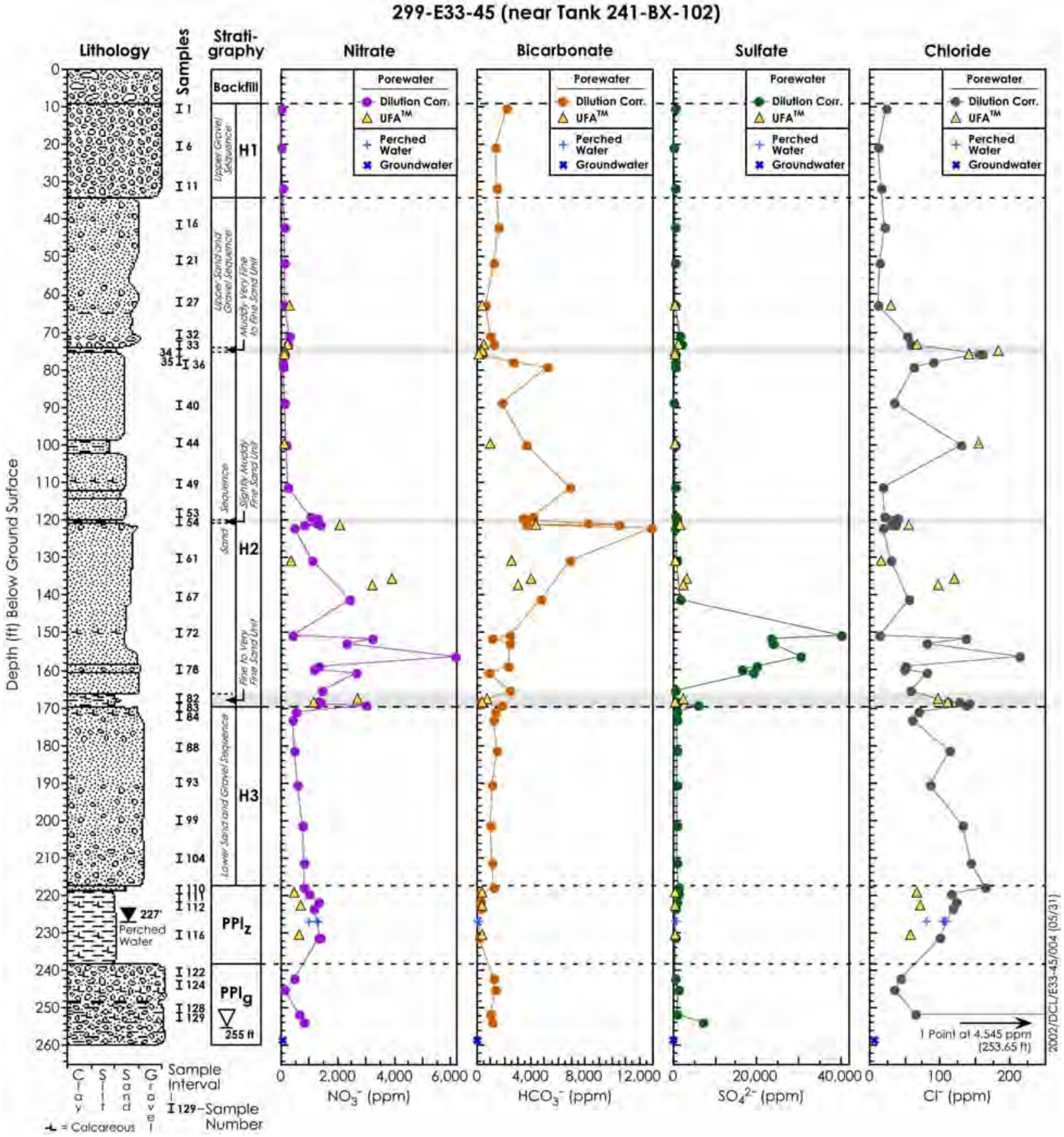

Figure 4.2a. Major Anions Calculated (from sediment-to-water extracts) and Actual Porewaters from Borehole 299-E33-45

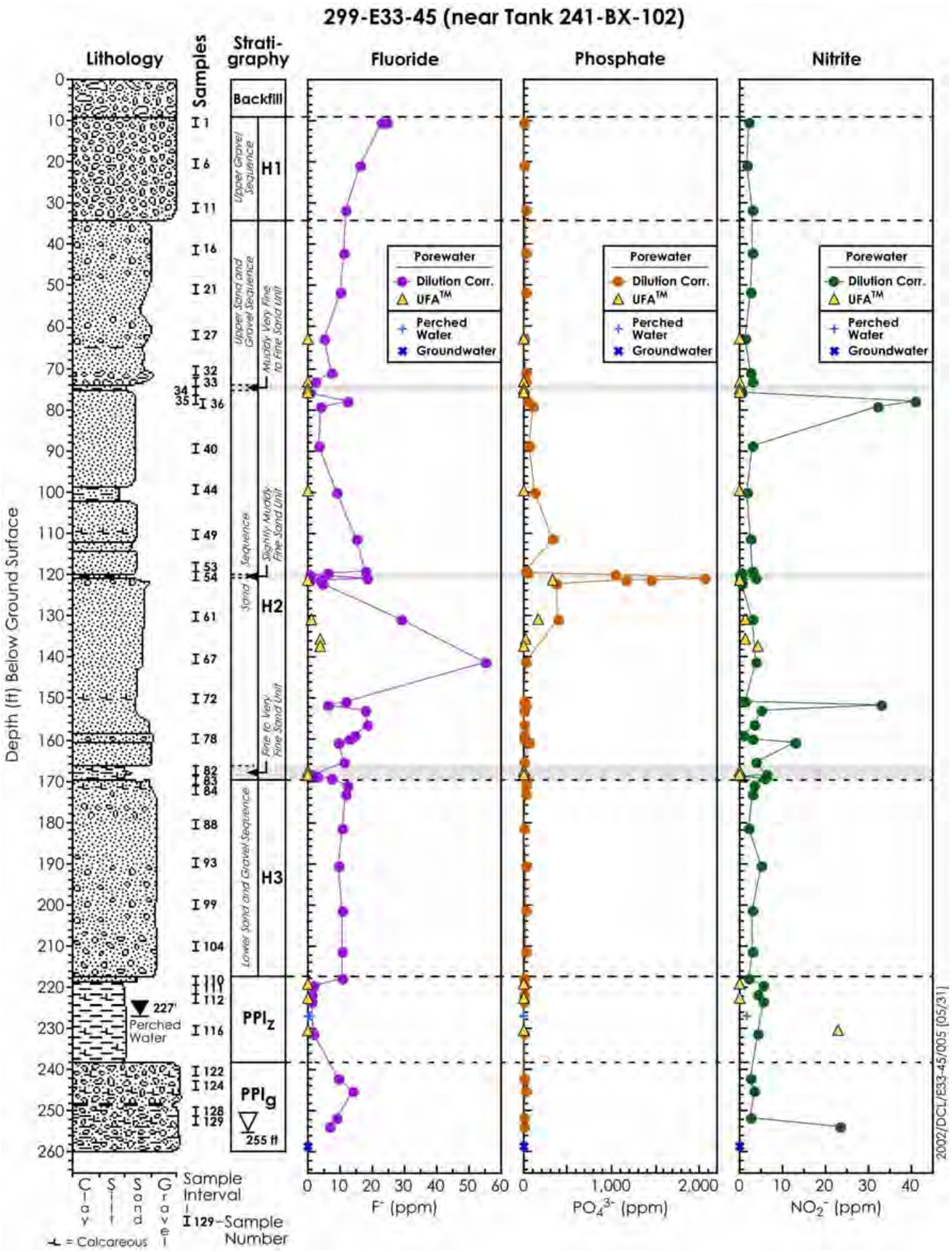

Figure 4.2b. 1:1 Sediment-to-Water Extract, Actual Porewater, Perched Water, and Groundwater Minor Anion Contents for Fluids Derived from Borehole 299-E33-45

Table 4.5. Comparison of Calculated with Actual Porewater Anion Concentrations for Borehole 299-E33-45 Vadose Zone Sediment (2 pages)

Sample Identification	Depth (ft)$^{(a)}$	Dilution Factor	Dilution Corrected Porewater mg/L						
			Nitrate	Fluoride	Nitrite	Chloride	Sulfate	Phosphate	Bicarbonate
Hanford H2 upper sand sequence									
27A	62.99	14.72	146	5.2	1.5	13	352	7	670
27A-UFA		1	311	<0.016	<0.073	30	595	<0.14	412
33A	73.39	31.48	245	2.5	3.2	59	1962	16	1267
33A-UFA		1	211	<0.016	<0.073	67	1229	<0.14	438
H2 muddy very fine sand lens									
34C-UFA	74.90	1	142	<0.016	<0.073	182	414	<0.14	395
34A	75.65	4.91	127	0.4	0.5	159	420	5	335
34A-Dup		4.56	126	0.3	0.5	155	417	0	312
34A-UFA		1	124	<0.016	<0.073	142	320	<0.14	186
H2 middle sand sequence									
44B-UFA	99.59	1	93	<0.016	<0.073	154	309	<0.14	997
44A	100.09	19.04	182	9.1	1.9	130	319	115	3598
H2 muddy very fine sand lens									
54A	120.89	14.98	1259	18.5	3.9	35	858	2055	8247
H2 middle sand sequence (continued)									
54	121.24	39.38	796	3.9	<0.26	30	679	1457	10516
55	121.34	6.77	1364	0.4	0.1	38	860	1169	3592
55-UFA		1	2078	<0.03	0.2	56	1501	328	4396
56	122.32	33.95	438	4.7	0.4	18	327	373	12936
61AB-UFA	130.7	1	353	0.9	1.3	16	252	155	2507
61A	130.95	25.93	1115	29	3.1	29	852	391	6827
64-UFA	135.5	1	3934	4.2	1.1	121	3258	22	3982
65-UFA	137.1	1	3199	4.0	4.0	98	2377	12	3060
67A	141.25	38.52	2390	55.1	3.9	55	1779	19	4712

Table 4.5. Comparison of Calculated with Actual Porewater Anion Concentrations for Borehole 299-E33-45 Vadose Zone Sediment (2 pages)

Sample Identification	Depth (ft)[(a)]	Dilution Factor	Dilution Corrected Porewater mg/L						
			Nitrate	Fluoride	Nitrite	Chloride	Sulfate	Phosphate	Bicarbonate
Fine-very fine sand lens									
82C-UFA	167.65	1	2717	<0.016	<0.073	97	2285	<0.14	787
82A	168.65	6.17	1262	1.9	6.2	110	685	3	221
82A-Dup		6.17	1410	1.9	6.2	128	765	3	204
82A-UFA		1	1132	<0.016	<0.073	111	617	<0.14	367
PPlz Mud Unit									
110B-UFA	218.95	1	462	<0.016	<0.073	68	548	<0.14	346
110A	219.45	5.32	989	1.7	5.3	116	1100	3	311
112B-UFA	222.65	1	707	<0.016	<0.073	72	289	<0.14	332
112A	223.65	5.31	1134	1.4	5.3	118	579	3	271
116C-UFA	230.45	1	652	<0.016	23.14	59	433	<0.14	355
116A	231.45	4.13	1370	2	4.1	100	603	2	177
116A-Dup		4.14	1335	2	4.1	99	610	2	187

(a) Multiply by 0.3048 to convert to meters

ID notes: UFA represents the actual porewater obtained by ultracentrifugation

< Values are reported as the detection limit for lowest standard that gave good value

Blue type signifies that actual porewater concentration is significantly lower than the calculated concentration from 1:1 sediment to water extract.

Red type signifies that concentration is much higher than expected natural background values

Green shading indicates samples for which both water extracts and porewater squeezings were performed on sediment from the same sleeve

Table 4.6. Calculated Porewater Cation Composition from Water Extracts of Vadose Zone Sediment from Borehole 299-E33-45 (3 pages)

Sample ID	Depth (ft bgs)$^{(a)}$	Dilution Factor	Dilution Corrected Porewater Concentration of Cations								
			Al	Ba	Ca	Fe	K	Mg	Na	Si	Sr
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Hanford H1 coarse sand											
01A	10.64	21.09	8.55E+00	3.50E-01	7.44E+01	1.45E+01	6.09E+01	1.56E+01	9.77E+02	3.00E+02	3.76E-01
06A	20.84	17.43	4.00E+00	1.51E-01	6.47E+01	4.26E+00	6.07E+01	1.48E+01	5.42E+02	2.30E+02	3.37E-01
11A	31.84	30.27	1.20E+00	9.77E-01	2.64E+02	(8.67E-01)	1.35E+02	7.51E+01	2.52E+02	3.18E+02	1.62E+00
Hanford H2 upper sand sequence											
16A	42.04	29.2	1.90E+00	1.19E+00	2.31E+02	(1.73E+00)	1.38E+02	8.82E+01	2.78E+02	2.84E+02	1.53E+00
21A	51.64	26.38	2.50E+00	1.14E+00	1.88E+02	(2.33E+00)	1.21E+02	7.42E+01	2.80E+02	2.56E+02	1.24E+00
27A	62.99	14.72	(4.95E-01)	3.00E-01	1.53E+02	(3.05E-01)	6.69E+01	5.06E+01	1.93E+02	1.50E+02	7.84E-01
32A	71.24	25.83	1.40E+00	6.82E-01	4.86E+02	(5.26E-01)	1.46E+02	1.47E+02	3.33E+02	2.47E+02	2.35E+00
33A	73.39	31.48	(4.88E-01)	5.23E-01	6.39E+02	<3.15E+00	1.26E+02	1.99E+02	4.08E+02	2.79E+02	2.55E+00
H2 muddy very fine sand lens											
34A	75.65	4.91	2.45E-01	8.42E-02	2.07E+02	<4.91E-01	3.24E+01	5.84E+01	1.19E+02	5.11E+01	9.13E-01
34A-Dup	75.65	4.56	2.28E-01	1.00E-01	2.00E+02	<4.56E-01	3.20E+01	5.66E+01	1.19E+02	4.95E+01	8.95E-01
H2 middle sand sequence											
35A	78.19	40.97	2.94E+00	3.02E-01	1.14E+02	(1.94E+00)	1.09E+02	4.31E+01	1.12E+03	3.73E+02	5.47E-01
36A	79.34	32.28	1.91E+01	3.51E-01	(1.66E+01)	1.64E+01	4.51E+01	4.84E+00	3.18E+03	4.10E+02	(8.57E-02)
40A	88.65	27.63	1.73E+01	3.46E-01	8.08E+01	1.78E+01	6.44E+01	5.49E+01	6.71E+02	2.78E+02	3.00E-01
44A	100.09	19.04	2.55E+01	3.36E-01	2.58E+01	2.19E+01	3.22E+01	6.22E+00	2.12E+03	2.81E+02	(1.09E-01)
49A	111.14	25.85	4.35E+01	4.50E-01	3.05E+01	5.31E+01	4.72E+01	1.16E+01	4.26E+03	4.43E+02	(1.37E-01)
53A	119.04	31.4	4.21E+01	5.10E-01	5.92E+01	4.32E+01	6.42E+01	1.55E+01	2.38E+03	4.28E+02	(2.38E-01)
H2 muddy very fine sand lens											
54C Fine	120.14	7.02	<3.51E+00	6.08E-02	3.68E+01	9.35E-01	2.60E+01	9.04E+00	2.31E+03	4.50E+01	1.21E-01
54C DUP Fine	120.14	9.27	<4.64E+00	1.34E-01	4.23E+01	(1.42E-01)	2.98E+01	1.07E+01	2.21E+03	5.38E+01	1.33E-01

Table 4.6. Calculated Porewater Cation Composition from Water Extracts of Vadose Zone Sediment from Borehole 299-E33-45 (3 pages)

Sample ID	Depth (ft bgs)(a)	Dilution Factor	Dilution Corrected Porewater Concentration of Cations								
			Al	Ba	Ca	Fe	K	Mg	Na	Si	Sr
			mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
54C Upper	120.14	14.98	(7.35E-01)	1.24E-01	4.53E+01	(1.35E+00)	3.86E+01	5.71E+00	1.74E+03	1.37E+02	1.87E-01
54A	120.89	39.38	6.18E+01	4.82E-01	6.37E+01	6.42E+01	7.89E+01	2.33E+01	6.68E+03	6.24E+02	(2.20E-01)
H2 middle sand sequence (continued)											
54	121.24	36.16	(1.15E+01)	2.87E-01	3.15E+01	7.54E+00	6.82E+01	5.71E+00	5.26E+03	3.59E+02	(1.60E-01)
55	121.34	6.77	<3.39E+00	(1.63E-02)	3.91E+01	(1.12E-01)	3.31E+01	1.32E+01	2.36E+03	4.21E+01	1.11E-01
56	122.32	33.95	(1.59E+01)	1.48E-01	2.29E+01	1.53E+01	5.94E+01	3.16E+00	4.61E+03	3.72E+02	(1.10E-01)
61A	130.95	25.93	1.17E+01	1.19E-01	2.67E+01	9.97E+00	5.09E+01	2.62E+00	5.01E+03	3.23E+02	(1.30E-01)
67A	141.25	38.52	4.21E+01	5.19E-01	6.38E+01	4.41E+01	5.89E+01	1.36E+01	4.03E+03	4.12E+02	(2.78E-01)
72C	150.55	28.44	<1.42E+01	2.98E-01	8.51E+02	(2.17E-01)	2.96E+02	2.53E+02	7.74E+03	1.98E+02	3.89E+00
72A	151.55	33.05	2.18E+00	5.32E-01	1.56E+03	(1.00E+00)	3.67E+02	4.55E+02	1.05E+04	2.70E+02	6.76E+00
73	152.7	30.98	<1.55E+01	6.09E-01	1.78E+03	(2.02E-01)	3.75E+02	5.10E+02	8.15E+03	1.81E+02	7.45E+00
75	156.2	33.88	<1.69E+01	6.83E-01	2.28E+03	(1.12E+00)	5.02E+02	7.59E+02	1.19E+04	2.10E+02	9.63E+00
77	159.1	28.82	<1.44E+01	3.77E-01	1.23E+03	(1.32E-01)	3.22E+02	3.78E+02	7.54E+03	1.84E+02	5.27E+00
78C	159.85	27.04	<1.35E+01	3.84E-01	1.38E+03	(1.54E-01)	3.39E+02	3.78E+02	8.59E+03	1.67E+02	5.88E+00
78A	160.85	26.29	1.60E+00	4.20E-01	1.22E+03	(6.20E-01)	2.78E+02	3.23E+02	8.88E+03	1.99E+02	5.05E+00
81	165.55	21.84	(1.03E+00)	1.51E-01	1.47E+02	(1.44E+00)	1.24E+02	4.25E+01	9.89E+02	1.52E+02	7.76E-01
H2–fine-very fine sand lens											
82A	168.65	6.17	9.83E-02	2.25E-01	4.27E+02	(9.25E-02)	6.38E+01	1.26E+02	2.07E+02	6.52E+01	1.79E+00
82A-Dup	168.65	6.17	7.41E-02	2.27E-01	4.70E+02	(1.17E-01)	6.13E+01	1.37E+02	2.17E+02	6.78E+01	1.97E+00
82	169.1	5.78	<2.89E+00	1.42E-01	3.85E+02	(1.85E-02)	6.56E+01	1.14E+02	1.85E+02	4.87E+01	1.67E+00
83D	169.55	12.01	<6.00E+00	4.42E-02	2.53E+02	(3.30E-02)	8.22E+01	9.42E+01	3.70E+03	8.10E+01	1.36E+00
Hanford H3 Lower sand unit											
83A	171.05	35.27	6.57E+00	5.45E-01	4.26E+02	4.76E+00	1.54E+02	1.12E+02	3.81E+02	3.50E+02	1.88E+00
84A	173.35	31.43	4.81E+00	4.65E-01	3.24E+02	3.56E+00	1.36E+02	8.74E+01	4.00E+02	3.09E+02	1.53E+00
88A	181.65	21.76	7.55E+00	3.26E-01	1.70E+02	8.84E+00	8.35E+01	4.11E+01	8.01E+02	2.85E+02	7.78E-01

Table 4.6. Calculated Porewater Cation Composition from Water Extracts of Vadose Zone Sediment from Borehole 299-E33-45 (3 pages)

Sample ID	Depth (ft bgs)[a]	Dilution Factor	Dilution Corrected Porewater Concentration of Cations								
			Al	**Ba**	**Ca**	**Fe**	**K**	**Mg**	**Na**	**Si**	**Sr**
			mg/L	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
93A	190.65	29.65	1.03E+01	7.25E-01	3.99E+02	6.76E+00	1.49E+02	1.10E+02	3.08E+02	2.99E+02	1.94E+00
99A	201.35	30.75	1.17E+01	1.81E+00	4.51E+02	7.78E+00	1.56E+02	1.23E+02	3.70E+02	3.36E+02	2.65E+00
104A	211.42	29.56	8.64E+00	7.71E-01	4.30E+02	5.06E+00	1.51E+02	1.12E+02	3.49E+02	3.02E+02	2.17E+00
110D	217.95	34.26	(2.53E-01)	1.14E+00	6.03E+02	(9.14E-02)	9.40E+01	1.55E+02	3.98E+02	2.76E+02	3.12E+00
PPlz Mud unit											
110A	219.45	5.32	1.60E-02	2.08E-01	5.58E+02	(2.78E-02)	3.01E+01	1.59E+02	1.89E+02	5.43E+01	2.31E+00
111A	221.75	4.03	1.14E-02	1.99E-01	5.30E+02	(2.53E-02)	2.08E+01	1.59E+02	1.66E+02	4.10E+01	2.06E+00
112A	223.65	5.31	(7.63E-02)	3.16E-01	4.36E+02	1.36E-01	3.00E+01	1.33E+02	1.35E+02	4.52E+01	1.79E+00
116A	231.45	4.13	(3.31E-02)	2.28E-01	4.12E+02	(6.90E-02)	4.29E+01	1.49E+02	1.47E+02	4.13E+01	2.11E+00
116A-Dup	231.45	4.14	(1.48E-02)	2.75E-01	4.07E+02	(4.48E-02)	4.33E+01	1.51E+02	1.50E+02	4.21E+01	2.13E+00
PPlg Gravelly unit											
122A	241.89	24.16	8.91E+00	1.20E+00	2.55E+02	7.31E+00	1.13E+02	1.21E+02	3.92E+02	3.01E+02	2.19E+00
124A	245.25	33.06	1.71E+00	7.03E-01	3.24E+02	(8.69E-01)	1.45E+02	9.46E+01	4.88E+02	3.66E+02	1.86E+00
128A	251.75	23.88	2.42E+00	1.09E+00	3.46E+02	3.54E+00	1.29E+02	9.18E+01	3.32E+02	2.37E+02	2.12E+00
129A	253.65	23.18	6.53E+00	6.45E-01	3.49E+02	3.71E+00	1.02E+02	9.28E+01	1.64E+02	2.55E+02	1.96E+00

(a) Multiply by 0.3048 to convert to meters
Values in parentheses are below level of quantification but spectra look useable
< Values are reported as the detection limit for lowest standard that gave good value
Blue type signifies significantly lower values than most of profile (perhaps ion exchanged or leached away)
Red type signifies that concentration is much higher than expected natural background values
Pink shading indicates possible analytical error.

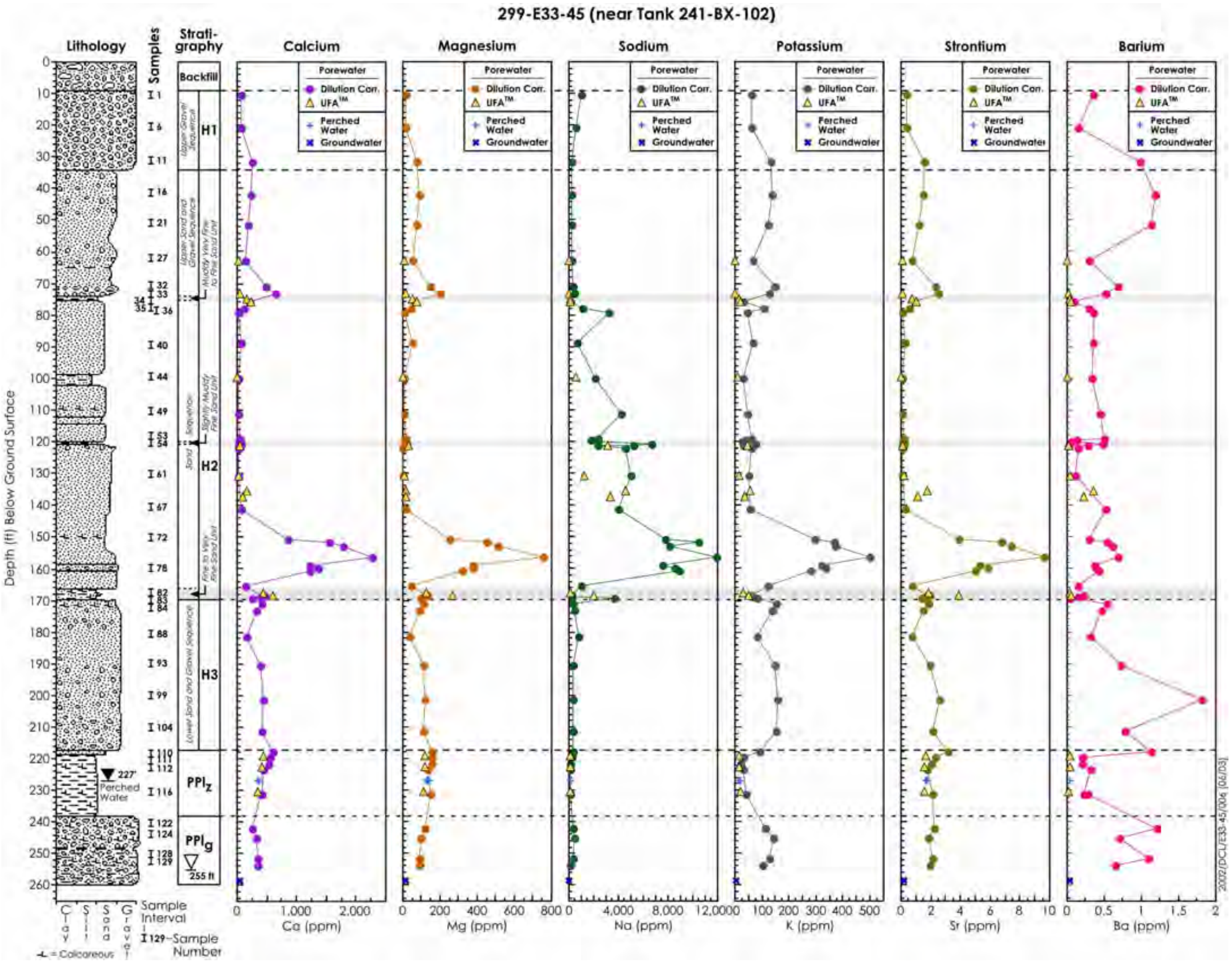

Figure 4.3. Cations Calculated (from Sediment-to-Water Extracts) and Actual Porewaters for Borehole 299-E33-45 Sediment

There is also a smaller peak in the divalent alkaline earth cations and potassium at the base of the Hanford H2 upper sand sequence that might be caused by horizontal migration of fluids on top of the fine-grained lens at 74.5 ft (22.7) bgs. There is no indication of elevated sodium at this depth suggesting that ion exchange might be pushing the other cations out in front of the fluid from the tank overfill. That is, the horizontal migration of tank overfill fluids did not travel much beyond this position at 74.5 ft bgs. The plume at 150 to 165 ft bgs does not show significant separation of the divalent cations from the high sodium from the BX-102 tank overfill. This differs from the cation profile from borehole 299-W23-19 that shows very distinct separation of the divalent cations from the sodium plume (see Figure 4.4 in Serne et al. 2002b) or the less pronounced but still discernable separation from the sodium profile at the two more saline plumes between tanks SX-108 and SX-109 (see Figure 4.3 in both Serne et al. 2002c and 2002d). Based on personal communication with Dr. Carl Steefel at Lawrence Livermore National Laboratory, the ion exchange separation of the divalent cations that are naturally the dominant cations on Hanford sediment exchange sites from the invading high sodium fluids is maximized when the invading sodium concentrations are not large and when the ion exchange capacity of the sediments is moderate. This was the case at borehole 299-W23-19. The sodium concentrations observed at 299-E33-45 are intermediate (i.e., 5 times more concentrated than at 299-W23-19 and ten to thirty times less concentrated than the pore fluids around tanks SX-108 and SX-109). The cation exchange capacity of the sediments near the BX-102 tank is smaller than the cation exchange capacity for the sediments below the SX tank farm. Both of these facts would make the separation of divalent cations from the sodium porewater plume at 299-E33-45 less than that observed at 299-W23-19. However, it seems strange that some separation is not observable at 299-E33-45 if the tank fluids were percolating predominantly in a vertical direction through the sediments. If the flow of high sodium fluids was predominately horizontal through the sediments at 299-E33-45, one would expect to find the divalent cations diminished in sediments that have been contacted with large amounts of tank fluids. Therefore the observed profile may be caused by the fact that sodium from the tank overfill just reached the sediments that were sampled by placement of borehole 299-E33-45. That is, the invading sodium has not had a chance to push the divalent cations out in front of the sodium tank liquor plume no matter whether the flow is vertical or horizontal. If the tank fluid migrated mainly in the horizontal direction, this would be equivalent to saying that the hydrologic driving force for the tank overfill pushed fluid out about 70 ft horizontally from the side of the tank and then dissipated. Another borehole, preferably closer to tank BX-102, might shed additional information about the ion exchange situation in the sediments “down-dip” from the tank. However, the spectral gamma data from neighboring dry monitoring wells suggests that uranium from the overfill has in fact moved even farther away from the side of the tank (DOE-GJPO 1997, 1998, 2000; Myers 1999; Wood et al. 2000) so this hypothesis, that the original tank overfill fluids may not have traveled further than 70 ft to the east of tank BX-102 may not be correct.

The maximum sodium concentration in the porewater is calculated to be about 0.5 M (in the zone of 151 to 156 ft bgs), which is considerably lower than the estimated concentration present in tank BX-102 at the time of the overfill (i.e., 2.92 M). The nitrate and sulfate porewater concentrations are also elevated in this zone at values that range from 0.05 to 0.1 M and 0.32 to 0.42 M, respectively. Both nitrate and sulfate were major components of metals waste that was neutralized with sodium hydroxide and sodium carbonates prior to disposal into the tanks. The original tank fluids should have contained more nitrate than sulfate so it is confusing that the water extracts at this depth in borehole 299-E33-45 contain higher molar concentrations of sulfate.

The comparison of cation concentrations in the actual porewaters, obtained by ultracentrifugation, with the dilution-corrected water extract cation values are shown on Figure 4.3 and Table 4.7. As found for the anions, the actual porewaters have the same or lower concentrations for most of the cations than the dilution-corrected 1:1 sediment to water extracts. However, as shown in Figure 4.3, the comparison of the actual porewaters from ultracentrifugation with the dilution-corrected water extracts agrees adequately to define the vertical distribution of vadose zone pore fluids that are influenced by the tank BX-102 overfilling. Analytical problems on the more saline UFA squeezings did not allow quantification of the soluble aluminum concentrations with a useful (sensitive) detection limit. The actual porewater concentrations for barium, iron, and silicon are considerably lower than the estimates from the sediment to water extracts, for potassium and sodium the actual porewater concentrations are slightly lower than the calculated values, but the agreement for calcium, magnesium, and strontium is good.

The agreement between the total sulfur measured by inductively coupled plasma (ICP) spectroscopy, converted to sulfate, with the direct determination of sulfate in the water extracts by ion chromatography is shown in Table 4.8. In almost all cases, the agreement is excellent, thus showing that all the water-extractable sulfur is in fact sulfate. This comparison also allows the IC measurement for sample 129A to be discarded as erroneous. As mentioned above, the porewater sulfate concentrations are highly elevated only in a narrow zone within the middle sand sequence of the H2 unit between 140 and 166 ft bgs. There also appears to be a thin shallow zone between 71 and 74 ft bgs that contains slightly elevated sulfate. Where the UFA squeezings were obtained, the sulfate agreement with dilution-corrected 1:1 sediment to water extracts is very good. Also shown in Table 4.8, the agreement between the ICP phosphorous as phosphate and the IC phosphate is acceptable when there are significant amounts of phosphate in the water extracts but when there is low phosphate present, the ICP data shows a positive bias in that some spectral interference is being interpreted as a small amount of phosphate.

Table 4.6 and Figure 4.4 show the porewater concentration of aluminum, iron, and silicon. The H2 middle sequence sand unit (75 to 121 ft bgs) shows higher concentrations of water extractable aluminum and iron, perhaps signifying the presence of more amorphous aluminum and iron compounds from the reaction of the native sediment with the BX-102 tank overfill fluids with subsequent precipitation of amorphous or more soluble crystalline aluminum and iron containing solids. The silicon concentrations calculated from the dilution corrected 1:1 sediment to water extracts do not show any obvious pattern. The silicon concentrations of actual porewaters obtained by ultracentrifugation are lower than the calculated porewater values suggesting that water extraction is dissolving silicon bearing solids. The same is true for the water soluble iron data. It is likely that the Hanford H2 middle sand sequence contains water leachable compounds of aluminum, silicon, and iron that may be indicative of secondary (probably amorphous) precipitates from reaction of the sediments with tank fluids.

Table 4.7. Comparison of Actual to Calculated (from 1:1 water extracts) Porewaters–Cations (2 pages)

Sample ID	Depth (ft)[(a)]	Dilution Factor	Dilution Corrected Porewater mg/L								
			Al	Ba	Ca	Fe	K	Mg	Na	Si	Sr
Hanford H2 upper sand sequence											
27A	62.99	14.72	(4.95E-01)	3.00E-01	1.53E+02	(3.05E-01)	6.69E+01	5.06E+01	1.93E+02	1.50E+02	7.84E-01
27A-UFA		1	<5.00E+00	(7.17E-03)	2.08E+01	(1.62E-01)	(1.91E+00)	6.50E+00	1.28E+01	(2.08E+00)	8.30E-02
33A	73.39	31.48	(4.88E-01)	5.23E-01	6.39E+02	<3.15E+00	1.26E+02	1.99E+02	4.08E+02	2.79E+02	2.55E+00
33A-UFA			<5.00E+00	(1.19E-02)	3.92E+01	(1.37E-01)	(2.00E+00)	1.19E+01	1.41E+01	(1.98E+00)	1.48E-01
H2 muddy very fine sand lens											
34C-UFA	74.90	1	<5.00E+00	3.33E-02	1.72E+02	(8.23E-02)	1.58E+01	4.89E+01	7.55E+01	1.47E+01	7.88E-01
34A	75.65	4.91	2.45E-01	8.42E-02	2.07E+02	<4.91E-01	3.24E+01	5.84E+01	1.19E+02	5.11E+01	9.13E-01
34A-Dup		4.56	2.28E-01	1.00E-01	2.00E+02	<4.56E-01	3.20E+01	5.66E+01	1.19E+02	4.95E+01	8.95E-01
34A-UFA		1	<5.00E+00	4.95E-02	2.29E+02	(3.21E-01)	2.13E+01	7.22E+01	1.02E+02	1.50E+01	1.04E+00
H2 middle sand sequence											
44B-UFA	99.59	1	<5.00E+00	(1.06E-02)	6.46E+00	(1.21E-01)	(8.27E+00)	1.50E+00	5.17E+02	1.31E+01	3.39E-02
44A	100.09	19.04	2.55E+01	3.36E-01	2.58E+01	2.19E+01	3.22E+01	6.22E+00	2.12E+03	2.81E+02	(1.09E-01)
H2 muddy very fine sand lens											
54A	120.89	14.98	6.18E+01	4.82E-01	6.37E+01	6.42E+01	7.89E+01	2.33E+01	6.68E+03	6.24E+02	(2.20E-01)
H2 middle sand sequence (continued)											
54	121.24	39.38	(1.15E+01)	2.87E-01	3.15E+01	7.54E+00	6.82E+01	5.71E+00	5.26E+03	3.59E+02	(1.60E-01)
55	121.34	6.77	<3.39E+00	(1.63E-02)	3.91E+01	(1.12E-01)	3.31E+01	1.32E+01	2.36E+03	4.21E+01	1.11E-01
55-UFA		1	1.18E+01	3.20E-02	3.82E+01	9.40E-02	4.80E+01	2.81E+01	3.10E+03	1.05E+01	9.80E-02
56	122.32	33.95	(1.59E+01)	1.48E-01	2.29E+01	1.53E+01	5.94E+01	3.16E+00	4.61E+03	3.72E+02	(1.10E-01)
61AB-UFA	130.7	1	8.80E+00	1.00E-01	2.85E+01	4.31E+00	1.52E+01	4.62E+00	1.22E+03	2.01E+01	1.90E-01
61A	130.95	25.93	1.17E+01	1.19E-01	2.67E+01	9.97E+00	5.09E+01	2.62E+00	5.01E+03	3.23E+02	(1.30E-01)
64-UFA	135.5	1	2.80E+01	3.20E-01	1.61E+02	9.00E-01	5.70E+01	1.41E+01	4.55E+03	9.01E+00	1.74E+00
65-UFA	137.1	1	2.00E+01	2.40E-01	1.05E+02	3.40E-01	3.79E+01	1.72E+01	3.33E+03	8.02E+00	1.15E+00
67A	141.25	38.52	4.21E+01	5.19E-01	6.38E+01	4.41E+01	5.89E+01	1.36E+01	4.03E+03	4.12E+02	(2.78E-01)

Table 4.7. Comparison of Actual to Calculated (from 1:1 water extracts) Porewaters–Cations (2 pages)

Sample ID	Depth (ft)$^{(a)}$	Dilution Factor	Dilution Corrected Porewater mg/L								
			Al	Ba	Ca	Fe	K	Mg	Na	Si	Sr
Fine-very fine sand lens											
82C-UFA	167.65	1	<5.00E+00	3.69E-02	4.34E+02	(3.77E-01)	3.04E+01	1.26E+02	1.46E+02	1.39E+01	1.85E+00
82A	168.65	6.17	9.83E-02	2.25E-01	4.27E+02	(9.25E-02)	6.38E+01	1.26E+02	2.07E+02	6.52E+01	1.79E+00
82A-Dup		6.17	7.41E-02	2.27E-01	4.70E+02	(1.17E-01)	6.13E+01	1.37E+02	2.17E+02	6.78E+01	1.97E+00
82A-UFA		1	<5.00E+00	3.36E-02	4.50E+02	(9.96E-02)	1.53E+01	1.20E+02	1.06E+02	1.55E+01	1.66E+00
PPlz Mud Unit											
110B-UFA	218.95	1	<5.00E+00	3.36E-02	4.50E+02	(9.96E-02)	1.53E+01	1.20E+02	1.06E+02	1.55E+01	1.66E+00
110A	219.45	5.32	1.60E-02	2.08E-01	5.58E+02	(2.78E-02)	3.01E+01	1.59E+02	1.89E+02	5.43E+01	2.31E+00
112B-UFA	222.65	1	<5.00E+00	4.15E-02	4.14E+02	4.66E+00	1.59E+01	1.22E+02	1.00E+02	1.32E+01	1.59E+00
112A	223.65	5.31	(7.63E-02)	3.16E-01	4.36E+02	1.36E-01	3.00E+01	1.33E+02	1.35E+02	4.52E+01	1.79E+00
116C-UFA	230.45	1	<5.00E+00	2.68E-02	3.44E+02	(1.14E-01)	2.32E+01	1.13E+02	1.16E+02	1.07E+01	1.61E+00
116A	231.45	4.13	(3.31E-02)	2.28E-01	4.12E+02	(6.90E-02)	4.29E+01	1.49E+02	1.47E+02	4.13E+01	2.11E+00
116A-Dup		4.14	(1.48E-02)	2.75E-01	4.07E+02	(4.48E-02)	4.33E+01	1.51E+02	1.50E+02	4.21E+01	2.13E+00

(a) Multiply by 0.3048 to convert to meters
ID notes: UFA represents the actual porewater obtained by ultracentrifugation
Values in parentheses are below level of quantification but spectra look useable
< Values are reported as the detection limit for lowest standard that gave a good value
Blue type signifies actual porewater concentration is significantly lower than calculated concentration from 1:1 sediment to water extract.
Red type signifies that concentration is much higher than expected natural background values.
Shading indicates samples for which UFA samples were also analyzed

Table 4.8. Comparison of ICP Sulfur and Phosphorous as Sulfate and Phosphate with IC Sulfate and Phosphate (mg/L) for Dilution Corrected Water Extracts (2 pages)

Sample ID	**Depth (ft bgs)[(a)]**	**SO IC**	**SO_4 ICP**	**% Difference**	**PO_4 IC**	**PO_4 ICP**	**% Difference**
Hanford H1 coarse sand							
01A	10.64	439	452	0.7%	7	(15.0)	73%
06A	20.84	174	185	1.6%	<9	(9.3)	"---"
11A	31.84	308	320	0.9%	<15	(5.9)	"---"
Hanford H2 upper sand sequence							
16A	42.04	340	353	1.0%	<15	(6.3)	"---"
21A	51.64	301	312	0.9%	<13	(5.4)	"---"
27A	62.99	352	361	0.6%	<7	(3.3)	"---"
32A	71.24	1429	1459	0.5%	<13	(3.8)	"---"
33A	73.39	1962	2031	0.9%	<16	(9.7)	"---"
H2 muddy very fine sand lens							
34A	75.65	420	432	0.7%	5	5.4	7%
34A-Dup	75.65	417	432	0.9%	0	4.6	200%
H2 middle sand sequence							
35A	78.19	513	502	0.5%	41	45.0	9%
36A	79.34	383	393	0.6%	95	108.4	13%
40A	88.65	205	208	0.4%	54	92.3	52%
44A	100.09	319	339	1.5%	115	141.7	21%
49A	111.14	309	320	0.9%	319	344.0	8%
53A	119.04	470	494	1.2%	<16	48.1	"---"
H2 muddy very fine sand lens							
54C Fine	120.14	852	469	14.5%	1043	839.7	22%
54C DUP Fine	120.14	600	1131	15.3%	1172	1306.1	11%
54C Upper	120.14	791	838	1.4%	52	52.0	0%
54A	120.89	858	868	0.3%	2055	2017.2	2%
H2 middle sand sequence (continued)							
54	121.24	679	713	1.2%	1457	1448.4	1%
55	121.34	860	881	0.6%	1169	1100.6	6%
56	122.32	327	338	0.8%	373	398.4	7%
61A	130.95	852	843	0.3%	391	385.7	1%
67A	141.25	1779	1802	0.3%	<19	(6.2)	"---"
72C	150.55	40183	18774	18.2%	2	1.3	42%
72A	151.55	23196	24231	1.1%	<17	32.2	"---"

Table 4.8. Comparison of ICP Sulfur and Phosphorous as Sulfate and Phosphate with IC Sulfate and Phosphate (mg/L) for Dilution Corrected Water Extracts (2 pages)

Sample ID	**Depth (ft bgs)[(a)]**	**SO IC**	**SO_4 ICP**	**% Difference**	**PO_4 IC**	**PO_4 ICP**	**% Difference**
73	152.7	23775	21848	2.1%	<0.43	(0.6)	"---"
75	156.2	30379	29073	1.1%	<0.47	<2.6	"---"
77	159.1	19946	19158	1.0%	<0.40	(0.2)	"---"
78C	159.85	16556	21621	6.6%	<0.38	(0.4)	"---"
78A	160.85	19253	20275	1.3%	<66	24.2	"---"
81	165.55	425	442	1.0%	<0.31	(0.9)	"---"
H2 –fine-very fine sand lens							
82A	168.65	685	746	2.1%	<3	6.3	"---"
82A-Dup	168.65	765	813	1.5%	<3	7.4	"---"
82	169.1	694	669	0.9%	<0.09	0.8	"---"
83D	169.55	5911	5926	0.1%	23	14.6	45%
Hanford H3 Lower sand unit							
83A	171.05	693	698	0.2%	<18	38.8	"---"
84A	173.35	630	639	0.3%	<16	37.2	"---"
88A	181.65	631	632	0.0%	<11	27.7	"---"
93A	190.65	677	664	0.5%	<15	27.2	"---"
99A	201.35	893	881	0.3%	<15	28.0	"---"
104A	211.42	712	728	0.6%	<15	28.2	"---"
110D	217.95	1062	1143	1.8%	1	(2.5)	87%
PPlz Mud unit							
110A	219.45	1100	1235	2.9%	<3	9.1	"---"
111A	221.75	918	913	0.1%	<2	9.7	"---"
112A	223.65	579	596	0.7%	<3	9.7	"---"
116A	231.45	603	618	0.6%	<2	5.5	"---"
116A-Dup	231.45	610	617	0.3%	<2	6.3	"---"
PPlg Gravelly unit							
122A	241.89	614	603	0.5%	<12	26.5	"---"
124A	245.25	1075	1047	0.6%	<16	(4.3)	"---"
128A	251.75	654	653	0.0%	<11	(2.0)	"---"
129A	253.65	6932	326	45.5%	<11	(1.2)	"---"

(a) Multiply by 0.3048 to convert to meters.
Pink shading indicates values where significant contamination is present
Purple shading indicates values is suspect (too high); analytical flyer

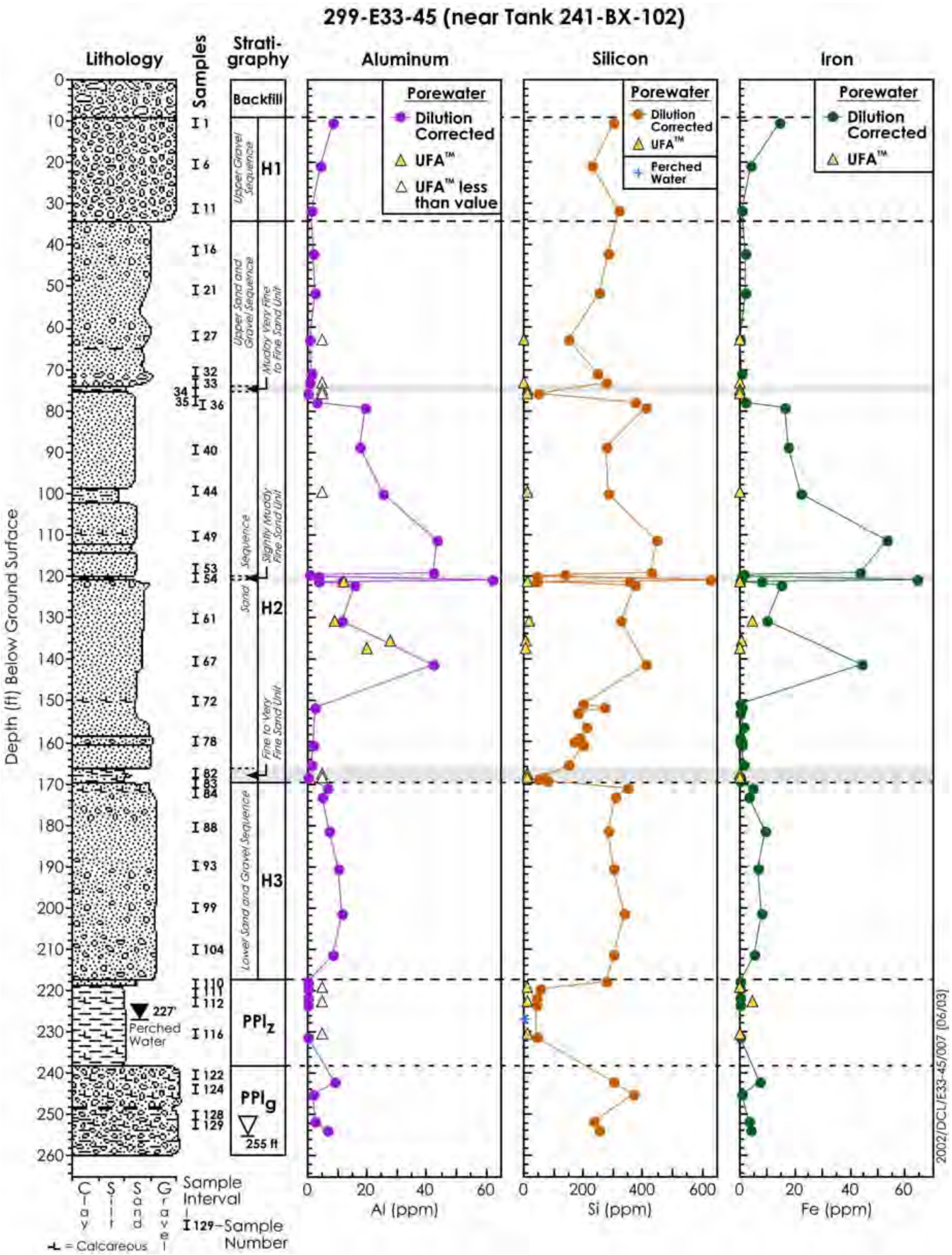

Figure 4.4. Pore Fluid Concentrations of Aluminum, Iron, Silicon, and Manganese (Calculated from Sediment-to-Water Extracts) and Actual Porewaters for BX-102 Borehole Sediment

Table 4.9 shows the dilution-corrected 1:1 sediment-to-water extract trace metal concentrations and Table 4.10 shows the comparison of the calculated porewater versus the actual porewater trace metal composition, respectively. The vertical distributions of several trace metal porewater concentrations are shown in Figure 4.5. Table 4.9 and Figure 4.5 show that there are elevated concentrations of uranium and technetium-99 in the vadose zone porewater between 120 and 167 ft (36.6 and 50.9 m) bgs (within the middle sand sequence of Hanford H2. There appears to be a second less concentrated plume of technetium-99 within the contact between the H3 unit and the PPlz unit (200 to 240 ft bgs). There is indication of a second deeper but less concentrated plume of uranium in the upper portion of the H3 unit (between 170 and 200 ft bgs) but no elevated uranium in the PPlz or in the perched water. The porewater data for chromium, arsenic, and selenium are not consistent or of sufficient quality, because of low concentrations, to evaluate their vertical distributions and to determine whether BX-102 tank overfill fluids have reached the borehole. We also do not know whether the neutralized bismuth phosphate uranium metals waste contained significantly elevated concentrations of trace metals such as chromium and selenium. Thus, unlike at the SX tank farm, RCRA regulated trace metals may not be a good leak indicator for vadose zone sediments around the BX tank farm.

There is very good agreement between the technetium-99 concentrations found in the actual porewater and the dilution corrected sediment-water extracts in all regions and lithologies. Further, the technetium-99 concentration in the perched water also agrees with the nearby dilution corrected water extracts. There are obvious elevated concentrations of technetium-99 in the PPlz but not the PPlg unit down to the water table. This may imply that the source of technetium in the groundwater reached the water table at another position than vertically through the sediments at 299-E33-45. It is also possible that the technetium-99 in the groundwater in the vicinity of 299-E33-45 did not come from the overfilling of tank BX-102. More discussion will follow in Section 4.2.3 where constituent ratios are evaluated.

For uranium, the dilution corrected sediment-water extracts agree with the actual porewater concentrations for samples taken between 75 and 168 ft (22.4 and 51.2 m) bgs where the main uranium plume resides. For two samples at 63 and 73 ft bgs, the actual porewater uranium concentrations are significantly lower than the dilution corrected sediment-water extracts suggesting that some uranium precipitate is dissolving during water extraction. In Appendix D of the WMA B-BX-BY FIR (Knepp 2002a) there is more discussion on whether there is any indication of excess uranium solid phase present in the borehole sediments at these depths. There is no indication that uranium has penetrated below 200 ft (61 m)or into the fine-grained PPlz strata at this borehole. Thus the source of the uranium in the groundwater nearby is also not definitively explained from the data generated from this borehole.

There was no indication of the presence of other trace constituents such as molybdenum, lead, silver, and cadmium as found under tank SX-108 that leaked highly concentrated REDOX waste.

Table 4.9. Calculated Porewater Trace Metal Composition for Water Extracts of Sediment from Borehole 299-E33-45 (2 pages)

Sample ID	Depth (ft bgs)[(a)]	Dilution Factor	Cr ug/L	As ug/L	Se ug/L	Tc 99 pCi/L	U 238 ug/L
Hanford H1 coarse sand							
01A	10.64	21.09	3.31E+01	6.79E+02	6.31E+01	<4.47E+04	4.41E+01
06A	20.84	17.43	8.28E-01	2.20E+02	1.93E+01	<3.70E+04	1.46E+01
11A	31.84	30.27	<3.78E+02	2.21E+02	(9.84E+00)	<6.42E+04	1.23E+01
Hanford H2 upper sand sequence							
16A	42.04	29.2	<3.65E+02	2.69E+02	(2.34E+01)	<6.19E+04	1.31E+01
21A	51.64	26.38	<3.30E+02	2.86E+02	(7.25E+00)	<5.59E+04	1.12E+01
27A	62.99	14.72	(7.21E+00)	1.74E+02	(4.41E+00)	<3.12E+04	4.34E+00
32A	71.24	25.83	<3.23E+02	2.04E+02	<6.46E+01	<5.48E+04	1.12E+01
33A	73.39	31.48	<3.93E+02	(6.83E+01)	(2.07E+01)	<6.67E+04	2.97E+04
H2 muddy very fine sand lens							
34A	75.65	4.91	(4.91E+00)	4.20E+01	1.64E+01	<1.04E+04	2.75E+03
34A-Dup	75.65	4.56	(5.27E+00)	4.06E+01	1.46E+01	<9.67E+03	2.68E+03
H2 middle sand sequence							
35A	78.19	40.97	(1.19E+01)	1.05E+03	(2.09E+01)	5.21E+03	2.24E+04
36A	79.34	32.28	<4.03E+02	4.95E+02	(1.05E+00)	(6.84E+04)	8.11E+04
40A	88.65	27.63	(2.44E+01)	2.22E+02	(4.32E+00)	(5.86E+04)	9.02E+03
44A	100.09	19.04	(1.67E+01)	4.31E+02	(2.07E+01)	<4.04E+04	1.15E+04
49A	111.14	25.85	(2.80E+01)	9.61E+02	(2.45E+01)	<2.19E+03	9.34E+04
53A	119.04	31.4	(1.24E+01)	8.78E+02	<7.85E+01	<2.26E+04	1.83E+05
H2 muddy very fine sand lens							
54C Fine	120.14	7.02	N/A	N/A	N/A	1.31E+05	6.58E+05
54C Dup Fine	120.14	9.27	N/A	N/A	N/A	9.21E+04	6.51E+05
54C Upper	120.14	14.98	N/A	N/A	N/A	(9.50E+04)	2.68E+05
54A	120.89	39.38	(4.41E+01)	3.41E+03	(5.02E+01)	1.09E+05	6.61E+05
H2 middle sand sequence (continued)							
54	121.24	36.16	N/A	N/A	N/A	9.93E+04	6.34E+05
55	121.34	6.77	N/A	N/A	N/A	1.56E+05	6.28E+05
56	122.32	33.95	N/A	N/A	N/A	(4.55E+04)	2.21E+05
61A	130.95	25.93	(2.42E+01)	3.85E+03	(9.27E+00)	1.32E+05	5.91E+05
67A	141.25	38.52	(4.55E+01)	7.32E+02	(2.31E+00)	2.82E+05	3.89E+05
72C	150.55	28.44	N/A	N/A	N/A	(3.95E+04)	2.03E+05
72A	151.55	33.05	<4.13E+02	2.51E+02	(4.30E+01)	3.35E+05	9.29E+04
73	152.7	30.98	N/A	N/A	N/A	1.32E+05	1.42E+05
75	156.2	33.88	N/A	N/A	N/A	5.36E+05	2.51E+05
77	159.1	28.82	N/A	N/A	N/A	1.60E+05	1.46E+05
78C	159.85	27.04	N/A	N/A	N/A	1.28E+05	1.42E+05
78A	160.85	26.29	<3.29E+02	(1.13E+02)	(2.74E+01)	3.49E+05	7.04E+04
81	165.55	21.84	N/A	N/A	N/A	1.36E+05	9.08E+04

Table 4.9. Calculated Porewater Trace Metal Composition for Water Extracts of Sediment from Borehole 299-E33-45 (2 pages)

Sample ID	Depth (ft bgs)(a)	Dilution Factor	Cr ug/L	As ug/L	Se ug/L	Tc 99 pCi/L	U 238 ug/L
H2–fine-very fine sand lens							
82A	168.65	6.17	(7.59E+00)	(2.99E+01)	(9.31E+00)	6.20E+04	5.32E+03
82A-Dup	168.65	6.17	(2.02E+00)	(2.70E+01)	(1.34E+01)	7.47E+04	4.69E+03
82	169.1	5.78	N/A	N/A	N/A	2.13E+04	4.36E+03
83D	169.55	12.01	N/A	N/A	N/A	(3.98E+05)	4.54E+05
Hanford H3 Lower sand unit							
83A	171.05	35.27	(6.53E+01)	3.27E+02	(1.86E+01)	<7.48E+04	4.80E+03
84A	173.35	31.43	<3.93E+02	3.07E+02	(2.38E+01)	<6.66E+04	7.77E+03
88A	181.65	21.76	(1.87E+01)	3.15E+02	(1.02E+01)	<4.61E+04	7.03E+04
93A	190.65	29.65	<3.71E+02	2.03E+02	(4.16E+01)	<6.29E+04	4.79E+04
99A	201.35	30.75	<3.84E+02	2.02E+02	(3.84E-01)	(5.21E+03)	1.91E+01
104A	211.42	29.56	(1.74E+01)	(1.63E+02)	(3.16E+01)	(3.01E+04)	6.28E+00
110D	217.95	34.26	N/A	N/A	N/A	7.84E+04	(1.71E+01)
PPlz Mud unit							
110A	219.45	5.32	(5.08E+00)	(1.72E+01)	2.27E+01	7.91E+04	2.76E+02
111A	221.75	4.03	(6.61E+00)	(8.11E+00)	2.20E+01	5.12E+04	7.13E+00
112A	223.65	5.31	(2.42E+00)	(1.78E+01)	2.89E+01	6.83E+04	1.69E+00
116A	231.45	4.13	(1.73E+00)	(1.17E+01)	1.48E+01	2.96E+04	1.25E+01
116A-Dup	231.45	4.14	(2.19E+00)	(1.11E+01)	1.63E+01	2.98E+04	1.69E+01
PPlg Gravelly unit							
122A	241.89	24.16	<3.02E+02	2.05E+02	(2.79E+01)	(8.20E+03)	8.70E+00
124A	245.25	33.06	<4.13E+02	2.69E+02	(1.72E+02)	<7.01E+04	4.79E+00
128A	251.75	23.88	(1.05E+01)	1.06E+02	(4.78E+01)	(1.11E+04)	5.07E+00
129A	253.65	23.18	<2.90E+02	1.05E+02	6.86E+01	(1.97E+04)	4.11E+01

(a) Multiply by 0.3048 to convert to meters
Depth represents the vertical depth in feet
ID notes: Dup represents a duplicate water extract on a separate aliquot of sediment
NA = not analyzed
Values in parentheses are below level of quantitation but dilutions and spectra looked adequate
Red type signifies that concentration is much higher than expected natural background values

Table 4.10. Comparison of Actual to Calculated (from 1:1 Water Extracts) Porewaters–Trace Metals

			Dilution Corrected Porewater				
Sample ID	**Depth (ft)(a)**	**Dilution Factor**	**Cr ug/L**	**As ug/L**	**Se ug/L**	**Tc-99 pCi/L**	**U-238 ug/L**
Hanford H2 upper sand sequence							
27A	62.99	14.72	7.21	174.18	(4.41)	<3.12E+04	4.34
27A-UFA		1	(1)	N/A	(81)	(6.78E+02)	(0.19)
33A	73.39	31.48	<3.93E+02	68.30	(20.69)	<6.67E+04	2.97E+04
33A-UFA		1	<20	N/A	(119)	(1.87E+02)	577
H2 muddy very fine sand lens							
34C-UFA	74.90	1	(2)	N/A	(19)	(2.88E+02)	2.99E+03
34A	75.65	4.91	4.91	41.99	16.4	<1.04E+04	2.75E+03
34A-Dup		4.56	5.27	40.56	14.6	<9.67E+03	2.68E+03
34A-UFA		1	(12)	N/A	(102)	(8.31E+02)	3.25E+03
H2 middle sand sequence							
44B-UFA	99.59	1	(12)	N/A	(39)	(1.49E+03)	4.51E+03
44A	100.09	19.04	16.66	430.79	(20.71)	<4.04E+04	1.15E+04
H2 muddy very fine sand lens							
54A	120.89	14.98	(4.41E+01)	3.41E+03	(5.02E+01)	1.09E+05	6.61E+05
H2 middle sand sequence (continued)							
54	121.24	39.38	NA	NA	NA	9.93E+04	6.34E+05
55	121.34	6.77	NA	NA	NA	1.56E+05	6.28E+05
55-UFA		1	8.36E+02	2.40E+03	<100	2.4E+05	6.69E+05
56	122.32	33.95	N/A	N/A	N/A	(4.55E+04)	2.21E+05
61AB-UFA	130.7	1	3.91E+02	2.85E+03	1.61.E+02	4.1E+04	4.40E+05
61A	130.95	25.93	(2.42E+01)	3.85E+03	(9.27E+00)	1.32E+05	5.91E+05
64-UFA	135.5	1	1.72E+03	3.56E+03	<1000	3.6E+05	2.48E+06
65-UFA	137.1	1	1.18E+03	9.52E+02	<1000	2.9E+05	1.35E+06
67A	141.25	38.52	(4.55E+01)	7.32E+02	(2.31E+00)	2.82E+05	3.89E+05
Fine-very fine sand lens							
82C-UFA	167.65	1	(16)	N/A	<5000	7.16E+05	7.39E+03
82A	168.65	6.17	7.59	29.90	(9.31)	6.20E+04	5.32E+03
82A-Dup		6.17	2.02	26.99	(13.38)	7.47E+04	4.69E+03
82A-UFA		1	480	N/A	<5000	5.87E+04	7.80E+03
PPlz Mud Unit							
110B-UFA	218.95	1	(1)	N/A	<5000	1.01E+05	1.19E+03
110A	219.45	5.32	5.08	17.21	22.7	7.91E+04	276
112B-UFA	222.65	1	(11)	N/A	<5000	7.56E+04	27.2
112A	223.65	5.31	2.42	17.82	28.9	6.83E+04	1.69
116C-UFA	230.45	1	<20	N/A	<5000	9.16E+03	67.1
116A	231.45	4.13	1.73	11.71	14.8	2.96E+04	12.5
116A-Dup		4.14	2.19	11.14	16.3	2.98E+04	16.9

(a) Multiply by 0.3048 to convert to meters

Values in parentheses are below quantification value but data and spectra appear useable

ID notes: NA = not analyzed ; UFA represents the actual porewater obtained by ultracentrifugation

Blue type = actual porewater concentration is significantly lower than calculated concentration from 1:1 sediment to water extract

Red type signifies that concentration is much higher than expected natural background values

Green shading indicates samples for which water extracts and ultracentrifugation were both performed on sediment aliquots from the same sleeve

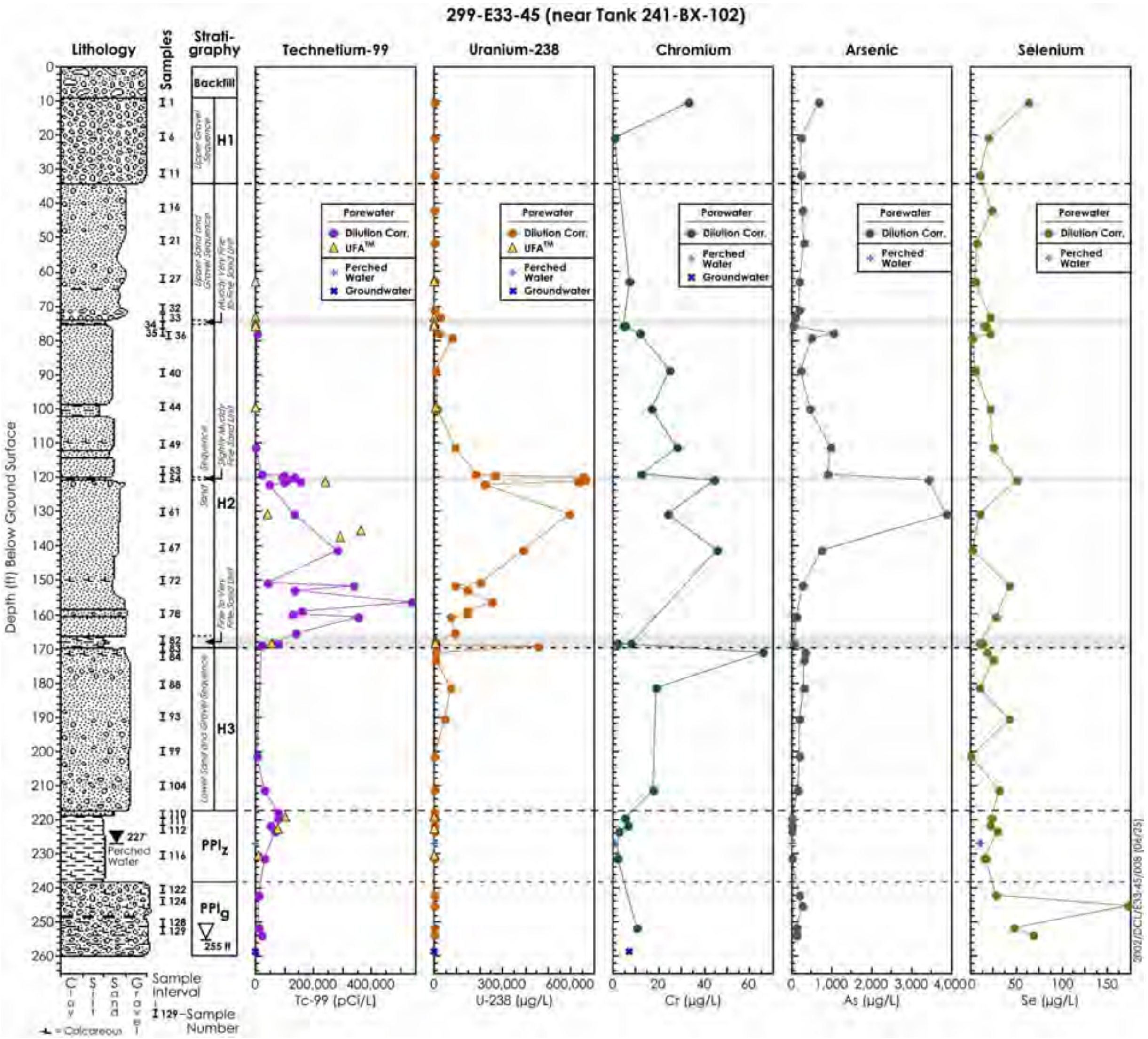

Figure 4.5. Trace Metals Pore Fluid (Calculated from Sediment-to-Water Extracts) and Actual Porewaters for BX-102 Borehole Sediment

4.2.3 Porewater Solute Ratios

Besides plotting individual constituent porewater profiles versus depth, Table 4.11 and Table 4.12 show ratios of some of the major constituents in bismuth phosphate metals waste versus chloride, a constituent that is not present in the waste stream at high concentrations. The ratios for several key parameters versus each other are shown in Table 4.13 and Table 4.14. Ratios have the units of pCi/mg for the technetium-99 to chloride, µg/mg for the uranium to chloride and mg/mg for the rest. The ratios in Table 4.11 are color coded as follows. Because many of the water extracts did not contain measurable technetium-99, ratios using the technetium-99 detection limit in the numerator become less than values. These values are shaded in dark gray because the information is not as useful. The ratios that are shaded in pale yellow indicate values that are higher than background values that are determined for porewaters where it is not believed that tank overfill fluids are present. Therefore, ratios highlighted in pale yellow represent samples where some tank overfill fluids may be present. The bright pink shaded values represent samples where the constituent in the numerator is present at its highest values, strongly suggesting the presence of tank BX-102 overfill fluids in the vadose zone sediments. The ratios of bismuth phosphate constituents to chloride are shown in Figure 4.6 versus lithology and depth. Values for some ratios for the estimated waste streams in tank BX-102 at the time of the 1951 overfill and the estimated waste stream in tank BX-101 at the time (1970 to 1972) of the suspected junction box leak are also shown in the figures. The ratios for nearby cribs (i.e., 216-B7A, 216-B7B, and 216-B8) are the same as the 1951 overfill because the waste disposed to the cribs was supernatant from the BX-101/BX-102/BX-103 cascade line during the 1950s. That is, unlike WMA S-SX, the wastes disposed to nearby cribs and trenches at the BX tank farm have the same chemical composition as the BX tanks during the time period when bismuth phosphate wastes were present. Therefore, the component ratios that could be used as a key discrimination tool at WMA S-SX to differentiate crib waste from tank waste in the vadose zone porewater and groundwater are not as useful for differentiating between crib and tank sources at the BX tank farm. However, because there appears to be two types of tank waste that leaked in the area just east of tanks BX-101 and BX-102, the ratio tool might be useful for differentiating the two waste types. Table 4.11 and Table 4.12 (for the UFA squeezings and perched water and groundwater) also lists the various ratios for the metals waste present in BX-102 during 1951 and the ratios for the cesium recovery waste present in tank BX-101 in the late 1960s and early 1970s. See the WMA B-BX-BY FIR Section 3.2.1.6 (Knepp 2002a) for more discussion about the two waste streams and hypothesized leak events.

Within the shallow Hanford H2 upper sand sequence (between 10 and 20 ft bgs) there is indication of some excess sodium. This might represent surface or shallow pipeline leaks of high sodium solutions. There are no other relatively high ratios noted in the upper sand sequence of H2 or the thin fine-grained lens between 74.5 to 75.5 ft (33.8 to 36.6) bgs. Below this fine-grained lens within the H2 middle sand sequence there are very high ratios for uranium, nitrate, sodium, and technetium to chloride starting between 111 and 120 ft bgs, dependent upon constituent. There is an indication of tank overfill liquids throughout most of this H2 middle sand sequence. The sulfate to chloride ratio is high in a thinner zone deeper in this Hanford H2 middle sand sequence. The uranium-chloride and sodium-chloride ratios in this H2 middle sand sequence are most similar to the metal waste composition that leaked from tank BX-102 in 1951 but technetium-chloride and nitrate-chloride ratios are lower than expected for metals waste composition. Conversely, the sulfate-chloride ratio is too large for either waste stream in this stratum. One plausible explanation is that potable water, which contains chloride and sulfate, might have mixed with the metals waste changing the ratios of the more mobile anions and but impacting to a lesser extent the reactive uranium and sodium. It would appear that the porewaters in the H2 middle sand sequence are closer to being 1951 metals waste than 1971 cesium recovery waste but several of the ratios do not currently correspond to either waste stream, if the waste stream composition estimates are correct. Whatever the source, there appears to be too little technetium-99 in the porewaters for either waste composition.

There is no indication of significant amounts of tank overfill fluid in the strata below the Hanford H2 middle sand sequence suggesting that the bulk of the leaked fluid resides “sandwiched” between the thin fine-grained lenses between 120 and 167 ft (36.6 to 50.9 m) bgs all within the H2 middle sand sequence.

One method to evaluate vertical migration of mobile tank overfill constituents would be to plot ratios of the key contaminants versus nitrate or some other conservative (non-sorbing) constituent in the tank fluid. If tank liquor dilution with extant porewater, potable water line leaks, or recharge water were the only reasons for the decrease in concentrations for all the mobile constituents, then the ratios of one to another should remain constant from the source to the farthest extent of migration.

The porewater ratios of the key bismuth phosphate metals waste constituents versus each other are shown in Table 4.13 and Table 4.14 and Figure 4.7 and Figure 4.8. These ratios have the units of pCi/mg for the technetium-99 to any stable chemical, µg/mg for the uranium to other stable constituents, and mg/mg for chemicals versus each other. For the ratios where technetium or uranium are in the denominator, the units are the reciprocal of those just stated. Also shown are the ratios for the two waste streams that are plausible sources of the vadose zone contamination. The data for the waste streams are taken from Jones et al. 2001.

The ratios in Table 4.13 are color coded as follows. Because many of the water extracts did not contain measurable technetium-99, ratios using the technetium-99 detection limit become either less than values (when ^{99}Tc is in the numerator) or greater than values (when ^{99}Tc is in the denominator). These values are shaded in dark gray because the information is not as useful. Those ratios that are bracketed by parentheses indicate that one or both of the constituents were present at low concentrations that may be less reliable than ratios for situations when the analytes were present at large enough concentrations to yield precise data. The ratios that are shaded in pale yellow indicate values that are higher than background values (determined for porewaters where it is not believed that tank overfill fluids are present). The pale yellow ratios represent samples where the tank overfill constituent in the numerator appears to be present in higher than normal concentrations relative to both the constituent in the denominator and background where neither may be present above natural conditions. The bright pink shaded values represent samples where the constituent in the numerator is present at its highest values relative to the constituent in the denominator. If the two constituents were from one source, not interacting with the sediment, and were both migrating vertically through the vadose zone, the ratios would remain fairly constant regardless of the possibility that uncontaminated water (from water line leaks or natural recharge) might be diluting the contaminant plume.

Within the shallow Hanford H2 upper sand sequence, between 10 and 20 ft bgs, there is indication of some excess sodium relative to nitrate. This might represent surface or shallow pipeline leaks of high sodium solutions. In the upper sand sequence of the H2 unit at depth 73.4 ft bgs, there is one sample (i.e., sample 33A) that shows elevated water leachable uranium compared to nitrate and sulfate. The technetium-99 concentrations in this sample were too low to quantitate. This high uranium ratio to the two most common anions in the tank waste fluid might be caused by the horizontal migration of some BX-102 tank overfill solution (bismuth phosphate metals waste) right above the contact with the thin fine-grained (likely less permeable) lens between 74.5 and 75.5 ft bgs. It is unclear why uranium would migrate faster than nitrate.

There are no relatively high ratios noted in the thin fine-grained lens at 74 to 75 ft bgs. Below this fine-grained lens within the H2 middle sand sequence, there are very high ratios for technetium to nitrate in two samples (i.e., samples 36A and 40A) where the technetium concentrations are less precise. If these two values are ignored, the rest of the technetium to nitrate ratios in the H2 middle sand sequence average 100 ±25 pCi/mg. This suggests that technetium and nitrate could be migrating vertically at this location without interaction with the sediments. If the technetium and nitrate compositions of the metals waste are accurately known from old bismuth phosphate records, the ratio should be ~287 pCi/mg. This is about 3 times larger than the ratio observed in the sediment porewater. This is another indication of lower than expected technetium-99. The other possible waste stream from the 1971 cesium recovery waste has even more technetium relative to nitrate so mixing of the two waste streams does not explain the observed low technetium to nitrate ratio.

The uranium to nitrate ratio is somewhat constant at a value of 500 ug/mg in the zone between 111 and 151 ft bgs but then sharply drops to a value of 80 ± 20 ug/mg where it remains over the depths of 152 to 167.2 ft bgs (the contact with the fine-grained lens separating H2 unit from H3). The ratio for the metals waste should be 826 ug/mg suggesting that some uranium has been removed relative to nitrate in the entire profile. Geochemical reactions wherein uranium adsorbs or precipitates in the sediment are plausible explanations. The observed uranium to nitrate ratio in the porewaters is much too high to be related to the 1971 cesium recovery waste stream.

The sodium to nitrate ratio is high in a thin zone between 78 and 80 ft bgs at which point it drops down to values that range between 0.7 and 18 mg/mg within the H2 middle sand sequence where it is believed most of the tank fluid resides. The decreasing ratio suggests that sodium is interacting with the sediments and not traveling as deep as the nitrate. The waste stream sodium to nitrate ratio for the two streams that are suspected to be present range from 1.4 to 2 mg/mg so neither waste stream could account for the observed ratio being much higher.

Between 120 ft bgs and 150 ft bgs, the uranium to techetium-99 ratio is approximately 5 ± 2 ug/pCi in the porewater, the ratio then drops to values between 0.2 to 1 ug/pCi for the remaining 17 ft of the H2 middle sand sequence. This suggests that uranium is interacting with the sediment more than the technetium-99. Given that it is believed the technetium inventory is low, the observed uranium-technetium ratio is much closer to the metals waste ratio than cesium recovery waste.

There is no consistent value for the sodium to technetium ratio in the Hanford H3 middle sand sequence. Based on geochemical knowledge, the ratio would decrease with depth if porewater flow were vertical. The uranium to sodium ratio shows maximum values between 119 and 150 ft bgs suggesting that uranium is more mobile than sodium. The uranium to sulfate and technetium-99 to sulfate ratios both show high values between 111 and 141 ft bgs. Below this depth, the ratios both decrease. But as shown in Figure 4.2a and Table 4.11, the sulfate concentrations dramatically increase at about 150 ft bgs compared to values in shallower porewater. Thus, the ratios of other constituents to sulfate should decrease near 150 ft bgs. All the ratios versus sulfate are closer to being from the 1951 metals waste composition than the 1971 cesium recovery waste.

There are no large ratio values in Table 4.11 through Table 4.14 for the fine-grained lens that separates the H2 unit from the deeper H3 unit that would suggest the presence of tank fluids. Deeper within the Hanford H3 unit and Plio-Pleistocene units, there are a few porewater samples that appear to show elevated uranium concentrations versus nitrate but there is no obvious trend. There is, however, a zone between 211 ft (64.3 m) bgs and the perched water found at 227 ft (69.2 m) bgs where the technetium-99 to nitrate ratio ranges from 40 to 90 pCi/mg. Above and below this zone, the ratio is 16 to 50 pCi/mg. Shallower, where there are obvious tank overfill fluids present, this ratio averaged 100 ± 25 pCi/mg. These data suggest that the technetium in porewaters above and below the zone at 211 to 227 ft bgs has interacted some with sediments if flow was vertical. The ratio in the zone between 211 to 227 ft bgs is somewhat lower than in the main tank leak plume but still greater than in zones right above and below. This change in technetium-99 to nitrate ratio might be explained by two different sources for the water that carries the contaminants. As stated previously, the technetium to nitrate ratios for the two plausible tank waste compositions are much higher, 287 and 1150 pCi/mg for the metals waste and cesium recovery waste.

The ratios of technetium-99 to nitrate, uranium to nitrate, uranium to technetium are plotted in Figure 4.7 and Figure 4.8 for the dilution corrected porewaters, ultracentrifuged porewaters, perched water, and groundwater as a function of depth. The technetium-99 to nitrate ratio for the perched water at 227 ft bgs is ~1.8 pCi/mg and for the groundwater at 258.7 ft bgs is 43 pCi/mg. This suggests that there may be a source of water that contains nitrate but not technetium that is feeding the perched water zone but it has not changed the ratio in the surrounding sediments nor diluted the groundwater that is found only 21 ft deeper. The data certainly do not present a clear picture on what might be occurring in the Plio-Pleistocene units. That is, whether this zone is a mixture of two or more waters with different chemical compositions or a zone of sediment water interactions that change the composition of porewater.

The comparable ratios for the ultracentrifuged waters are shown in Table 4.12 and Table 4.14. The data are fairly consistent with the discussions based on Table 4.11 and Table 4.13. Overall, the ratio approach where the main contaminants from the leaking tank are ratioed against each other does not give a clear picture on the geochemistry of the vadose zone porewaters at borehole 299-E33-45. In general, the majority of the ratios are closer to being from the 1951 metals waste solution that escaped tank BX-102 during a cascading accident. It is wondered whether the flow of water in the vadose zone sediments at this borehole may in fact be dominated by horizontal gradients caused by the thin fine-grained lenses. If such is the case, then the simple approaches just described have little relevancy. The ratio approach was of much more value in interpreting the porewater data at the SX tank farm (Serne et al. 2002b, c, d).

Table 4.11. Ratio of the Mobile Contaminants in Bismuth Phosphate Metals Waste to Chloride Found in Dilution Corrected 1:1 Water to Sediment Extracts (2 pages)

Sample ID	Depth[a] Ft bgs	U/Cl ug/mg	NO_3/Cl mg/mg	^{99}Tc/Cl pCi/mg	Na/Cl mg/mg	SO_4/Cl mg/mg
1951 Metal Waste		6.12E+04	7.41E+01	2.13E+04	1.52E+02	4.98E+01
1971 Cs Recovery		1.19E+02	2.58E+01	2.97E+04	3.66E+01	2.72E+00
H1 Coarse Sand						
01A	10.64	1.84E+00	9.17E-01	<1.86E+03	4.07E+01	1.83E+01
06A	20.84	1.22E+00	2.00E+00	<3.08E+03	4.52E+01	1.45E+01
11A	31.84	6.85E-01	3.22E+00	<3.57E+03	1.40E+01	1.71E+01
H2 Upper Sand Sequence						
16A	42.04	6.22E-01	6.62E+00	<2.95E+03	1.32E+01	1.62E+01
21A	51.64	7.47E-01	8.87E+00	<3.73E+03	1.87E+01	2.01E+01
27A	62.99	3.34E-01	1.12E+01	<2.40E+03	1.48E+01	2.71E+01
32A	71.24	2.12E-01	5.49E+00	<1.03E+03	6.28E+00	2.70E+01
33A	73.39	5.03E+02	4.15E+00	<1.13E+03	6.92E+00	3.33E+01
H2-Muddy Very Fine Sand Lens						
34A	75.65	1.73E+01	7.99E-01	<6.55E+01	7.48E-01	2.64E+00
34A-Dup	75.65	1.73E+01	8.13E-01	<6.24E+01	7.68E-01	2.69E+00
H2 Middle Sand Sequence						
35A	78.19	2.46E+02	6.48E-01	5.73E+01	1.23E+01	5.64E+00
36A	79.34	1.31E+03	1.00E+00	1.10E+03	5.13E+01	6.18E+00
40A	88.65	2.58E+02	2.80E+00	1.67E+03	1.92E+01	5.86E+00
44A	100.09	8.85E+01	1.40E+00	<3.11E+02	1.63E+01	2.45E+00
49A	111.14	4.92E+03	1.37E+01	<1.15E+02	2.24E+02	1.63E+01
53A	119.04	8.32E+03	4.83E+01	<1.03E+03	1.08E+02	2.14E+01
54C Fine	120.14	1.99E+04	3.69E+01	3.96E+03	7.00E+01	2.58E+01
54C DUP Fine	120.14	2.50E+04	3.42E+01	3.54E+03	8.50E+01	2.31E+01
54C Upper	120.14	6.88E+03	3.30E+01	2.44E+03	4.46E+01	2.03E+01
54A	120.89	1.89E+04	3.60E+01	3.10E+03	1.91E+02	2.45E+01
54	121.24	2.11E+04	2.65E+01	3.31E+03	1.75E+02	2.26E+01
55	121.34	1.65E+04	3.59E+01	4.10E+03	6.21E+01	2.26E+01
56	122.32	1.23E+04	2.43E+01	2.53E+03	2.56E+02	1.82E+01
61A	130.95	2.04E+04	3.84E+01	4.56E+03	1.73E+02	2.94E+01
67A	141.25	7.07E+03	4.35E+01	5.13E+03	7.33E+01	3.23E+01
72C	150.55	1.45E+04	3.04E+01	2.82E+03	5.53E+02	2.87E+03
72A	151.55	6.73E+02	2.33E+01	2.43E+03	7.61E+01	1.68E+02
73	152.7	1.75E+03	2.83E+01	1.63E+03	1.01E+02	2.94E+02
75	156.2	1.17E+03	2.88E+01	2.51E+03	5.56E+01	1.42E+02
77	159.1	2.87E+03	2.58E+01	3.14E+03	1.48E+02	3.91E+02
78C	159.85	2.97E+03	2.36E+01	2.68E+03	1.79E+02	3.45E+02

Table 4.11. Ratio of the Mobile Contaminants in Bismuth Phosphate Metals Waste to Chloride Found in Dilution Corrected 1:1 Water to Sediment Extracts (2 pages)

Sample ID	Depth$^{(a)}$ Ft bgs	U/Cl ug/mg	NO$_3$/Cl mg/mg	^{99}Tc/Cl pCi/mg	Na/Cl mg/mg	SO$_4$/Cl mg/mg
78A	160.85	8.58E+02	3.21E+01	4.26E+03	1.08E+02	2.35E+02
81	165.55	1.54E+03	2.45E+01	2.31E+03	1.68E+01	7.20E+00
H2-Fine Very Fine Sand Lens						
82A	168.65	4.83E+01	1.15E+01	5.64E+02	1.88E+00	6.23E+00
82A-Dup	168.65	3.67E+01	1.10E+01	5.84E+02	1.70E+00	5.98E+00
82	169.1	3.07E+01	9.12E+00	1.50E+02	1.30E+00	4.89E+00
83D	169.55	3.34E+03	2.20E+01	2.93E+03	2.72E+01	4.35E+01
H3 Unit						
83A	171.05	6.86E+01	7.80E+00	<1.07E+03	5.44E+00	9.90E+00
84A	173.35	1.29E+02	6.93E+00	<1.11E+03	6.67E+00	1.05E+01
88A	181.65	6.17E+02	4.18E+00	<4.05E+02	7.03E+00	5.54E+00
93A	190.65	5.51E+02	6.84E+00	<7.22E+02	3.54E+00	7.78E+00
99A	201.35	1.44E-01	5.82E+00	3.92E+01	2.78E+00	6.71E+00
104A	211.42	4.39E-02	5.62E+00	2.10E+02	2.44E+00	4.98E+00
Plio-Pleistocene Mud (PPlz)						
110D	217.95	1.04E-01	4.94E+00	4.78E+02	2.43E+00	6.48E+00
110A	219.45	2.38E+00	8.53E+00	6.82E+02	1.63E+00	9.48E+00
111A	221.75	5.80E-02	1.06E+01	4.16E+02	1.35E+00	7.46E+00
112A	223.65	1.43E-02	9.61E+00	5.79E+02	1.14E+00	4.91E+00
116A	231.45	1.25E-01	1.37E+01	2.96E+02	1.47E+00	6.03E+00
116A-Dup	231.45	1.70E-01	1.35E+01	3.01E+02	1.52E+00	6.16E+00
Plio-Pleistocene Gravelly Sand (PPlg)						
122A	241.89	1.98E-01	1.11E+01	1.86E+02	8.91E+00	1.40E+01
124A	245.25	1.41E-01	3.12E+00	<2.06E+03	1.44E+01	3.16E+01
128A	251.75	7.81E-02	1.00E+01	1.71E+02	5.11E+00	1.01E+01
129A	253.65	9.04E-03	1.75E-01	4.33E+00	3.61E-02	1.53E+00

Pink shaded values indicate high amount of tank fluid contamination is present
Grey shading indicates values are less useful because of non-detects
Yellow shaded values indicate low amount of tank fluid contamination is present

Table 4.12. Ratio of the Mobile Contaminants in Bismuth Phosphate Metals Waste to Chloride Found in Actual Porewaters, Perched Water, and Groundwater

Sample ID	**Depth (ft)(a)**	**U/Cl ug/mg**	**NO$_3$/Cl mg/mg**	**^{99}Tc/Cl pCi/mg**	**Na/Cl mg/mg**	**SO$_4$/Cl mg/mg**
H2 Upper Sand Sequence						
27A-UFA	62.99	(6.35.E-03)	10.41	(2.27E+01)	4.28E-01	19.89
33A-UFA	73.39	8.61	3.15	(2.79E+00)	2.11E-01	18.36
34C-UFA	74.90	16.40	0.78	(1.58E+00)	4.14E-01	2.27
H2-Muddy Very Fine Sand Lens						
34A-UFA	75.65	22.86	0.87	(5.84E+00)	7.17E-01	2.25
H2 Middle Sand Sequence						
44B-UFA	99.59	29.19	0.60	(9.66E+00)	3.35E+00	2.00
55-UFA	121.34	11992	37.22	4.29E+03	5.56E+01	26.89
61AB-UFA	130.7	27041	21.67	2.50E+03	7.52E+01	15.48
64-UFA	135.5	20577	32.64	3.01E+03	3.77E+01	27.03
65-UFA	137.1	13739	32.58	2.97E+03	3.39E+01	24.22
82C-UFA	167.65	76.30	28.06	7.39E+03	1.51E+00	23.59
H2-Fine Very Fine Sand Lens						
82A-UFA	168.65	70.18	10.18	5.28E+02	9.54E-01	5.56
Plio-Pleistocene Mud (PPlz)						
110B-UFA	218.95	17.36	6.76	1.48E+03	1.55E+00	8.03
112B-UFA	222.65	0.38	9.79	1.05E+03	1.38E+00	4.00
Perched	227	0.340	12.06	21.10	1.09	6.08
116C-UFA	230.45	1.14	11.11	1.56E+02	1.98E+00	7.38
Plio-Pleistocene Gravelly Sand (PPlg)						
GW(1)	258.7	1.272	6.87	303.90	2.36	5.27
GW(2)	258.7	1.271	6.76	283.53	2.16	5.08
1951 Metal Waste		6.12E+04	7.41E+01	2.13E+04	1.52E+02	4.98E+01
1971 Cs Recovery		1.19E+02	2.58E+01	2.97E+04	3.66E+01	2.72E+00

Parentheses indicate one or both of the constituents are present near its detection limit so values are less precise
Perched = perched water (excess standing water) extracted from borehole casing with bailer during hiatus in drilling
GW = one sample of groundwater was taken but submitted to two independent laboratories for analyses (1) and (2)

Table 4.13. Ratio of Main Bismuth Phosphate Constituents in Dilution Corrected 1:1 Water Extracts Versus Each Other (3 pages)

Sample ID	Depth ft [(a)]	^{99}Tc/NO$_3$ pCi/mg	U/NO$_3$ ug/mg	Na/NO$_3$ mg/mg	U/^{99}Tc ug/pCi	Na/^{99}Tc mg/pCi	U/Na ug/mg	U/SO$_4$ ug/mg	^{99}Tc/SO$_4$ pCi/mg	Na/SO$_4$ mg/mg
1951 Metal Waste		2.87E+02	826	2.04	2.88	7.11E-03	405	1.23E+03	4.28E+02	3.05
1971 Cs Recovery		1.15E+03	4.6	1.42	4.03E-03	1.23E-03	3.28	4.38E+01	1.09E+04	13.5
H1 Coarse Sand										
01A	10.64	<2032.3	2.01	44.4	>9.9E-04	>2.2E-02	2.01E+00	1.01E-01	<1.02E+02	2.23E+00
06A	20.84	<1539.7	0.61	22.6	>4.0E-04	>1.5E-02	6.08E-01	8.39E-02	<2.12E+02	3.11E+00
11A	31.84	<1106.5	0.21	4.3	>1.9E-04	>3.9E-03	2.13E-01	4.01E-02	<2.08E+02	8.18E-01
H2 Upper Sand Sequence										
16A	42.04	<445.4	0.09	2.0	>2.1E-04	>4.5E-03	9.40E-02	3.84E-02	<1.82E+02	8.18E-01
21A	51.64	<420.5	0.08	2.1	>2.0E-04	>5.0E-03	8.43E-02	3.72E-02	<1.86E+02	9.30E-01
27A	62.99	<213.7	0.03	1.3	>1.4E-04	>6.2E-03	2.97E-02	1.23E-02	<8.86E+01	5.48E-01
32A	71.24	<188.2	0.04	1.1	>2.1E-04	>6.1E-03	3.86E-02	7.86E-03	<3.83E+01	2.33E-01
33A	73.39	<272.4	121.2	1.7	>4.5E-01	>6.1E-03	1.21E+02	1.51E+01	<3.40E+01	2.08E-01
Muddy Very Fine Sand Lens										
34A	75.65	<82.0	21.7	0.9	>2.6E-01	>1.1E-02	2.17E+01	6.55E+00	<2.48E+01	2.83E-01
34A-Dup	75.65	<76.7	21.3	0.9	>2.8E-01	>1.2E-02	2.13E+01	6.44E+00	<2.32E+01	2.85E-01
H2 Middle Sand Sequence										
35A	78.19	88.3	379.8	19	4.2992	2.15E-01	3.80E+02	4.37E+01	1.02E+01	2.18E+00
36A	79.34	(1103.7)	1308.4	51.3	1.1855	4.65E-02	1.31E+03	2.12E+02	(179)	8.30E+00
40A	88.65	(597.8)	92	6.8	0.154	1.15E-02	9.20E+01	4.40E+01	(286)	3.27E+00
44A	100.09	<221.8	63.2	11.6	>2.8E-01	>5.3E-02	6.32E+01	3.61E+01	<1.27E+02	6.65E+00
49A	111.14	<8.4	359.3	16.4	>4.3E+01	>1.9E+00	3.59E+02	3.02E+02	<7.09E+00	1.38E+01
53A	119.04	<21.3	172.4	2.2	>8.1E+00	>1.1E-01	1.72E+02	3.90E+02	<4.82E+01	5.06E+00
54C Fine	120.14	(107.1)	539.7	1.9	5.0405	1.77E-02	5.40E+02	7.72E+02	(153)	2.71E+00
54C DUP Fine	120.14	103.5	731.1	2.5	7.0664	2.40E-02	7.31E+02	1.08E+03	1.53E+02	3.68E+00
54C Upper	120.14	(73.9)	208.7	1.4	2.8234	1.83E-02	2.09E+02	3.39E+02	(120)	2.20E+00

Table 4.13. Ratio of Main Bismuth Phosphate Constituents in Dilution Corrected 1:1 Water Extracts Versus Each Other (3 pages)

Sample ID	Depth ft [(a)]	^{99}Tc/NO$_3$ pCi/mg	U/NO$_3$ ug/mg	Na/NO$_3$ mg/mg	U/^{99}Tc ug/pCi	Na/^{99}Tc mg/pCi	U/Na ug/mg	U/SO$_4$ ug/mg	^{99}Tc/SO$_4$ pCi/mg	Na/SO$_4$ mg/mg
54A	120.89	86.2	525.3	5.3	6.0946	6.16E-02	5.25E+02	7.71E+02	1.26E+02	7.79E+00
54	121.24	124.8	796.7	6.6	6.3839	5.29E-02	7.97E+02	9.34E+02	1.46E+02	7.75E+00
55	121.34	114.2	460.3	1.7	4.0295	1.51E-02	4.60E+02	7.30E+02	1.81E+02	2.74E+00
56	122.32	(103.8)	504.5	10.5	4.858	1.01E-01	5.04E+02	6.76E+02	(139)	1.41E+01
61A	130.95	118.5	530.2	4.5	4.4744	3.79E-02	5.30E+02	6.94E+02	1.55E+02	5.88E+00
67A	141.25	118.1	162.7	1.7	1.378	1.43E-02	1.63E+02	2.19E+02	1.59E+02	2.27E+00
72C	150.55	(92.8)	476.6	18.2	5.134	1.96E-01	4.77E+02	5.05E+00	(0.984)	1.93E-01
72A	151.55	104.1	28.9	3.3	0.2776	3.14E-02	2.89E+01	4.01E+00	1.44E+01	4.53E-01
73	152.7	57.8	61.9	3.6	1.071	6.15E-02	6.19E+01	5.97E+00	5.57E+00	3.43E-01
75	156.2	87.1	40.8	1.9	0.4688	2.22E-02	4.08E+01	8.27E+00	1.76E+01	3.92E-01
77	159.1	122	111.5	5.7	0.9136	4.70E-02	1.11E+02	7.34E+00	8.04E+00	3.78E-01
78C	159.85	113.3	125.6	7.6	1.1092	6.69E-02	1.26E+02	8.60E+00	7.76E+00	5.19E-01
78A	160.85	132.7	26.7	3.4	0.2014	2.54E-02	2.67E+01	3.65E+00	1.81E+01	4.61E-01
81	165.55	94.2	62.8	0.7	0.6661	7.25E-03	6.28E+01	2.14E+02	3.21E+02	2.33E+00
Fine Very Fine Sand Lens										
82A	168.65	49.1	4.2	0.2	0.0858	3.34E-03	4.21E+00	7.76E+00	9.05E+01	3.02E-01
82A-Dup	168.65	53	3.3	0.2	0.0628	2.90E-03	3.33E+00	6.13E+00	9.77E+01	2.84E-01
82	169.1	16.4	3.4	0.1	0.2046	8.69E-03	3.36E+00	6.28E+00	3.07E+01	2.67E-01
83D	169.55	(132.9)	151.5	1.2	1.1404	9.30E-03	1.52E+02	7.68E+01	(67.3)	6.26E-01
H3 Unit										
83A	171.05	<136.9	8.8	0.7	>6.4E-02	>5.1E-03	8.80E+00	6.93E+00	<1.08E+02	5.50E-01
84A	173.35	<160.2	18.7	1	>1.2E-01	>6.0E-03	1.87E+01	1.23E+01	<1.06E+02	6.35E-01
88A	181.65	<96.7	147.4	1.7	>1.5E+00	>1.7E-02	1.47E+02	1.11E+02	<7.31E+01	1.27E+00
93A	190.65	<105.6	80.5	0.5	>7.6E-01	>4.9E-03	8.05E+01	7.08E+01	<9.28E+01	4.55E-01
99A	201.35	(6.7)	0.02	0.5	0.0037	7.10E-02	2.47E-02	2.14E-02	(5.84)	4.14E-01

Table 4.13. Ratio of Main Bismuth Phosphate Constituents in Dilution Corrected 1:1 Water Extracts Versus Each Other (3 pages)

Sample ID	Depth ft [(a)]	^{99}Tc/NO$_3$ pCi/mg	U/NO$_3$ ug/mg	Na/NO$_3$ mg/mg	U/^{99}Tc ug/pCi	Na/^{99}Tc mg/pCi	U/Na ug/mg	U/SO$_4$ ug/mg	^{99}Tc/SO$_4$ pCi/mg	Na/SO$_4$ mg/mg
104A	211.42	(37.5)	0.01	0.4	0.0002	1.16E-02	7.82E-03	8.82E-03	(42.2)	4.90E-01
Plio-Pleistocene Mud (PPlz)										
110D	217.95	96.8	0.02	0.5	0.0002	5.07E-03	2.11E-02	1.61E-02	7.39E+01	3.75E-01
110A	219.45	79.9	0.28	0.2	0.0035	2.39E-03	2.79E-01	2.51E-01	7.19E+01	1.72E-01
111A	221.75	39.2	0.01	0.1	0.0001	3.24E-03	5.46E-03	7.77E-03	5.58E+01	1.81E-01
112A	223.65	60.3	0.00	0.1	0.0000	1.98E-03	1.49E-03	2.92E-03	1.18E+02	2.33E-01
116A	231.45	21.6	0.01	0.1	0.0004	4.96E-03	9.11E-03	2.07E-02	4.91E+01	2.44E-01
116A-Dup	231.45	22.3	0.01	0.1	0.0006	5.03E-03	1.26E-02	2.77E-02	4.89E+01	2.46E-01
Plio-Pleistocene Gravelly Sand (PPlg)										
122A	241.89	(16.8)	0.02	0.8	0.0011	4.78E-02	1.79E-02	1.42E-02	(13.3)	6.38E-01
124A	245.25	<661.2	0.05	4.6	>6.8E-05	>7.0E-03	4.52E-02	4.46E-03	<6.52E+01	4.54E-01
128A	251.75	(17.1)	0.01	0.5	0.0005	2.98E-02	7.78E-03	7.76E-03	(17)	5.08E-01
129A	253.65	(24.8)	0.05	0.2	0.0021	8.34E-03	5.18E-02	5.93E-03	(2.84)	2.37E-02

Parentheses indicate one or both of the constituents are present near its detection limit so values are less precise
> = value in denominator is below detection limit
< = value in numerator is below detection limit
Pink shaded values indicate high amount of tank fluid contamination is present
Grey shading indicates values are less useful because of non-detects
Yellow shaded values indicate low amount of tank fluid contamination is present

Table 4.14. Ratio of Main Mobile Bismuth Phosphate Constituents in Porewater, Perched Water, and Groundwater Versus Each Other

Sample ID	**Depth ft[(a)]**	**^{99}Tc/NO$_3$ pCi/mg**	**U/NO$_3$ ug/mg**	**Na/NO$_3$ mg/mg**	**U/^{99}Tc ug/pCi**	**Na/^{99}Tc mg/pCi**	**U/Na ug/mg**	**U/SO$_4$ ug/mg**	**^{99}Tc/SO$_4$ pCi/mg**	**Na/SO$_4$ mg/mg**
1951 Metal Waste		2.87E+02	826	2.04	2.88	7.11E-03	405	1.23E+03	4.28E+02	3.05
1971 Cs Recovery		1.15E+03	4.6	1.42	4.03E-03	1.23E-03	3.28	4.38E+01	1.09E+04	13.5
H2 Upper Sand Sequence										
27A-UFA	62.99	(2.18E+00)	(0.00)	4.11E-02	(2.80E-04)	(1.89E-02)	(1.48E-02)	(3.19E-04)	(1.14E+00)	2.15E-02
33A-UFA	73.39	(8.86E-01)	2.74	6.70E-02	(3.09E+00)	(7.56E-02)	4.09E+01	4.69E-01	(1.52E-01)	1.15E-02
34C-UFA	74.90	(2.03E+00)	21.08	5.32E-01	(1.04E+01)	(2.62E-01)	3.96E+01	7.22E+00	(6.96E-01)	1.82E-01
H2-Muddy Very Fine Sand Lens										
34A-UFA	75.65	(6.69E+00)	26.21	8.22E-01	(3.91E+00)	(1.23E-01)	3.19E+01	1.02E+01	(2.60E+00)	3.19E-01
H2 Middle Sand Sequence										
44B-UFA	99.59	(16.08)	48.57	5.57E+00	(3.02E+00)	(3.46E-01)	8.72E+00	1.46E+01	(4.83E+00)	1.67E+00
55-UFA	121.24	1.2E+02	3.22E+02	1.49E+00	2.79E+00	1.30E-02	2.16E+02	4.46E+02	1.6E+02	2.07E+00
61A/B-UFA	130.7	1.2E+02	1.25E+03	3.47E+00	1.08E+01	3.01E-02	3.60E+02	1.75E+03	1.6E+02	4.86E+00
64-UFA	135.5	9.2E+01	6.30E+02	1.16E+00	6.83E+00	1.25E-02	5.45E+02	7.61E+02	1.1E+02	1.40E+00
65-UFA	137.1	9.1E+01	4.22E+02	1.04E+00	4.62E+00	1.14E-02	4.05E+02	5.67E+02	1.2E+02	1.40E+00
82C-UFA	167.65	51.87	2.72	7.39E+03	1.03E-02	0.00	5.06E+01	3.23E+00	3.13E+02	6.39E-02
H2-Fine Very Fine Sand Lens										
82A-UFA	168.65	51.87	6.89	9.37E-02	1.33E-01	0.00	7.36E+01	1.26E+01	9.51E+01	1.72E-01
Plio-Pleistocene Mud (PPlz)										
110B-UFA	218.95	218.83	2.57	2.29E-01	1.17E-02	0.00	1.12E+01	2.16E+00	1.84E+02	1.93E-01
112B-UFA	222.65	106.91	0.04	1.41E-01	3.60E-04	0.00	2.72E-01	9.41E-02	2.61E+02	3.46E-01
Perched	227	1.75	0.03	0.09	1.61E-02	0.05	3.11E-01	5.60E-02	3.47E+00	1.80E-01
116C-UFA	230.45	14.04	0.10	1.78E-01	7.33E-03	0.01	5.79E-01	1.55E-01	2.11E+01	2.68E-01
Plio-Pleistocene Gravelly Sand (PPlg)										
GW(1)	258.7	44.22	0.19	0.34	0.00	0.01	5.39E-01	2.41E-01	5.77E+01	4.47E-01
GW(2)	258.7	41.91	0.19	0.32	0.00	0.05	5.87E-01	2.50E-01	5.58E+01	4.26E-01

Parentheses indicate one or both of the constituents are present near its detection limit so values are less precise

Perched = perched water (excess standing water) extracted from borehole casing with bailer during hiatus in drilling

GW = one sample of groundwater was taken but submitted to two independent labs for analyses (1) and (2)

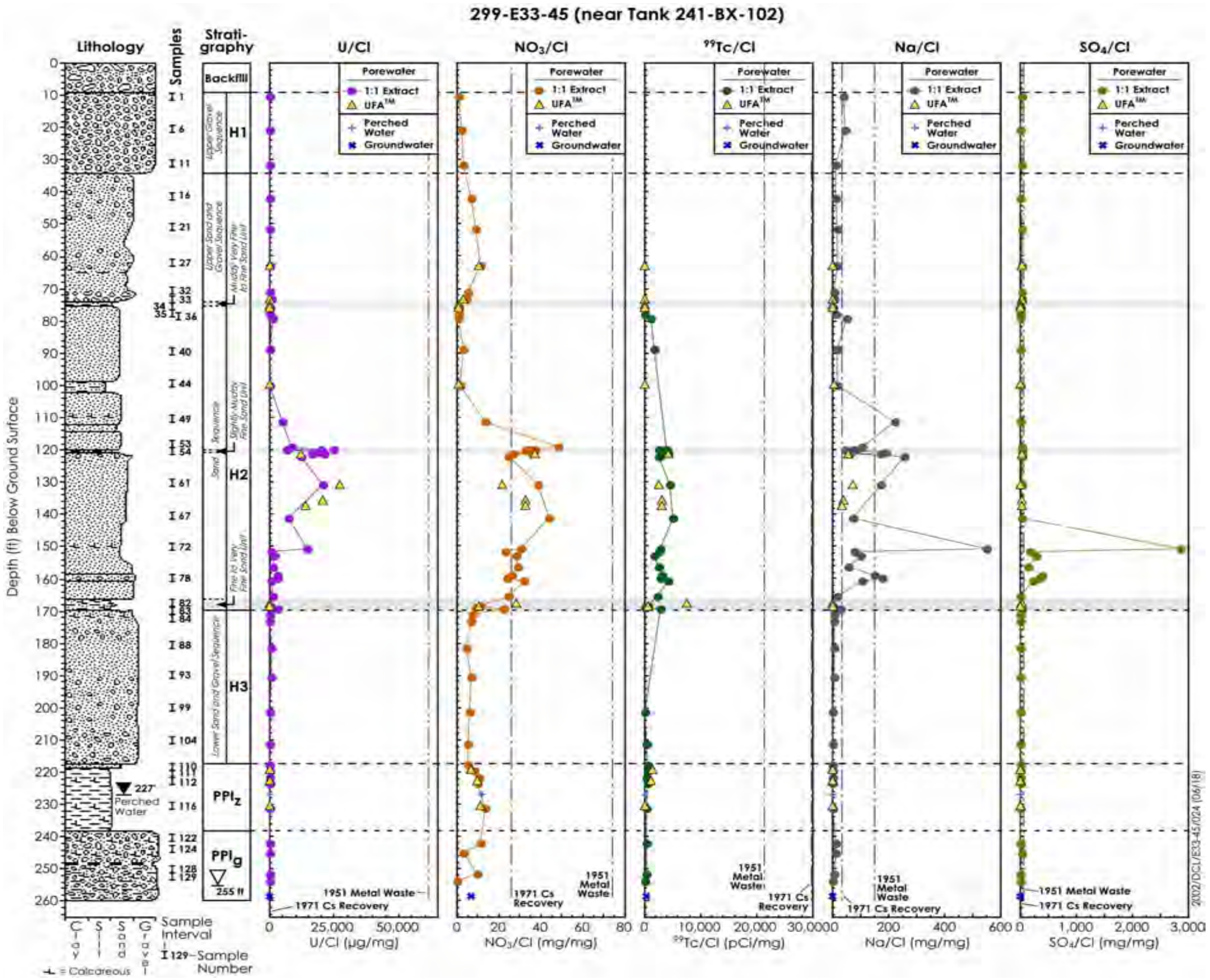

Figure 4.6. Porewater Ratios of Key Constituents in Bismuth Phosphate Waste to Chloride

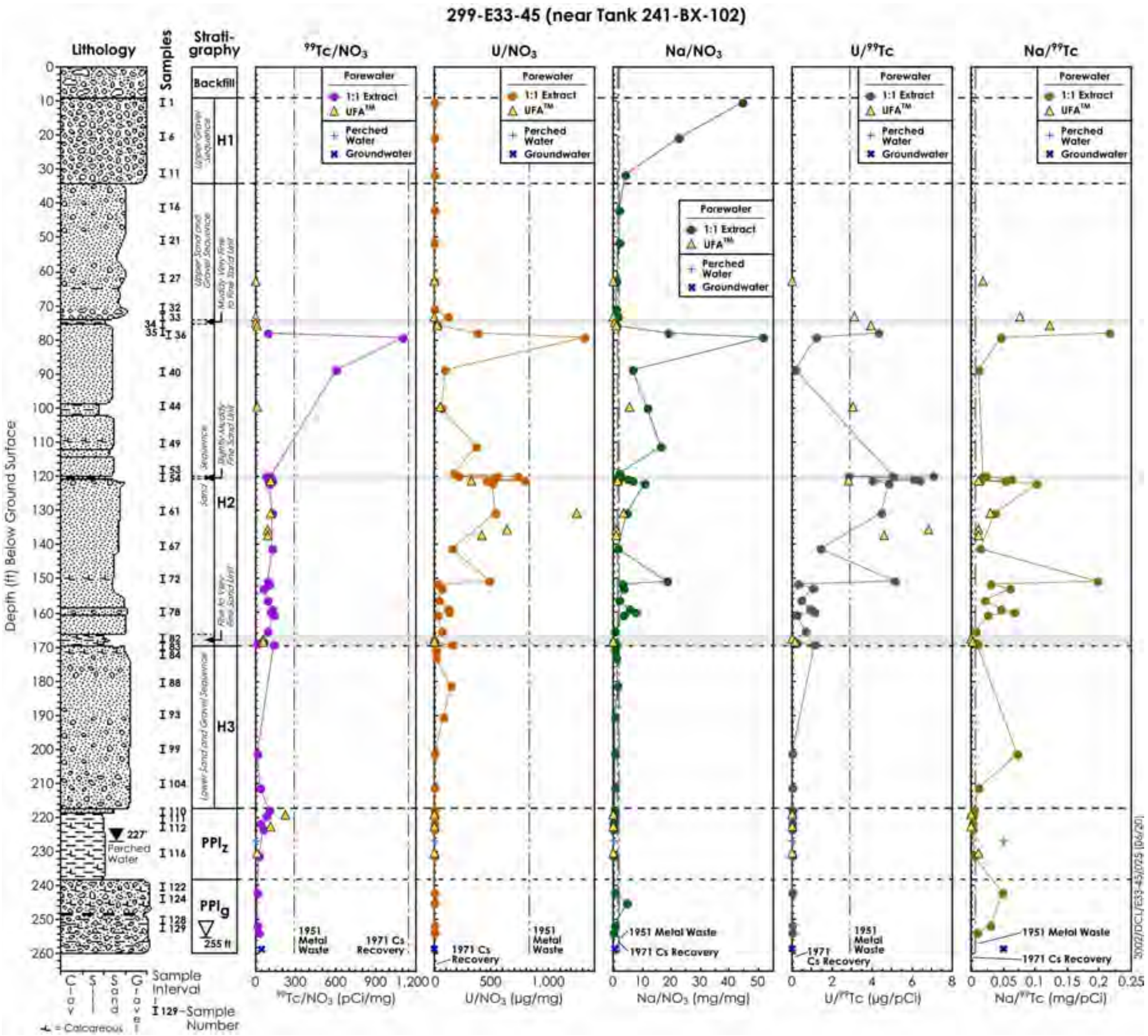

Figure 4.7. Porewater Ratios for Key Bismuth Phosphate Waste Constituents to Nitrate and Technetium (Mobile Species)

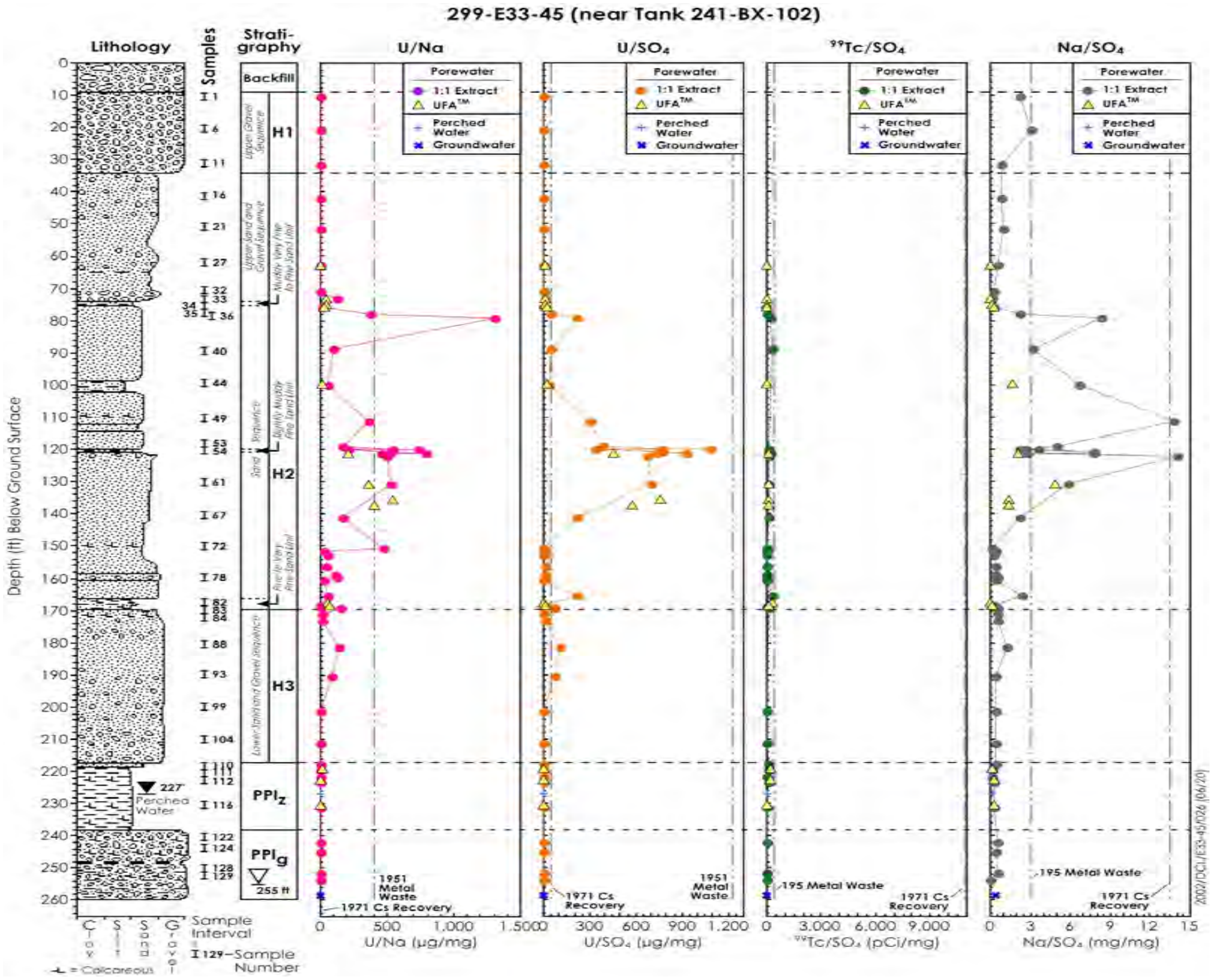

Figure 4.8. Porewater Ratios for Key Bismuth Phosphate Constituents versus Each Other

4.3 Radionuclide Content in Vadose Zone Sediment

The sediment cores from borehole 299-E33-45 posed no worker dose challenges (i.e., did not contain much gamma radioactivity). The radioanalytical analyses performed on the sediment included direct gamma energy analysis and tritium analysis of the one to one water extracts (assumed to be equivalent to the standard procedure used at WMA SX, distillation of tritium out of the sediment and condensation on special targets). The technetium-99 and uranium-238 contents of the UFA porewater, water extracts, perched water, groundwater, and strong acid extracts were analyzed by ICP-MS.

4.3.1 Gamma Energy Analysis

The GEA radionuclide content of the sediment is shown in Table 4.15. Uranium-238, uranium-235, potassium-40, and antimony-125 concentrations were the only isotopes present besides natural daughter products of uranium and thorium. The vertical distributions of uranium and potassium-40 in the vadose zone sediment are plotted in Figure 4.9. The uranium-238 activity first appears in the Hanford H2 unit just above the first thin lens at 74.5 ft (22.7 m) bgs. At about 90 ft bgs, there is little indication of significantly elevated concentrations of uranium down to ~111 ft bgs. Between 111 and 120 ft bgs, the uranium content averages about 100 ppm. In the thin lens at 120 ft bgs, which may be a paleosol, the uranium concentration is very high (up to 1,649 ppm in the finest-grained material from this sleeve). Below 120 ft bgs down to 145 ft bgs, the uranium content is quite high (reaching values between 200 and 500 ppm). Between 145 and 167.2 ft bgs, in the lower portion of the H2 middle sand sequence, there are slightly elevated uranium concentrations (i.e., between 50 and 200 ppm). Within the fine-grained lens between 167.2 and 169.8 ft bgs, the uranium concentration increases again to values between 200 and 400 ppm. Below in the Hanford H3 lower sand sequence and the Plio-Pleistocene sediments, there is no indication of elevated uranium in the sediments. In general, the uranium-235 data agree with the uranium-238 data and show very slight enrichment over the activity ratio for natural uranium. That is, the uranium-235 is slightly enriched as would be expected for uranium fuel.

The potassium-40 distribution is somewhat featureless. There are no signs of elevated potassium-40 in the fine-grained lens within the Hanford formation sediments. At most, a slightly increased concentration of potassium-40 in the Plio-Pleistocene silts is noted in comparison to the shallower Hanford H3 unit and deeper Plio-Pleistocene gravelly sands.

Using large samples and long count times, low levels of antimony-125 were found in a few samples between 90 and 102 ft (27.4 and 31.1 m) bgs. Past historical gross gamma and recent spectral gamma logging had shown small amounts of antimony-125 in nearby vadose zone monitoring wells. The antimony-125 has been attributed to leaks from a junction pit on top of tank BX-101 in the early 1970s. At the very low antimony-125 concentrations (0.04 to 0.1 pCi/g) that were found in a few samples, it is difficult to confirm that a second source of fluid from tank BX-101 environs has reached the vadose zone sediments at borehole 299-E33-45. With a half-life of 2.7 years, antimony-125 is decaying at a fast rate making it difficult to use as a vadose zone tracer of past leak events. There was undoubtedly some antimony-125 present in the 1951 overfill of tank BX-102 besides the leak in the early 1970s from BX-101 such that it cannot be stated unequivocally that the very faint indication found in the sediments is an indication that the second leak source (i.e., early 1970s cesium recovery waste from the junction box on top of tank BX-101) is present in the vadose zone sediments at 299-E33-45.

Table 4.15. Gamma Energy Analysis of Vadose Zone Sediment (5 pages)

Sample	Depth (ft)(a)	^{238}U ± Uncertainty ug/g		^{40}K ± Uncertainty pCi/g		^{125}Sb ± Uncertainty pCi/g	
H1 Coarse Sand							
01C	9.64	<6.4		10.8	0.6	<0.313	
01B	10.14	<7.8		11.6	1.3	<0.391	
01A	10.64	<8.1		12.7	0.9	<0.356	
06D	19.34	<7.7		13.8	1.7	<0.305	
06C	19.84	<7.5		14.3	1.4	<0.379	
06B	20.34	<8.9		14.1	0.8	<0.449	
06A	20.84	<8.1		13.2	1.7	<0.319	
11D	30.39	<7.9		14.7	0.9	<0.336	
11C	30.84	<6.9		13.4	1.3	<0.336	
11B	31.34	<6.8		12.8	0.7	<0.331	
11A	31.84	<9.4		16.4	1.7	<0.490	
Hanford Formation H2 Unit– upper sand sequence							
16D	40.54	<9.8		16.2	0.9	<0.515	
16C	41.04	<9.3		18.0	1.1	<0.405	
16B	41.54	<9.5		18.6	1.9	<0.479	
16A	42.04	<8.2		17.3	1.6	<0.394	
21D	50.14	<12.7		19.2	2.2	<0.394	
21C	50.64	<10.7		19.8	2.0	<0.556	
21B	51.14	<8.1		16.5	0.9	<0.382	
21A	51.64	<8.3		18.7	1.0	<0.399	
27D	61.49	<10.5		20.5	2.2	<0.530	
27C	61.99	<8.1		20.1	0.9	<0.402	
27B	62.49	<9.3		21.1	2.4	<0.429	
27A	62.99	<13.1		18.8	2.0	<0.482	
32D	69.74	<11.4		17.8	0.9	<0.389	
32C	70.24	<12.0		18.1	1.8	<0.371	
32B	70.74	<13.3		16.6	1.8	<0.479	
32A	71.24	<12.3		20.6	1.8	<0.425	
33D	71.89	<12.7		16.5	1.9	<0.426	
33C	72.39	<14.9		18.0	2.0	<0.499	
33B	72.89	369.9	88.9	19.3	1.6	<0.456	
33A	73.39	80.2	21.5	19.5	2.1	<0.511	
33	73.89	89.2	30.6	18.1	1.1	NA	
34D	74.15	61.1	24.1	20.4	1.0	<0.527	
Hanford Formation H2 Unit–muddy very fine sand							
34C	74.9	61.6	5.1	17.4	1.6	<0.431	

Table 4.15. Gamma Energy Analysis of Vadose Zone Sediment (5 pages)

Sample	Depth (ft)(a)	^{238}U ± Uncertainty ug/g		^{40}K ± Uncertainty pCi/g		^{125}Sb ± Uncertainty pCi/g	
34B	75.15	175.5	48.5	17.2	1.0	<0.524	
34A	75.65	44.2	42.8	18.4	2.1	<0.365	
Hanford Formation H2 Unit–middle sand sequence							
34	76.15	<14.7		16.5	0.9	NA	
35D	76.69	30.9	32.1	19.9	0.9	<0.382	
35C	77.19	9.6	2.3	19.7	1.7	<0.367	
35B	77.69	<12.6		17.1	1.8	<0.443	
35A	78.19	24.1	12.4	17.1	1.4	<0.363	
35	78.69	<15.6		17.8	1.2	NA	
36D	77.84	56.0	15.9	17.5	2.0	<0.390	
36C	78.34	51.0	20.5	17.2	1.7	<0.496	
36B	78.84	65.7	18.9	18.8	1.7	<0.03	
36A	79.34	122.1	47.3	18.0	1.1	<0.03	
37	82.49	351.6	135.0	19.0	1.2	<0.03	
38	84.78	184.4	122.5	16.8	1.0	NA	
39	86.245	78.5	46.4	16.2	0.9	NA	
40D	87.15	98.4	28.1	18.1	1.9	<0.486	
40C	87.65	79.8	23.8	19.5	0.9	<0.454	
40B	88.15	102.5	21.6	15.9	2.3	<0.410	
40A	88.65	<11.9		17.1	1.4	<0.396	
40	90	<14.5		18.2	1.2	0.055	0.021
41	92.715	20.8	20.8	18.9	1.0	NA	
42	94.69	16.8	9.9	16.6	0.8	NA	
43	97.015	<18.0		18.4	1.4	0.096	0.035
44D	98.59	34.0	17.4	18.8	1.6	<0.441	
44C	99.09	<8.6		17.1	2.6	<0.464	
44B	99.59	<14.3		15.8	1.9	<0.523	
44A	100.09	<16.1		18.1	2.0	<0.540	
44	100.44	26.0	10.1	18.5	1.0	0.100	0.032
45	101.765	<11.4		18.0	0.9	0.044	0.024
46	103.845	<15.8		20.4	1.3	NA	
47	106.515	<14.0		21.2	1.0	NA	
48	108.415	31.9	14.4	19.0	0.9	NA	
49D	109.64	11.8	8.8	16.5	2.1	<0.383	
49C	110.14	19.3	18.6	15.6	1.7	<0.473	
49B	110.64	11.7	32.1	19.7	2.1	<0.434	
49A	111.14	10.2	5.6	17.1	1.8	<0.379	
49	111.49	<15.2		21.1	1.4	NA	
50	112.39	187.2	92.8	19.9	1.0	NA	
51	113.69	128.5	62.7	18.2	0.9	NA	

Table 4.15. Gamma Energy Analysis of Vadose Zone Sediment (5 pages)

Sample	Depth (ft)(a)	^{238}U ± Uncertainty ug/g		^{40}K ± Uncertainty pCi/g		^{125}Sb ± Uncertainty pCi/g	
52	115.74	87.0	33.0	20.4	1.3	NA	
53D	117.54	137.1	32.4	18.3	1.0	<0.528	
53C	118.04	110.4	30.9	17.8	0.9	<0.437	
53B	118.54	142.2	44.9	16.2	1.8	<0.375	
53A	119.04	139.2	37.5	18.3	1.7	<0.494	
53	119.39	94.6	32.4	19.9	1.0	NA	
54D	119.39	111.9	26.6	17.8	0.9	<0.409	
54C	120.14	1648.8	386.6	17.8	2.1	<0.496	
54B	120.39	106.4	41.3	16.2	2.0	<0.419	
54A	120.89	41.7	13.5	16.1	1.3	<0.388	
54	121.24	57.5	19.2	16.6	0.8	NA	
55	121.34	549.6	196.3	21.9	1.5	NA	
56	122.315	222.7	120.1	17.0	0.9	NA	
57	123.845	399.6	143.3	18.2	0.9	NA	
58	125.5	98.4	36.3	21.0	1.3	NA	
59	127.4	33.2	16.8	19.5	1.0	NA	
60	128.65	<12.7		19.4	0.9	NA	
61D	129.45	75.4	31.2	16.7	2.2	<0.409	
61C	129.95	171.4	44.9	16.9	1.8	<0.513	
61B	130.45	252.6	61.3	17.4	1.7	<0.407	
61A	130.95	405.5	107.0	16.9	2.5	<0.492	
61	131.3	289.7	162.9	16.3	1.2	NA	
62	132.35	112.0	36.9	17.8	1.0	NA	
63	134.1	242.6	93.4	18.4	0.9	NA	
64	135.5	599.3	206.7	16.0	1.2	NA	
65	137.1	770.3	268.5	20.0	1.0	NA	
66	138.95	447.0	132.0	17.2	0.9	NA	
67D	139.75	495.1	118.0	16.3	0.9	<0.506	
67C	140.25	400.4	95.2	16.6	0.8	<0.439	
67B	140.75	492.4	124.6	18.0	1.1	<0.436	
67A	141.25	282.5	70.8	15.9	1.8	<0.548	
67	141.6	219.4	102.0	16.7	1.2	NA	
68	142.55	76.3	21.9	18.6	0.9	NA	
69	144.45	51.4	24.6	18.1	0.8	NA	
70	146.6	NA(b)	NA	18.1	1.2	NA	
71	148.6	51.2	25.6	18.9	0.9	NA	
72D	150.05	51.2	25.6	16.1	1.5	<0.386	
72C	150.55	85.1	37.2	15.3	2.1	<0.376	
72B	151.05	63.5	22.7	15.4	0.9	<0.467	
72A	151.55	56.0	16.9	16.1	0.8	<0.404	

Table 4.15. Gamma Energy Analysis of Vadose Zone Sediment (5 pages)

Sample	Depth (ft)(a)	^{238}U ± Uncertainty ug/g		^{40}K ± Uncertainty pCi/g		^{125}Sb ± Uncertainty pCi/g	
72	151.9	48.8	24.7	17.8	0.9	NA	
73	152.7	49.4	23.2	19.1	1.3	NA	
74	154.05	72.6	34.8	17.0	0.9	NA	
75	156.2	94.1	30.3	19.8	0.9	NA	
76	158.4	121.8	42.5	17.6	1.2	NA	
77	159.1	150.8	94.3	17.8	1.0	NA	
78D	159.35	160.6	52.9	15.8	2.0	<0.412	
78C	159.85	150.0	41.0	17.2	1.8	<0.507	
78B	160.35	123.5	32.4	15.4	1.4	<0.421	
78A	160.85	154.7	48.2	16.8	1.6	<0.399	
79	162.1	103.8	64.5	17.6	0.9	NA	
80	163.55	44.3	21.5	18.6	1.2	NA	
81	165.55	68.8	23.9	19.3	1.0	NA	
82D	167.15	51.6	22.1	17.2	1.0	<0.532	
Hanford Formation H2 Unit–fine/very fine sand							
82C	167.65	74.58	21.1	17.9	1.7	<0.444	
82B	168.15	307.31	87.1	16.5	1.2	<0.459	
82A	168.65	<12.52		14.8	1.6	<0.404	
83D	169.55	164.50	41.6	17.8	2.5	<0.515	
Hanford Formation H3 Unit							
83C	170.05	<13.74		17.5	1.8	<0.473	
83	171.4	13.24	10.5	16.6	0.9	NA	
84D	171.85	<13.14		15.1	0.9	<0.452	
84C	172.35	<11.89		16.6	1.6	<0.394	
84A	173.35	<13.17		13.8	1.2	<0.394	
87	179.2	14.05	9.1	17.4	0.9	<0.353	
88D	180.15	29.16	17.2	20.9	2.0	<0.526	
88C	180.65	15.89	7.6	16.6	2.0	<0.354	
88B	181.15	30.87	19.3	15.4	1.6	<0.469	
88A	181.65	30.12	38.7	16.1	1.5	<0.406	
89	182.7	28.28	17.9	17.1	1.1	NA	
90	184.4	27.53	16.4	17.7	1.0	NA	
91	186.2	28.18	10.7	18.8	0.9	NA	
93D	189.15	25.44	7.4	14.0	1.8	<0.363	
93C	189.65	29.50	17.7	14.8	1.7	<0.484	
93B	190.15	27.32	12.6	14.4	1.4	<0.372	
93A	190.65	19.81	3.9	16.3	1.9	<0.327	
99D	199.85	<12.37		16.8	1.8	<0.451	
99C	200.35	<11.15		16.9	0.8	<0.388	
99B	200.85	<12.40		17.3	1.1	<0.374	

Table 4.15. Gamma Energy Analysis of Vadose Zone Sediment (5 pages)

Sample	Depth (ft)(a)	^{238}U ± Uncertainty ug/g		^{40}K ± Uncertainty pCi/g		^{125}Sb ± Uncertainty pCi/g	
99A	201.35	<12.49		16.5	1.5	<0.474	
104D	209.92	<9.96		14.9	0.7	<0.340	
104C	210.42	<10.44		13.8	1.7	<0.324	
104B	210.92	<11.51		12.3	1.4	<0.410	
104A	211.42	<10.65		14.6	0.8	<0.382	
Plio-Pleistocene Fine-Grained Mud Unit (PPlz)							
110D	217.95	<13.41		15.9	2.5	<0.425	
110C	218.45	<14.09		16.1	1.8	<0.530	
110B	218.95	<11.83		18.7	1.6	<0.380	
110A	219.45	<13.08		19.5	1.1	<0.372	
111D	220.25	<13.17		16.3	1.9	<0.464	
111C	220.75	<10.85		17.2	0.9	<0.361	
111B	221.25	<12.58		19.8	2.2	<0.379	
111A	221.75	<13.14		22.7	2.2	<0.466	
112D	222.15	<12.73		17.3	1.5	<0.418	
112C	222.65	<12.73		16.2	1.1	<0.348	
112B	223.15	<13.11		16.2	1.9	<0.469	
112A	223.65	<11.69		17.8	0.9	<0.396	
116D	229.95	<10.82		16.3	1.3	<0.374	
116C	230.45	<9.07		13.9	1.4	<0.303	
116B	230.95	<10.50		15.8	0.8	<0.358	
116A	231.45	<14.36		18.0	2.1	<0.496	
Plio-Pleistocene Gravely Sand Unit (PPlg)							
122D	240.39	<13.44		16.6	1.9	<0.440	
122C	240.89	<11.06		10.8	1.5	<0.374	
122B	241.39	<10.29		11.6	1.4	<0.355	
122A	241.89	<9.72		12.4	1.3	<0.328	
124D	243.75	<11.03		15.1	1.4	<0.395	
124C	244.25	<10.11		14.2	1.7	<0.347	
124B	244.75	<11.57		14.8	1.3	<0.402	
124A	245.25	<9.60		14.2	1.6	<0.328	
128A	251.75	<9.90		13.4	1.3	<0.365	
129A	253.65	<10.44		9.3	1.2	<0.375	

(a) Multiply by 0.3048 to convert to meters

(b) NA = not analyzed

Pink shading indicates antimony-125 data for selected large volume samples that were counted for long periods

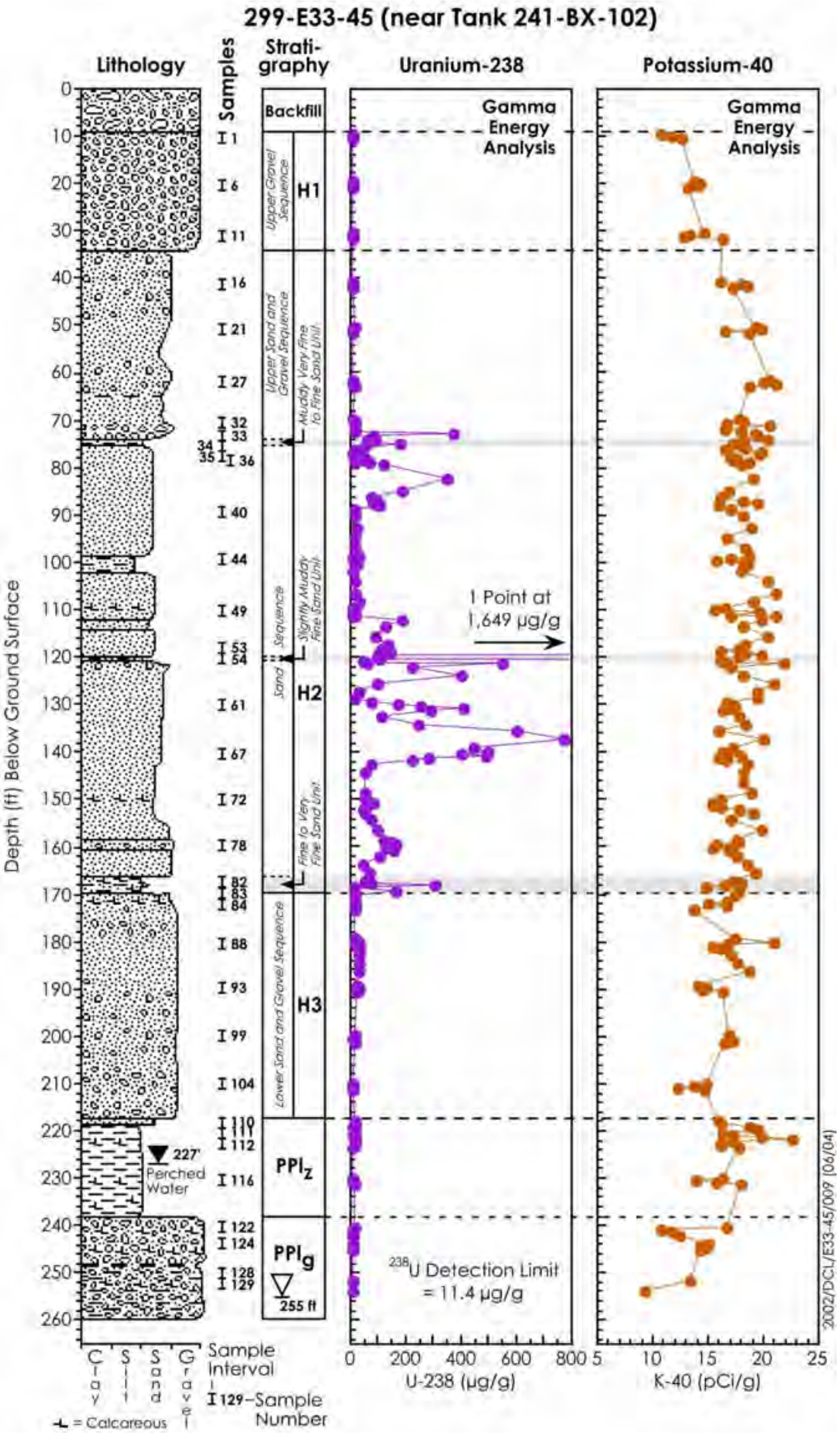

Figure 4.9. Uranium-238 and Potassium-40 Content in Sediment from Borehole 299-E33-45

4.3.2 Uranium Content in Sediment

Table 4.16 and Figure 4.10 show the agreement between measuring the total uranium content in the sediments using three different methods. The three methods are: 1) measuring uranium-238 by the gamma emission from its short-lived thorium-234 daughter and converting activity to mass, 2) directly measuring total uranium mass by x-ray fluorescence (XRF), and 3) performing a strong nitric acid extraction and measuring the uranium-238 mass by ICP-MS. In general, the agreement between the three methods is good when there is elevated uranium concentrations caused by the tank overfill. When the uranium content of the sediments is dominated by naturally occurring uranium, the acid extract data show much lower concentrations than the total uranium concentrations measured by GEA and XRF. This shows that the natural uranium is bound tightly in crystal lattice sites in minerals that are only partially dissolved in the 8 M nitric acid extraction. The comparisons that are deemed good are highlighted in pale yellow and the few that show disappointing agreements are highlighted in pink in Table 4.16.

An indication of the present uranium mobility is calculated based on the ease of water extraction of the uranium compared to the total uranium in the sediment. If one assumes that the dilution corrected 1:1 water extract is equivalent to the uranium content in the porewater, then an in situ Kd value can be calculated. Table 4.17 shows in situ Kd values based on the three different methods for measuring the total uranium in the dry sediment. In all cases, the total uranium measured also includes the uranium that was in the porewater such that a small correction is made to calculate the actual amount of uranium that is associated with the sediment itself. The values in Table 4.17 that are in red type show low Kd values that indicate some uranium mobility or alternatively a significant fraction of the uranium is in the porewater. Values that have gray shading signify that the total measurement in the sediment was close to, or at the detection limit of, the acid extract or XRF measurement technique. Table 4.16 also shows the percentage of the total uranium that is water extractable. The water extractable percentages for those sediments that contain measurable amounts of uranium from the BX-102 tank overfill range from 0.09 to 12% of the total uranium. Despite the relatively low percentage that is water leachable, the calculated in situ desorption Kd values for these samples, shown in Table 4.17, are quite low (i.e., range 0.07 to 2.36 mL/g; average 0.82 mL/g with 0.68 mL/g standard deviation). The in situ Kd values may be biased low because the calculated uranium concentrations in the porewater are inflated by dissolution of uranium solids and the fact that the moisture content is so low in the contaminated sediments. The true in situ Kd values are likely larger than the values presented based on the comparison of the actual porewaters (obtained by UFA centrifugation) with the dilution corrected porewater concentrations (calculated from the 1:1 water to sediment extracts). More discussion on the future leachability and fate of uranium in these vadose zone sediments is found in the Science and Technology Project contribution to the Appendix D of the WMA B-BX-BY FIR (Knepp 2002a) and Section 6 of this report.

As discussed above, the bulk of the elevated uranium is found between the depths of 73.5 to 90 and 111 to 169 ft bgs, however, based on the rather low in situ Kd values, it is suggested that Hanford-processed uranium must also be present at concentrations slightly above natural background as deep as the contact between the Hanford formation H3 and the Plio-Pleistocene mud unit, PPlz. The in situ Kd values for uranium are distinctly higher in the PPlz and PPlg strata suggesting that no Hanford processing derived uranium is present in these units. This observation, based on large increases in the calculated in situ Kd, shows that water extracts may be a very sensitive technique to look for contaminants that are slightly mobile to completely mobile in the vadose zone. Based on the total uranium content in the vadose zone sediments, it is not considered that Hanford derived uranium had penetrated below the fine-grained lens separating the Hanford formation H2 unit from the H3 unit. However, the in situ uranium Kd data suggest that Hanford derived uranium might have penetrated the entire Hanford formation down to the Plio-Pleistocene mud unit at ~220 ft bgs.

4.3.3 Technetium-99 Content in the Vadose Zone Sediments

Table 4.18 shows the acid extract and water extract data for technetium-99 in units of pCi/g of dry sediment. These data, in concert with the calculated and actual porewater data in Table 4.9 and Table 4.10 (also shown in Figure 4.5), were used to define the vertical penetration of technetium-99 at borehole 299-E33-45.

Technetium in the borehole 299-E33-45 sediments appears to show a bimodal vertical distribution. The first unequivocal indication of technetium contamination occurs in the fine-grained material at 120 ft (36.6 m) bgs. The bulk of the technetium is found in the Hanford formation H2 middle sand sequence between 120 and 170 ft (36.6 and 51.8 m) bgs. Within the Hanford formation H3 unit between 190 ft bgs and the top of the Plio-Pleistocene mud unit, there is little or no detectable technetium-99. A second deeper and lower concentration plume of technetium is found in the PPlz mud unit between 220 and 240 ft (57.1 and 73.2 m) bgs. As mentioned in the discussion of constituent ratios, there is some indication that the technetium-99 to nitrate ratios for the two lobes of this bimodal technetium plume differ, which suggests two different sources of contamination. However, because the total technetium-99 in the vadose zone sediments is present at or below 20 pCi/g dry sediment the precision is not as good as would be wanted. As shown in Table 4.18, all of the acid extract data for technetium is below the quantitation limit. It is believed that the acid extract data are all biased high leading to the appearance that some of the technetium is not water extractable. Figure 4.13 shows the data and the calculated in situ Kd values for technetium-99 assuming that the acid extract data are usable. The technetium-99 Kd values are also tabulated in Table 4.18 where many of the values are less than values because the water extracts had no technetium above detection limits. Despite the appearance that some of the technetium is not acid extractable, the calculated Kd values are quite low and likely are not different from zero.

4.3.4 Tritium Content in Vadose Zone Sediments

Table 4.19 lists the tritium content of the 1:1 sediment to water extracts, perched water samples, and groundwater samples taken once the borehole reached total depth. To compare the concentration of these fluids, all the sediment extracts were dilution corrected to represent porewater. Those extracts that appear to contain measurable tritium above the detection limit are highlighted in purple and the dilution corrected values are converted to pCi/L, the standard units for reporting concentrations in groundwater. The vertical distribution of water extractable tritium in the vadose zone sediments shows tritium appearing at ~100 ft bgs in the H2 middle sand sequence with generally continuous occurrence down to the fine-grained lens that separates the Hanford H2 from the H3 sediments. There is one sample within the H3 unit at 211 ft bgs that appears to have tritium present but all other samples in the H3 unit do not have statistically significant indications that tritium is present. The Plio-Pleistocene mud unit (PPlz), the perched water (within the PPlz), and the groundwater also show strong indications that tritium is present. The maximum concentrations of tritium in the dilution corrected porewaters occurs between 140 and 160 ft (42.7 and 48.8 m) bgs in the Hanford H2 middle sand sequence This distribution may represent the current depth of penetration of the bulk of the 1951 uranium metals waste BX-102 tank overfill.

The second deeper occurrence of tritium in the fine grained Plio-Pleistocene may represent a second source of contaminated fluid, recall that this zone does not contain any signs of elevated uranium, the key contaminant of interest from the 1951 BX-102 tank overfill.

4.3.5 Other Radionuclides

No strontium-90 or actinides analyses were performed on sediments from borehole 299-E33-45 because the acid extracts did not show any indication of more gross beta and alpha contents than could be accounted for by the measured technetium-99 and uranium-238, respectively.

Table 4.16. Comparison of Uranium Contents in Vadose Sediments from Borehole 299-E33-45 (2 pages)

Sample ID	Depth (ft)(a)	^{238}U-GEA ug/g	^{238}U-XRF ug/g	^{238}U-Acid Extract ug/g	^{238}U-Water Extract ug/g	Water Leachable %
H1 Coarse Sand						
01A	10.64	8.1	—	—	0.002	0.03%
06A	20.84	8.1	—	—	0.001	0.01%
11A	31.84	9.4	—	—	0.000	0.00%
Hanford formation H2 Unit– upper sand sequence						
16A	42.04	8.2	10.4	0.53	0.000	0.00%
21A	51.64	8.3	—	—	0.000	0.01%
27A	62.99	13.1	—	—	0.000	0.00%
32A	71.24	12.3	—	—	0.000	0.00%
33A	73.39	80.2	173.3	—	0.944	0.19%
Hanford formation H2 Unit–muddy very fine sand						
34A	75.65	44.2	99.3	59.2	0.560	0.09%
Hanford formation H2 Unit–middle sand sequence						
35A	78.19	24.1	—	—	0.547	2.27%
36A	79.34	122.1	—	—	2.513	2.06%
40A	88.65	11.9	14.0	6.2	0.326	0.63%
44A	100.09	16.1	14.6	5.3	0.604	0.99%
49A	111.14	10.2	—	—	3.614	35.42%
53A	119.04	139.2	246.0	—	5.831	0.76%
54C	120.14	1648.8	1449.0	1471.0	—	—
54A	120.89	41.7	25.5	—	16.797	12.49%
61A	130.95	405.5	356.0	—	22.804	1.50%
67A	141.25	282.5	289.0	—	10.096	0.88%
72A	151.55	56.0	32.1	48.7	2.812	0.69%

Table 4.16. Comparison of Uranium Contents in Vadose Sediments from Borehole 299-E33-45 (2 pages)

Sample ID	Depth (ft)[(a)]	^{238}U-GEA ug/g	^{238}U-XRF ug/g	^{238}U-Acid Extract ug/g	^{238}U-Water Extract ug/g	Water Leachable %
78A	160.85	154.7	101.2	—	2.676	0.52%
Hanford formation H2 Unit–fine/very fine sand						
82A	168.65	12.5	129.8	—	0.8115	6.48%
83D	169.55	164.50	119.1	136.5	—	—
Hanford formation H3 Unit						
83	171.4	13.24	—	—	0.136	1.03%
84A	173.35	13.2	—	—	0.247	1.88%
88A	181.65	30.12	—	—	3.231	10.73%
93A	190.65	19.81	12.1	19.8	1.616	1.04%
99A	201.35	12.5	—	—	0.001	0.00%
104A	211.42	10.6	—	—	0.000	0.00%
Plio-Pleistocene Fine-Grained Mud Unit (PPlz)						
110D	217.95	13.4	<7.7	0.54	—	—
110A	219.45	13.1	—	—	0.053	0.41%
111A	221.75	13.1	24.8	2.1	0.002	0.00%
112A	223.65	11.7	—	v	0.000	0.00%
116A	231.45	14.4	10.1	1.1	0.004	0.01%
Plio-Pleistocene Gravely Sand Unit (PPlg)						
122A	241.89	9.7	<8.8	2.5	0.000	0.00%
124A	245.25	9.6	—	—	0.000	0.00%
128A	251.75	9.9	—	—	0.000	0.00%
129A	253.65	10.4	—	—	0.002	0.02%

— indicates uranium measurement was not performed

Pink shading indicates poor agreement in uranium contents between one or more methods

Yellow shading indicates good agreement in uranium content between all three methods

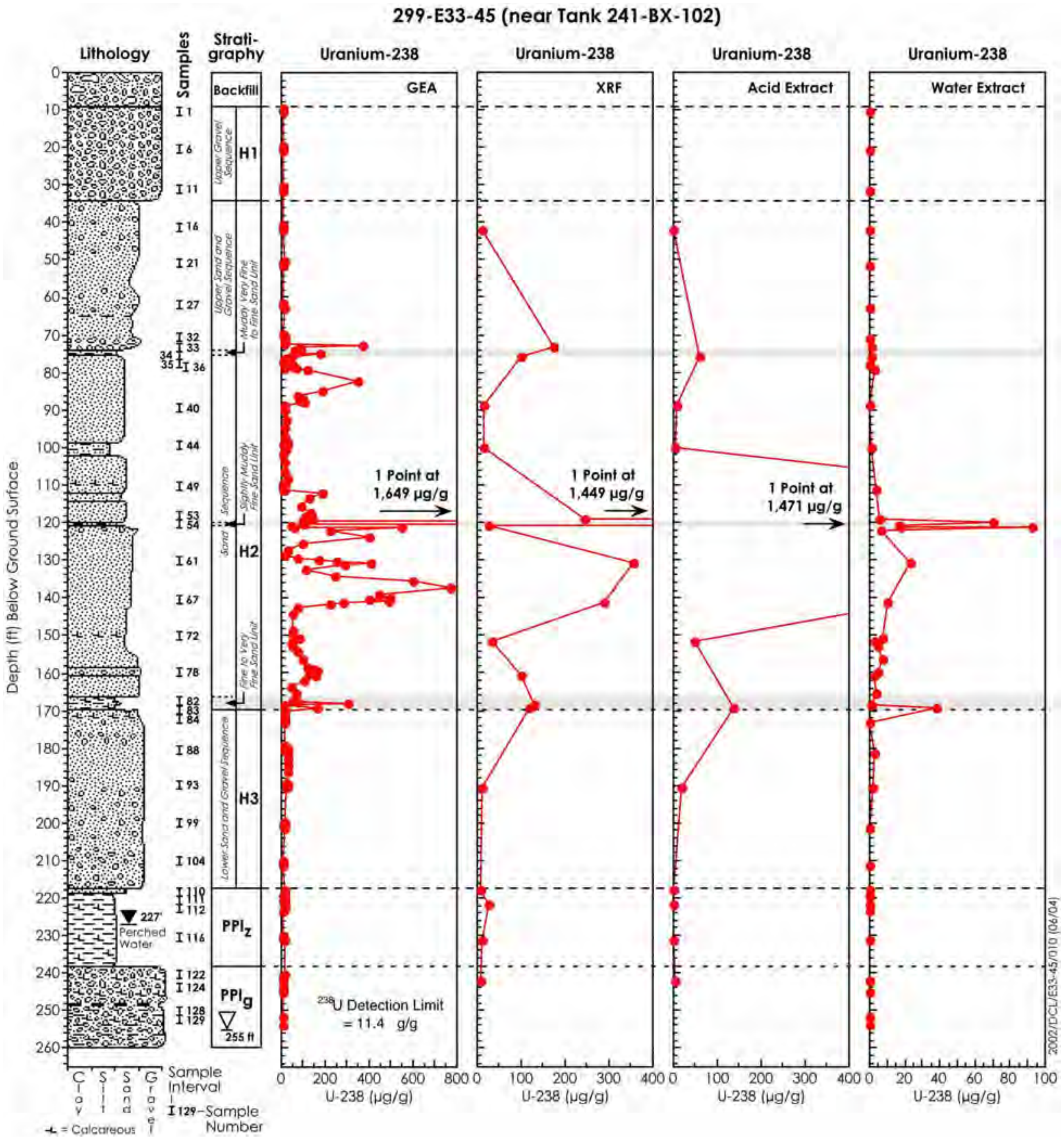

Figure 4.10. Three Independent Methods of Estimating Uranium-238 in Vadose Sediment (pCi/g)

Table 4.17. Calculated In Situ Kd Values (mL/g) for Uranium in the Vadose Zone Sediments from Borehole 299-E33-45

Sample ID	Depth ft-bgs	U GEA mL/g	U XRF-Ind mL/g	U Acid mL/g
Hanford formation H2 unit-upper sand sequence				
16A	42.04	NA	NA	(40.2)
33A	73.39	2.67	NA	
Hanford formation H2 unit-muddy very fine sand lens				
34A	75.65	15.8	19.6	21.3
Hanford formation H2 unit-middle sand sequence				
35A	78.19	1.05	NA	NA
36A	79.34	1.47	1.01	NA
40A	88.65	NA	1.52	0.65
44A	100.09	NA	1.22	0.40
49A	111.14	0.07	NA	NA
53A	119.04	0.73	1.31	NA
Hanford formation H2 unit- very fine paleosol sand lens				
54C Fine	120.14	1.19	5.40	5.48
54C Upper	120.14	2.36	NA	NA
Hanford formation H2 unit-middle sand sequence				
54A	120.89	0.04	0.01	NA
61A	130.95	0.65	0.56	NA
67A	141.25	0.70	0.72	NA
72A	151.55	0.57	0.41	0.49
78A	160.85	2.16	1.40	NA
Hanford formation H2 unit-/ very fine sand lens				
No samples tested				
Hanford formation H3 unit				
83D	169.55	0.28	0.18	0.22
88A	181.65	0.38	NA	NA
93A	190.65	0.38	0.22	0.38
PPlz (mud)				
110D	217.95	NA	<450	(31.3)
111A	221.75	NA	3478	297.9
116A	231.45	NA	809	91.4
PPlg (gravelly sand)				
122A	241.89	NA	<1012	293

Parentheses indicate values of one or both or the values forming the Kd are near detection limit and not as precise as other Kd values
NA = a uranium value was not measured so Kd can not be calculated
Values in red type suggest that uranium is moderately to strongly mobile
Grey shading indicates values for total uranium in sediment are near detection limit and Kd value is less accurate than Kd values in red type

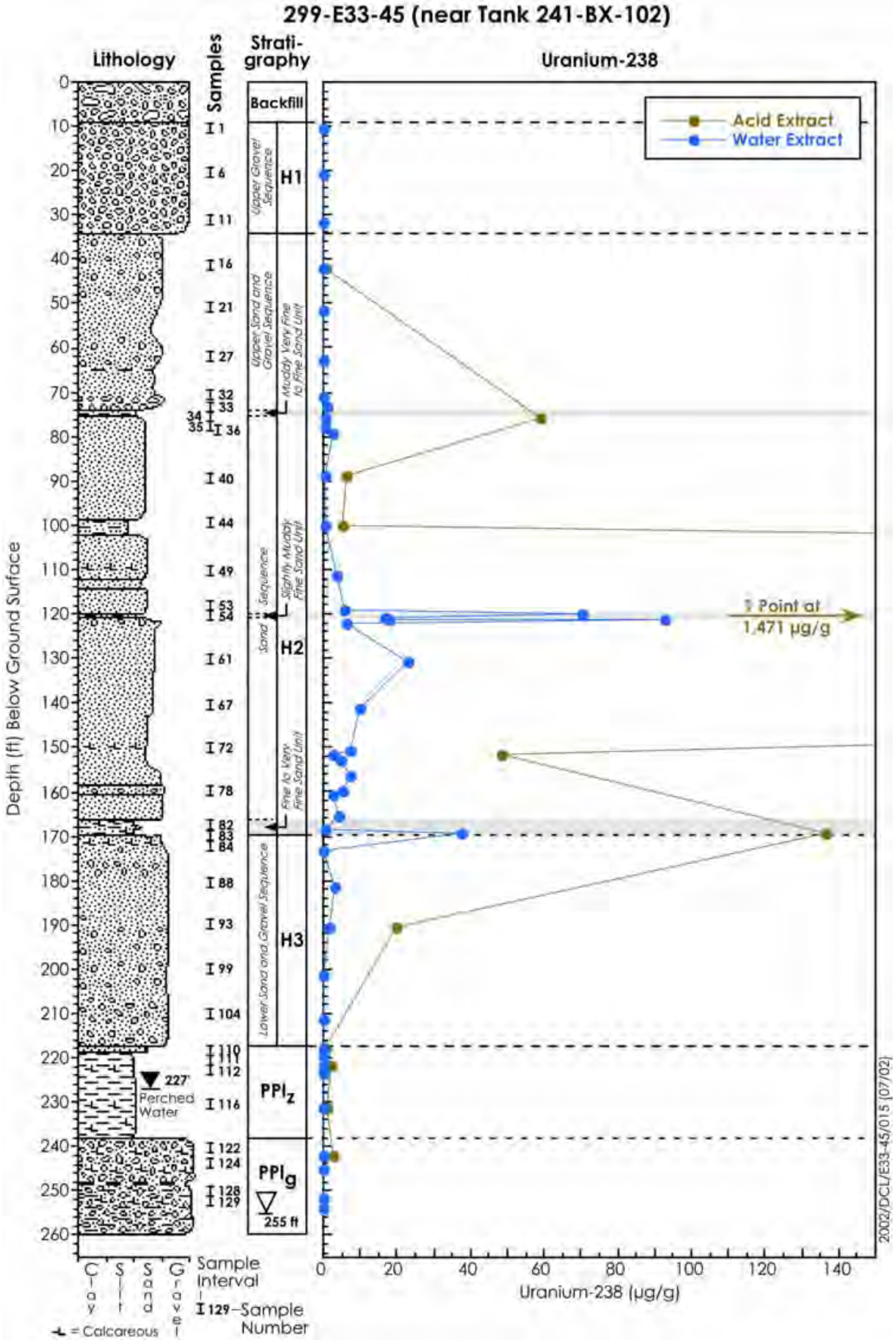

Figure 4.11. Concentration of Uranium-238 in BX-102 Borehole Sediment that is Water or Acid Extractable

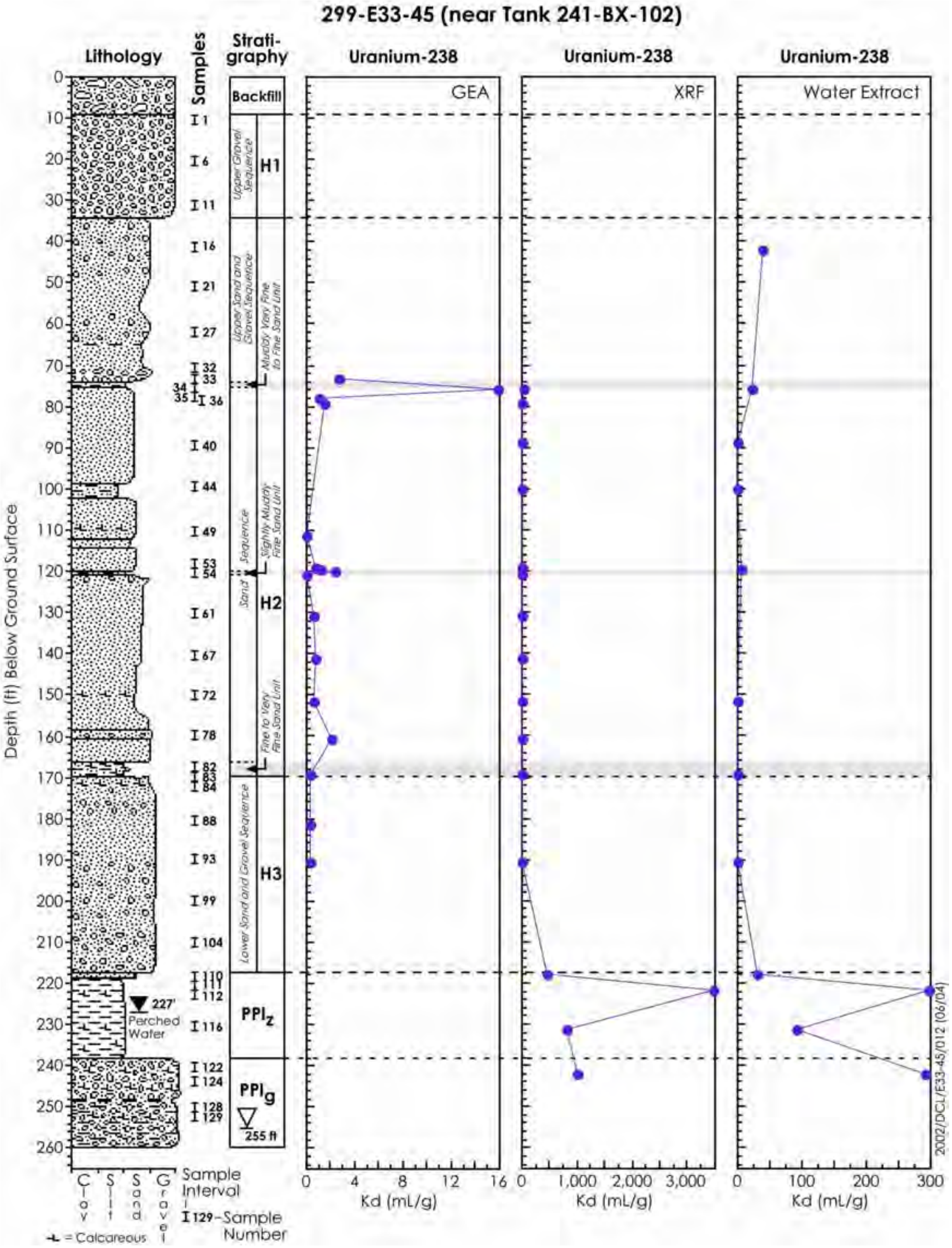

Figure 4.12. Uranium Desorption Kd Values

Table 4.18. Technetium-99 Content and In Situ Kd (mL/g) in Sediment (based on 8 M Nitric Acid Extracts and Water Extracts) (2 pages)

Sample ID	**Depth ft-bgs**	**^{99}Tc Water Extract pCi/g**	**^{99}Tc Acid Extract pCi/g**	**^{99}Tc Kd mL/g**
Hanford formation H2 unit-upper sand sequence				
01A	10.64	<2.12		
06A	20.84	<2.12		
11A	31.84	<2.12		
16A	42.04	<2.12	(6.60)	<0.072
21A	51.64	<2.12		
27A	62.99	<2.12		
32A	71.24	<2.13		
33A	73.39	<2.12		
Hanford formation H2 unit-muddy very fine sand lens				
34A	75.65	<2.12	(6.78)	<0.432
Hanford formation H2 unit-middle sand sequence				
35A	78.19	(0.13)		
36A	79.34	<2.12		
40A	88.65	<2.12	(7.47)	<0.091
44A	100.09	<2.12	(7.95)	<0.145
49A	111.14	(0.08)		
53A	119.04	(0.72)		
Hanford formation H2 unit- very fine paleosol sand lens				
54C Fine	120.14	18.6	(30.54)	0.091
54C Upper	120.14	6.3		
Hanford formation H2 unit-middle sand sequence				
54A	120.89	2.8		
54	121.24	2.7		
55	121.34	23.0		
56	122.32	1.3		
61A	130.95	5.1		
67A	141.25	7.3		
72A	151.55	10.1	(18.42)	0.025
73	152.7	4.3		
75	156.2	15.8		
77	159.1	5.6		
78C	159.85	4.7		
78A	160.85	13.3		

Table 4.18. Technetium-99 Content and In Situ Kd (mL/g) in Sediment (based on 8 M Nitric Acid Extracts and Water Extracts) (2 pages)

Sample ID	Depth ft-bgs	^{99}Tc Water Extract pCi/g	^{99}Tc Acid Extract pCi/g	^{99}Tc Kd mL/g
Hanford formation H2 unit-/ very fine sand lens				
81	165.55	6.2		
82A	168.65	10.0		
82A-Dup	168.65	12.1		
82	169.1	3.7		
Hanford formation H3 unit				
83D	169.55	33.1	(44.06)	0.027
83A	171.05	<2.12		
84A	173.35	<2.12		
88A	181.65	<2.12		
93A	190.65	<2.12	(6.11)	<0.097
99A	201.35	(0.17)		
104A	211.42	(1.02)		
PPlz (mud)				
110D	217.95	2.3	(10.06)	0.099
110A	219.45	15.2		
111A	221.75	12.7	(18.04)	0.104
112A	223.65	13.2		
116A	231.45	7.2	(15.52)	0.282
116A-Dup	231.45	7.2		
PPlg (gravelly sand)				
122A	241.89	(0.34)	(5.35)	0.611
124A	245.25	<2.13		
128A	251.75	(0.48)		
129A	253.65	(0.85)		

Values in **bold type** are reliable
Parentheses indicate values at or near the detection limit that are less reliable

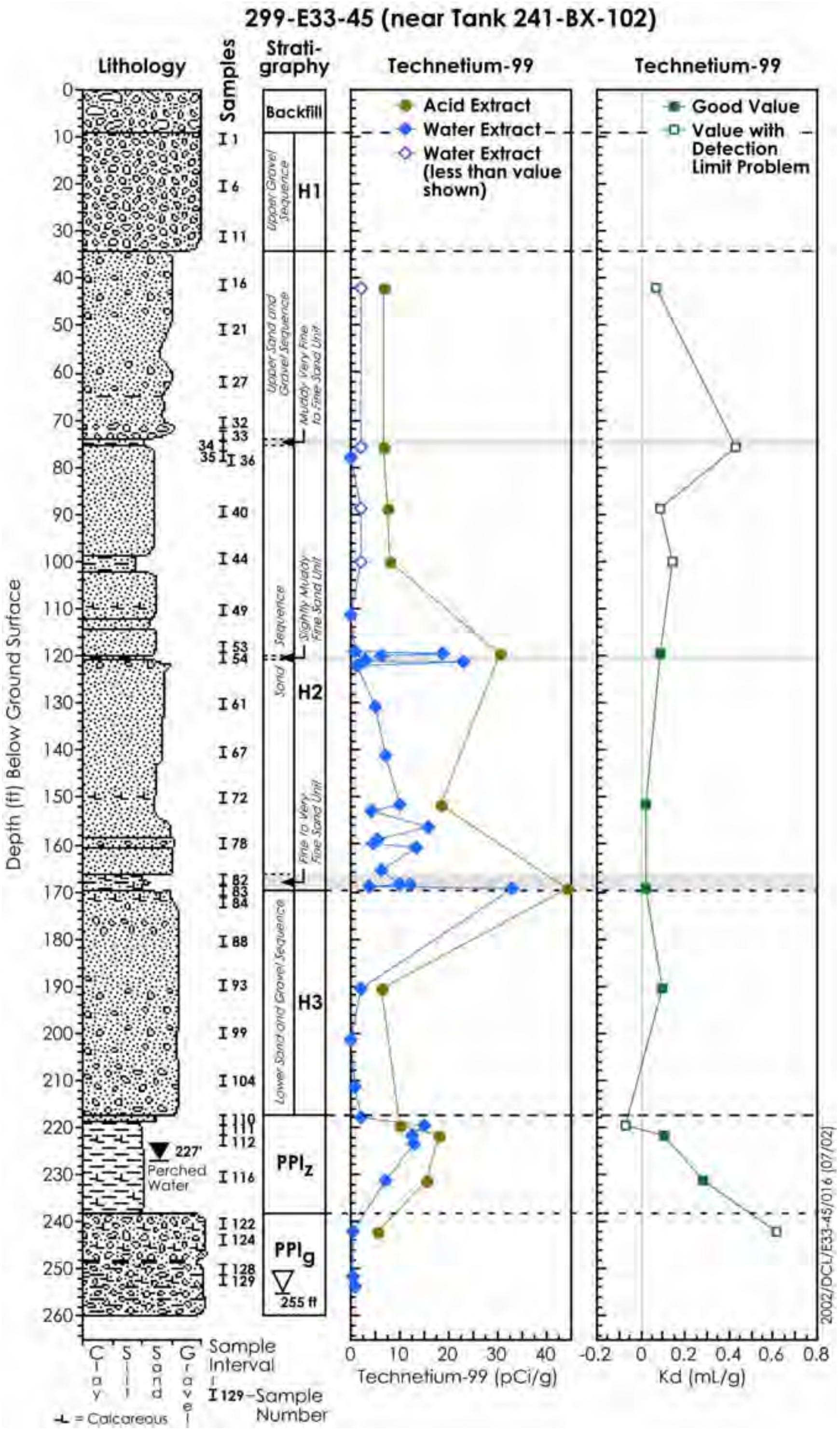

Figure 4.13. Concentration of Technetium-99 (pCi/g) and In Situ Kd Values (mL/g) in Vadose Zone Sediments from Borehole 299-E33-45

Table 4.19. Tritium Content in Water Extracts, Perched Water and Groundwater (pCi/L) (2 pages)

Sample ID	Depth (ft bgs)(a)	Dilution Factor	Dilution Corrected Porewater Concentration		
			1:1 Extract Tritium	± Uncertainty	Porewater
			pCi/mL	pCi/mL	pCi/L
Hanford H1 coarse sand					
01A	10.64	21.09	<2.04E+00	—	—
06A	20.84	17.43	<1.72E+00	—	—
11A	31.84	30.27	<2.92E+00	—	—
Hanford H2 upper sand sequence					
16A	42.04	29.2	6.63E+00	2.92E+01	—
21A	51.64	26.38	<2.52E+00	—	—
27A	62.99	14.72	<1.39E+00	—	—
32A	71.24	25.83	2.35E+00	2.57E+01	—
33A	73.39	31.48	1.43E+00	3.15E+01	—
H2 muddy very fine sand lens					
34A	75.65	4.91	<4.80E-01	—	—
34A-Dup	75.65	4.56	<4.46E-01	—	—
H2 middle sand sequence					
35A	78.19	40.97	1.58E+01	4.15E+01	—
36A	79.34	32.28	1.76E+01	3.31E+01	—
40A	88.65	27.63	<2.60E+00	—	—
44A	100.09	19.04	2.45E+01	2.05E+01	2.45E+04
49A	111.14	25.85	5.30E+01	2.88E+01	5.30E+04
53A	119.04	31.4	4.64E+01	3.41E+01	4.64E+04
H2 muddy very fine sand lens					
54C Fine	120.14	7.02	—	—	—
54C DUP Fine	120.14	9.27	—	—	—
54C Upper	120.14	14.98	—	—	—
54A	120.89	39.38	1.71E+02	4.96E+01	1.71E+05
H2 middle sand sequence (continued)					
54	121.24	36.16	—	—	—
55	121.34	6.77	—	—	—
56	122.32	33.95	—	—	—
61A	130.95	25.93	1.77E+02	3.56E+01	1.77E+05
67A	141.25	38.52	2.50E+02	5.25E+01	2.50E+05
72C	150.55	28.44	—	—	—
72A	151.55	33.05	2.58E+02	4.75E+01	2.58E+05
73	152.7	30.98	—	—	—
75	156.2	33.88	—	—	—
77	159.1	28.82	—	—	—
78C	159.85	27.04	—	—	—
78A	160.85	26.29	2.33E+02	3.94E+01	2.33E+05
81	165.55	21.84			
H2 –fine-very fine sand lens					
82A	168.65	6.17	3.89E+01	8.34E+00	3.89E+04
82A-Dup	168.65	6.17	5.11E+01	8.97E+00	5.11E+04
82	169.1	5.78	—	—	—

Table 4.19. Tritium Content in Water Extracts, Perched Water and Groundwater (pCi/L) (2 pages)

Sample ID	Depth (ft bgs)(a)	Dilution Factor	Dilution Corrected Porewater Concentration		
			1:1 Extract Tritium	± Uncertainty	Porewater
			pCi/mL	pCi/mL	pCi/L
83D	169.55	12.01	—	—	—
Hanford H3 Lower sand unit					
83A	171.05	35.27	1.12E+01	3.57E+01	—
84A	173.35	31.43	1.58E+01	3.22E+01	—
88A	181.65	21.76	7.94E+00	2.21E+01	—
93A	190.65	29.65	<1.46E+01	—	—
99A	201.35	30.75	2.30E+01	3.24E+01	—
104A	211.42	29.56	4.03E+01	3.20E+01	4.03E+04
110D	217.95	34.26	—	—	—
PPlz Mud unit					
110A	219.45	5.32	5.30E+01	8.18E+00	5.30E+04
111A	221.75	4.03	3.39E+01	5.89E+00	3.39E+04
112A	223.65	5.31	4.49E+01	7.76E+00	4.49E+04
Perched	227	1	—	—	7.55E+04
116A	231.45	4.13	2.24E+01	5.44E+00	2.24E+04
116A-Dup	231.45	4.14	4.69E+00	4.62E+00	4.69E+03
PPlg Gravelly unit					
122A	241.89	24.16	7.16E+00	2.43E+01	—
124A	245.25	33.06	<3.17E+00	—	—
128A	251.75	23.88	9.24E+00	2.43E+01	—
129A	253.65	23.18	1.32E+01	2.38E+01	—
GW(1)	258.7	1	—	—	2.52E+03
GW(2)	258.7	1	—	—	2.41E+03

< Values were below the detection limit

— indicates no measurements made or tritium value is uncertain

Perched = excess standing water in borehole extracted with bailer during hiatus in drilling

GW = one sample of groundwater was taken but submitted to two independent laboratories

Purple shaded values indicate best quality data

4.4 Total Cyanide Content of the Vadose Zone Sediments

It was noticed during analyses of the groundwater data returned from an independent laboratory that there was a small amount of cyanide present at 299-E33-45. The value was 24 parts per billion (ug/L). It was originally thought that this could not have come from tank BX-102 and thus, if it could be shown that there was no cyanide in the vadose zone sediments from borehole 299-E33-45, then the contamination in the perched water and groundwater within and below the PPlz unit likely came from a source other than tank BX-102. Several samples of the vadose zone sediment, the perched water, and groundwater sample were analyzed for total cyanide. For the sediments, small (~1 g) aliquots were digested in caustic solution and the digestate measured colorimetrically. Five-ml aliquots of the perched water and groundwater that had been stored for ~14 months (but not specifically preserved to fix the cyanide content) were also analyzed. The results are shown in Table 4.20. The vadose zone sediment contains very little total cyanide but two samples, one in the fine-grained lens between the bottom of the Hanford H2 and the top of H3 units and one in the PPlg coarse gravel just above the water table appear to contain cyanide above the detection limit. The perched water contains 5.4 ug/L and the stored groundwater contained ~9 ug/L compared to a value of 21ug/L in the sample specifically preserved and sent to the analytical laboratory.

The cyanide results are not conclusive and upon further review of the BX-102 history, it was decided that after the 1951 tank overfill that waste containing cyanide was stored in the tank during the 1970s and because the plug in the outlet port that was compromised during the 1951 overfill had never been fixed, it was possible that some cyanide could have escaped tank BX-102 after 1951. Therefore, the one statistically significant cyanide value at ~170 ft bgs at borehole 299-E33-45 might be real. There definitely seems to be a faint trace of cyanide deep in the profile within the perched water, groundwater, and coarse-grained PPlg sediment in between the two water samples. The source of the cyanide cannot be attributed to a specific disposal facility at this time.

Table 4.20. Total Cyanide Concentration in Samples (ug/mL or ug/g) (2 pages)

Sample ID	**Depth ft bgs**	**Amount Sampled**	**ug CN Found**	**Concentration ug/g or ug/mL**
Hanford H1 coarse sand				
No sample analyzed				
Hanford H2 upper sand sequence				
27A	62.99	0.9453 g	0.01427	< 2.12E-02
33A	73.39	1.0541 g	0.01291	< 1.90E-02
H2 muddy very fine sand lens				
No sample analyzed				
H2 middle sand sequence				
No sample analyzed				
H2 muddy very fine sand lens				
54A	120.89	1.1765 g	0.005439	< 1.70E-02
H2 middle sand sequence (continued)				
55	121.34	0.9356 g	0.01291	< 2.14E-02
72A	151.55	1.0591 g	0.01155	< 1.89E-02
H2–fine-very fine sand lens				
83D	169.55	1.0238 g	0.05303	5.18E-02
Hanford H3 Lower sand unit				
99A	201.35	1.0035 g	0.02379	< 1.99E-02
PPlz Mud unit				
110A	219.45	1.0965 g	-0.004079	< 1.82E-02

Table 4.20. Total Cyanide Concentration in Samples (ug/mL or ug/g) (2 pages)

Sample ID	Depth ft bgs	Amount Sampled	ug CN Found	Concentration ug/g or ug/mL
112A	223.65	1.0809 g	-0.009518	< 1.85E-02
Perched Water	227	5 mL	0.02719	5.44E-03
PPlg Gravelly unit				
122A	241.89	1.0231 g	0.01019	< 1.95E-02
129A	253.65	1.0323 g	0.05983	5.80E-02
GW(1)	258.7	5 mL	0.04487	8.97E-03
GW(2)	258.7			2.19E-02

Perched and groundwater units ug/mL all others are ug/g dry sediment
Green shading indicates samples with measurable cyanide present

4.5 Total Carbon, Calcium Carbonate, and Organic Carbon Content of Vadose Zone Sediment

Table 4.21 shows the total carbon, inorganic carbon, and organic carbon contents of the vadose zone sediment at selected depths. The inorganic carbon was also converted to the equivalent calcium carbonate content. The sediment in the Hanford H1 unit is relatively low in carbonate and organic carbon. The entire Hanford H2 unit including the upper and middle sand sequences and the three thin, fine-grained lenses show a fairly uniform distribution for inorganic carbon between 1.3 and 2.0% as calcium carbonate. The Hanford H3 unit shows slightly less calcium carbonate. The fine-grained PPlz mud shows slightly higher calcium carbonate, ranging from 1.8 to 2.3% by weight, and slightly higher organic carbon content. The coarse-grained PPlg contains the least calcium carbonate, <0.85% and low organic carbon content. There is no evidence of rich calcareous zones in the entire profile such is found underlying the PPlz unit in the 200 West Area.

Table 4.21. Carbon Content in Vadose Sediment from 299-E33-45 (2 pages)

Sample Identification	Depth ft[(a)]	Total Carbon % wt	Organic Carbon % wt	Inorganic Carbon % wt	IC as $CaCO_3$ % wt
Hanford H1 coarse sand					
01A	10.64	0.10	0.020	0.08	0.67
06A	20.84	0.14	0.022	0.12	1.00
11A	31.84	0.23	0.040	0.19	1.58
H2 Upper Sand Sequence					
16A	42.04	0.22	0.045	0.21	1.75
21A	51.64	0.23	0.045	0.18	1.50
27A	62.99	0.27	0.036	0.24	2.00
32A	71.24	0.20	0.019	0.18	1.50
33A	73.39	0.24	0.028	0.22	1.83

Table 4.21. Carbon Content in Vadose Sediment from 299-E33-45 (2 pages)

Sample Identification	Depth ft$^{(a)}$	Total Carbon % wt	Organic Carbon % wt	Inorganic Carbon % wt	IC as CaCO$_3$ % wt
Muddy Very Fine Sand Lens #1					
34A	75.65	0.19	0.041	0.15	1.25
H2 Middle Sand Sequence					
35A	78.19	0.22	0.029	0.19	1.58
36A	79.34	0.23	0.009	0.22	1.83
40A	88.65	0.22	0.055	0.16	1.33
44A	100.09	0.19	0.027	0.16	1.33
49A	111.14	0.22	0.026	0.19	1.58
53A	119.04	0.25	0.053	0.20	1.67
Muddy Very Fine Sand Lens #2					
54C Upper	120.14	0.24	0.055	0.19	1.58
H2 Middle Sand Sequence					
54A	120.89	0.20	0.015	0.19	1.58
61A	130.95	0.18	0.042	0.14	1.17
67A	141.25	0.14	0.014	0.13	1.08
72A	151.55	0.18	0.075	0.16	1.33
78A	160.85	0.17	0.040	0.13	1.08
Fine Very Fine Sand Lens #3					
82A	168.65	0.21	0.041	0.16	1.33
83D	169.55	0.19	0.004	0.19	1.58
H3 Unit					
83A	171.05	0.18	0.012	0.16	1.33
84A	173.35	0.17	0.039	0.13	1.08
88A	181.65	0.20	0.035	0.16	1.33
93A	190.65	0.15	0.028	0.12	1.00
99A	201.35	0.15	0.042	0.11	0.92
104A	211.42	0.13	0.028	0.11	0.92
Plio-Pleistocene Mud (PPlz)					
110D	217.95	0.16	0.027	0.14	1.17
110A	219.45	0.30	0.050	0.25	2.08
111A	221.75	0.30	0.076	0.22	1.83
112A	223.65	0.33	0.047	0.28	2.33
116A	231.45	0.31	0.052	0.25	2.08
Plio-Pleistocene Gravelly Sand (PPlg)					
122A	241.89	0.14	0.047	0.10	0.83
124A	245.25	0.16	0.064	0.10	0.83
128A	251.75	0.06	0.006	0.05	0.42
129A	253.65	0.12	0.027	0.09	0.75

(a) Multiply by 0.3048 to convert to meters

4.6 8 M Nitric Acid Extractable Amounts of Selected Elements

The amount of material that was extractable from the vadose zone sediment into 8 M nitric acid is shown in Table 4.22. Prior to gaining access to an x-ray fluorescence unit that can determine the total composition of contaminated sediment directly, the laboratory had no accurate method to determine directly the total elemental composition of the contaminated sediment. As described in Serne et al. (2002a), total fusion digestion of sediment as well as 8 M nitric acid was attempted. Neither technique works well for Hanford vadose zone sediment. The total fusion dilutes the acid-extract solution too much to get useful data for most trace metals and based on the x-ray fluorescence analyses, the 8 M nitric acid extraction dissolves only a few percent to at best 50% of various constituents.

The 8 M nitric acid extraction is a protocol used by the U.S. Environmental Protection Agency to estimate the maximum concentrations of regulated metals in contaminated sediment that would be biologically available. Aliquots of contaminated sediment from borehole 299-E33-45 were subjected to the acid extraction to search for obvious signs of elevated concentrations of elements from leaked tank fluids.

At the present time, data for acid extracts of sediment from nearby clean boreholes are not available to compare with data from borehole 299-E33-45 to evaluate whether some constituents that are acid extractable appear elevated in the contaminated sediments. Table 4.22 shows the mass of selected constituents that was acid extractable per gram of sediment. Figure 4.14 and Figure 4.15 compare the concentrations of water versus acid extractable cations as a function of depth. None of the acid extract data show signs of elevated concentrations that can be attributed to the presence of tank overfill solution. This finding differs from the SX-108 slant borehole data where acid extract data exceeded the comparable values in acid extracts from clean boreholes by at least 10 times. However, the water extractable sodium in sample 72A at ~152 ft bgs shows that a much higher percentage of the acid extractable sodium was also water extractable. This suggests that some tank fluid is present at this depth. In general, the percentage of these common cations that was water extractable versus acid extractable are quite low, similar to natural sediments that do not contain large amounts of waste. For the slant borehole sediments under SX-108, greater than 80% of the sodium that was acid extractable was also water extractable showing the large mass of sodium that leaked from the SX-108 tank (see Serne et al. 2002c for more details).

Table 4.22. Acid-Extractable Major Element Content of the Vadose Sediment from Slant Borehole

Sample ID	**Depth ft bgs[(a)]**	**Ca ug/g**	**Mg ug/g**	**Na ug/g**	**K ug/g**	**Sr ug/g**	**Ba ug/g**	**Al ug/g**	**Si ug/g**	**Fe ug/g**
H1 Coarse Sand										
No Samples Analyzed										
H2 Upper Sand Sequence										
16A	42.04	8.08E+03	4.79E+03	- - -	1.06E+03	2.82E+01	7.07E+01	6.24E+03	(3.69E+01)	1.45E+04
Muddy Very Fine Sand Lens										
34A	75.65	9.28E+03	6.12E+03	- - -	2.33E+03	4.04E+01	7.54E+01	1.09E+04	(7.51E+01)	1.72E+04
H2 Middle Sand Sequence										
40A	88.65	7.84E+03	5.09E+03	- - -	1.08E+03	2.80E+01	5.24E+01	6.85E+03	(9.26E+01)	1.47E+04
44A	100.09	7.61E+03	5.48E+03	- - -	1.60E+03	3.21E+01	6.89E+01	8.18E+03	(8.16E+01)	1.49E+04
54C	120.14	1.14E+04	6.22E+03	- - -	1.72E+03	6.69E+01	8.61E+01	8.76E+03	(3.54E+01)	1.45E+04
72A	151.55	6.63E+03	5.05E+03	- - -	1.10E+03	3.00E+01	5.78E+01	6.73E+03	(1.04E+02)	1.45E+04
Fine Very Fine Sand Lens										
83D	169.55	9.90E+03	5.93E+03	- - -	1.42E+03	4.67E+01	7.04E+01	8.89E+03	7.42E+01	1.64E+04
H3 Unit										
93A	190.65	6.68E+03	4.33E+03	- - -	9.75E+02	3.33E+01	6.57E+01	6.52E+03	8.28E+01	1.52E+04
Plio-Pleistocene Mud (PPlz)										
110D	217.95	7.51E+03	5.62E+03	- - -	1.35E+03	3.72E+01	6.31E+01	8.22E+03	9.94E+01	1.44E+04
111A	221.75	1.23E+04	1.08E+04	- - -	3.42E+03	6.62E+01	2.07E+02	2.63E+04	2.43E+01	3.39E+04
116A	231.45	1.24E+04	6.85E+03	- - -	1.95E+03	5.73E+01	1.28E+02	1.07E+04	5.79E+01	1.90E+04
Plio-Pleistocene Gravelly Sand (PPlg)										
122A	241.89	5.62E+03	4.02E+03	- - -	1.06E+03	3.37E+01	7.70E+01	6.72E+03	8.25E+01	1.68E+04

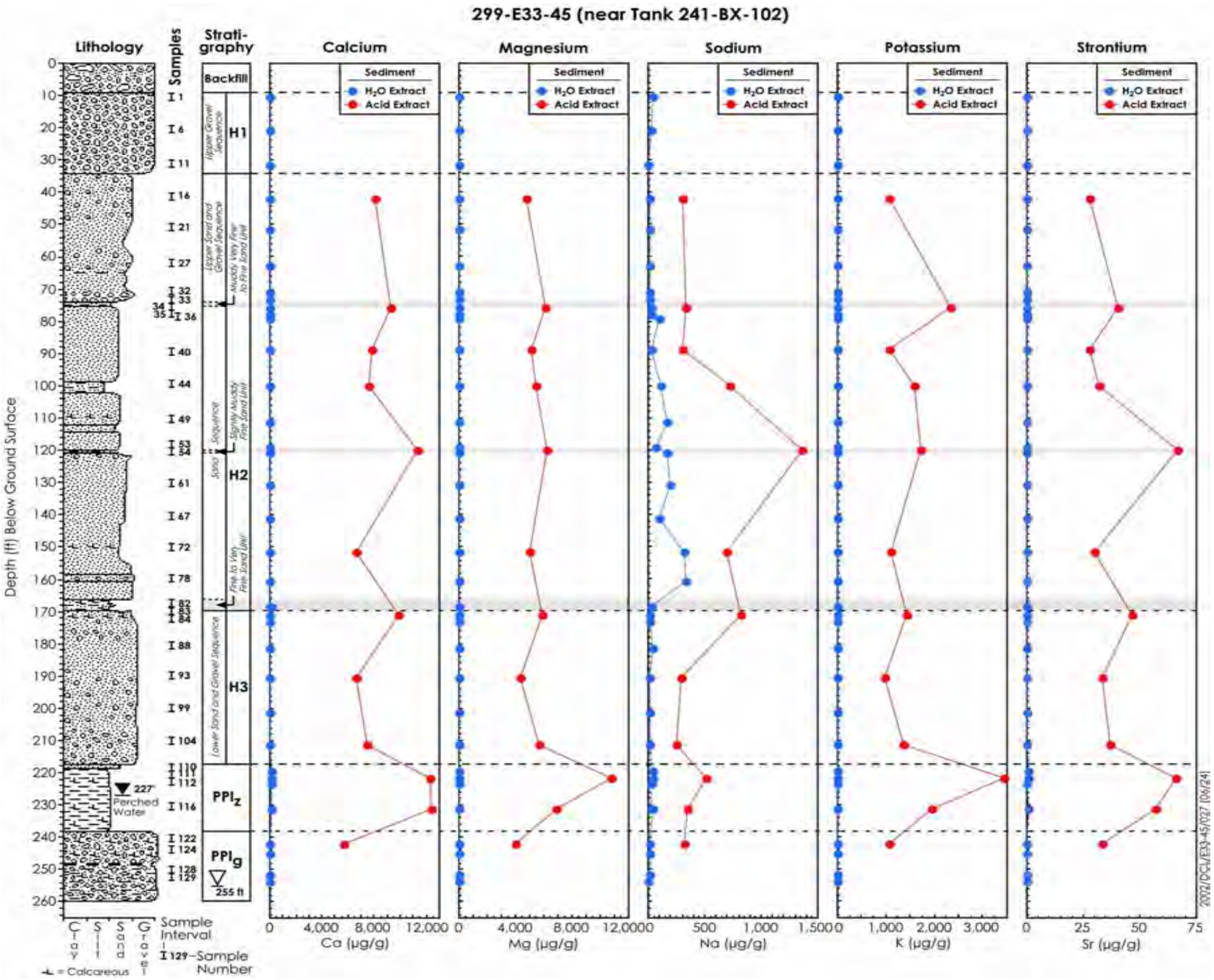

Figure 4.14. Comparison Between Acid and Water Extractable Concentrations of Major Cations

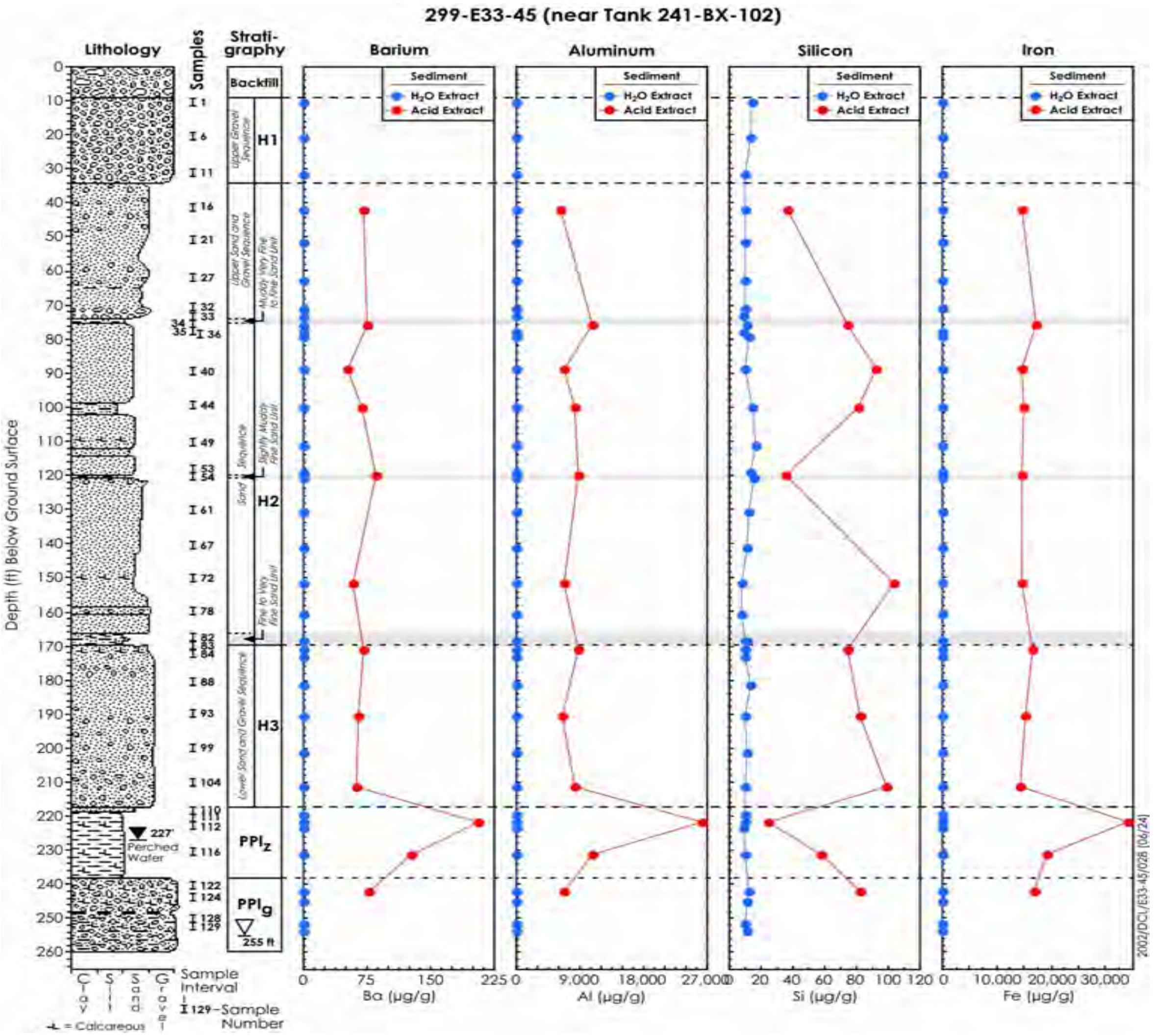

Figure 4.15. Comparison Between Acid and Water Extractable Concentrations of Barium, Aluminum, Silicon, and Iron

4.7 Sediment Total Oxide Composition

Twelve samples of the bulk vadose zone sediment from borehole 299-E33-45 were crushed and analyzed with x-ray fluorescence to obtain the complete composition of the sediment. Additional aliquots of the same sediment were subjected to particle size analysis and the sand, silt, and clay separates were retained. The total oxide composition of the bulk sediments was used to aid in the quantification of mineralogy that will be discussed in Section 4.10.

The total elemental oxide composition for the bulk sediment is shown in Table 4.23. Using two types of x-ray fluorescence instruments, all natural elements from sodium through uranium could be analyzed. The laboratory lacks the capability for measuring the concentrations of only carbon, beryllium, boron, fluorine, lithium, and nitrogen. However, the carbon content of the bulk sediment was analyzed as discussed in Section 4.5 so data for that component is available. The beryllium, boron, fluorine, and lithium content of the sediment likely is small; therefore, the oxide mass of the sediment should be able to be calculated and come close to 100% mass balance. It was assumed that the iron present in the sediment is all iron (III) oxide though there may be some reduced (i.e., ferrous oxides) iron also present.

The mass balances for the bulk sediment vary from 89 to 102%. The missing mass for samples 16A and 34A in the Hanford H2 unit and sample 116A in the PPlz unit are caused by low silica values and perhaps low alumina values. As found for uncontaminated sediment from outside other tank farms, the Hanford formation sediment is dominated by silica and alumina. Calcium, carbonate, iron, magnesium, potassium, sodium, and titanium make up most of the rest of the oxides. There is not a large database of elemental compositions but when compared to the two clean RCRA boreholes near SX tank farm (Serne et al. 2002a), the contaminated sediment at 299-E33-45 does not show significantly higher contents of any element, except perhaps the phosphorus oxide in sample 54C, which has been described as a possible paleosol. It is also possible that this sample contains phosphate from the 1951 overfill of tank BX-102 because this sample contains very high concentrations of technetium-99 and uranium.

Table 4.23. Total Composition of the Vadose Zone Sediment from 299-E33-45 Percent Weight as Oxides (2 pages)

ID	**16A**	**34A**	**40A**	**44A**	**54C**	**72A**	**83D**	**93A**	**110D**	**111A**	**116A**	**122A**
Depth (ft)[a]	**42.04**	**75.65**	**88.65**	**100.09**	**120.14**	**151.55**	**169.55**	**190.65**	**217.95**	**221.75**	**231.45**	**241.89**
Unit	**H2**	**H2**	**H2**	**H2**	**H2**	**H2**	**H2**	**H3**	**PPlz**	**PPlz**	**PPlz**	**PPlg**
CO_2	0.77	0.55	0.59	0.59	0.70	0.59	0.70	0.44	0.51	0.81	0.92	0.37
Na_2O	2.19	1.77	2.32	2.36	2.08	2.77	3.35	2.81	2.75	1.81	1.78	2.50
MgO	0.84	1.54	1.20	1.32	2.36	1.12	1.97	1.26	1.46	2.14	1.97	1.34
Al_2O_3	10.37	11.35	10.46	12.36	12.78	11.49	12.55	12.29	13.05	15.59	11.51	11.52
SiO_2	64.60	64.83	71.51	71.96	64.50	71.16	70.23	72.08	73.87	62.83	59.46	65.42
Fe_2O_3	3.94	3.91	3.98	3.30	4.06	3.77	4.45	4.92	3.59	6.06	4.80	5.12
Cr_2O_3	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
P_2O_5	<0.25	0.34	<0.27	0.25	1.14	<0.25	<0.30	<0.30	<0.27	0.26	<0.27	0.27
SO_3	<0.08	<0.09	<0.07	0.07	<0.10	0.11	<0.10	0.15	0.18	0.17	<0.09	<0.08

Table 4.23. Total Composition of the Vadose Zone Sediment from 299-E33-45 Percent Weight as Oxides (2 pages)

ID	**16A**	**34A**	**40A**	**44A**	**54C**	**72A**	**83D**	**93A**	**110D**	**111A**	**116A**	**122A**
Depth (ft)(a)	**42.04**	**75.65**	**88.65**	**100.09**	**120.14**	**151.55**	**169.55**	**190.65**	**217.95**	**221.75**	**231.45**	**241.89**
Unit	**H2**	**H2**	**H2**	**H2**	**H2**	**H2**	**H2**	**H3**	**PPlz**	**PPlz**	**PPlz**	**PPlg**
Cl	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.04	0.06	0.04	<0.01	<0.01
K_2O	1.93	1.90	2.06	2.27	2.29	1.97	2.11	2.02	2.21	2.34	2.04	1.78
CaO	3.23	2.91	3.33	3.18	4.06	3.41	4.27	4.10	3.40	2.80	4.21	3.83
TiO_2	0.58	0.60	0.56	0.51	0.61	0.56	0.66	0.74	0.53	0.79	0.68	0.84
V_2O_5	<0.005	0.006	<0.005	<0.005	<0.005	<0.005	<0.006	0.014	<0.005	0.009	0.007	0.012
MnO	0.062	0.065	0.069	0.058	0.067	0.065	0.079	0.076	0.068	0.073	0.087	0.088
MnO	0.065	0.069	0.072	0.062	0.070	0.069	0.083	0.080	0.070	0.078	0.091	0.092
NiO	0.002	0.002	0.004	0.003	0.003	0.003	0.003	0.002	0.003	0.006	0.004	0.002
CuO	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.005	0.003	0.002
ZnO	0.006	0.007	0.006	0.006	0.006	0.006	0.007	0.007	0.006	0.013	0.008	0.008
SrO	0.041	0.036	0.038	0.042	0.046	0.045	0.046	0.044	0.049	0.036	0.047	0.044
UO_3	0.001	0.007	0.002	0.002	0.174	0.005	0.014	0.001	<0.001	0.003	0.001	<0.001
ZrO_2	0.016	0.026	0.013	0.012	0.022	0.013	0.018	0.013	0.015	0.018	0.018	0.016
SrO	0.038	0.029	0.028	0.034	0.032	0.039	0.034	0.031	0.037	0.032	0.039	0.043
BaO	0.092	0.083	0.095	0.091	0.095	0.091	0.096	0.093	0.098	0.107	0.100	0.092
Total	89.14	90.13	96.71	98.53	95.23	97.58	101.10	101.52	102.25	96.03	88.17	93.49

(a) Multiply by 0.3048 to convert to meters
Red type indicates phosphorus value for sample 54C may indicate some tank leak impact

4.8 Particle Size Measurements on Vadose Zone Sediment

The hydrometer method was used to determine the particle size distributions of several samples from 299-E33-45 as shown in Table 4.24. No wet sieving was done to separate the gravel and sand fractions from each other so the particle size data shows only combined gravel plus sand, silt, and clay fractions. The thin fine-grained lenses and Plio-Pleistocene silts are highlighted in yellow shading. One sample at the very top of the Plio-Pleistocene silt (i.e., sample 110D) does not contain very much silt and clay even though it is assigned to the PPlz silt layer.

Besides the hydrometer estimate of clay-size particles, the clay material was physically separated from the silt by performing numerous re-suspensions of the slurry and decanting off the clays after the silts had settled. The mineralogical characterization is described below in Section 4.10.

Table 4.24. Particle Size Distribution Percent Weight

Sample ID	Depth (ft)[(a)]	% Gravel plus% Sand	%Silt	%Clay	Facies
16A	42.04	96.2	1.7	2.1	H2-uss
34A	75.65	62	35.3	2.7	H2-vfs#1
40A	88.65	98	0.6	1.4	H2-mss
44A	100.09	95.5	2.9	1.6	H2-mss
54C	120.14	87	7.5	5.5	H2-vfs#2
72A	151.55	95.5	2.0	2.5	H2-mss
83D	169.55	92	5.5	2.5	H2-vfs#3
93A	190.65	96.7	1.7	1.6	H3
110D	217.95	96	2.0	2.0	PPlz
111A	221.75	2	39	49	PPlz
116A	231.45	77.5	18.8	3.7	PPlz
122A	241.89	94.4	3.2	2.4	PPlg
Yellow shading indicates fine-grained samples in the silt and clay columns					

4.9 Particle Density of Bulk Sediment

The particle density for each of the samples that were used in the hydrometer procedure is shown in Table 4.25. The values are similar to those of uncontaminated sediment from the same lithologic facies found in the 200 West Area (Serne et al. 2002a). The finest-grained samples from the Plio-Pleistocene silt layer have a lower particle density than the sediments from the other strata. The average value for all the Hanford formation sediments is 2.80 ± 0.070 g/cm^3 similar to the value 2.78 g/cm^3 often used for generic Hanford formation sediments.

Table 4.25. Particle Density of Bulk Sediment from Borehole 299-E33-45

Sample ID	Depth (ft bgs)[(a)]	Facies [(b)]	Ps[(c)]	σPs[(d)]
16A	42.04	H2-uss	2.77	0.018
34A	75.65	H2-vfs#1	2.81	0.043
40A	88.65	H2-mss	2.67	0.070
44A	100.09	H2-mss	2.89	0.050
54C	120.14	H2-vfs#2	2.81	0.074
72A	151.55	H2-mss	2.78	0.014
83D	169.55	H2-vfs#3	2.89	0.027
93A	190.65	H3	2.81	0.021
110D	217.95	PPlz	2.81	0.024
111A	221.75	PPlz	2.67	0.048
116A	231.45	PPlz	2.64	0.020
122A	241.89	PPlg	2.85	0.038

(a) Multiply by 0.3048 to convert to meters
(b) H2-uss = Hanford H2 Unit upper sand sequence, H2-mss = Hanford H2 unit middle sand sequence, H2-vfs# = various thin fine-grained lens in Hanford H2 unit, H3 = Hanford H3 unit, PPlz = Plio-Pleistocene silt layer, PPlg = Plio-Pleistocene gravelly layer
(c) Ps = Particle density g/cm3
(d) σ_{Ps} = standard deviation for 3 measurements of particle density

4.10 Mineralogy

XRD analysis of the twelve-bulk sediment samples from borehole 299-E33-45 shows the samples to all have a similar mineralogical signature. The sediments are mostly quartz and feldspar (both plagioclase and alkali-feldspar), with lesser amounts of mica, chlorite, and an amphibole. For example, the XRD tracing using a copper x-ray source of a typical sediment sample (e.g., sample 111A) is provided in Figure 4.16, along with a quartz reference pattern. The main reflection for quartz is 26.63° 2θ, followed by less intense reflections at 20.86, 36.53, 39.46, 42.43, 50.12, 59.92° 2θ. The primary reflections associated with feldspar minerals are found between 27.34° 2θ and 27.92° 2θ, with the higher 2θ values belonging to the plagioclase series. Chlorite and mica minerals were identified on the x-ray tracings by the reflections at 6.3° 2θ and 8.8° 2θ, respectively. The presence of an amphibole was established by the characteristic 100% reflection at 10.5° 2θ. Examples of x-ray diffractograms of the bulk sediment are presented in Appendix D.

Semi quantitative XRD results of the bulk sediment samples are presented in Table 4.26. Mineral concentrations in the sediment are predominately quartz (~28 to 40 wt-%), plagioclase feldspar (~19 to 35 wt-%) and potassium feldspar (~7 to 14 wt-%) with lesser amounts of amphibole (1 to 8 wt-%). Plagioclase feldspar is 2 to 4 times more abundant than potassium feldspar. Clay minerals identified in the whole rock sediment included mica and chlorite. Mica concentrations ranged from a low of 16 wt-% (sample 93A) to a high of 27 wt-% (sample 111A), with an average concentration of 19±4 wt-%. Chlorite concentrations were <8-wt% in all sediments analyzed. Smectite and kaolinite minerals were not identified in the whole rock sediment samples due in part to the sample preparation technique and the low overall concentration, respectively.

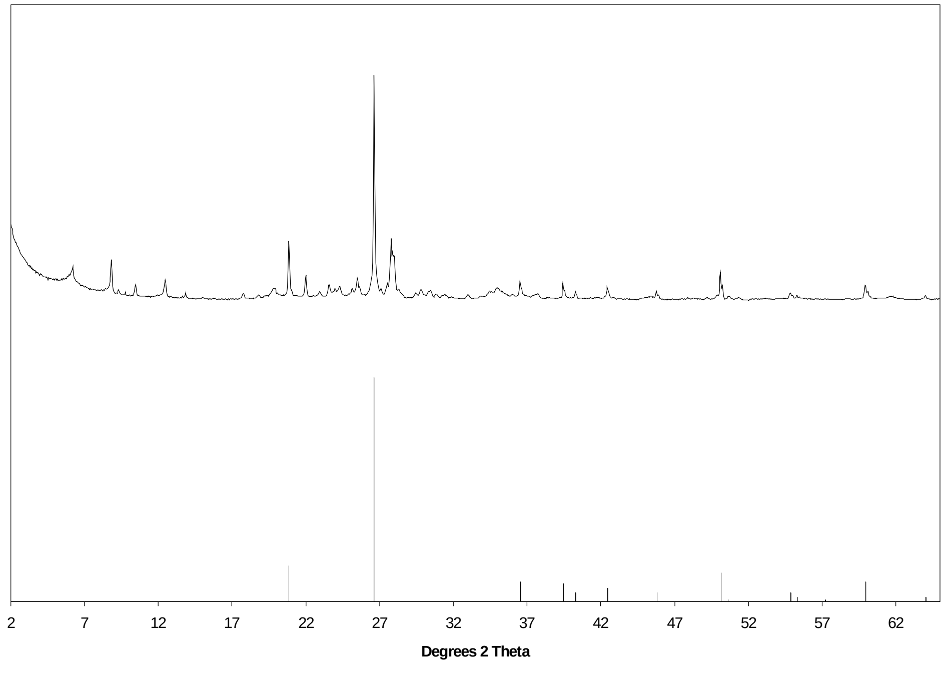

Figure 4.16. XRD Tracing of Bulk Sediment Sample 11A (221.8 ft bgs) Along with a Standard Reference Pattern for Quartz

One indicator used to measure the reliability of whole pattern fitting is to ratio the weighted and calculated errors from the refinement process, which is expected to be close to one in an ideal refinement. This ratio, referred to as the "goodness of fit," is provided for each sample in the last column of Table 4.26. The goodness of fit ranged from a low of 0.56 (sample 16A) to a high of 0.97 (sample 111A). Difficulty in obtaining exact matches for the mica and feldspars presented some problems within the refinement process, which is indicated by the lower goodness of fit for some of the samples.

X-ray diffraction analysis was performed on the <2 micron fraction of each sample and the results are presented below. The clay fraction (<2 micron) is dominated by four clay minerals: illite (8.88° 2θ), smectite (5.28° 2θ), chlorite (6.24° 2θ), and kaolinite (12.5° 2θ), with minor amounts of quartz (26.63° 2θ), feldspar (~27.9° 2θ), and amphibole (10.5° 2θ). Figure 4.17 provides XRD-tracings of a typical clay fraction (from sample 111A) following four different treatments. Smectites are considered the fraction of the magnesium-saturated sub-sample that gives a basal reflection at 5.85° 2θ and expands to 5.28° 2θ upon solvation with ethylene glycol. Saturation with a K^+ cation shifts the reflection to 7.3° 2θ followed by the irreversible collapse to 8.88° 2θ after heating for one hour at 575 °C.

Table 4.26. Semiquantitative Mineral Composition for Bulk Samples in Weight Percent

Sample ID	**Depth[(a)]**	**Geologic Unit**	**Quartz**	**K Feldspar**	**Plagioclase**	**Amphibole**	**Mica**	**Chlorite**	**Goodness of fit[(b)]**
16A	42.0	H2	29	12	32	1	23	4	0.56
34A	75.7	H2	40	16	21	5	12	7	0.91
40A	88.7	H2	36	7	26	3	24	4	0.85
44A	100.1	H2	34	13	26	6	18	3	0.68
54C	120.1	H2	34	13	27	6	17	4	0.85
72A	151.6	H2	28	14	33	2	19	5	0.60
83D	169.6	H2	29	9	30	8	20	5	0.57
93A	190.7	H3	31	14	32	3	16	5	0.79
110D	218.0	PPlz	36	8	30	3	17	5	0.69
111A	221.8	PPlz	25	14	19	4	27	11	0.97
116A	231.5	PPlz	35	10	26	8	17	5	0.64
122A	241.9	PPlg	25	13	35	3	19	5	0.62

(a) Depth in vertical feet (multiply by 0.3048 to convert to meters)
(b) Values closest to 1.0 indicate a successful refinement

Illite is the simplest of the four clay mineral phases to identify in this sediment. The basal reflections are located at 8.88, 17.8, and 26.7° 2θ. The various treatments including cation saturation, solvation with ethylene glycol, and heating do not affect the structure of the illite. This is shown in Figure 4.17 by examination of the illite basal reflection at 8.88° 2θ. The increase in intensity of the 8.88° 2θ reflection between the heated and the unheated potassium-saturated sample is due to the incorporation of the smectite reflection resulting from the smectite structure collapsing.

Chlorites are identified by their basal series of diffraction peaks at 6.24, 12.5, 18.8, and 25.2° 2θ, which are unaffected by cation saturation or ethylene glycol solvation. Heating to 575 °C shifts the first order reflection to 6.37° 2θ and also tends to diminish or eliminate the higher order reflections (12.5, 18.8, and 25.2° 2θ) as shown in Figure 4.17. Kaolinite is difficult to identify in the presence of a chlorite mineral. Basal reflections characteristic to kaolinite are positioned at 12.5 and 24.9° 2θ, which are superimposed on the even-order chlorite peaks. These kaolinite reflections are unaffected by cation saturation and ethylene glycol solvation. When heated the kaolinite structure becomes amorphous and the reflections are eliminated. Positive identification of kaolinite in the presence of chlorite can be determined by examination of the 24.9 to 25.2° 2θ region of the XRD tracing. The kaolinite basal reflection at 24.9° 2θ can be distinguished from the chlorite 25.2° 2θ reflection. Furthermore, published reports characterizing similar clay fractions of Hanford sediment identify kaolinite by electron microscopy. Examples of x-ray diffractograms of the oriented clay sediment saturated with magnesium (II) and ethylene glycol solvated are presented in Appendix D.

The scans were collected from 2 to 45° 2θ with a 0.04° step and 2-second dwell time. The black line represents the magnesium-saturated, air-dried fraction and the blue line represents the same fraction solvated with ethylene glycol. The green line indicates the saturation with K^+ cation and the red line is the K^+-saturated sample heated to 575 °C for one hour.

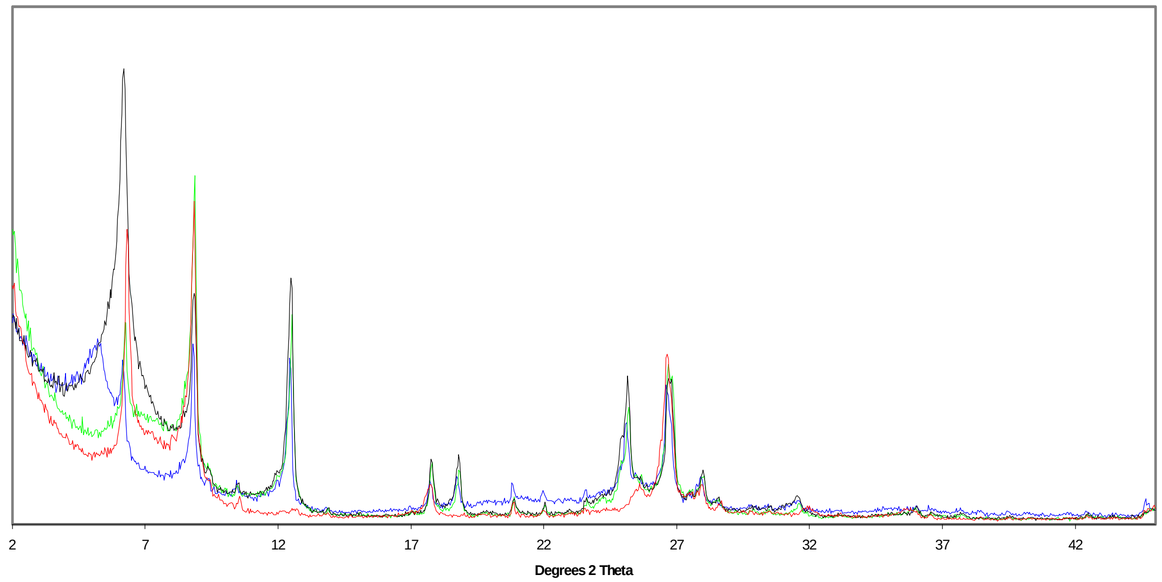

Figure 4.17. XRD tracings of preferentially oriented clay slides taken of sample 111A (221.8 ft bgs)

The semi-quantitative abundance of minerals in the clay fraction is given in Table 4.27. Overall, smectite and illite are the dominant minerals in the clay fraction with 73 to 85 wt-%. Smectites range in concentrations from as high as 40 wt-% (sample 93A depth 33.4 m [190.7 ft bgs]) to as low as 24 wt-%; illite occurred between ~38 and 55 wt-%. Chlorite concentrations were as low as 10 wt-% (sample 44A 30.5 m [100.1 ft] bgs) and as high as 20 wt-% (72A 46.2 m [151.6 ft] bgs). Minor amounts of kaolinite (<9 wt-%) were detected at all depths. Quartz, feldspar, and amphibole made up only trace amounts of the clay fraction. Normalization factors ranged from a low of 0.78 to a high of 1.78, with half of the samples having values above 1.30. The high normalization factors for samples 54C, 72A, 93A, 111A, 116A, and 122A are most likely the result of poorly oriented sediment on the XRD slide. Quantitative analysis is considered good if errors amount to ±10% of the amounts present for major constituents and ±20% for minerals whose concentrations are less than 20% (Moore and Reynolds 1997).

TEM analysis on sediments from borehole 299-E33-45 were not performed because there was little evidence of contaminant interaction with the sediments and the XRD data adequately defined the mineralogy of the sediments for the purposes of defining the vertical extent of contamination.

Table 4.27. Semiquantitative Analysis of the Clay Fraction from Borehole 299-E33-45 in Weight Percent

Sample ID	Depth (ft)[(a)]	Geologic Unit	Smectite	Illite	Chlorite	Kaolinite	Normalization Factor
16A	42.0	H2	28	50	14	7	0.87
34A	75.7	H2	38	44	11	7	1.02
40A	88.7	H2	34	47	14	5	1.18
44A	100.1	H2	35	50	10	4	0.96
54C	120.1	H2	24	55	14	7	1.78
72A	151.6	H2	28	47	20	5	1.31
83D	169.6	H2	35	38	18	9	1.10
93A	190.7	H3	40	39	14	7	1.67
110D	218.0	PPlz	31	47	15	7	0.78
111A	221.8	PPlz	25	52	16	7	1.39
116A	231.5	PPlz	37	39	18	7	1.33
122A	241.9	PPlg	28	50	14	7	1.44
(a) Depth in vertical feet (multiply by 0.3048 to convert to meters)							

4.11 Matric Suction Potential Measurements

Water-potential measurements have been included in the Hanford Tank Farm Vadose Zone Characterization Program to document the energy state of porewaters in the tank farm sediments. At the tank farms, vegetation is absent, surface soils are coarse-textured, and the potential for drainage (recharge) is high (Gee 1987; Gee et al. 1992). However, actual drainage rates are generally unknown. Attempts are currently being made to status the soil water matrix potential and use the analysis to confirm the occurrence of recharge within the Hanford Site tank farms.

The status of soil water can be defined by either the amount of water in the soil (water content) or by the force that holds water to the soil matrix (i.e., the matric potential or suction) (Or and Wraith 2002). In recent studies, Serne et al. (2000b, d) measured both water content (gravimetrically) and matric water potential (filter paper method) on core samples obtained from boreholes in the SX tank farm environs. The filter paper method (ASTM 2002) was used. The same measurements were made at boreholes 299-E33-45, 299-E33-46, and 299-E33-338, within the B and BX tank farms. All cores and many grab samples were selected from the surface to the water table and analyzed. A sandwich of three Whatman catalog #42 filter papers was placed in the sediment, sealed, and equilibrated for at least 21 days. The water content of the middle filter paper (not allowed to collect sediment particles) was subsequently measured and the water potential obtained from a predetermined water-retention characteristic curve. The filter paper method provides a good estimate of water potentials over the range from -0.01 to -2 MPa (1 to 200 m [3.3 to 656 ft] suction head) (Deka et al. 1995).

Table 4.28 and Figure 4.18 show the matric potentials as a function of depth for the 299-E33-45 samples. Also plotted in Figure 4.18 is the gravity head expressed in pressure units (MPa). The gravity head is zero at the water table and increases linearly with height to the soil surface. For 299-E33-45, the water potentials, as measured for the core samples (blue symbols in Figure 4.18) are much less than the gravity potential from the surface down to 70 m (230 ft). The general trend is that the water potentials are consistent with a draining profile (i.e., water potentials wetter than -0.01 MPa). Below 70 m (230 ft) and to the water table at ~76 m (~250 ft), there appears to be a drier condition than above that depth. Note that the lower depths contain coarse materials, so sample handling (e.g., drying) may be responsible for the apparent drier matric potentials. The red symbols in Figure 4.18 represent grab samples that were obtained in the field during the clean out of the drive barrel used to remove material between coring events. The process of obtaining the grab samples likely lead to some drying during the selection of material and filling of the sample jars. This leads to the spikes in matric potential that are inconsistently drier than the materials from the cores. It appears that borehole 299-E33-45 has a matric potential profile that strongly suggests drainage is occurring. The green line in Figure 4.18 is the theoretical line that represents the steady state unit gradient condition, which represents the profile for matric potential in a sediment profile that is neither draining nor drier than (actively evapotranspiring) equilibrium. Matric potential values to the left of the unit gradient line suggest a draining profile.

For borehole 299-E33-338 (C3391), located outside the southeast corner of the B tank farm in relatively undisturbed terrain, the matric potential data are considerably drier than at borehole 299-E33-45 (east of tank BX 102), particularly near the surface. However, the 299-E33-338 matric potential data (Figure 4.19) are consistent with the hypothesis that non-vegetated areas, with coarse-textured surfaces, drain more than areas with similar soil, but with vegetation present. It appears that the wetting from meteoric sources has not reached to the water table at the 299-E33-338 site.

Table 4.28. Matric Potential Data for Borehole 299-E33-45 Sediments as a Function of Depth (3 pages)

Depth ft bgs	Measured Core MPa	Measured Grab MPa	Theoretical Matric Potential MPa
H1 Coarse Sand			
9.89	0.0075		0.747
10.89	0.0312		0.744
19.59	0.0162		0.718
20.09	0.0661		0.716
21.09	0.0273		0.713
30.59	0.0062		0.684
31.09	0.0271		0.682
31.59	0.0451		0.681
H2 Unit–upper sand sequence			
32.09	0.0244		0.679
40.79	0.0289		0.653
41.29	0.0075		0.651
41.79	0.0084		0.650
42.29	0.0061		0.648
50.39	0.0090		0.624
50.89	0.0047		0.622
51.39	0.0062		0.621
51.89	0.0073		0.619
61.74	0.0035		0.589
62.24	0.0037		0.588
62.74	0.0031		0.586
63.24	0.0027		0.584
69.99	0.0061		0.564
70.49	0.0129		0.562
70.99	0.0054		0.561
71.49	0.0034		0.559
71.99		0.0180	0.558
H2 Unit–middle sand sequence			
102.99		0.0049	0.463
105.59		0.0031	0.455
107.44		0.0038	0.450
109.39		0.0075	0.444
109.89	0.0032		0.442
110.39	0.0035		0.441
110.89	0.0024		0.439
111.39	0.0034		0.438
111.59		0.0054	0.437
113.19		0.0050	0.432
114.19		0.0048	0.429
117.29		0.0035	0.420
117.79	0.0031		0.418
118.29	0.0022		0.417
118.79	0.0056		0.415
119.29	0.0035		0.414
119.49		0.0144	0.413
119.64	0.0080		0.413
120.64	0.0037		0.410
120.64	0.0048		0.410
121.34	0.0104		0.407
121.34		0.0132	0.407
120.74			0.409
123.29		0.0183	0.401
126.6		0.0119	0.391
124.4		0.0078	0.398
128.2		0.0585	0.386
H2 Unit–fine/very fine sand			
167.9	0.0044		0.265
168.4	0.0021		0.264
168.9	0.0024		0.262
169.1		0.0023	0.262
H3 Unit			
169.8	0.0086		0.260
170.3	0.0654		0.258
170.8	0.0154		0.257
171.3	0.0576		0.255
171.5		0.3882	0.255
172.1	0.0890		0.253
172.6	0.0419		0.251
173.1	0.0274		0.250
173.6	0.0725		0.248
173.8		0.5080	0.247
175.6		0.1817	0.242
178.2		0.7162	0.234
180.2		1.4997	0.228
180.4	0.0026		0.227
180.9	0.0050		0.226
181.4	0.0175		0.224
180.9	0.0246		0.226
183.3		0.2440	0.219
185.5		0.1927	0.212
186.9		0.0156	0.208
189.9		1.2193	0.198
189.4	0.0254		0.200

Table 4.28. Matric Potential Data for Borehole 299-E33-45 Sediments as a Function of Depth (3 pages)

Depth ft bgs	Measured Core MPa	Measured Grab MPa	Theoretical Matric Potential MPa
72.14	0.0065		0.557
72.64	0.0040		0.556
73.14	0.0063		0.554
73.64	0.0263		0.553
74.14		0.0029	0.551
H2 Unit–muddy very fine sand			
74.4	0.0046		0.550
74.9	0.0055		0.549
75.4	0.0030		0.547
H2 Unit–middle sand sequence			
75.9	0.0027		0.546
76.4		0.0017	0.544
76.94	0.3101		0.543
77.44	0.0182		0.541
77.44	0.0257		0.541
78.44	0.0100		0.538
78.94		0.0127	0.537
78.09	0.0033		0.539
78.59	0.0023		0.538
79.09	0.0016		0.536
79.59	0.0012		0.535
83.39		0.0123	0.523
85.59		0.0093	0.516
86.9		0.0100	0.512
87.4	0.0019		0.511
87.9	0.0015		0.509
88.4	0.0010		0.508
88.9	0.0013		0.506
129.1		0.0360	0.384
129.7		0.0107	0.382
130.2	0.0140		0.380
130.7	0.0142		0.379
131.2	0.0131		0.377
131.4		0.0181	0.377
133.3		0.0199	0.371
134.9		0.0113	0.366
136.1		0.0489	0.362
138.1		0.0230	0.356
139.8		0.0122	0.351
140	0.0116		0.351
140.5	0.0075		0.349
141	0.0095		0.347
141.5	0.0126		0.346
141.7		0.5043	0.345
143.4		0.0286	0.340
145.5		0.0432	0.334
147.7		0.0089	0.327
149.5		0.0353	0.322
150.3	0.0101		0.319
150.8	0.0141		0.318
151.3	0.0343		0.316
151.8	0.0220		0.315
152		0.0140	0.314
153.4		0.0033	0.310
154.7		0.0147	0.306
157.7		0.0102	0.297
189.9	0.0157		0.198
191.4	0.0391		0.194
190.9	0.0130		0.195
200.1	0.0635		0.167
200.6	0.0677		0.166
201.1	0.1346		0.164
201.6	0.0601		0.163
210.17	0.0456		0.137
210.67	0.0716		0.135
211.17	0.0571		0.134
211.67	0.0367		0.132
Fine-Grained Mud Unit (PPlz)			
218.2	0.0149		0.112
218.7	0.0433		0.111
219.2	0.0572		0.109
219.7	0.0561		0.108
220.5	0.0338		0.105
221	0.2848		0.104
221.5	0.0198		0.102
222	0.0172		0.101
222.4	0.0105		0.099
-222.9	0.0106		1.457
223.4	0.0041		0.096
223.9	0.0057		0.095
Gravely Sand Unit (PPlg)			
240.64	0.5888		0.044
241.14	0.3429		0.042
241.64	0.4012		0.041

Table 4.28. Matric Potential Data for Borehole 299-E33-45 Sediments as a Function of Depth (3 pages)

	Measured		Theoretical
Depth ft bgs	Core MPa	Grab MPa	Matric Potential MPa
91.1		0.2546	0.500
93.69		0.0019	0.492
95.69		0.0017	0.486
98.34		0.0015	0.477
98.84	0.0009		0.476
99.34	0.0017		0.474
99.84	0.0031		0.473
100.34	0.0025		0.471
100.54		0.5506	0.471
159.1		0.0258	0.292
159.1		0.0076	0.292
159.6	0.0058		0.291
160.1	0.0187		0.289
160.6	0.0140		0.288
161.1	0.0104		0.286
162.9		0.0000	0.281
164.2		0.0460	0.277
166.9		0.0059	0.269
167.4	0.0085		0.267
242.14	0.4224		0.039
244	1.2304		0.034
244.5	1.8102		0.032
245	1.4710		0.030
245.5	0.4945		0.029
251	0.3259		0.012
251.5	0.3933		0.011
252	0.1399		0.009
253.4	0.3389		0.005
253.9	0.0402		0.003

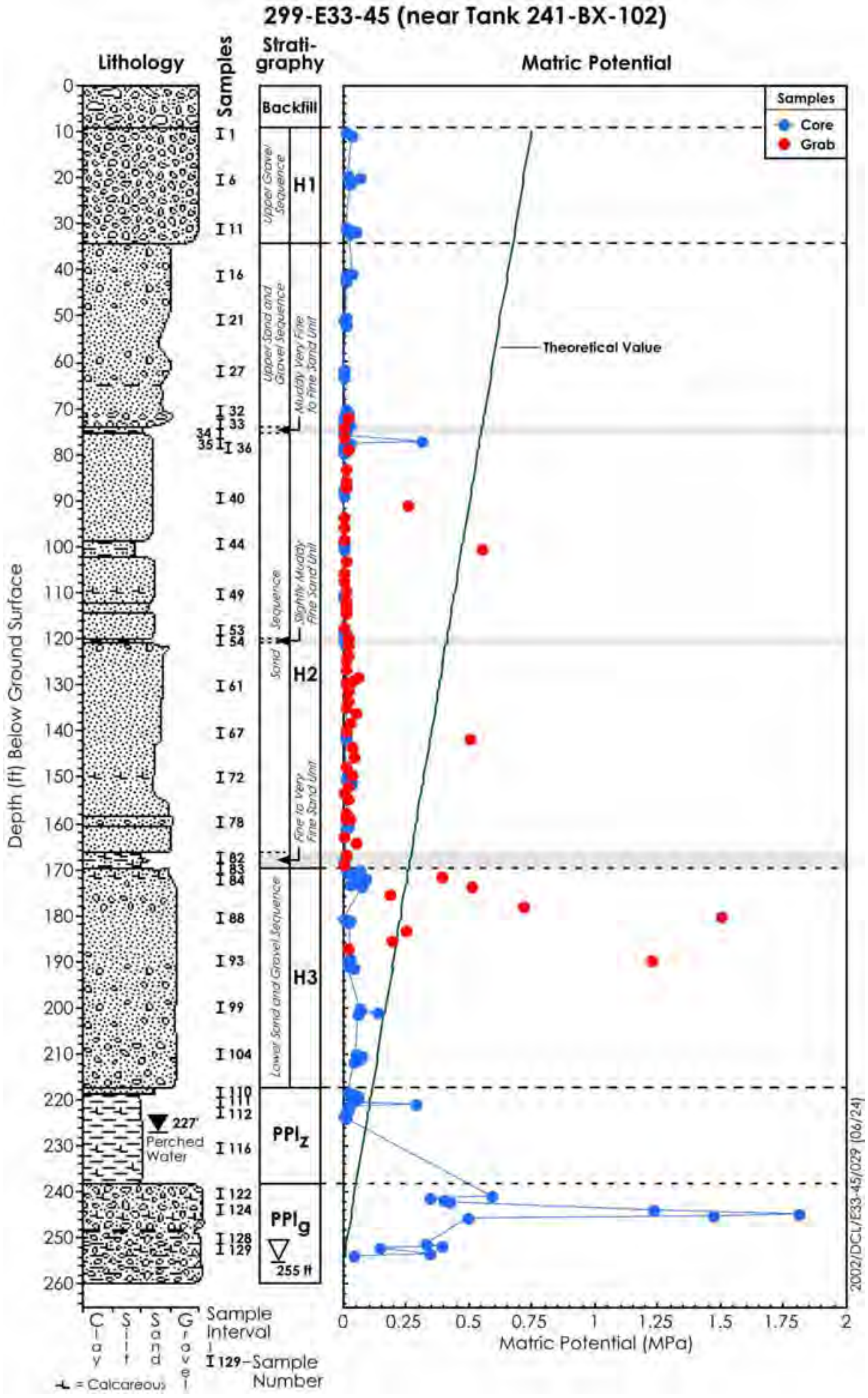

Figure 4.18. Matric Water Potential Measured by Filter Paper Technique on Core Samples from Borehole 299-E33-45

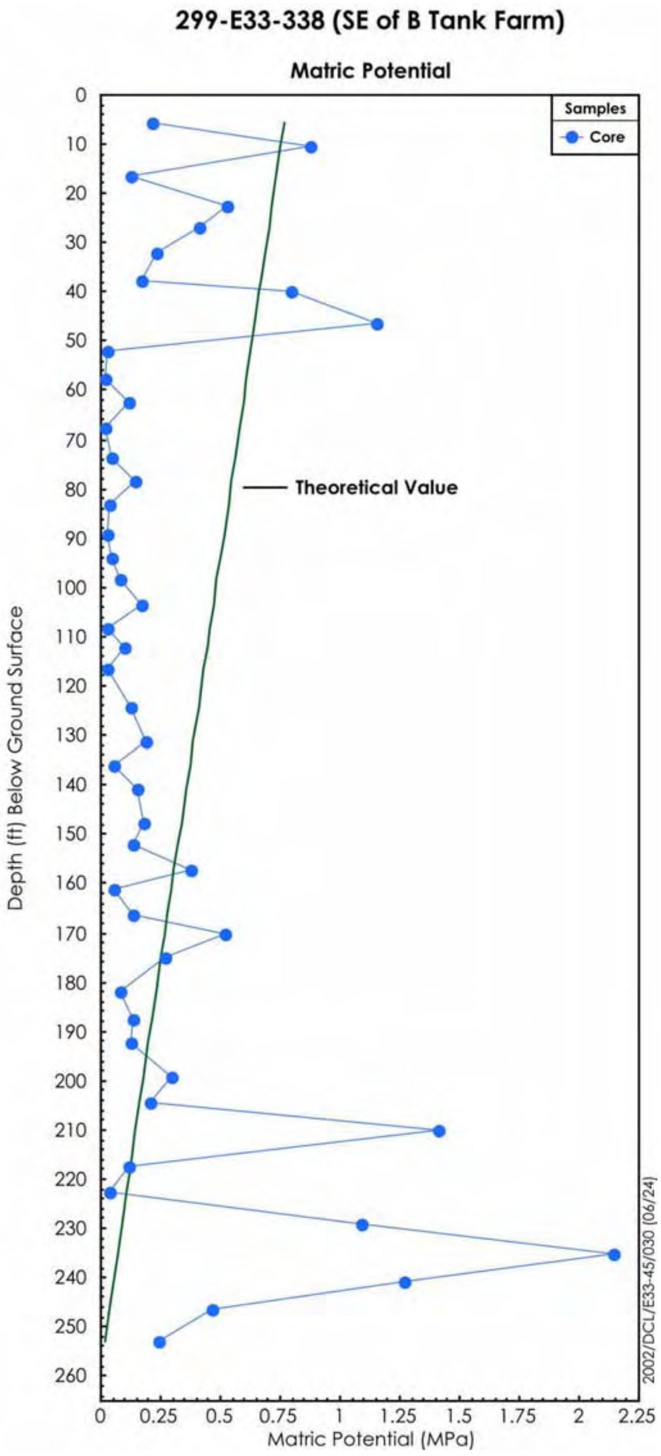

Figure 4.19. Matric Water Potential Measured by Filter Paper Technique on Core Samples from Borehole 299-E33-338 Located Outside the Southeast Perimeter of the B Tank Farm

4.12 Perched Water and Groundwater Analyses

The chemical composition of the perched water and groundwater are shown in Figure 4.20 through Figure 4.22 and reported in Table 4.29. The data for actual and calculated porewater (obtained from the dilution corrected 1:1 water extracts) parameters for samples from the deeper vadose zone are also shown in the figures. The water data are also found on several of the preceding figures and tables and discussed in the interpretation of the porewater data. In general, the perched water contains more dissolved common cations and anions and notably more tritium than the groundwater. In general, the concentrations of the common cations and anions are similar to those found in the nearby dilution corrected vadose zone sediment porewaters. For a few of the constituents, the perched water and groundwater have similar concentrations, alkalinity, fluoride, phosphate, aluminum, barium, and silicon. These constituents are likely controlled by dissolution reactions with the sediments. The high tritium concentration in the perched water may be an important finding and could reflect an origin from crib disposal. Thus, the perched water may be remnant water from past crib disposals that arrived at the borehole from horizontal flow along the less water conductive fine-grained PPlz unit.

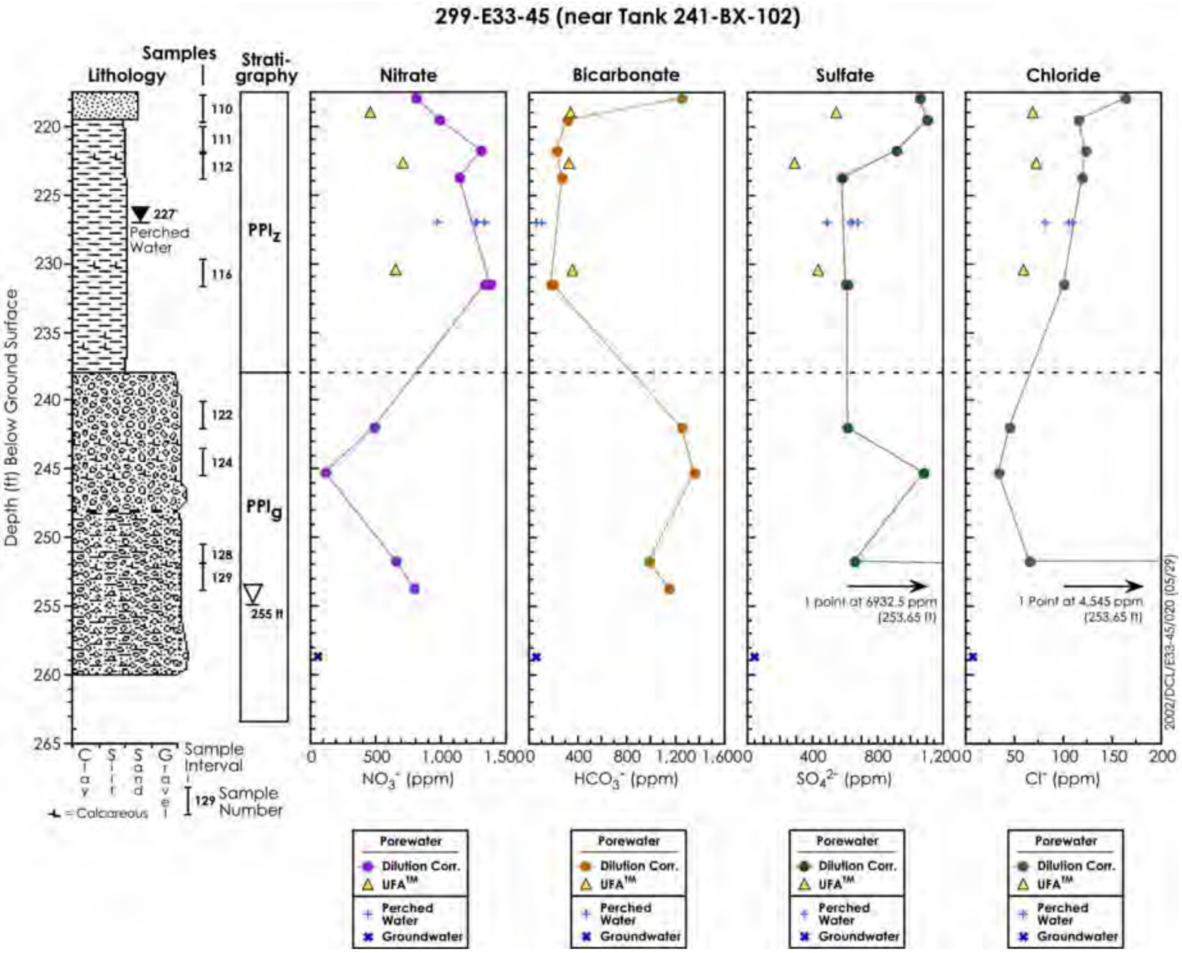

Figure 4.20. Values for Major Anions in the Perched and Groundwater Compared to Calculated Porewater from the Deep Vadose Zone

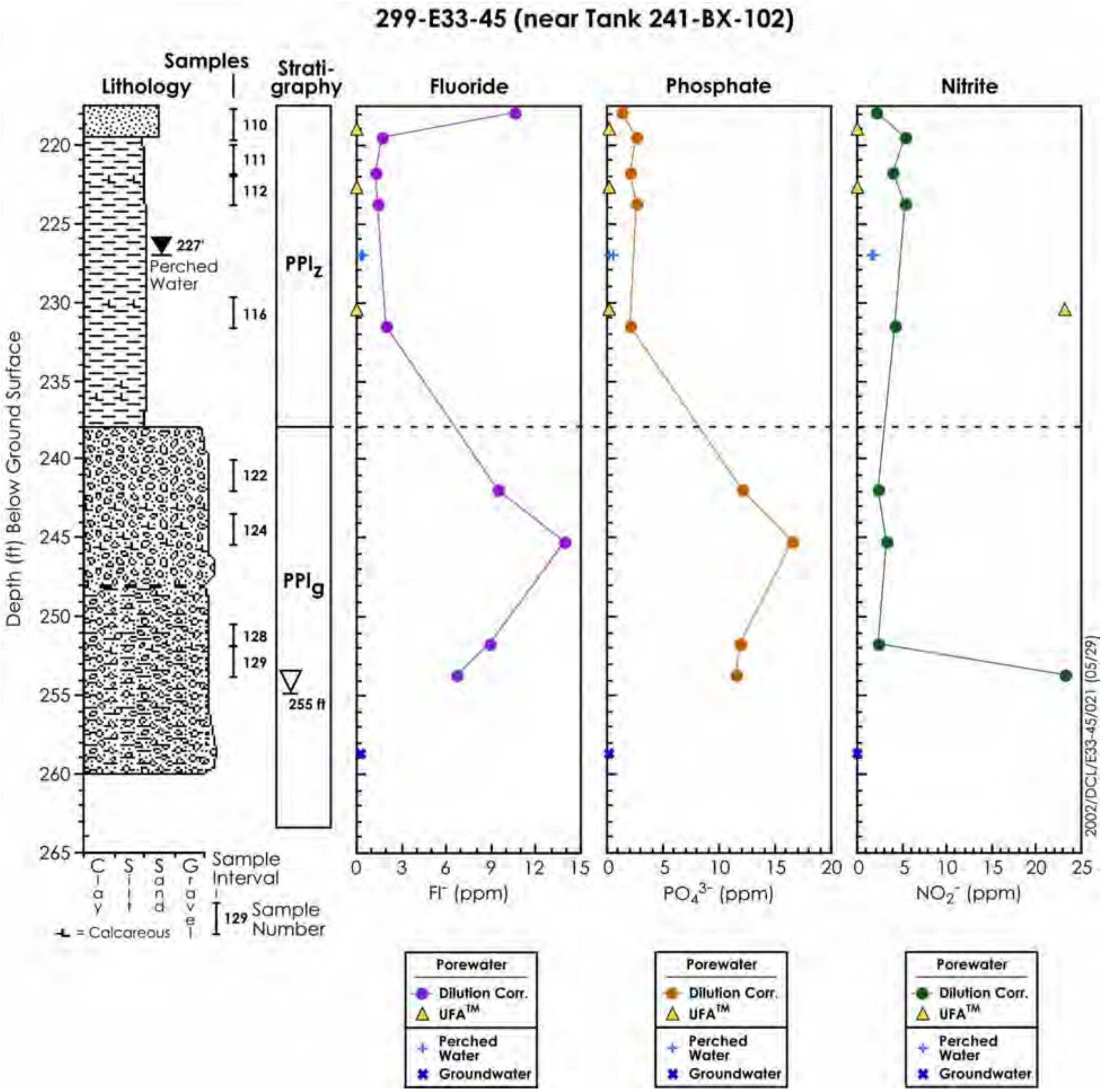

Figure 4.21. Minor Anion Composition in the Perched and Groundwater Compared to Calculated Porewater from the Deep Vadose Zone

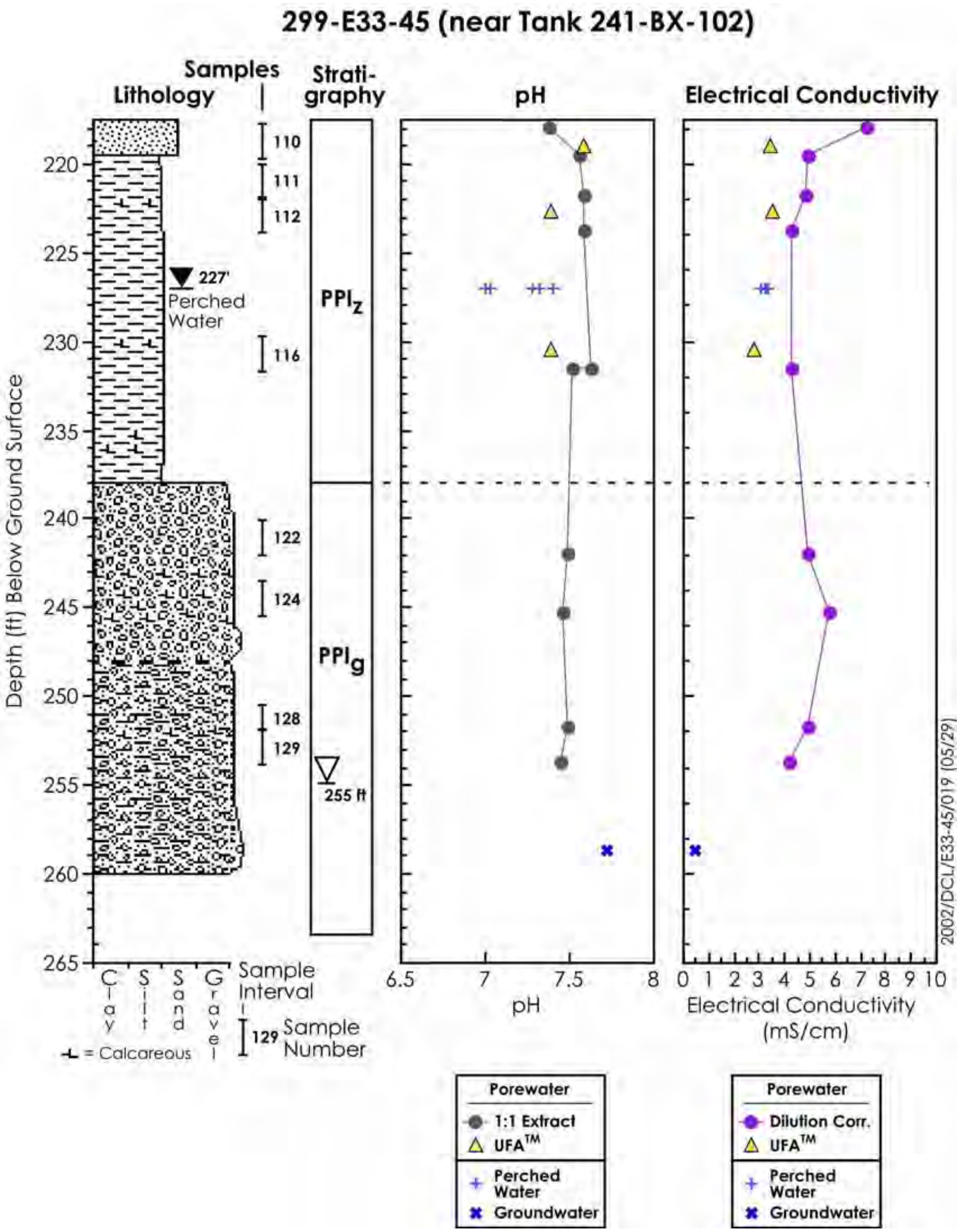

Figure 4.22. pH and Electrical Conductivity Values for the Perched and Groundwater Compared to Calculated Porewater from the Deep Vadose Zone

Table 4.29. Composition of Perched and Groundwater Taken from Borehole 299-E33-45

Constituent	Units	Groundwater		Perched Water Sample Identification				
		Contract Lab	PNNL Lab	117A	117B	117C	118	118dup
pH Measurement		7.92	7.53	7.279	7.316	7.408	6.995	7.031
Specific Conductance	uS/cm	440	449	3.33	3.32	3.05	3.25	3.32
Total organic carbon	ug/L	795	—	—	—	—	—	—
Alkalinity	mg/L	110	126	102	105	101	64	64
Chloride	mg/L	8.5	8.1	106.3	109.5	81.1	105.0	105.2
Cyanide	ug/L	21.4	9.0(a)	5.44(a)	—	—	—	—
Fluoride	mg/L	0.35	0.32	0.35	0.33	0.33	0.39	0.40
Nitrate	mg/L	57.5	55.7	1274.0	1331.6	977.9	1266.4	1263.2
Nitrite	mg/L	0.0887	<0.080	1.70	1.87	1.76	1.58	1.54
Sulfate	mg/L	43.2	42.7	646.1	673.3	489.6	638.2	635.5
Phosphate	mg/L	—	<0.240	0.55	<0.240	<0.240	<0.240	<0.240
Aluminum	ug/L	<125	(2)	(33)	(37)	(36)	(43)	(37)
Barium	ug/L	46.8	49	39	40	38	45	47
Cadmium	ug/L	<0.24	(1)	(1)	(1)	(1)	(1)	(1)
Calcium	mg/L	45.2	41.3	377.0	381.4	359.5	365.3	366.6
Chromium	ug/L	7	10	(0.76)	(0.82)	(0.71)	(0.50)	(1.42)
Cobalt	ug/L	<8.2	(1)	15	16	15	5	6
Copper	ug/L	<8.2	(20)	0	(1)	(1)	(2)	(1)
Iron	ug/L	<20.4	(34)	14	0	0	1912	1949
Magnesium	mg/L	13.1	12.5	135.0	135.4	127.7	137.3	138.2
Manganese	ug/L	16.9	19	2051	2057	2264	1981	2004
Nickel	ug/L	<37.5	12	16	17	18	10	10
Potassium	mg/L	6.64	6.87	18.7	16.1	15.4	16.5	16.7
Sodium	mg/L	18.4	19.1	111.8	112.1	105.5	112.3	113.4
Strontium	mg/L	0.233	0.281	1.77	1.78	1.68	1.81	1.80
Silicon	mg/L	—	19	8.09	8.19	7.23	3.60	3.59
Zinc	ug/L	12.7	95	28	28	45	11	10
Technetium-99	pCi/L	2410	2462	2295	2253	1870	553	553
Tritium	pCi/L	2410	2520	75383	75788	75360	79865	75450
Uranium	ug/L	10.8	10.3	35.5	35.8	32.2	11.6	11.4

(a) sample measured after ~1 yr storage with no preservatives
— = not analyzed
Parentheses indicate values below quantitation limit but deemed usable

5.0 Uranium Leach/Desorption Tests

In this section, the results of the leaching/desorption tests performed on three selected contaminated samples from borehole 299-E33-45 are presented. The tests were performed to help determine the mobility of the uranium that is present in the borehole sediment from the 1951 overfill of tank BX-102. The selected sediment samples were contacted with various solutions for set time periods in batch tests. After the designated times, the slurries were centrifuged to separate the solution from the sediment and aliquots of solution were removed and analyzed.

The observed solution concentrations of uranium for each time period and solution type are shown in Table 5.1. The pH and electrical conductivity values measured on these same solutions are shown in Table 5.3 and Table 5.1 Table 5.3, respectively. The uranium and pH data in these tables are also plotted in Figure 5.1 and Figure 5.2, respectively. The leach tests show that simulated vadose zone porewater (see Section 3.3.12 for composition) continued to remove uranium from the two more contaminated sediments (i.e., sample 61A at 131 ft bgs and sample 67A at 141 ft bgs) for the 28-day contact period. For the shallowest sediment, sample 51A at 121 ft bgs, the uranium concentration appears to reach a steady state value after about 3 days of leaching with approximately 65 percent of the total uranium leached.

As shown in Figure 5.1, the leach curves for replicate samples agree. Only one data point for the 16-day contact sample for sample 67A-1 seems to be erroneously high compared to its replicate 67A-2 and values agree at the next sampling interval. The uranium concentrations in solution are related to the total amount of uranium in the contaminated sediment. That is, the higher the starting concentration of total uranium in the sediment, the higher the concentration in the leachate. Solution concentrations reach 25 to 35 mg/L uranium in these near neutral pH solutions. As shown in Appendix D of the WMA B-BX-BY FIR (Knepp 2002a), the dissolved uranium is exclusively in the U(VI) state.

These uranium concentrations in the batch leachates are lower by a factor of 20 than the concentrations found in the actual porewater and dilution corrected 1:1 sediment to water extracts (Tables 4.9 and 4.10) suggesting that solubility limited equilibrium concentrations have not been reached in the batch leach tests. The dilution corrected sediment to water extracts and actual porewaters had slightly elevated pH values. Perhaps the observed lower concentration of dissolved uranium in the batch leach tests is a reflection of the importance of carbonate complexation on keeping uranium in solution.

The pH and electrical conductivity versus time for the uranium leach tests, shown in Table 5.2 and Table 5.3 and in Figure 5.2, do not show any significant changes from the values for the initial solutions. Both the simulated porewater and 0.02 M sodium bicarbonate solutions have pH values between 7.6 and 8.1 that are very similar to Hanford groundwater and uncontaminated vadose zone porewater. At these pH values, U(VI) in solution is dominated by the di- and tri-carbonato complexes [$UO_2(CO_3)_2^{2-}$ and $UO_2(CO_3)_3^{4-}$] dependent on the total carbonate and uranium concentrations. After contact with the contaminated sediments, the pH of the simulated porewater does appear to rise a few tenths of a pH unit and the electrical conductivity rises about 5 percent suggesting a small amount of dissolution of material from the sediment.

Table 5.1. Uranium Solution Concentrations versus Time

	54A-1	**54A-2**	**61A-1**	**61A-2**	**67A-1**	**67A-2**
U(tot) ug/g	**33.6±11.5**		**380.8±35.0**		**285.8±4.6**	
Total Days	**Uranium Solution Concentration (ug/L)**					
	Simulated Porewater (I= 26 mN)					
0.167	3372	3298	6806	6404	1481	1445
1	5286	5303	11184	10622	5224	5153
2	6006	5538	13604	13604	9305	8706
3	5578	5364	15089	15190	11495	11542
7	5858	5970	17666	18102	20012	20123
10	5722	5612	18140	18259	22972	24936
16	5436	5525	19673	20197	38305	28421
21	5377	5401	20422	20946	31659	30720
28	5210	5374	23614	23003	31408	32729
	$NaHCO_3$ (I= 20 mN)					
35	1410	1029	12552	12650	10064	9546
67	1581	1560	18579	19719	15983	16240
	(a)	(b)	(a)	(b)	(a)	(b)
70	3212	1917	22151	50517	9992	21258
(a) 0.5 M sodium carbonate/bicarbonate solution (pH 10) (b) 3.13 M citric acid solution (pH 1.4)						

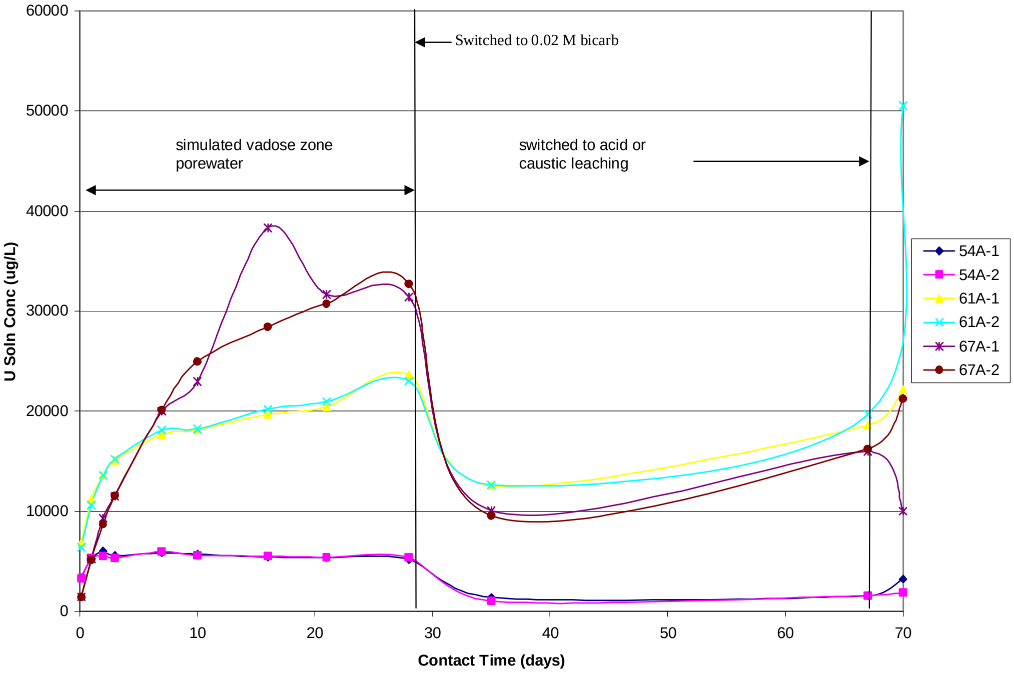

Figure 5.1. Uranium Solution Concentrations as Function of Time

Table 5.2. Ending pH Values for the Uranium Leach Solutions

	54A-1	**54A-2**	**61A-1**	**61A-2**	**67A-1**	**67A-2**
U(tot) ug/g	**33.6±11.5**		**380.8±35.0**		**285.8±4.6**	
Total Days	**pH of Effluent Solution**					
	Simulated Porewater (I= 26 mN; pH =8.08 ±0.04)					
0.167	8.18	8.15	8.26	8.17	8.07	8.04
1	8.19	8.21	8.27	8.22	7.94	7.91
2	8.22	8.27	8.23	8.23	7.95	7.97
3	8.28	8.39	8.34	8.38	8.11	8.14
7	8.33	8.32	8.32	8.35	8.06	8.05
10	8.39	8.40	8.35	8.32	8.07	8.04
16	8.36	8.30	8.36	8.34	8.04	8.06
21	8.37	8.40	8.24	8.30	8.04	8.03
28	8.34	8.37	8.35	8.33	8.04	8.07
	$NaHCO_3$ (I= 20 mN; pH =7.65)					
35	7.91	7.91	7.87	7.85	7.73	7.77
67	NM	NM	NM	NM	NM	NM
	(a)	(b)	(a)	(b)	(a)	(b)
70	9.62	1.77	9.61	1.76	9.6	1.76

(a) 0.5 M sodium carbonate/bicarbonate solution (starting pH 10)
(b) 3.13 M citric acid solution (starting pH 1.4)
NM = not measured

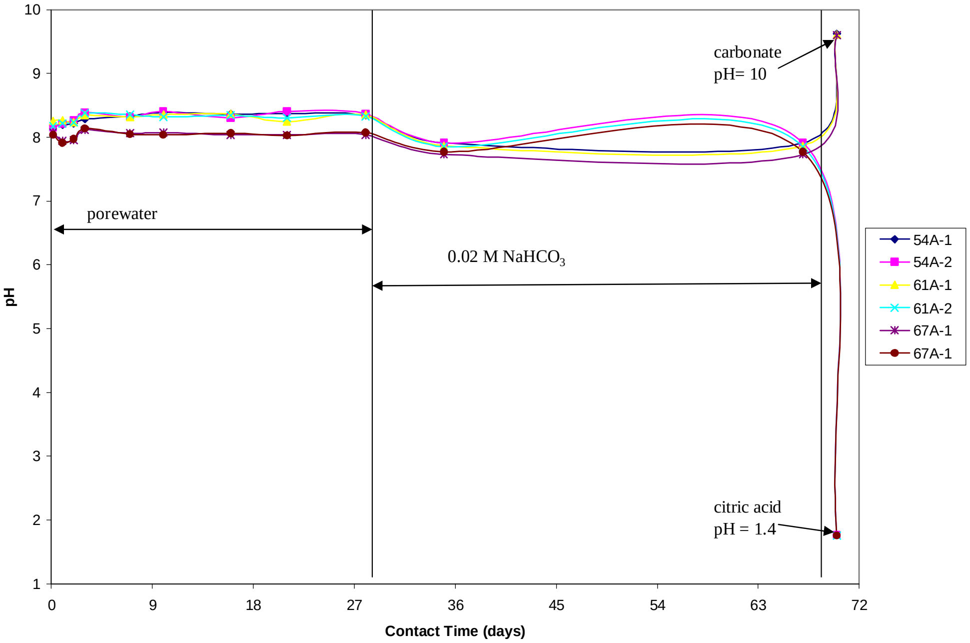

Figure 5.2. Effluent pH for the Leachates in Contact with Contaminated Sediment

Table 5.3. Electrical Conductivity of the Uranium Leach Solutions

	54A-1	**54A-2**	**61A-1**	**61A-2**	**67A-1**	**67A-2**
U(tot) ug/g	**33.6±11.5**		**380.8±35.0**		**285.8±4.6**	
Total Days	**Electrical Conductivity (mS/cm)**					
	Simulated Porewater (I= 26 mN; EC =2.103 ± 0.064)					
0.167	2.28	2.29	2.31	2.31	2.21	2.23
1	2.28	2.31	2.32	2.30	2.19	2.17
2	2.30	2.18	2.30	2.30	2.09	2.16
3	2.28	2.30	2.34	2.32	2.17	2.16
7	2.28	2.28	2.30	2.30	2.14	2.12
10	2.28	2.27	2.28	2.21	2.12	2.14
16	2.12	2.14	2.17	2.18	2.01	2.03
21	2.22	2.10	2.26	2.09	1.91	2.00
28	2.25	2.28	2.28	2.26	2.11	2.10
	NaHCO3 (I= 20 mN; EC = 1.581)					
35	1.779	1.800	1.788	1.763	1.734	1.662
67	NM	NM	NM	NM	NM	NM
	(a)	(b)	(a)	(b)	(a)	(b)
70	NM	NM	NM	NM	NM	NM
(a) 0.5 M sodium carbonate/bicarbonate solution (starting pH 10) (b) 3.13 M citric acid solution (starting pH 1.4) NM = not measured						

The cumulative amount of uranium that is leached versus time is shown in Table 5.4 and Figure 5.3. The total amount of uranium in sample 54A was not precisely determined using two independent techniques. The XRF and GEA methods gave values that differed by 33%, whereas the agreement for the other two sediments was 1.6 and 9%. The percentage of uranium leached after 28 days with simulated porewater varied from ~80% for the least contaminated to 25% for the most contaminated sediment.

These leach trends might suggest that the results are controlled by solubility of a discrete U(VI) bearing solid but the concentrations in solution for the two more contaminated samples (i.e., 61A and 67A) did not reach a steady state concentration after 28 days. Further, actual porewaters were shown to contain at least 20 times higher solution concentrations at pH values approximately 1 to 1.5 units more alkaline. More discussion on the uranium fate in these sediments is found in Appendix D of the WMA B-BX-BY FIR (Knepp 2002a).

Table 5.4. Cumulative Percentage of Uranium Leached from Selected Contaminated Sediments from Borehole 299-E33-45

	54A-1	**54A-2**	**61A-1**	**61A-2**	**67A-1**	**67A-2**
Total Days	**Cumulative Percentage Uranium Leached**					
Simulated Porewater (I= 26 mN; EC =2.103 ± 0.064)						
0.167	30.56%	29.89%	5.36%	5.04%	1.55%	1.52%
1	49.95%	50.06%	9.17%	8.70%	5.59%	5.51%
2	59.67%	55.39%	11.66%	11.61%	10.23%	9.60%
3	59.42%	57.16%	13.54%	13.57%	13.18%	13.19%
7	65.32%	65.90%	16.37%	16.66%	22.93%	23.00%
10	67.63%	66.26%	17.67%	17.74%	27.43%	29.46%
16	68.50%	68.86%	19.83%	20.22%	45.13%	34.86%
21	71.25%	71.07%	21.45%	21.87%	40.84%	39.27%
28	72.98%	74.09%	25.04%	24.59%	42.79%	43.53%
$NaHCO_3$ (I= 20 mN; EC = 1.581)						
35	83.73%	80.03%	35.74%	35.46%	52.48%	52.30%
67	85.59%	85.81%	41.69%	42.44%	60.14%	60.97%
	(a)	(b)	(a)	(b)	(a)	(b)
70	120.04%	106.19%	62.10%	89.35%	72.37%	87.00%

(a) 0.5 M sodium carbonate/bicarbonate solution (starting pH 10)
(b) 3.13 M citric acid solution (starting pH 1.4)

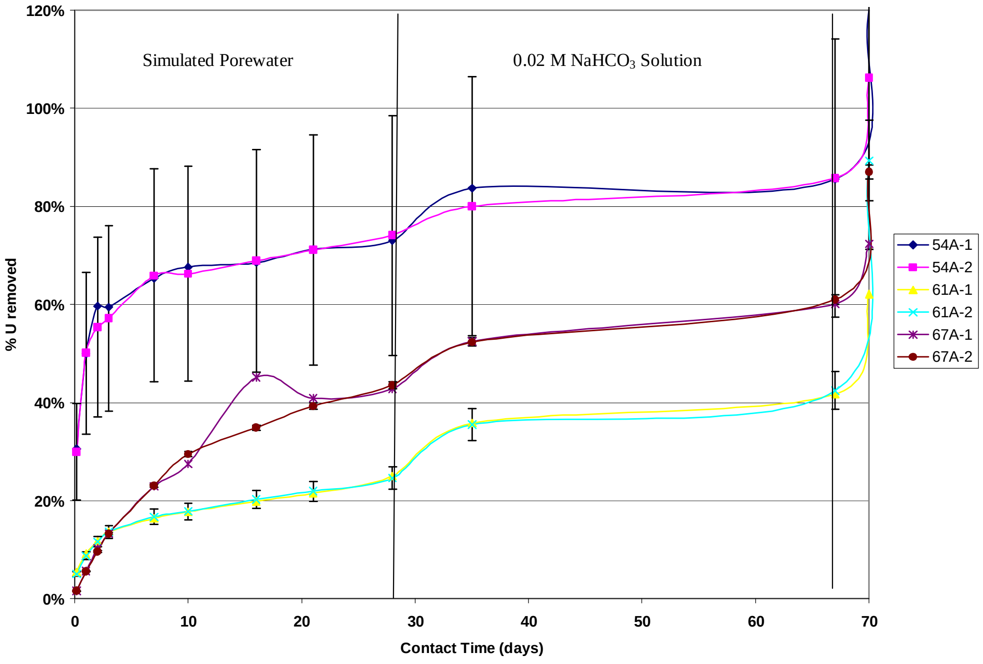

Figure 5.3. Cumulative Percentage Uranium Leached from the Contaminated Sediments versus Contact Time

The desorption Kd values that can be calculated from the batch leach tests are shown in Table 5.5 and Figure 5.4. Also shown in Table 5.5 are the data from Section 4 where the 1:1 sediment to water extractable uranium is compared with the total uranium in the sediment to calculate an in situ Kd value. The sediment to water extraction occurred over approximately two days (a one hour vigorous shaking of one part distilled water and one part by weight sediment followed by ~24 hours of settling prior to separating the solution). The pH of the water extracts for these three sediments was between 9 and 9.5 and the electrical conductivities were between 0.5 and 0.8 mS/cm. The Kd values calculated from the batch leaching tests were determined on sediment contacted at a 1:3 solid to solution ratio for the time periods shown in Table 5.5. The pH values of the leach solutions were between 7.6 and 8.1 and the electrical conductivities were 1.7 to 2.2 mS/cm. Based on the Kd values shown in Table 5.5, the uranium in the contaminated sediment was moderately to extremely mobile dependent upon amount of uranium contamination in the sediment, pH, and the chemical composition of the extracting solution. Despite the fact that it took over 28 days to leach the majority of the uranium out of the sediment, the desorption Kd values were low and when used in simple fate and transport codes would predict significant migration of uranium. More discussion on the processes that control the association of uranium from the bismuth phosphate overfill at BX-102 and the long-term fate of uranium in the vadose zone proximate to the BX tank farm is found in the WMA B-BX-BY FIR (Knepp 2002a).

Table 5.5. Desorption Kd Value for Uranium Leached from Selected Contaminated Sediments from Borehole 299-E33-45

	54A-1	**54A-2**	**61A-1**	**61A-2**	**67A-1**	**67A-2**
Total Days	**Desorption Kd for Uranium Leached versus Time**					
Simulated Porewater (I= 26 mN; EC =2.103 ± 0.064)						
0.167	6.8	7.0	53.0	56.5	190.0	194.8
1	3.1	3.1	30.9	32.7	51.7	52.4
2	2.2	2.7	24.7	24.7	27.6	29.7
~2 days	0.01 to 0.04(c)		0.56 to 0.65(c)		0.70 to 0.72(c)	
3	2.4	2.6	21.8	21.7	21.6	21.5
7	2.0	1.9	18.0	17.5	11.0	10.9
10	1.9	2.0	17.3	17.2	9.0	8.1
16	1.9	1.9	15.5	15.0	4.1	6.5
21	1.8	1.8	14.6	14.2	5.3	5.7
28	1.7	1.6	12.1	12.5	5.2	4.9
NaHCO$_3$ (I= 20 mN; EC = 1.581)						
35	3.8	6.4	19.5	19.4	13.5	14.3
67	3.0	3.0	12.0	11.1	7.1	6.9
	(a)	(b)	(a)	(b)	(a)	(b)
70	—	—	6.5	0.8	7.9	1.7

(a) 0.5 M sodium carbonate/bicarbonate solution (starting pH 10)
(b) 3.13 M citric acid solution (starting pH 1.4)
(c) In situ Kd values calculated from the 1:1 water extract and total uranium in sediments
— Desorption Kd cannot be calculated because % leached exceeded 100%

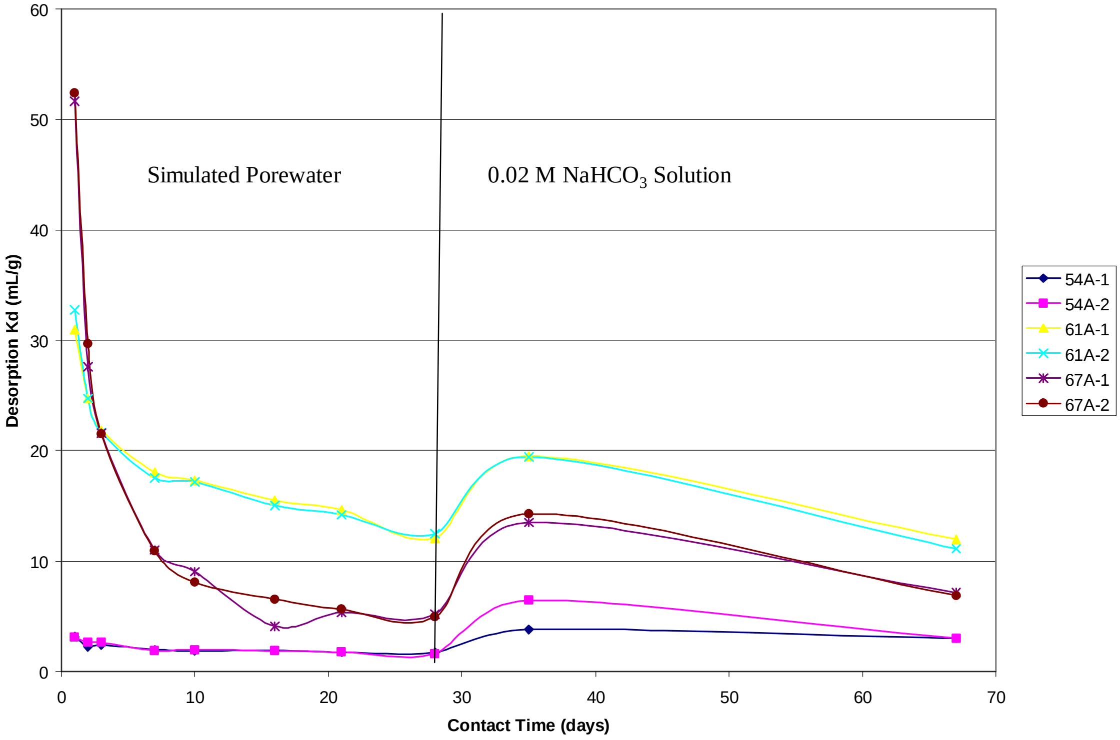

Figure 5.4. Desorption Kd Values for the Uranium Contaminated Sediments Leached with Simulated Porewater and 0.02 M Sodium Bicarbonate Solution as a Function of Time

6.0 Summary and Conclusions

In this section, information on the meaning of the borehole 299-E33-45 sediment characterization data is presented. Conclusions are included to aid in making decisions on what interim actions and future studies are needed to make current and future tank farm operations less likely to unfavorably affect the environment.

6.1 Conceptual Model of the Geology at Borehole 299-E33-45

The backfill is believed to extend from the ground surface to a depth of approximately 3 m (9 ft) where it contacts with the Hanford formation. Based on the lithologies observed during drilling and observed in core samples from this well, the Hanford formation beneath the backfill can locally be subdivided into an upper gravel-dominated unit and three sand sequences separated by thin and distinctly finer (muddy/silty) units. A few other thin muddy (silty) facies are found within the major Hanford formation sand sequences that are not considered contacts between two lithologies.

Consistent with Lindsey et al. (2001), the upper gravel dominated unit is referred to as the Hanford H1 unit. The upper two sand sequences and intercalated mud units above a depth of 51.8 m (169.8 ft) have been assigned to the Hanford H2 unit, while those below this depth, but above a depth of 66.4 m (218 ft) are assigned to the Hanford H3 unit.

Hanford H1 is gravel to muddy sandy gravel, ranging from 90 to 50 percent gravel. The samples generally display no cementation or obvious sedimentary structure, and only weak to no reaction to hydrochloric acid. The bottom of the H1 unit is ~34 ft bgs.

The Hanford H2 unit can be further subdivided into two sand sequences and two distinct and thin mud/silt units. The uppermost sand sequence extends from the base of the H1 unit to a depth of 22.7 m (74.5 ft) where it contacts with a thin, approximately 30 cm (1 ft) thick, muddy very fine to fine sand layer. The thin fine-grained layer is muddy, very fine to fine sand with an estimated 30% mud (interpreted to be mostly silt). The materials are well stratified to laminated with one prominent coarse sand layer. The H2 middle sand sequence is 27.9 m (91.5 ft) thick and extends from a depth of 23.0 m (75.5 ft) to 50.9 m (167 ft), where it overlies a thin, fine-grained sequence of very fine sand to muddy very fine sand. This second fine-grained unit is approximately 0.8 m (2.6 ft) thick and is highly variable in texture. The top of this second fine-grained unit is characterized by a fairly sharp contact with the overlying medium sand at 51.0 m (167.2 ft). The upper 30 cm (12 in.) is weakly stratified to laminated mostly fine to very fine sand, with some slightly coarser (fine sand) stringers. This is believed to be a weakly developed paleosol. This layer is very compacted and moderately cemented and forms a very sharp contact with the underlying medium sand at 51.8 m (169.8 ft).

The Hanford H3 unit (lower sand sequence) is approximately 14.6 m (48 ft) thick extending from a depth of 51.8 m (169.8 ft) to 66.4 m (217.8 ft). This sand-dominated sequence consists predominantly of stratified coarse to medium sand with occasional pebbles up to 30 mm diameter. Based on the overall regional geology of the tank farm, the Hanford formation units appear to dip toward the northeast.

Materials underlying the Hanford H3 unit correlate to those referred to as the Hanford formation/ Plio-Pleistocene Unit(?) (Hf/PPu(?), a fine-grained eolian/overbank silt and a sandy gravel to gravelly sand. The locally thick silt facies is generally believed to be a pre-ice age flood deposit potentially equivalent to the early "Palouse" soil. The silt facies encountered in borehole 299-E33-45 is 6.3 m (20.9 ft) thick, extending from a depth of 66.4 m (217.8 ft) to a depth of 72.7 m (238.7 ft). This unit is believed to be equivalent to the Plio-Pleistocene silt unit (PPlz) that overlies an extensive caliche layer (PPlc) beneath the 200 West Area. These fine-grained sediments are characterized by stratified mud (silt) and sand deposits. The upper beds consist of massive (lacking internal laminations), well sorted, medium to fine sand grading to fine sand in places, with only minor amounts of mud (~5%). The mud (silt)-dominated beds are hard, moderate to strongly cemented with a weak reaction to hydrochloric acid. These materials are mostly silt, with some fine to very fine sand, and very little clay. There are some fine laminations and banding and/or mottling (color changes) present, due in part to the presence of iron oxide staining. However, these beds are often described as massive and homogeneous.

The PPlz (silt facies) was variably described as moist to dry, with the exception of a fully saturated zone between depths of 69.2 m (227.1 ft) and 70.7 m (231.9 ft). A water sample was collected from this perched water zone during drilling.

Below the PPlz, a gravelly sand sequence, labeled PPlg, of sandy gravel to gravelly sand was encountered at a depth of 72.8 m (238.7 ft). The sandy gravel to gravelly sand consists of 30 to 80% gravel, 15 to 65% sand, and up to 15% mud. These materials exhibit moderate to un-cemented fabric with strong to no reaction to dilute hydrochloric acid. Some caliche fragments were noted, exhibiting a strong reaction to hydrochloric acid. This gravel rich facies continues to at least the bottom of the borehole at 79.55 m (261 ft bgs). If the overlying silt facies is indeed equivalent to the upper Plio-Pleistocene unit, then this gravelly facies must be at least Plio-Pleistocene in age and cannot be correlative with the Hanford formation. Thus, these materials must either be equivalent to the pre-Missoula Gravels (Lindsey et al. 1994), or Ringold Formation gravel (Lindsey et al. 2001).

The geologists logs made during the drilling of 299-E33-45 indicate that the groundwater table was encountered at a depth of 77.7 m (255 ft). This suggests that the groundwater level has either dropped less than a meter (2 to 3 ft) or that the groundwater table may have actually reached a depth as high as 75 m (246 ft) bgs during the two high water eras (i.e., 1967 to 1968 and 1986 to –1989). If the high water mark was at 246 ft. bgs, then the observed perched water at 227 to 232 ft bgs is still much shallower and not likely a remnant “bath tub ring” from the historical high water level. Some other water source must have fed this perched zone.

In general, the near horizontal but dipping to the northeast, thin, fine-grained sediment layers within the H2 upper sand and middle sand sequences likely cause horizontal water flow within the vadose zone. The perched water zone within the PPlz unit is another indication of a zone in the vadose zone where horizontal water flow is important.

6.2 ertical Extent of Contamination

The following paragraphs describe measurements of various parameters that help to determine the extent of vertical migration of the BX-102 tank overfill plume. Several parameters were used including uranium, electrical conductivity, nitrate, pH, sodium, and technetium-99 concentrations in water extracts and, for uranium, direct gamma energy analyses of the sediment for the main indicators to determine the leading edge of the tank leak plume. The concentrations of acid-extractable or directly measured constituents in the sediment were used to delineate the total inventory of constituents within the plume.

Based on evaluating all these measurements, it is uncertain as to whether constituents from the tank BX-102 overfill in 1951 have reached the groundwater through the vadose zone near 299-E33-45. All of the data do not fit a simple hypothesis. A few data indicate that constituents from the 1951 tank overfill may have reached the groundwater nearby but most constituent distributions in the vadose zone sediment suggest that the plume has not penetrated below the very top of the PPlz layer, at 218 ft bgs (i.e., 37 ft above the current water table). It is not claimed that the information from one borehole can be extrapolated across the entire tank farm. However, when the data from borehole 299-E33-45, the historical gamma logging of the nearby dry wells, detailed geologic lithology models, and groundwater data over time are coupled, one consistent explanation cannot be developed.

The moisture content is a direct measure of the mass of fluid in the vadose zone sediment. One would logically assume that wetter than normal conditions would represent the existence of leaked tank liquor. However, the moisture profile seems to be dominated solely by the texture of the sediment, with fine-grained thin layers and the PPlz unit showing high moisture contents but not necessarily high electrical conductivity which is an obvious sign of tank fluids. Thus, moisture content is not considered to be indicative of the vertical migration of tank liquor from the tank BX-102 overfill.

The second parameter measured was the pH of water extracts of the vadose zone sediment. It was anticipated that the caustic tank liquor would alter the sediment pH dramatically. At borehole 299-E33-45, the pH profile shows that between 100 and 150 ft (30.48 and 45.72 m) bgs (in the Hanford formation H2 middle sand sequence), there are elevated values suggesting the presence of caustic waste interaction. The elevated pH zone values range from 8.2 to 9.55 between the depths of 100 to 150 ft bgs. There is one sample at 79 ft bgs that also has a pH value greater than 9.

The porewater electrical conductivity (calculated by multiplying the 1:1 sediment to water extract electrical conductivity by the dilution factor) shows a two-lobed elevated plume. The shallower lobe, between 24.08 and 36.58 m (79 and 120 ft) bgs, resides within the middle sand sequence in the Hanford H2 unit. The plume appears to pond on top of the fine-grained paleosol at 120 ft bgs. The more concentrated lobe resides between 45.72 and 52.73 m (150 to 173 ft) bgs with the most concentrated fluid between 150 and 160 ft bgs (within the Hanford H2 unit), perhaps ponding on the fine-grained wet zone (167 to 169.8 ft bgs) at the bottom of Hanford Unit H2. Some elevated electrical conductivity is found in the top three feet of the Hanford H3 unit, perhaps evidence of slow diffusion across the lithologic contact or perhaps indicative of the calcareous nature of this contact that may represent a much older surficial sediment that was exposed to rain fall and evapotranspiration in the geologic past. Thus, the leading edge of the tank overfill plume appears to reside currently at about 170 ft bgs, well above the water table at 255 ft bgs.

The fourth parameter that was measured to define the vertical extent of contamination was nitrate. Nitrate is perhaps the most sensitive chemical marker of tank leaks migrating through the vadose sediment. The nitrate concentration in tank liquor from tank BX-102 present at the time of the leak has been calculated to 0.53 M (~33,000 ppm), but the porewater in deep vadose zone sediment in the semi-arid region where the Hanford Site is located is not expected to contain more than several parts per million to perhaps a few tens of parts per million nitrate. The difference between the background nitrate baseline and the full-strength tank liquor is 1×10^4. Therefore, adding about 0.1 percent tank liquor into existing porewater should be readily measurable above the natural background. Thus, the 1:1 water extract nitrate data should be quite useful to trace the vertical extent of the tank leak plume.

There are obvious indications of high nitrate concentrations in borehole 299-E33-45 sediments starting at the contact between the H1 and H2 units at 34 ft bgs and extending down into the sediment of the fine-grained PPlz, perhaps all the way to the water table at 77.7 m (255 ft) bgs. The majority of the nitrate contamination resides between 35.1 and 51.8 m (115 and 170 ft) bgs with values reaching as high as 6.15 g/L or ~0.1M at 47.6 m (156.2 ft) bgs. The bulk of the water-extractable nitrate is bounded between two thin fine-grained lenses in the H2 middle sequence sand unit. The upper bound is the fine-grained lens at 120 ft bgs and lower boundary is the fine-grained 2.5 ft thick lens that forms the bottom of the H2 unit at 167 to 170 ft bgs. However, there also appears to be somewhat elevated nitrate throughout the H3 unit at a fairly constant porewater concentration of 600 ± 200 mg/L. The nitrate in the PPlz unit porewater is slightly higher than the nitrate in the H3 unit. There is a decrease in porewater nitrate in the PPlg unit down to the capillary fringe zone where nitrate increases to values similar to that in the groundwater. The nitrate data are one of the few parameters that suggest that the BX-102 overfill fluids might have reached the groundwater. An alternate source of nitrate within and below the PPlz at borehole 299-E33-45 could be the nearby cribs and trenches with horizontal transport within the perched water zone.

Two other anions are present in the bismuth phosphate waste stream, sulfate and phosphate. Both of these anions are known to react with sediments such that they are not considered to be as mobile as nitrate. However, their vertical profiles were also considered. Sulfate concentrations appear to be slightly elevated over most of the vertical profile but the most significant concentrations are found in a narrow zone within the middle sand sequence of the H2 unit between 140 and 166 ft bgs. The phosphate porewater distribution in the vadose zone sediment at borehole 299-E33-45 shows elevated concentrations between ~80 and 130 ft bgs within the H2 middle sand sequence, within the paleosol at 120 ft bgs, and just below the paleosol to 130 ft bgs. Unlike the porewater data from the SX tank farm studies, the anion data for borehole 299-E33-45 are not as clearly interpretable. Perhaps the more dilute waste type, (i.e., sodium hydroxide/carbonate neutralized bismuth phosphate) as opposed to the highly nitrate dominated REDOX waste stream at SX tank farm, is clouding the ability to define the vertical extent of the BX-102 overfill leak.

The fifth indicator species used was sodium in the water extract. Sodium is the dominant cation in tank liquor and, like nitrate, is present at near molar concentrations. The porewater sodium depth profile shows elevated concentrations from about 76 to 165 ft bgs. The maximum sodium porewater concentration is about 0.5 M in the zone from 150 to 165 ft bgs. The maximum calcium, magnesium, strontium, and potassium porewater concentrations occur at about 156 ft bgs at levels of 0.057 M, 0.031 M, 1×10^{-4} M, and 0.013 M, respectively. It seems plausible that the depleted zone for the common divalent cations, between 78 and 140 feet, is caused by sodium in the tank fluids exchanging most of the ion exchangeable divalent cations and pushing them either deeper in the profile or further away from the leak if the tank overfill fluid was mainly migrating horizontally. Thus, the sodium is similar to the electrical conductivity, sulfate, and phosphate in suggesting that the BX-102 overfill plume has reached the ~3-ft thick fine-grained contact between the H2 and H3 units at 167 to 170 ft bgs.

The vertical distribution of water extractable tritium in the vadose zone sediments shows tritium appearing at ~100 ft bgs in the H2 middle sand sequence with generally continuous occurrence down to the fine-grained lens that separates the H2 from the H3 sediments. The Plio-Pleistocene mud unit (PPlz), the perched water (within the PPlz), and the groundwater also show strong indications that tritium is present. The maximum concentrations of tritium in the dilution corrected porewaters occur between 140 and 160 ft bgs in the H2 middle sand sequence. This distribution, tritium highest between 140 and 160 ft bgs, may represent the current depth of penetration of the bulk of the 1951 uranium metals waste tank BX-102 overfill.

The significantly elevated uranium-238 activity first appears at 73.4 ft bgs in the Hanford H2 unit sediment just above the first thin lens (one-ft thick at 74.5 ft bgs). From about 90 ft to ~111 ft bgs, there is little indication that significantly elevated concentrations of uranium are present. Between 111 and 120 ft bgs, the uranium content averages about 100 ppm. In the thin lens at 120 ft bgs, which may be a paleosol, the uranium concentration is very high (up to 1,649 ppm in the finest grained material from this sleeve). Below 120 ft bgs down to 145 ft bgs, the uranium content in the sediment is quite high (reaching values between 200 and 500 ppm). Between 145 and 167.2 ft bgs, in the lower portion of the H2 middle sequence, there are slightly elevated uranium concentrations (between 50 and 200 ppm). Within the fine-grained lens between 167.2 and 169.8 ft bgs, the uranium concentration increases again to values between 200 and 400 ppm. Below, in the H3 lower sand sequence and the Plio-Pleistocene sediments, there is no significant indication of elevated uranium in the sediments.

Water extractions of the borehole sediments show a slightly different picture for uranium. Elevated concentrations of uranium are found in the vadose zone porewater between 120 and 167 ft bgs (within the middle sand sequence of H2). There is indication of a second deeper but less concentrated plume of water leachable uranium in the upper portion of the H3 unit (between 170 and 200 ft bgs) but no elevated water leachable uranium in the PPlz or PPlg. The perched water does contain a small concentration of uranium. The elevated uranium concentration in the sediment at 74.5 ft bgs and slightly elevated uranium concentrations between 111 and 120 ft bgs, are not manifested in the water extraction data. Both uranium data sets (i.e., total uranium in the sediment and water extractable uranium) suggest that the bulk of the BX-102 tank overfill plume, if not the entire plume, has not penetrated into the Plio-Pleistocene sediments at the borehole location. However, uranium should not be considered a totally unreactive species that would travel with no retardation in the vadose zone.

The last constituent that would be an indicator of the maximum extent of plume penetration is technetium-99. Elevated concentrations of technetium-99 are found in the vadose zone porewater between 120 and 167 ft bgs (within the middle sand sequence of H2). There appears to be a second less concentrated plume of technetium-99 within the contact between the H3 unit and the PPlz unit (220 to 235 ft bgs). Both the acid extractable and water extractable technetium-99 data support this conclusion, however, the water extractable data are of higher quality. There is very good agreement between the technetium-99 concentrations found in the actual porewater and the dilution corrected sediment-water extracts in all regions and lithologies. Further, the technetium-99 concentration in the perched water also agrees with the nearby dilution corrected water extracts. There are obvious elevated concentrations of technetium-99 in the PPlz but not in the PPlc unit down to the water table. This may imply that the source of technetium in the groundwater reached the water table at another position than vertically through the sediments at borehole 299-E33-45. It is also possible that the technetium-99 in the groundwater in the vicinity of 299-E33-45 did not come from the overfilling of tank BX-102.

In summary, the moisture content, pH, electrical conductivity, sodium, tritium, and uranium profiles do not suggest that the leading edge of the plume has penetrated below 170 ft bgs. The profiles of two constituents considered to be mobile, technetium-99 and nitrate, suggest that the leading edge of the plume may have penetrated all the way to groundwater and certainly into the PPlz mud unit that reaches ~235 ft bgs.

6.3 Detailed Characterization to Elucidate Controlling Geochemical Processes

The more detailed characterization activities of the cores from borehole 299-E33-45 added some insight on the processes that control the observed vertical distribution of contaminants and on their migration potential into the future. The first key finding was that the 1:1 sediment to water extracts give a reasonable estimate of the porewater chemistry in the vadose zone sediment. Porewater from fourteen sediments were extracted using an ultracentrifuge, including eleven samples from the H2 unit within the main uranium and technetium plumes and three samples from the PPlz unit below the zone where the water extracts suggest that there is evidence of elevated uranium or electrical conductivity. The true porewater electrical conductivity is somewhat lower than the dilution-corrected 1:1 sediment to water extracts but agreement on all but the samples at 100 and 130.7 ft bgs is acceptable. The dilution corrected porewater EC is significantly greater than the actual porewaters for these two depths. Between 131 and 160 ft bgs where the highest electrical conductivities are found, the UFA squeezed porewater and the calculated porewaters have similar EC values suggesting that high salt fluids are present. The actual porewaters have the same or lower concentrations for most of the anions and cations than the dilution-corrected 1:1 sediment to water extracts. The best agreements are found for chloride, nitrate, sulfate, sodium, calcium, magnesium, and strontium. The aluminum, silicon, fluoride, bicarbonate, barium, and potassium concentrations in actual porewater obtained by ultracentrifugation are lower than the calculated porewater values suggesting that water extraction is dissolving aluminum and silicon bearing solids and perhaps phosphate and fluoride bearing solids. The same is true for the water soluble iron data. It is likely that the Hanford H2 middle sand sequence contains water leachable compounds of aluminum, silicon, phosphate, and iron that may be indicative of secondary (probably amorphous) precipitates from reaction of the sediments with tank fluids.

There is very good agreement between the technetium-99 concentrations found in the actual porewater and the dilution corrected sediment-water extracts in all regions and lithologies. Further, the technetium-99 concentration in the perched water also agrees with the nearby dilution corrected water extracts. There are obvious elevated concentrations of technetium-99 in the PPlz but not in the PPlc unit down to the water table. This may imply that the source of technetium in the groundwater reached the water table at another place than through the sediments at 299-E33-45. It is also possible that the technetium-99 in the groundwater in the vicinity of 299-E33-45 did not come from the overfilling of tank

BX-102. For uranium, the dilution corrected sediment-water extracts agree with the actual porewater concentrations for samples taken between 75 and 168 ft bgs where the main uranium plume resides. For two samples at 63 and 73 ft bgs, the actual porewater uranium concentrations were significantly lower than the dilution corrected sediment-water extracts suggesting that some uranium precipitate was dissolving during water extraction or there was an analytical problem.

Because it is much easier to obtain a water extract of the vadose zone sediment, this finding is important to understanding the porewater chemistry throughout the vadose zone plumes under disposal facilities and leaking tanks. Constituents that showed the best agreement include electrical conductivity, nitrate, chloride, sulfate, sodium, calcium, magnesium, uranium, and technetium.

The porewaters in the sediment from the cores in the peak of the plume (i.e., in the Hanford formation H2 unit between 155 and 160 ft bgs) were dominated by sodium, sulfate, bicarbonate, and nitrate at 0.52, 0.42, 0.21, and 0.1 M, respectively. Calcium, magnesium, and potassium at concentrations of 0.057, 0.031, and 0.013 M, respectively, made up the rest of the cations. These concentrations are less than the concentrations in the waste stream that was inadvertently lost during the cascading event in 1951. The maximum concentration of technetium-99 calculated to be in the porewater was 5.36×10^5 pCi/L at 156 ft bgs, the same depth as the maximum for most constituents. The maximum uranium concentration in solution (i.e., 2.4 g/L) was obtained via UFA squeezing a sample at 131 ft bgs. Other values approaching or slightly above 1 g/L uranium were found between 120 and 170 ft bgs. There was no indication of the presence of other trace constituents such as selenium, molybdenum, lead, silver, or cadmium in the vadose zone sediments at borehole 299-E33-45 as found under the SX-108 tank that leaked highly concentrated REDOX waste.

The water-extractable cations suggest that an ion-exchange process is occurring between the contaminated porewater and the vadose zone sediment zone where tank fluid resides or has flowed through. The leading edge of the tank leak plume is enriched in alkaline earth cations that were displaced from the native sediment exchange sites. The depth profiles for the divalent alkaline earth cations calcium, magnesium, and strontium and the monovalent alkali cation potassium show remarkable similarities. All show elevated concentrations in a relatively thin zone between 140 and 165 ft bgs within the middle sand sequence of the H2 unit. The calcium, magnesium, and strontium porewater concentrations between 78 and 140 ft bgs appear to be lower than in the sediments directly above and below these depths suggesting that the alkaline earth cations have been stripped out of the sediments by the sodium from the leaked tank fluids. Barium differs from the other divalent cations and is present at low concentrations, perhaps reflecting only natural amounts are present that are not impacted by the tank leak. It is not clear why the highest concentration of porewater sodium is found at the same depth as the highest porewater concentrations of alkaline earth cations. If the flow of contaminated fluids was predominately vertical, it would be expected that the divalent cations that were stripped off the native sediment exchange sites are to be found slightly deeper than the sodium as was found at borehole 299-W23-19 near tank SX-115.

These ion exchange reactions, especially for borehole 299-W23-19 near tank SX-115, have been modeled by the Science and Technology Programs and reported in Appendix D of the WMA S-SX FIR, (Knepp 2002b). It was shown that the separation between the peaks of the divalent and monovalent cations increases as the concentration of the sodium in the invading tank liquor decreases and as the total ion exchange capacity of the sediment decreases. The porewater profile at 299-E33-45 should show similar separation in the peaks for calcium, magnesium, and strontium from the sodium peak. The data show no separation and no explanation is presented.

In summary, common ion exchange has been identified as influencing the distribution of contaminants in the vadose zone sediment and the maximum porewater concentrations of major constituents are more dilute than the tank fluids but do contain the expected high sodium, sulfate, nitrate, bicarbonate, and uranium.

6.4 Estimates of Sorption-Desorption Values

In this section, the measurement and data synthesis used to quantify the adsorption-desorption values for uranium and technetium-99 found in the sediment at borehole 299-E33-45 is discussed. The Kd for technetium-99 was estimated using one method. By combining the data from the dilution corrected 1:1 water extracts, which represent the porewater, with the activities measured on the total sediment using the strong acid extract, a semi-quantitative sense of the desorption Kd can be determined. For a contaminant that has very little water-soluble mass, such as cesium-137, the Kd can be approximated as the amount of mass in the total sample per gram of dry sediment divided by the amount of mass in the porewater per milliliter. For a contaminant that is quite soluble in the water extract (approximately equivalent to saying that the contaminant resides mainly in the porewater within the sediment), one needs to subtract the amount that was water extractable from the total amount present in the moist sediment sample to obtain a value for the amount that would remain on the solid at equilibrium with the pore fluid. This was the approach used for estimating both the uranium and technetium-99 in situ desorption Kd.

The technetium-99 acid extract data were very close to the detection limit so that the calculated desorption in situ Kd data are not of high quality in most instances. For the few data sets that had enough technetium present in both the water and acid extracts to allow the calculation, the technetium-99 in situ desorption Kd is quite small, meaning that the technetium-99 is not interacting significantly with the sediment. In the H2 sand units, the technetium desorption Kd values ranged from 0.025 to 0.091 mL/g and for the fine-grained PPlz unit, the technetium desorption Kd ranged from 0.09 to 0.28 mL/g.

Despite the appearance that some of the technetium is not acid extractable, the calculated desorption Kd values are quite low and likely are not different from zero suggesting that technetium-99 is not interacting with the sediment and will travel at the same speed as water that is slowly percolating through the vadose zone. The technetium in situ desorption Kd values of ~0 are consistent with a wealth of literature that finds essentially no technetium adsorption onto Hanford Site sediment from less saline waters (Kaplan and Serne 1995, 2000).

For uranium, the same calculation scheme using water and acid extracts (as well as the two other methods of determining the total uranium in field moist sediment, direct GEA and XRF) allow the following conclusions. Within the H2 upper sand sequence but shallower than 120 ft bgs, the uranium in situ desorption Kd value ranges from 0.07 to 1.5 mL/g. The desorption Kd values range from 0.01 to 1.4 mL/g below 120 ft down to 170 ft bgs, where the bulk of the uranium resides. Within the H3 unit, that lies between 170 and 218 ft bgs and where there is only a faint indication of elevated uranium, the uranium desorption Kd values range from 0.18 to 0.38 mL/g. Below the H3 unit within both the PPlz and

PPlg units where there is no indication of elevated uranium concentrations in the vadose zone, the calculated uranium desorption Kd is > 100 mL/g, which likely reflects that the uranium is naturally occurring and tightly bound in mineral lattice sights.

The second method used to determine the uranium desorption Kd values was laboratory batch leach tests using several samples of the more contaminated sediments from the H2 unit. Batch adsorption tests were performed on three sediments using a simulated pore fluid that contained mainly sodium bicarbonate with minor amounts of magnesium, sulfate, calcium, and nitrate. The simulated pore fluid represents the porewater in the borehole sediments above where the uranium plume was first encountered. If the long-term fate is that rainfall will recharge the vadose zone, the porewater would be pushed into the contaminated sediments and leaching might occur. The batch leach tests were performed for several months with the expectation that equilibrium (steady state) uranium solution concentrations would be attained. After 28 days for two of the samples tested, the uranium concentration in solution was still increasing. The contacting solution was replaced with a simple 0.02 M sodium bicarbonate solution to see if equilibrium would be reached. All the time-dependent data collected in the batch leach tests were used to calculate uranium desorption Kd values as a function of contact time with leachant. A summary of the results follows.

The desorption uranium Kd values stabilized after 7 days of leaching at values that ranged from 1.6 to 2.0, 12 to 18, and 5 to 11 mL/g for the three samples when in contact with the simulated porewater. The subsequent desorption Kd values on the residual contaminated sediment after changing to the simpler 0.02 M sodium bicarbonate solution ranged from 3 to 12 mL/g. The two methods of determining the uranium desorption Kd value lead to different Kd ranges. The first method, water versus acid extract approach, gave lower values than the more traditional batch leach test. Some of the differences were caused by the different chemical composition of the fluids used. The one to one water extracts lead to solutions with higher pH, dissolved carbonate, and total ionic strength than the simulated porewater and 0.02 M sodium bicarbonate solutions. Further discussions on uranium leachability from borehole 299-E33-45 sediments are found in Appendix D of the WMA B-BX-BY FIR (Knepp 2002a).

The water extractable percentages of uranium for those sediments that contain high amounts of uranium from the BX-102 tank overfill range from 0.09 to 12% of the total uranium. Despite the relatively low percentage that is water leachable, the calculated in situ desorption Kd values for these samples are quite low (i.e., range 0.07 to 2.36 mL/g; average 0.82 mL/g with 0.68 mL/g standard deviation).

Using the derived uranium in situ desorption Kd as a sensitive measure of how deep the plume may have reached, the Hanford processed uranium might be present at concentrations slightly above natural background as deep as the contact between the Hanford formation H3 unit and the Plio-Pleistocene, at 218 ft bgs. This depth is deeper than estimated by the bulk distribution of uranium, sodium, sulfate, and technetium-99 that is conclusively associated with the 1951 overfill event at BX-102. The in situ Kd values for uranium are distinctly higher in the PPlz and PPlc strata suggesting that no Hanford processing derived uranium is present and that the Kd values are high because only natural uranium that is much less water soluble is present. An explanation is not offered as to why natural uranium in the H3 unit might leach easily to give the low calculated in situ desorption Kd values.

One unresolved issue to surface from the data analysis is the depth of penetration of uranium and the 1951 tank overfill fluids. As stated above based on the total uranium content in the vadose zone sediments, it is not considered that Hanford derived uranium has penetrated below the fine-grained lens separating the Hanford formation H2 unit from the H3 unit (~170 ft bgs). However, the in situ uranium Kd data suggest that Hanford derived uranium might have penetrated the entire Hanford formation down to the Plio-Pleistocene mud unit at ~220 ft bgs.

6.5 Source of Contamination in the Deep Vadose Zone, Perched Water, and Groundwater

There are at least two known tank related sources for the contamination found in the vadose zone at borehole 299-E33-45 and the possibility that water line leaks and past disposal of liquids to cribs and trenches might have created the perched water found in the PPlz unit. Either of these sources or a combination could be the source of elevated uranium, technetium, and other constituents in the groundwater just east of the BX tank farm. In this section, the efforts to identify which source(s) are present in the sediments retrieved from drilling borehole 299-E33-45 are summarized.

Using large sediment samples and long count times, low levels of antimony-125 in a few samples between 90 and 102 ft bgs were found. Past historical gross gamma and recent spectral gamma logging (DOE-GJPO 1997, 1998, 2000) had shown small amounts of antimony-125 in nearby vadose zone monitoring wells. The antimony-125 has been attributed to leaks from a junction pit on top of tank BX-101 in the early 1970s. At the very low antimony-125 concentrations (0.04 to 0.1 pCi/g) that were found in a few samples, it is difficult to confirm that fluid from BX-101 environs has reached the vadose zone sediments at borehole 299-E33-45. There was undoubtedly some antimony-125 present in the 1951 overfill of tank BX-102 such that it cannot be stated unequivocally that the very faint indication of antimony-125 found in the sediments is an indication that the second leak source (i.e., early 1970s cesium recovery waste from the junction box on top of tank BX-101) caused the antimony-125 in the vadose zone sediments at 299-E33-45 that was observed.

Another source delineating constituent is cyanide, which was present in the 1970s cesium recovery waste stream but not the 1951 uranium metals waste. One statistically significant above background cyanide value was found at ~170 ft bgs at borehole 299-E33-45. Also, there is a definite faint trace of cyanide deep in the sediment profile in the coarse-grained PPlg sediment, in the perched water, and in the groundwater. Unfortunately, the source of the cyanide cannot be attributed to a specific disposal facility at this time. Finding cyanide, albeit in very low concentrations, in the vadose zone sediments, perched water, and groundwater at borehole 299-E33-45 does not conclusively lead to the conclusion that 1971 cesium recovery waste from junction box leaks at BX-101 is the source as originally thought. Upon further review of the BX-102 history, it was decided that after the 1951 tank overfill, waste containing cyanide was stored in the tank and that the cascade port that was compromised in the 1951 overfill likely allowed other fluids to escape tank BX-102 throughout the 1950s, 1960s, and 1970s. Therefore, finding very low concentrations of cyanide does not confirm the 1971 cesium recovery waste leak from the BX-101 junction box as the source.

Many waste streams have distinctly different compositions such that taking the ratios of two species in waste streams can often aid in determining the source of contamination, especially if the two species have no retardation tendencies. If so, then the ratio should remain constant even if the fluid is diluted with other water that does not contain either of the constituents.

Values for constituent ratios for the estimated waste streams in tank BX-102 at the time of the 1951 overfill and the estimated waste stream in BX-101 at the time of the suspected junction box leak (1970 to 1972) were calculated and compared to the same constituent ratios in the vadose zone porewaters. Unfortunately, the ratios for nearby cribs (i.e., 216-B7A, 216-B7B, and 216-B8) are the same as the 1951 overfill because the waste disposed to cribs was supernatant from the BX-101/BX-102/BX-103 cascade line during the 1950s. That is, unlike WMA SX, the wastes disposed to nearby cribs and trenches at BX tank farm have the same chemical composition as the BX tanks during the time period when bismuth phosphate wastes were present. Therefore, the component ratios that could be used as a key discrimination tool at WMA S-SX to differentiate crib waste from tank waste in the vadose zone porewater and groundwater are not as useful for differentiating between crib and tank sources at BX tank farm. However, the ratio methodology is still useful in differentiating the 1951 overfill from the 1970s junction box leaks.

Within the shallow H2 upper sand sequence (between 10 and 20 ft bgs), there is indication of some excess sodium based on ratioing sodium versus other constituents such as chloride or sulfate. This might represent surface or shallow pipeline leaks of high sodium solutions. There are no other relatively high ratios noted in the upper sand sequence of H2 or the thin fine-grained lens between 74.5 to 75.5 ft bgs. Below this fine-grained lens within the H2 middle sand sequence, there are very high ratios for uranium, nitrate, sodium, and technetium to chloride starting between 111 and 120 ft bgs, dependent upon constituent. The uranium/chloride and sodium/chloride ratios in this H2 middle sand sequence are most similar to the metal waste composition that leaked from tank BX-102 in 1951 but technetium/chloride and nitrate/chloride ratios are much lower than those for either the metals waste or cesium recovery waste composition. Conversely, the sulfate/chloride ratio is too large for either waste stream in this stratum. In summary, the preponderance of the porewater ratio values in the H2 middle sand sequence are closer to being 1951 metals waste than 1971 cesium recovery waste. Whatever the source, there appears to be too little technetium-99 in the porewaters for either waste composition.

All the ratios of constituents versus sulfate are closer to being from the 1951 metals waste composition than the 1971 cesium recovery waste in the H2 unit where the bulk of the contamination resides. The technetium to nitrate ratios for the two tank waste compositions are 287 and 1150 pCi/mg for the metals waste and cesium recovery waste, respectively. In the H2 middle sand sequence between 120 and 165 ft bgs where most of the contamination resides, the measured ratio is 100 ± 25 pCi/mg. In the three-foot thick fine-grained lens at 166 to 169 ft bgs, the ratio drops to 50 pCi/mg. Below this in the H3 unit, there is little technetium-99 present but the ratio appears to range from 10 to 30 pCi/mg. In the upper portion of the PPlz unit where the perched water resides, the technetium-99 to nitrate ratio rises to 60 to 100 pCi/mg. This change in technetium-99 to nitrate ratio might be explained by two different sources for the water that carries the contaminants or perhaps some sorption or reduction process is concentrating the technetium-99. In the coarse-grained PPlg unit, the ratio is ~20 pCi/mg. The technetium-99 to nitrate ratio for the perched water at 227 ft bgs is ~1.8 pCi/mg and for the groundwater at 258.7 ft bgs is 43 pCi/mg. This suggests that there may be a source of water that contains nitrate but not technetium that is feeding the perched water zone but it has not changed the ratio in the surrounding sediments nor diluted the groundwater that is found only 21 ft deeper. The data do not present a clear picture on what might be occurring in the Plio-Pleistocene unit.

The technetium to nitrate ratios in the H2 middle sand sequence between 120 and ~167 ft bgs average 100 ±25 pCi/mg. This suggests that technetium and nitrate could be migrating vertically at this location without interaction with the sediments, thus maintaining the constant ratio. But the ratio for the uranium metals waste from the bismuth phosphate process should be ~287 pCi/mg. This is about 3 times larger than the ratio observed in the sediment porewater. This is another indication of lower than expected technetium-99. The other possible waste stream from the 1971 cesium recovery waste lost from the BX-101 junction box has even more technetium relative to nitrate so mixing of the two waste streams does not explain the observed low ratio.

The uranium to nitrate ratio is somewhat constant at a value of 500 ug/mg in the zone between 111 and 151 ft bgs but then sharply drops to a value of 80 ± 20 ug/mg where it remains over the depths of 152 to 167.2 ft bgs (i.e., the contact with the fine-grained lens separating H2 unit from H3). The ratio for the metals waste should be 826 ug/mg suggesting that uranium has been removed relative to nitrate in the entire profile. Geochemical reactions wherein uranium adsorbs or precipitates in the sediment are a plausible explanation. The observed uranium to nitrate ratio in the porewaters is much too high to be related to the 1971 cesium recovery waste stream. Therefore, the 1951 metals waste overfill event dominates the sediments at 299-E33-45.

Between 120 ft bgs and 150 ft bgs, the uranium to techetium-99 ratio is approximately 5 ± 2 ug/pCi in the porewater. The ratio then drops to values between 0.2 to 1 ug/pCi for the remaining 17 ft of H2 middle sand sequence. This suggests that uranium is interacting with the sediment more than the technetium-99. Given that it is believed the technetium inventory is low, the observed uranium/technetium ratio is much closer to the metals waste ratio than cesium recovery waste.

The ratio approach was of much more value in interpreting the porewater data at the SX tank farm (Serne et al. 2002b, c, d). In general, the majority of the ratios in the Hanford formation sediments at borehole 299-E33-45 are closer to being from the 1951 metals waste solution that escaped tank BX-102 during a cascading accident.

In general, the perched water contains more dissolved common cations and anions and notably more tritium than the groundwater. The concentrations of the common cations and anions are similar to those found in the nearby dilution corrected vadose zone sediment porewaters.

The high tritium concentration in the perched water may be an important finding and could reflect an origin from crib disposal. Thus, the perched water may be remnant water from past crib disposals that arose from horizontal flow along the less water conductive fine-grained PPlz unit.

6.6 Other Characterization Observations

As part of the characterization of the contaminated sediment, parameters that can control contaminant migration were measured. Key parameters that were measured on borehole 299-E33-45 sediment include the calcium carbonate content, particle size distribution, bulk and clay size mineralogy, and soil water (or matric) potential, a measure of whether the sediment profile is conducive to draining or drying (via current or past evapotranspiration processes).

There were no zones of elevated calcium carbonate found in the sediment profile at borehole 299-E33-45. In general, all the sediments contain minor amounts of calcium carbonate. The sediment in the H1 unit is relatively low in calcium carbonate content, 0.7 to 1.6% by weight. The entire Hanford H2 unit including the upper and middle sand sequences and the three thin fine-grained lenses show a fairly uniform distribution for inorganic carbon between 1.3 and 2.0% as calcium carbonate. The H3 unit shows slightly less calcium carbonate, 0.9 to 1.3% by weight. The fine-grained PPlz mud shows slightly higher calcium carbonate, ranging from 1.8 to 2.3% by weight, and slightly higher organic carbon content than all the other units. The coarse-grained PPlg contains the least calcium carbonate, <0.85% and low organic carbon content. There is no evidence of rich calcareous zones in the entire profile such as found underlying the PPlz unit in the 200 West Area.

Particle size measurements showed that the bulk of the sediment in the Hanford H2 unit contained at least 90 weight percent sand excepting the thin layer at about 75 ft bgs that contained ~40% by weight silt and clay. The two other thin layers of finer-grained sediment at 120 and 167 ft bgs that were identified by visual inspection were either not captured exclusively in sampling for particle size measurement or the material has less silt and clay than the one-foot thick zone near 75 ft bgs. The PPlz zone between 217.8 and 238.7 ft bgs contains zones of very fine-grained (~98% by weight silt and clay) sediment that are several feet thick. The perched water lies within this zone.

X-ray diffraction (XRD) analyses of the bulk samples from seven depths in the H2 unit, one sample in the H3 unit, three samples in the PPlz unit, and one sample in the PPlg unit were performed. XRD analysis of the 12 bulk sediment samples from borehole 299-E33-45 shows the samples to all have a similar mineralogical signature. The sediments are mostly quartz and feldspar (both plagioclase and alkali-feldspar), with lesser amounts of mica, chlorite, and an amphibole. Semi quantitative mineral concentrations in the sediment are quartz (~28 to 40 wt-%), plagioclase feldspar (~19 to 35 wt-%) and potassium feldspar (~7 to 14 wt-%) with lesser amounts of amphibole (1 to 8 wt-%). Plagioclase feldspar is 2 to 4 times more abundant than potassium feldspar. Clay minerals identified in the bulk sample included mica and chlorite. Mica concentrations ranged from a low of 16 wt-% (sample 93A) to a high of 27 wt-% (sample 111A), with an average concentration of 19±4 wt-%. Chlorite concentrations were <8 wt-% in all sediments analyzed. Smectite and kaolinite minerals were not identified in the whole rock sediment samples due in part to the sample preparation technique and the low overall concentration, respectively. However, upon isolating the clay sized fraction (< 2 microns) from the bulk sediment, the mineral content for these clay-sized particles was dominated by illite and smectite with lesser amounts of chlorite and kaolinite. The clay sized particles from the H2, PPlz, and PPlg had very similar composition: illites 40 to 50%, smectite 28 to 37%, chlorite 10 to 18%, and kaolinite 4 to 7% by weight. The clay-sized fraction from the H3 unit had slightly more smectite (40%) and slightly less illite (40%) by weight. In general, none of the bulk or clay-sized mineral content differs from compositions for uncontaminated sediments underlying the Hanford Site. No signs of changes or sediment attack caused by interaction with the hypersaline and caustic fluids leaked from tanks were found. No microscopic or surface analyses such as scanning electron microscopy or transmission electron microscopy were performed that would better detect subtle interactions.

The general trend is that the water potentials at 299-E33-45 are consistent with a draining profile (i.e., water potentials wetter than -0.01 MPa). Below 70 m (230 ft) and to the water table at ~76 m (~250 ft), there appears to be a drier condition than above that depth. Note that the lower depths contain coarse materials, so sample handling (e.g., very slight drying) may be responsible for the apparent drier matric potentials. This is the third borehole within the operations area where gravel covers and vegetation removal occur at tank farms that suggest draining soil water profiles. However, as found outside the SX tank farm, a borehole outside B tank farm (i.e., 299-E33-338) does not show a draining profile all the way to the water table.

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Appendix A

Core Descriptions

Contents

Appendix A

Core Descriptions

A.1.0 Geological Description of Core Samples

The geologists' descriptions of each 6-in. core sample removed from the stainless steel liners are reproduced in this appendix. Each sheet lists observations made on all the liners for each sampling event (splitspoon). The ordering of the descriptions is from the shallowest core to the deepest core. The core liner identification (ID) number, depth interval, date opened, visual estimate of particle size, color, moisture condition, reaction to dilute hydrochloric acid, and other observations are listed on the forms.

Pacific Northwest National Laboratory

DAILY BOREHOLE LOG

Boring/Well No S01014 (299-E33-45) Depth 9.39 - 10.89 Date 2/8/01

Location 241-BX-102 Project Tank Farm Vadose Zone Proj.

Sheet 1 of 10

Logged by GV LAST

Reviewed by ______ Date ______

Lithologic Class. Scheme FOLK/WENTWORTH Procedure DSTEI-99-GVL-01 Rev 0

Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______

Drilling Contractor ______

Driller ______

Rig/Method ______

Depth Control Point ______

DEPTH (FT)	TIME	SAMPLES TYPE	SAMPLES ID NUMBER	CONTAMINATION INSTR.	CONTAMINATION READING	MOISTURE	GRAPHIC LOG C Z S G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H_2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
9.39 -	09:40	SS	S01014-01C			W		GRAVEL. - 90% Gravel, 5% Sand, 5% mud.			90% Full. COPIED NOTES FROM
9.89								Gravel upto 30 mm. Subangular to well			ANOTHER PAGE.
								rounded. Multilithologic. 1 mud clump			
								in middle. Moist color is 2.5Y 4/2. Weak			
								reaction to 25% HCl. No obvious structure			
								No cementation.			
9.89 -	10:15	SS	S01014-01B			W		GRAVEL. 85% Gravel, 8% Sand, 7% mud.			95% Full.
10.39								Gravel clasts upto 12 mm (broken). Subrounded.			
								Sand is mostly C-VC. Moist color is 2.5Y 4/2 to			
								3/2. Weak reaction to 25% HCl. No			
								cementation. No obvious structure. Muddier			
								zone in middle.			
10.39 -	10:30	SS	S01014-01A			M		GRAVEL. 90% Gravel, 8% Sand, 2% mud.			90% Full.
10.89								Gravel upto 40 mm. Subround - rounded,			Photo No. R0000266.JPG
								basalt and quartzites. Moist color is 2.5Y 3/2.			
								No obvious structure. No cementation.			
											Note: Using 25% HCl per ASTM.

W = Wet, M = Moist, D = Dry

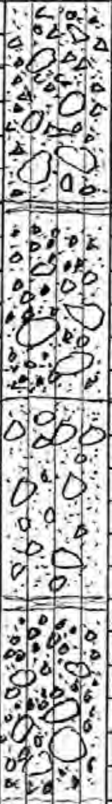
1998/DCL/PROC/DBL/001

Pacific Northwest National Laboratory

DAILY BOREHOLE LOG

Boring/Well No S01014 (299-E33-45) Depth 19.09 - 21.09 Date 2/08/01 Sheet 2 of 10
Location 241-SX-102 Project TankFarm VZ

Logged by GY LAST
Reviewed by ______ Date ______
Lithologic Class. Scheme FOLK/WENTWORTH Procedure DTBI-99-GRL-01 Rev 0
Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______
Drilling Contractor ______
Driller ______
Rig/Method ______
Depth Control Point ______

DEPTH (FT)	TIME	SAMPLES TYPE	SAMPLES ID NUMBER	CONTAMINATION INSTR.	CONTAMINATION READING	MOISTURE	GRAPHIC LOG C	Z	S	G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H_2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
19.09-	10:20	SS	S01014-06D			m					GRAVEL. 85% Gravel, 10% Sand, 5% mud.			95% Full.
19.59											Gravel upto >90mm, lots of smaller pebbles to			Photo P0000267.JPG
											granules. Sand is mostly medium. Moist			
											color is 2.5Y 3/2. No structure, no			
											cementation. Weak to no reaction to HCl.			
											Gravels are more angular - some granite			
19.59-	11:45	SS	S01014-06C			m-D					GRAVEL. 80% Gravel, 15% Sand, 5% mud.			95% Full
20.09											Some white & yellowish rock flour (No Rx).			Photo P0000268.JPG
											Gravels upto >30mm. Angular - Subround.			
											No Cementation. Weak to no Rx to HCl.			
											No structure.			
20.09-	10:00	SS	S01014-06B			m					MUDDY SANDY GRAVEL. 50% Gravel, 45%			105% Full. Copied notes over from
21.09											Sand, 5% mud. Gravel upto 50mm.			another page.
											Subrounded, mostly basalt. Sand mostly			
											C-VC. No reaction to 25% HCl. Moist			
											color is 2.5Y 4/2. Weak cementation.			
20.59-	10:55	SS	S01014-06A			m-D					GRAVEL, 80% Gravel, 15% Sand, 5% mud.			95% Full.
21.09											Gravel upto 40 mm, subrounded to angular.			Photo P0000269.JPG
											lots of quartzite. Sand VC-VF (mostly med.)			
											No cementation. Weak to no rx to HCl.			

W = Wet, M = Moist, D = Dry

Pacific Northwest
National Laboratory

DAILY BOREHOLE LOG

Boring/Well No S0114 (299-E33-45) Depth 30.19-32.09 Date 2/08/01
Location 241-BX-102 Project TankFarm VZ
Sheet 3 of 10

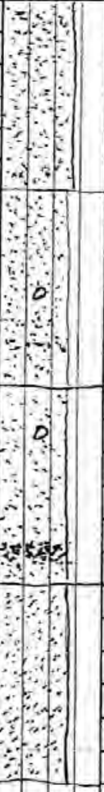
Logged by GV LAST
Reviewed by ______ Date ______
Lithologic Class. Scheme FOLK/WENTWORTH Procedure ~~[illegible]~~-97-GVL-01 Rev 0
Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______
Drilling Contractor ______
Driller ______
Rig/Method ______
Depth Control Point ______

DEPTH (FT)	TIME	SAMPLES		CONTAMINATION		MOISTURE	GRAPHIC LOG				LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H₂O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
		TYPE	ID NUMBER	INSTR.	READING		C	Z	S	G				
30.19-	11:05	SS	S01014-11D			m					SANDY GRAVEL. 70% Gravel, 25% Sand,			95% Full.
30.59											5% Mud. Gravels mostly basalt, subround, upto			Photo P0000270.JPG
											40mm. Sand mostly C. No cementation.			
											Wk to no rx to HCl. Moist color is 2.5Y 4/2 to			
											3/2			
30.59-	11:07	SS	S01014-11C			m					GRAVEL. 80% GRAVEL. 17% Sand, 3% Mud.			95% Full.
31.09											Gravel mostly basalt, subrounded, upto 30 mm.			Photo P0000271.JPG
											Sand mostly C-VC. Siltier at bottom.			
											No cementation. Wk rx to HCl. Moist			
											color is 2.5Y 4/2 to 4/3.			
31.09	11:20	SS	S01014-11B			m					GRAVEL, 85% Gravel. 10% Sand, 5% mud.			100% Full
31.59											Gravel mostly basalt, subrounded, upto 40mm.			Photo P0000272.JPG
											Sand mostly C-M. No structure. No cementation.			
											Weak Rx to HCl. Moist color is 2.5Y 4/2 to 4/3.			
31.59-	11:30	SS	S01014-11A			m					SANDY GRAVEL. 60% Gravel, 35% Sand, 5% mud			95% Full.
32.09											Gravel mostly basalt upto ~30mm. Subrounded.			Photo P0000273.JPG
											Sand is mostly C-VC. Moist color is 2.5Y 4/2,			
											No cementation. Wk to no Rx to HCl.			

W = Wet, M = Moist, D = Dry

Pacific Northwest National Laboratory	**DAILY BOREHOLE LOG**	Boring/Well No S01014 (299-E33-45) Depth 40.29-42.29 Date 2/08/01 Location 241-BX-102 Project Tankfarm VZ	Sheet 4 of 10

Logged by G V LAST
Reviewed by ______ Date ______
Lithologic Class. Scheme FOLK / WENTWORTH Procedure PNNL-99-DVL-01 Rev 0
Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______
Drilling Contractor ______
Driller ______
Rig/Method ______
Depth Control Point ______

DEPTH (FT)	TIME	SAMPLES TYPE	SAMPLES ID NUMBER	CONTAMINATION INSTR.	CONTAMINATION READING	MOISTURE	GRAPHIC LOG C Z S G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H₂O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
40.29-	11:35	SS	S01014-16D			m		SAND. 95% Sand, 5% mud.			100% Full
40.79								Sand is multilithologic. Mostly Coarse.			Photo P0000274.JPG
								Moist color is 2.5Y 4/2. No			
								Cementation. Wk-No Rx to HCl.			
40.79-	11:45	SS	S01014-16C			m		SAND. 95% Sand, 5% mud. Sand is			100% Full
41.29								multilithologic and mostly C-M, Some			Photo P0000275.JPG
								C-VC laminations. Moist color is 2.5Y4/2.			
								No cementation. Wk-no Rx. to HCl, except			
								1 caliche fragment. 1 med. (10mm) pebble.			
41.29-	11:55	SS	S01014-16B			m		SAND. 95% Sand, 5% mud. Sand is			100% Full
41.79								multilithologic and mostly c-m. Some			Photo P0000276.JPG
								stratifications (~6mm) of C-VC sand. 1			
								med. (10mm) pebble. Moist color is 2.5Y4/2.			
								No cementation. Wk-no Rx. except 1 small			
								caliche fragment			
41.79	12:00	SS	S01014-16A			m		SAND. 95% Sand, 5% mud. Sand is			95% Full
42.29								mostly C. and multilithologic. No			Photo P0000277.JPG
								structure or pebbles found. Moist			
								color is 2.5Y4/2. No cementation.			
								Weak-no reaction except caliche			
								fragment.			

W = Wet, M = Moist, D = Dry

Pacific Northwest National Laboratory

DAILY BOREHOLE LOG

Boring/Well No S01014(299-E33-45) Depth 49.89-51.89 Date 02/08/01

Location 241-BX-102 Project TANK FARM VZ

Sheet 5 of 10

Logged by G V LAST

Reviewed by ________ Date ________

Lithologic Class. Scheme ________ Procedure ________ Rev ________

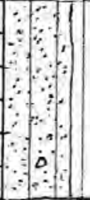
Steel Tape/E-Tape ________ / ________ Field Indicator Equip. 1) ________ 2) ________

Drilling Contractor -

Driller ________

Rig/Method ________

Depth Control Point ________

DEPTH (FT)	TIME	SAMPLES		CONTAMINATION		MOISTURE	GRAPHIC LOG				LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H_2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
		TYPE	ID NUMBER	INSTR.	READING		C	Z	S	G				
49.89-	12:20	SS	S01014-21D			m					SAND. 95% Sand, <5% mud. Sand is			100% Full
50.39											multilithologic and mostly C. More			Photo P0000278.JPG
											finer m. Sand near top. Moist color is 2.5Y4/2			" 279.JPG
											No cementation. Wk Rx to HCl.			" 280.JPG
50.39-	12:25	SS	S01014-21C			m					SAND. 95% Sand, <5% mud. Sand is			100% Full.
50.89											multilithologic and mostly C. 1 fine			Photo P0000281.JPG
											(6mm) pebble. Moist color is 2.5Y4/2.			
											No cementation. Wk. Rx to HCl.			
											No obvious structure.			
50.89-	12:30	SS	S01014-21B			m					SLIGHTLY GRAVELLY SAND. 5% Gravel, 90%			100% Full.
51.39											Sand, 5% Mud. Gravel is most m-F pebble			Photo P0000282.JPG
											(up to about 10 mm). Sand is multilithologic mostly			
											C. Top is gravellier, bottom is sand. No Cementation.			
											Wk Rx. Moist color is 2.5Y4/2.			
51.39-	12:35	SS	S01014-21A			m					SAND. 92% Sand, 3% Gravel, 5% mud.			95% Full.
51.89											More gravel near bottom. Gravel is F-VF Pebble			Photo P0000283.JPG
											up to 8-10mm. Sand is multilithologic			
											and mostly C. No cementation. Wk Rx to			
											HCl. Moist color is 2.5Y4/2.			

W = Wet, M = Moist, D = Dry

1998/DCL/PROC/DBL/001

Pacific Northwest National Laboratory

DAILY BOREHOLE LOG

Boring/Well No S01014 (299-E33-45) Depth 61.24-63.24 Date 02/08/01
Location 241-BX-102 Project Tank Farm VZ
Sheet 6 of 10

Logged by GV LAST
Reviewed by ______ Date ______
Lithologic Class. Scheme FOLK/WENTWORTH
Procedure D7781-99-GVL-01 Rev 0
Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______
Drilling Contractor -
Driller ______
Rig/Method ______
Depth Control Point ______

DEPTH (FT.)	TIME	SAMPLES		CONTAMINATION		MOISTURE	GRAPHIC LOG				LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H_2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
		TYPE	ID NUMBER	INSTR.	READING		C	Z	S	G				
61.24	13:00	SS	S01014-27D			M					SAND. 2% Gravel, 93% Sand, 5% mud.			100% Full.
61.74											Gravel upto 15mm (scattered). Sand is			Photo P0000284.JPG
											multilithologic and most Med. Moist.			
											color is 2.5Y 4/2-5/2. No cementation.			
											Wk Rx to HCl except caliché fragment.			
											No obvious structure.			
61.74	13:05	SS	S01014-27C			M					SAND. Trace of gravel. 95% Sand, 5% mud.			100% Full
62.24											Gravel upto 10mm. Sand is multilithologic			Photo P0000285.JPG
											and mostly C-M. Moist color is 2.5Y 4/2.			
											No cementation. Wk Rx. No obvious			
											structure.			
62.24	13:15	SS	S01014-27B			M					SAND. Trace of gravel. 95% Sand, 5% mud.			100% Full.
62.74											Gravel upto 16mm. Sand is multilithologic,			Photo P0000286.JPG
											and mostly med. Moist color is 2.5Y 4/2-5/2.			
											No cementation. Wk Rx except for			
											caliche fragment. No obvious structure.			
62.74	13:25	SS	S01014-27A			M.					SAND. Mostly M-VF more mud. Some pebbles			95% Full. Took most samples except
63.24											SAND. 95% Sand, 5% mud. Sand is			VFA from fine grained top
											multilithologic more basalt, and VC-C.			Photo P0000287.JPG
											Weak Rx to HCl. Fine grained top has			
											Wk-St. Rx. No cementation			

W = Wet, M = Moist, D = Dry

Pacific Northwest National Laboratory	**DAILY BOREHOLE LOG**	Boring/Well No S01014 (299-E33-45) Depth 69.49-71.49 Date 02/08/01 Location 241-BX-102 Project Tank Farm VZ	Sheet 7 of 10

Logged by GV LAST

Reviewed by ______ Date ______

Lithologic Class. Scheme FOLK/WENTWORTH Procedure DTPSL-99-GVL-01 Rev 0

Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______

Drilling Contractor ______

Driller ______

Rig/Method ______

Depth Control Point ______

DEPTH (FT.)	TIME	SAMPLES		CONTAMINATION		MOISTURE	GRAPHIC LOG C Z S G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H_2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
		TYPE	ID NUMBER	INSTR.	READING						
69.49-	13:30	SS	S01014-32D	Gm	~20-40	M		SAND, 95% Sand 5% mud. Sand is			98% Full
69.99								multilithologic and mostly medium. Some			Photo P0000288.JPG
								pebbles to 10 mm. Moist color is 2.5Y 4/1-3/2,			
								WK Rx. No cementation. No obvious			
								structure			
								SAND. Most C Sand. WK Rx.			
69.99	13:40	SS	S01014-32C	Gm	0	M-D		SAND. 95% SAND, <5% mud. Sand is			99% Full
70.49								multilithologic w/ more quartz. Some			Photo P0000 289.JPG
								VF-F pebble. Sand is most C. WK			
								Rx to HCl. No cementation. No			
								obvious structure			
70.49	13:50	SS	S01014-32B	Gm	0	M		SAND. 95% Sand <5% mud. Sand is			100% Full
70.99								multilithologic, back to 50% basaltic? Mostly			Photo P0000 290.JPG
								M-C Sand. WK Rx to HCl. No cementation.			P0000 291.JPG
								No obvious structure.			
70.99	14:00	SS	S01014-32A	Gm	0	M-D		SAND. 95% Sand <5% mud. Sand is multilithologic, and mostly C. WK Rx to HCl.			60% Full
71.49											Photo P0000 292.JPG
								No Cementation. No obvious structure.			

W = Wet, M = Moist, D = Dry

1998/DCL/PROC/DBL/001

Pacific Northwest National Laboratory	DAILY BOREHOLE LOG	Boring/Well No S01614 (299-E33-45) Depth ______ Date 02/08/01	Sheet
		Location 241-By-162 Project TankFarm V2	8 of 10

Logged by GV LAST
Reviewed by ______ Date ______
Lithologic Class. Scheme FOLK/WENTWORTH
Procedure ~~PNNL~~-??-SVL-01 Rev 0
Steel Tape/E-Tape ______ / ______
Field Indicator Equip. 1) ______ 2) ______
Drilling Contractor ______
Driller ______
Rig/Method ______
Depth Control Point ______

DEPTH (FT)	TIME	SAMPLES		CONTAMINATION		MOISTURE	GRAPHIC LOG				LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H_2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
		TYPE	ID NUMBER	INSTR.	READING		C	Z	S	G				
72.64-	1535	SS	S01014-33D	GM	0	m					SAND. 95% Sand <5% mud. Some			105% Full
72.14											VF-F Pebble-1 to 35 mm. Sand is			Photo P0001293.JPG
											multilithic and most C. Wk Rx to HCl			
											No cementation. No structure.			
72.14	1545	SS	S01014-33C	GM	0	m					SAND. 5% Gravel, 90% Sand <5%			100% Full
72.64											mud. 1 large (55 mm) subangular basalt			Photo P0001294.JPG
											clast. Sand mostly M, wk. Rx to HCl.			
											No cementation. No structure			
											moist color 2.5Y 5/2			
72.64	1550	SS	S01014-33B	GM	0	m					SAND: 95% Sand <5% mud.			100% Full
73.14											SAND is mostly C at Top and M on			Photo P0001295.JPG
											bottom, wk. Rx to HCl. No cementation.			
											No structure. Moist Color is 2.5Y 5/2			
73.14	1600	SS	S01014-33A	GM	0	m-D					Sand. 95% Sand <5% mud.			80% Full
73.64											Sand is mostly med. - multilithologic.			Photo P0001296.JPG
											Wk rx to HCl. No cementation. Moist			
											Color is 2.5Y 5/2. No obvious structure			
											Finer and drier than above			

W = Wet, M = Moist, D = Dry

Pacific Northwest
National Laboratory

DAILY BOREHOLE LOG

Boring/Well No S01614 (2~~77~~-E33-45) Depth ______ Date 02/08/01
Location 241-BX-102 Project TankFarm VZ
Sheet 9 of 10

Logged by GU LAST
Reviewed by ______ Date ______
Lithologic Class. Scheme FOLK/WENTWORTH Procedure [illegible]-DL-01 Rev 0
Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______
Drilling Contractor ______
Driller ______
Rig/Method ______
Depth Control Point ______

DEPTH (FT)	TIME	SAMPLES		CONTAMINATION		MOISTURE	GRAPHIC LOG C Z S G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H₂O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
		TYPE	ID NUMBER	INSTR.	READING						
73.90-	16:10	SS	S01614-34D	Gm	0	M-W		SAND. 95% Sand, 5% mud.			101% Full. Filter paper had some
74.40								Sand is multilithologic and mostly C-M.			yellow staining.
								Cementation is wk to moderate. Wk-no			Photo P0000297.JPG
								Rx to HCl. Moist color is 2.5Y 5/2.			
74.40-	16:20	SS	S01614-34C	Gm	0	M		SAND. 95% Sand, 5% mud, Sand mostly			98% Full Took samples of both
74.90								M. some muddier at bottom. Wk rx to HCl			Fine and coarse.
								(stronger than below.)			Photo P0000298.JPG
						M		MUDDY SAND. 70% Sand, 30% mud.			
								Sand is VF-F sand. Moist color is 2.5Y 4/2-			
								4/3. Wk-no rx to HCl. Stratified to laminated.			
74.90-	16:30	SS	S01614-34B			M		MUDDY SAND. 70% Sand 30% mud. stratified.			100%
75.40								Sand is mostly F to VF. Wk reaction to HCl.			Photo P0000299.JPG
								Moist color is 2.5Y 4/2			
								SAND. mostly C.			
								MUDDY SAND. Sand is mostly V.F. Wk			
								rx to HCl.			
75.40-	16:40	SS	S01614-34A			M-W		MUDDY SAND. 70% SAND. 30% mud.			75%
75.90								SAND is mostly VF to F. Moist color is 2.5Y			Photo P0000300.JPG
								4/2 to 4/3. Wk to no reaction to HCl. Stratified.			
								SAND. 95% SAND 5% mud. Sand is			
								mostly C. WK reaction to HCl (stronger			
								than fines above.			

W = Wet, M = Moist, D = Dry

1998/DCL/PROC/DBL/001

Pacific Northwest National Laboratory

DAILY BOREHOLE LOG

Boring/Well No S01014 (299-E33-45) Depth 76.44-78.44 Date 02/08/01 Sheet 10 of 10
Location 241-BX-102 Project Tank Farm VZ

Logged by GV Last
Reviewed by Date
Lithologic Class. Scheme FOLK/WENTWORTH Procedure DJTBI-99-GUL-01 Rev 0
Steel Tape/E-Tape / Field Indicator Equip. 1) 2)

Drilling Contractor
Driller
Rig/Method
Depth Control Point

DEPTH (FT)	TIME	SAMPLES		CONTAMINATION		MOISTURE	GRAPHIC LOG				LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H_2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
		TYPE	ID NUMBER	INSTR.	READING		C	Z	S	G				
76.44	1650	SS	S01014-35D			D					SAND, >95% Sand, <5% mud.			80% Full.
76.94											Sand is mostly C. Multilithologic. Wk			PHOTO P0000301.JPG
											Rx to HCl. No structure. No cementation.			
											Lighter color - less silt - drier.			
76.94	1700	SS	S01014-35C	Gm	0	M-D					SAND. <5% Gravel, 90% Sand, <5% mud.			98% Full
77.44											Sand is multilithologic, and mostly C-VC.			PHOTO P0000302.JPG
											Some v.f. pebble. Wk-no Rx to HCl.			PHOTO P0000303.JPG
											No cementation. Moist color 2.5Y 5/2.			
77.44	1705	SS	S01014-35B			M					SAND. 95% Sand, <5% mud. Sand is			98% Full
77.94											mostly C-VC Sand, multilithologic. Several			PHOTO P0000304.JPG
											pebbles to 10mm. Wk-no Rx to HCl.			
											No cementation. Moist color 2.5Y 4/2			
77.94	1715	SS	S01014-35A			M					Sand, >95% Sand, <5% mud. Sand at top			80% Full
78.44											is most C-VC w/ some V.F. Pebble. Sand on			PHOTO P0000305.JPG
											bottom is most C-M with some fine sand. No			
											Rx to HCl. Moist color is 2.5Y 4/2. Some			
											stratification.			

W = Wet, M = Moist, D = Dry

Pacific Northwest National Laboratory

DAILY BOREHOLE LOG

Boring/Well No S01014 (299-E33-45) Depth 77.59-79.59 Date 2/12/01

Location 241-BX-102 Project Tankfarm VZ

Sheet 1 of 5

Logged by G.V LAST

Reviewed by ______ Date ______

Lithologic Class. Scheme FOLK/WENTWORTH Procedure PNNL-99-GVL-01 Rev 0

Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______

Drilling Contractor ______

Driller ______

Rig/Method ______

Depth Control Point ______

DEPTH (FT)	TIME	SAMPLES		CONTAMINATION		MOISTURE	GRAPHIC LOG				LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H_2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
		TYPE	ID NUMBER	INSTR.	READING		C	Z	S	G				
77.59-	14:00		S01014-36D			m					SAND. >95% Sand <5% mud. Sand is			95% Full.
78.09											mostly C. Some VC Sand - V.F. Pebble.			P0000306.JPG
											Wk reaction to HCl. No cementation.			
											Moist color is 2.5Y 4/2. Very little			
											mud. Multi-lithologic sand.			
78.09-	14:10		S01014-36C			m-w					SAND, >95% Sand <5% mud. Sand is			100% Full
78.59											mostly C-m. Looks wetter than above.			P0000307.JPG
											No rx to HCl. No cementation.			
											Moist color is 2.5Y 4/2-3/2			
											Very little mud - no binder. Maybe			
											more basalt.			
78.59-	14:25		S01014-36B			m-W					SAND. >95% Sand <5% mud. Sand is			98% Full
79.09											mostly C. Wk-No Rx to HCl. No			P0000308.JPG
											cementation. Moist color 2.5Y 4/2.			
79.09	14:30		S01014-36A			m-W					SAND. >95% Sand <5% mud. Sand is			95% Full
79.59											mostly C. Wk-no Rx to HCl.			P0000309.JPG
											No cementation. Moist color 2.5Y			
											4/2.			

W = Wet, M = Moist, D = Dry

Pacific Northwest National Laboratory	DAILY BOREHOLE LOG	Boring/Well No S01014 (299-E33-45)	Depth 86.90-88.90	Date 02/12/01	Sheet 2 of 5
		Location 241-BX-102	Project TANK FARM V2		

Logged by GV LAST

Reviewed by ______ Date ______

Lithologic Class. Scheme FOLK/WENTWORTH Procedure PNNL-GJ-01 Rev 0

Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______

Drilling Contractor ______

Driller ______

Rig/Method ______

Depth Control Point ______

DEPTH (FT.)	TIME	SAMPLES TYPE	SAMPLES ID NUMBER	CONTAMINATION INSTR.	CONTAMINATION READING	MOISTURE	GRAPHIC LOG C Z S G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H₂O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
86.90 87.40	19:25	SS	S01014-40D			m-W		SAND. >95% SAND <5% mud. Sand is mostly C-M. 1 pebble to 6 mm. Look finer than above - more F-VF sand. Moist color is 2.5Y 4/2. Wk rx to HCl. Wk cementation, some clods.			100% Full. P0000310.JPG
87.40 87.90	1930	SS	S01014-40C			m-W		SAND. >95% Sand <5% mud. Sand is mostly C-M. Wk. cementation - some clods. Wk Rx to HCl. Moist color 2.5Y 4/2. Some finer grained areas. No obvious structure.			100% Full. PHOTO P0000311.JPG
87.90 88.90	1935	SS	S01014-40B			m-W		SAND. >95% Sand <5% sand Sand is mostly C. (coarser than above). Moist color is 2.5Y 4/2. Wk no Rx to HCl. Weak cementation. multilithologic sand. No structure			100% Full PHOTO P0000312.JPG
88.40 88.90	1940	SS	S01014-40A			m-W		SAND. >95% Sand <5% mud. Sand is mostly C. Moist color 2.5Y 4/2. Wk Rx to HCl. Weak cementation. Multilithologic sand. No structure.			85% Full. PHOTO P0000313.JPG

W = Wet, M = Moist, D = Dry

1998/DCL/PROC/DBL/001

Pacific Northwest National Laboratory	**DAILY BOREHOLE LOG**	Boring/Well No S0D14 (277E33-45) Depth 98.34-100.34 Date 02/12/01 Location 241-BX-102 Project TANK FARM VZ Sheet 3 of 5

Logged by GV LAST

Reviewed by ____ Date ____

Lithologic Class. Scheme FOLK/WENTWORTH Procedure DSTBI-99-GV-01 Rev 0

Steel Tape/E-Tape ____ / ____ Field Indicator Equip. 1) ____ 2) ____

Drilling Contractor ____

Driller ____

Rig/Method ____

Depth Control Point ____

DEPTH (FT)	TIME	SAMPLES TYPE	SAMPLES ID NUMBER	CONTAMINATION INSTR.	CONTAMINATION READING	MOISTURE	GRAPHIC LOG C	Z	S	G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H₂O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
98.34-	14:50	SS	S0D14-44D			M-W					SAND. >95% sand <5% mud. Sand is			100% Full.
98.84											most C with some VCS - VF Pebble up to			PHOTO P0000314.JPG
											6 mm at top. Sand is most C-M			
											at bottom. Wk-no rx. Most			
											color 2.5Y4/2. No cementation.			
98.84-	1455	SS	S0D14-44C			M-W					SAND. >95% sand <5% mud. Sand on			100% Full. SAMPLES FROM FINER
99.34											bottom is most M. Wk. Rx to HCl.			BOTTOM MATERIALS.
											No cementation. Moist color is			PHOTO P0000315.JPG
											2.5Y 4/2. Good contact with C			
											sand on top.			
99.34	15:05	SS	S0D14-44B			M-W					SAND. >95% SAND; 5% mud. Sand			100% Full. Took UFA sample.
99.84											is mostly M. Wk. Rx to HCl. No			PHOTO P0000316.JPG
											cementation. Moist color is 2.5Y4/2-			
											5/2.			
99.84-	15:16	SS	S0D14-44A			M-W					SAND. >95% SAND, <5% mud. Sand			85% Full. Subcored samples,
100.34											is mostly M-F sand. Wk Rx to			after Filter paper removed,
											HCl. No cementation. Moist			to avoid any contamination on
											color is 2.5Y 4/2.			outside of sleeve.
														PHOTO P0000317.JPG

W = Wet, M = Moist, D = Dry

1998/DCL/PROC/DBL/001

Pacific Northwest National Laboratory	**DAILY BOREHOLE LOG**	Boring/Well No S0104 (299-E33-45) Location 241-BX-102	Depth 109.39 - 111.39 Date 02/02/01 Project Tank Farm VZ	Sheet 4 of 5

Logged by G V LAST

Reviewed by ______ Date ______

Lithologic Class. Scheme FOLK/WENTWORTH Procedure DT(B)-99-GVL-01 Rev 0

Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______

Drilling Contractor ______

Driller ______

Rig/Method ______

Depth Control Point ______

DEPTH (FT.)	TIME	SAMPLES		CONTAMINATION		MOISTURE	GRAPHIC LOG				LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H₂O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
		TYPE	ID NUMBER	INSTR.	READING		C	Z	S	G				
109.39-	15:20	SS	S0104-99D			m					SAND, >95% SAND <5% mud, Sand is			100% Full
109.89											most C-m. Very unconsolidated at			PHOTO P0000318.JPG
											top. Middle portion wk-mod.			
											cemented with wk-str.* Rx to HCl.			
											Moist color is 2.5Y 4/2-5/2.			
109.89	15:25	SS	S0104-99C			m					SAND. >95% Sand <5% mud, Sand is			100% Full
110.39											mostly C-m. Wk Rx to HCl. No			PHOTO P0000319.JPG
											cementation. Moist color is 2.5Y			
											4/2-5/2. No structure.			
110.39-	15:30	SS	S0104-99B			m					SAND, >95% Sand <5% mud. Sand is			100% Full
110.89											mostly C-m. Wk Rx to HCl. No cem-			PHOTO P0000320.JPG
											entation. Moist color is 2.5Y 4/2-5/2			
											No structure			
110.89-		SS	S0104-99A								SAND. >95% SAND <5% mud. Sand is			80% Full
111.39											mostly C-m. Maybe a little finer			PHOTO P0000321.JPG
											at bottom. No obvious structure.			
											wk Rx to HCl. Moist Color is 2.5Y 4/2-			
											5/2.			

W = Wet, M = Moist, D = Dry

1998/DCL/PROC/DBL/001

Pacific Northwest National Laboratory	DAILY BOREHOLE LOG	Boring/Well No S01014 (299-E33-45) Location 241-BX-102	Depth 117.29 – 119.29 Date 02/12/01 Project TANK FARM VZ	Sheet 5 of 5

Logged by G.V. LAST
Reviewed by ____ Date ____
Lithologic Class. Scheme FOLK/WENTWORTH Procedure PNTBI-99-GVL-01 Rev 0
Steel Tape/E-Tape ____ / ____ Field Indicator Equip. 1) ____ 2) ____

Drilling Contractor -
Driller
Rig/Method
Depth Control Point

DEPTH (FT.)	TIME	SAMPLES		CONTAMINATION		MOISTURE	GRAPHIC LOG				LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H₂O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
		TYPE	ID NUMBER	INSTR.	READING		C	Z	S	G				
117.29-	15:45	SS	S01014-53D			m					SAND. >95% SAND, <5% MUD. Sand			100% FULL. SAMPLES FROM FINER
117.79											is mostly m. Changes to C sand near			TOP STUFF
											bottom. Moist color is 2.5Y4/2.			PHOTO P0000322.JPG
											Wk-no Rx to HCl. No cementation.			
117.79-	15:55	SS	S01014-53C			M					SAND. >95% Sand, <5% mud. Sand			100% Full.
118.29											most C; with some V.F. Pebbles.			PHOTO P0000323.JPG?
											Wk-no reaction to HCl. No cementation.			
											Moist color 2.5Y4/2. No structure.			
118.29-	16:05	SS	S01014-53B			m					SAND. 95% Sand, <5% mud. Sand is			100% Full.
118.79											mostly C. with some VC sand and			PHOTO P0000323.JPG?
											VF. Pebbles. Small lens of M. sand			324,
											near bottom. Wk Rx to HCl. No			
											cementation. Moist color is 2.5Y4/2.			
118.79-	16:15	SS	S01014-53A			m					SAND. 95% Sand. <5% mud. Sand is			80% Full.
119.29											mostly C-M. Some VF. Pebbles.			PHOTO P0000325.JPG
											Wk. Rx to HCl. Moist color is 2.5Y4/2.			
											No cementation.			

W = Wet, M = Moist, D = Dry

Pacific Northwest National Laboratory	**DAILY BOREHOLE LOG**	Boring/Well No S01014 (299-E33-45) Depth 119.14 - 121.14 Date 2/14/01 Location 241-BX-102 Project TANK FARM VZ CHAR.	Sheet 1 of 1

Logged by GV LAST Print ______ Sign ______ Print ______ Sign ______

Reviewed by ______ Print ______ Sign Date ______

Lithologic Class. Scheme FOLK/WENTWORTH Procedure DTTBS-99-GVL-01 Rev 0

Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______

Drilling Contractor ______

Driller ______

Rig/Method ______

Depth Control Point ______

DEPTH (FT)	TIME	SAMPLES TYPE	SAMPLES ID NUMBER	CONTAMINATION INSTR.	CONTAMINATION READING	MOISTURE	GRAPHIC LOG C Z S G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H_2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
119.14	9:00	SS	S01014-59D			m		SAND. >95% Sand <5% mud. Sand is			100% FULL. CONTAINS SLUFF?
119.64								mostly C-M. Multilithologic. WK Rx to			DEPTH INDICATES SLUFF.
								HCl. No cementation. Color (moist)			PHOTO P0000327.JPG
								is 2.5Y 4/2. Maybe finer near			
								bottom.			
119.64	9:10	SS	S01014-59C			m		SAND. >95% Sand <5% mud. Mostly,			100% FULL. GEA w/ Moisture & Water Extract
120.14								Medium Sand. WK Rx to HCl			
								SAND. 95% Sand 5% mud. Mostly			Some stratification in F. Sand. Took
								Fine Sand, Wk-Sr Rx, 2.5Y 5/2. Wk. Lmnd			samples out of fine sand.
								SAND. >95% SAND. <5% mud. Mostly			PHOTO P0000328.JPG
								C-M Sand. WK Rx to HCl.			
120.14	9:20	SS	S01014-59B			M		SAND >95% Sand <5% mud. Sand is			100% FULL
120.64								most C. Some VC. Sand and scattered			PHOTO P0000329.JPG
								pebbles to 10mm. Some V.F. Sand nodules			
								as well. Wk. Rx to HCl. Wk cementation			
								Moist color is 2.5Y 4/2.			
120.64	9:25	SS	S01014-59A			M-D		SAND >95% Sand <5% Mud. Sand is			95% FULL
121.14								C to V.C. VC. Sand to V.F. Pebble Basalt			PHOTO P0000330.JPG
								clasts. 2.5Y 4/2. Wk-no Rx to HCl.			
								No cementation			

W = Wet, M = Moist, D = Dry

Pacific Northwest National Laboratory	**DAILY BOREHOLE LOG**	Boring/Well No S01614 (299-E33-45) Depth 129.20-131.20 Date 02/14/01 Location 241-BX-102 Project TANK FARM VZ CHAR.	Sheet 2 of 11

Logged by G V LAST
Print Sign Print Sign
Reviewed by Date
Print Sign
Lithologic Class. Scheme FOLK/WENTWORTH Procedure PPB1-99-SVL-01 Rev 0
Steel Tape/E-Tape / Field Indicator Equip. 1) 2)

Drilling Contractor -
Driller
Rig/Method
Depth Control Point

DEPTH (FT.)	TIME	SAMPLES TYPE	SAMPLES ID NUMBER	CONTAMINATION INSTR.	CONTAMINATION READING	MOISTURE	GRAPHIC LOG C	GRAPHIC LOG Z	GRAPHIC LOG S	GRAPHIC LOG G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H₂O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
129.20-	0930	ss	S01614-61D			M					SAND >95% Sand <5% mud. Mostly			100% FULL
129.70											C-M Sand. 2.5Y 4/2. Wk Rx.			PHOTO P0000331.JPG
											No cementation			
129.70-	9:35	ss	S01614-61C			M					SAND >95% Sand <5% mud. Sand is			100% FULL
130.20											mostly C-M. Moist color 2.5Y 4/2.			PHOTO P0000332.JPG
											Wk Rx to HCl. Wk to no cementation.			
											No structure.			
130.20-	9:55	SS	S01614-61B			M					SAND. >95% Sand <5% mud. Sand is			100% FULL
130.70											mostly C-M, Moist color 2.5Y 4/2. Wk-			PHOTO P0000333.JPG
											No Rx to HCl. Wk to no cementation.			
											No structure			
130.70	10:05	ss	S01614-61A			M					SAND. >95% Sand <5% mud. Sand is			80% FULL
131.20											mostly C-M. Moist color is 2.5Y 4/2-			PHOTO P0000334.JPG
											5/2. Wk-no Rx to HCl. No to Wk			
											cementation. No obvious structure			

W = Wet, M = Moist, D = Dry

1998/DCL/PROC/DBL/001

Pacific Northwest
National Laboratory

DAILY BOREHOLE LOG

Boring/Well No S41014 (299-E33-45) Depth 139.50-141.50 Date 2/14/01

Location 241-BX-102 Project TANK FARM VZ CHAR

Sheet 3 of 11

Logged by G.V. LAST

Reviewed by ______ Date ______

Lithologic Class. Scheme FOLK/WENTWORTH Procedure D9TB1-99-GVL-01 Rev 0

Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______

Drilling Contractor ______

Driller ______

Rig/Method ______

Depth Control Point ______

DEPTH (FT)	TIME	SAMPLES TYPE	SAMPLES ID NUMBER	CONTAMINATION INSTR.	CONTAMINATION READING	MOISTURE	GRAPHIC LOG C	Z	S	G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H_2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
139.50-	10:10	SS	S41014-67D			M	*				SAND, >95% Sand <5% mud. Sand			100% Full.
140.00								*			is Mostly C-M. 1 stratification near			PHOTO P0000335.JPG
											top is wk-mod. cemented & drygreen/			
											wk-Strg Rx. Rest of sample is blk			
								O			Rx. 1 pebble to 25mm, near bottom			
											color is darker 2.5Y 4/2.			
140.00	10:15	SS	S41014-67C			M					SAND. >95% Sand <5% mud. Sand			100% Full
140.50											is mostly C-M, Maybe more M than			PHOTO P0000336.JPG
											C. Wk-no Rx to HCl. No cementation,			
											Moist Color is 2.5Y 4/2.			
140.50	10:20	SS	S41014-67B			M					SAND. >95 Sand, <5% Mud. Sand is			102% Full
141.00											mostly C-M. No-Rx to HCl. No			PHOTO P0000337.JPG
											cementation, No structure, Moist			
											Color is 2.5Y 4/2.			
141.00	10:30	SS	S41014-67A			M					SAND, >95% Sand. <5% mud, Sand is			80% Full.
141.50											mostly C-M. Some VF. Pebble - 1 up to			PHOTO P0000338.JPG
											20 mm, near bottom, Wk-no Rx to			
											HCl. No cementation, Moist color			
							O				is 2.5Y 4/2			

W = Wet, M = Moist, D = Dry

1998/DCL/PROC/DBL/001

Pacific Northwest
National Laboratory

DAILY BOREHOLE LOG

Boring/Well No S01014 (299-E33-45) Depth 149.80- 151.80 Date 2/14/01
Location 241-BX-102 Project TANK FARM VZ CHAR.

Sheet 4 of 11

Logged by GV LAST

Reviewed by ______ Date ______

Lithologic Class. Scheme FOLK/WENTWORTH Procedure PTG-59 GL-01 Rev 0

Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______

Drilling Contractor –

Driller ______

Rig/Method ______

Depth Control Point ______

DEPTH (FT)	TIME	SAMPLES		CONTAMINATION		MOISTURE	GRAPHIC LOG				LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H₂O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
		TYPE	ID NUMBER	INSTR.	READING		C	Z	S	G				
149.80	1040	SS	S01014-72D			M					SAND >95% Sand <5% mud. Sand is			100% Full.
150.30											mostly M. Some silt/v.f sand			
											nodules near top. Mod. Cemented with			
	-										Wk-Strg. Rx to HCl. Rest of sample			
											has wk Rx to HCl. Moist color is			
											2.5Y 4/2-5/2. No cementation.			
150.30	1045	SS	S01014-72C			M					SAND >95% Sand <5% mud. Sand is			100% Full. Dryer at bottom.
150.80											mostly C on top M on bottom. Top is			PHOTO P0000342.JPG
											wetter than bottom with no-wk Rx to HCl.			
											and dkr color. Bottom is drier, with			
						M-D					wk Rx to HCl, & lighter color. 2.5Y 4/2-			
											5/2.			
150.85	1050	SS	S01014-72B			M					SAND >95% Sand <5% mud. Sand is			102% Full.
151.30											mostly M. Wk Rx to HCl. No to wk			PHOTO P0000343.JPG
											cementation Moist color is 2.5Y 5/2			
											No obvious structure.			
151.30	1055	SS	S01014-72A			M					SAND, >95% Sand <5% mud. Sand is			85% Full.
151.80											mostly M. on top. Coarsens slightly			PHOTO P0000344.JPG
											to C/M to bottom. Color is 2.5Y 5/2			
											Wk Rx to HCl = No cementation			

W = Wet, M = Moist, D = Dry

1998/DCL/PROC/DBL/001

Pacific Northwest National Laboratory	**DAILY BOREHOLE LOG**	Boring/Well No S0014 (299-E33-45) Depth 159.10-161.10 Date 2/14/01 Location 241-BY-102 Project TANK FARM VZ CHAR.	Sheet 5 of 11

Logged by GV Last

Reviewed by ______ Date ______

Lithologic Class. Scheme Folk / Wentworth Procedure PNNL-97-GVL-01 Rev 0

Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______

Drilling Contractor -

Driller ______

Rig/Method ______

Depth Control Point ______

DEPTH (FT)	TIME	SAMPLES		CONTAMINATION		MOISTURE	GRAPHIC LOG				LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H_2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
		TYPE	ID NUMBER	INSTR.	READING		C	Z	S	G				
159.10	11:00	SS	S0014-78D			m					SAND. >95% Sand <5% mud. Sand			90% Full
159.60											is mostly M-C. Wk to no. Rx to			PHOTO P0000345.JPG
											HCl. Wk to no. comentation. moist Color is			
	-										darker - 2.5Y4/2.			
159.60	1105	SS	S0014-78C			m					SAND. >95% Sand <5% mud. Sand			99% Full
160.10											mostly m. Wk Rx to HCl. Wk			PHOTO P0000346.JPG
											comentation. Color is lighter. 2.5Y5/2.			
160.10-	1110	SS	S0014-78B			m					SAND. >95% Sand <5% mud. Sand			102% Full
160.60											is mostly med. some V.F pebbles.			PHOTO P0000347.JPG
											Wk-no reaction to HCl. Moist color is			
											darker 2.5Y4/2. No-wk. cementation			
160.60	1115	SS	S0014-78A			M					SAND. >95% Sand <5% mud. Sand			75-80% Full
161.10											is mostly Med. Some pebbles to 8mm			PHOTO P0000348.JPG
											No reaction to HCl. Wk-No cementation.			
											Moist color is 2.5Y4/2.			

Pacific Northwest National Laboratory

DAILY BOREHOLE LOG

Boring/Well No S01014 (299-E33-45) Depth 166.90-169.90 Date 02/14/01 Sheet 6 of 11

Location 241-BX-102 Project TANK FARM VZ CHAR.

Logged by GV LAST

Reviewed by ________ Date ________

Lithologic Class. Scheme FOLK/WENTWORTH Procedure PNNL-SP-GVL-01 Rev 0

Steel Tape/E-Tape ____ / ____ Field Indicator Equip. 1) ________ 2) ________

Drilling Contractor ________

Driller ________

Rig/Method ________

Depth Control Point ________

DEPTH (FT)	TIME	SAMPLES TYPE	SAMPLES ID NUMBER	CONTAMINATION INSTR.	CONTAMINATION READING	MOISTURE	GRAPHIC LOG C	GRAPHIC LOG Z	GRAPHIC LOG S	GRAPHIC LOG G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H_2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
166.90	11:25	SS	S01014-82D			M								80% Full
167.40											SAND, ≥95% Sand <5% mud. Sand is			PHOTO P0000349.JPG
											mostly Med. Color 2.5Y 5/2. Wk-St Rxn to			
											HCl.			
											SAND. 90% Sand 10% mud. Sand is			
											F-VF. Wk-St Rx to HCl. Wk-Mod. cementation			
167.40	11:30	SS	S01014-82C			M					SAND. 90% Sand 10% mud. Sand is			100% FULL. TOOK UFA sample.
167.90											most V.F. sand. Some F sand stringers.			PHOTO P0000350.JPG
											Wk to Stg or even Stg Rx to HCl. Wk-			
											Mod. cementation. Very platy at bottom.			
											Hints of some stratification/lamination			
167.90	11:40	SS	S01014-82B			M-W					SAND. 90% SAND 10% mud. Sand is			100% Full. Took samples from
168.40											most F-VF. Wk-Stg Rx to HCl. Wk-			Finer materials.
											mod. cementation. Stratified to laminated.			PHOTO P0000351.JPG
											SAND 90% SAND, 10% mud. Sand			
											most med. Poorly sorted. Mod. cementation			
168.90	11:50	SS	S01014-82A			W					SAND. 90% sand, 10% mud. Sand			90% Full. Sample is much wetter
169.90											is poorly sorted ranges to C. Sand.			than above Finer Sand. Took
											Mostly Med? Rx to HCl is Wk-Stg or even			UFA sample.
											Stg. Wk-mod. cementation. Moist/wet			PHOTO P0000352.JPG
											color is 2.5Y 4/2. Wetter that Fine Sand			
											above. Laminated.			

W = Wet, M = Moist, D = Dry

Pacific Northwest
National Laboratory

DAILY BOREHOLE LOG

Boring/Well No S01014 (299-E33-45) Depth 169.30-171.30 Date 2/14/01
Location 241-BX-102 Project Tank Farm VZ Char.
Sheet 7 of 11

Logged by GV LAST
Reviewed by ______ Date ______
Lithologic Class. Scheme FOLK/WENTWORTH Procedure DTB1-99-GVL-01 Rev 0
Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______
Drilling Contractor ______
Driller ______
Rig/Method ______
Depth Control Point ______

DEPTH (FT)	TIME	SAMPLES TYPE	SAMPLES ID NUMBER	CONTAMINATION INSTR.	CONTAMINATION READING	MOISTURE	GRAPHIC LOG C Z S G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
169.30	12:30	SS	S01014-83D			M		SAND. 90% Sand 10% mud. Most. Fine			100% FULL.
169.80								Sand, Rx to HCl is Wk-Str. Wk. to Mod.			PHOTO P0000 354.JPG
								cementation. Moist color 2.5Y 4/2.			355.JPG
								SILTY SAND. 70% Sand 30% Mud.			
								Mostly V.F. Sand. Cores well. Mod. Cementation			
169.80	12:35	SS	S01014-83C			M		SILTIER, than above. Very compacted.			100% FULL
170.30						M-D		SAND. >95% Sand. <5% mud. Sand mostly			PHOTO P0000 356.JPG
								med.-poorly sorted. Moderately cemented.			
								Wk-str. Rx to HCl. Moist color 2.5Y			
								4/2			
170.30	12:40	SS	S01014-83B			M-D		SAND. >95% Sand. <5% mud. Sand is			100% FULL
170.80								most Med at top. Mostly C at bottom.			PHOTO P0000357.JPG
								N. Rx at bottom. Wk cementation.			
								Moist color is 2.5Y 4/2. Some V.F. pebble			
170.80	12:45	SS	S01014-83A			M-D		SAND. >95% sand <5% mud. Sand is			80% FULL
171.30								most CM, poorly sorted. Some V.F.			PHOTO P0000358.JPG
								pebbles. No Rx to HCl. Wk to no cementation.			
								Moist color is 2.5Y 4/2			

W = Wet, M = Moist, D = Dry

Pacific Northwest National Laboratory	**DAILY BOREHOLE LOG**	Boring/Well No S01014 (299-E33-45) Location 241-BX-102
Depth 171.60-173.60	Date 2/14/01 Project Tank Farm VZ Chars	Sheet 8 of 11

Logged by GV Last

Reviewed by ______ Date ______

Lithologic Class. Scheme FOLK/WENTWORTH

Procedure DTTB1-99-GUL-01 Rev 0

Steel Tape/E-Tape ______ / ______

Field Indicator Equip. 1) ______ 2) ______

Drilling Contractor -

Driller ______

Rig/Method ______

Depth Control Point ______

DEPTH (FT)	TIME	SAMPLES TYPE	SAMPLES ID NUMBER	CONTAMINATION INSTR.	CONTAMINATION READING	MOISTURE	GRAPHIC LOG C Z S G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H_2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
171.60-	1250	SS	S01014-B9D			m-D		SAND, >95% Sand <5% mud. Sand is			75% Full
172.10								mostly M-F. poorly sorted. No Rx to			PHOTO P0000360.JPG
								HCl. No cementation. Color is 2.5Y5/2			
								One pebble to 9 mm.			
172.10	1255	SS	S01014-B9C			m-D		SAND >95% sand <5% mud. Sand is			100-98% Full
172.60								mostly med. Some V.C sand to VF			PHOTO P0000361.JPG
								pebbles. Wk-No Rx. No cementation.			
								Moist color is 2.5Y 4/2			
172.60	13:00	SS	S01014-B9B			m-D		SAND, >95% Sand <5% mud. Sand is			100% Full
173.10								mostly M. Poorly sorted. Moist color			PHOTO P0000362.JPG
						m		is 2.5Y 4/2. No Rx to HCl. No			
								cementation.			
173.10	13:05	SS	S01014-B9A			m		SAND, >95% Sand <5% mud. Sand is			65% Full
173.60								mostly M. Moist color is 2.5Y 4/2.			PHOTO P0000363.JPG
								No-wk Rx to HCl. No cementation.			

W = Wet, M = Moist, D = Dry

Pacific Northwest
National Laboratory

DAILY BOREHOLE LOG

Boring/Well No S01014 (299-E33-45) Depth 179.90- Date 2/14/01

Location 241-BX-102 Project TANK FARM VZ CHAR.

Sheet 9 of 11

Logged by GV LAST

Reviewed by

Date

Lithologic Class. Scheme FOLK/WENTWORTH

Procedure DATBI-77-GU-01 Rev 0

Steel Tape/E-Tape /

Field Indicator Equip. 1) 2)

Drilling Contractor -

Driller

Rig/Method

Depth Control Point

DEPTH (FT)	TIME	SAMPLES		CONTAMINATION		MOISTURE	GRAPHIC LOG C Z S G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H_2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
		TYPE	ID NUMBER	INSTR.	READING						
179.90-	1525	SS	S01014-88D								40% Full.
180.90											PHOTO P0000364.JPG
								SAND. >95% Sand <5% mud. Sand			
						m-W		most. M. Pebble upto 12mm. Wk Rx			
								to HCl.			
180.40	1530	SS	S01014-88C			m-W		SAND. >95% Sand <5% mud. Sand			98% FULL.
180.90								mostly med. Some pebbles upto			PHOTO P0000365.JPG
								30 mm. Especially near top. Wk to no			
								Rx to HCl. Wk to no. cementation.			
180.90	1535	SS	S01014-88B			m		SAND. >95% Sand <5% mud. Sand			100% Full
181.40								mostly med. lookes drier. Wk to no.			PHOTO P0000366.JPG
								Rx to HCl. No to wk cementation			
								GRAVELLY SAND. 10% Gravel, 85% Sand, 5%			
								mud. Wk to no Rx to HCl.			
181.40	1540	SS	S01014-88A			m		GRAVELLY SAND. 10% Gravel. 85% Sand			75% Full
181.90								5% mud. Moist color 2.5Y 4/2 - 5/2.			PHOTO P0000367.JPG
								Wk-No Rx Pebbles are subangular			
								basaltic - up to 25 mm.			

W = Wet, M = Moist, D = Dry

Pacific Northwest National Laboratory	DAILY BOREHOLE LOG	Boring/Well No S01014 (299-E33-45) Depth 188.90-190.90 Date 2/14/01 Location 241-BX-102 Project TANK FARM VZ CHAR	Sheet 10 of 11

Logged by GV Last
Reviewed by ______ Date ______
Lithologic Class. Scheme FOLK/WENTWORTH Procedure PNNL-99-GVL-01 Rev 0
Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______
Drilling Contractor ______
Driller ______
Rig/Method ______
Depth Control Point ______

DEPTH (FT)	TIME	SAMPLES		CONTAMINATION		MOISTURE	GRAPHIC LOG C Z S G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H₂O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
		TYPE	ID NUMBER	INSTR.	READING						
188.90-	1550	SS	S01014-93D								75% FULL.
189.40								SAND. 95% Sand, 5% mud. Sand is			
						m		mostly Med. Color (Moist) = 2.5Y4/2-5/2,			
								Wk Rx to HCl.			
								-SLIGHTLY GRAVELLY SAND. 5% V.F. Pebble,			
								>90% sand <5% mud. Wk to No Rx.			
189.40	1555	SS	S01014-93C			m		SAND. <5% Gravel ≥90% Sand <5%			98% FULL.
189.90								mud. Sand is mostly Med. Some			
								V.F. Pebble up to 14 mm. Wk to No Rx to			
								HCl. Wk to no cementation. Color is			
								2.5Y 4/2.			
189.90	1600	SS	S01014-93B			m		SAND, <5% Gravel, >90% Sand, <5% mud.			100% FULL.
190.40								Sand mostly m-VC. (similar to above).			
								VF Pebble to 12 mm. Wk to no rx. to HCl.			
								Wk to no cementation. Moist color is			
								2.5Y 4/2.			
190.40	1610	SS	S01014-93A			m		SAND. ≥95% Sand <5% mud. Some VF			75% FULL
190.90								Pebble Wk Rx to HCl. Sand mostly Med.			PHOTO P0000371
								-SAND. <5% Gravel, >95% Sand <5% mud.			
								Pebbles to 30mm. Sand mostly C-M.			
								Moist color 2.5Y 4/2.			

W = Wet, M = Moist, D = Dry

1998/DCL/PROC/DBL/001

Pacific Northwest National Laboratory

DAILY BOREHOLE LOG

Boring/Well No S01014 (299-E33-45) Depth 199.60-201.60 Date 02/14/01

Location 241-BX-102 Project TANK FARM VZ CHAR

Sheet 11 of 11

Logged by GV LAST

Reviewed by ______ Date ______

Lithologic Class. Scheme FOLK/WENTWORTH Procedure PNNL-99-GVL-01 Rev 0

Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______

Drilling Contractor -

Driller ______

Rig/Method ______

Depth Control Point ______

DEPTH (FT)	TIME	SAMPLES TYPE	SAMPLES ID NUMBER	CONTAMINATION INSTR.	CONTAMINATION READING	MOISTURE	GRAPHIC LOG C	Z	S	G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
199.60- 200.10	16:15	SS	S0104-99D			M-D					SAND. >95% Sand <5% mud. Sand is mostly C-M. poorly sorted, Wk to no reaction to HCl, Wk to no cementation color is 2.5Y5/2.			100% Full.
200.10 200.60	16:20	SS	S0104-99C			M					SAND. >95% Sand <5% mud. Sand is mostly M. poorly sorted. Wk Rx to HCl Wk cementation. Color is 2.5Y 4/2-5/2.			100% Full
200.60 201.10	16:25	SS	S0104 -99B			M-D					SAND, >95% Sand <5% mud. Sand mostly M. better sorted. Wk Rx to HCl Wk to Mod. cemented, Moist color is 2.5Y 5/2.			100% Full. PHOTO PC000374.JPG
201.10 201.60	16:30	SS	S0104-99A			M-D					SAND, >95% Sand <5% mud, Sand is most C-M, Wk to no Rx to HCl, Wk cementation. Moist color is 2.5Y4/2-5/2. Looks a little coarser at bottom than top			85% Full

W = Wet, M = Moist, D = Dry

1998/DCL/PROC/DBL/001

Pacific Northwest National Laboratory	**DAILY BOREHOLE LOG**	Boring/Well No S01014 (299-E33-45) Location 291-BX-102	Depth 209.67 - 211.67 Date 02/15/01 Project TANK-FARM VZ CHAR	Sheet 1 of 9

Logged by GV LAST

Reviewed by ______ Date ______

Lithologic Class. Scheme FOLK/WENTWORTH

Procedure DYTBI-99-GVL-01 Rev 0

Steel Tape/E-Tape ______ / ______

Field Indicator Equip. 1) ______ 2) ______

Drilling Contractor ______

Driller ______

Rig/Method ______

Depth Control Point ______

DEPTH (FT)	TIME	SAMPLES		CONTAMINATION		MOISTURE	GRAPHIC LOG				LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H_2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
		TYPE	ID NUMBER	INSTR.	READING		C	Z	S	G				
209.67 210.17	725	SS	S01014-104D			D					SAND >95% Sand <5% mud. Sand mostly C-M. Stratified with finer grained (M) sand (30mm strata). Wk Rx to HCl. Mod-Str Cementation. Moist color is 2.5Y 4/2. 1 pebble to 8mm.			100% FULL PHOTO P0000376.JPG
210.17 210.67	0730	SS	S01014-104C			M-D					SAND. >95% Sand <5% mud. Sand is mostly C-M. Wk.-no Rx to HCl. Mod-Str. cementation. Stratified. Moist color 2.5Y 4/2			100% FULL
210.67 211.17	0735	SS	S01014-104B			M-D					SAND, >95% Sand <5% mud. Sand is mostly C-M. Wk-no Rx to HCl. Mod-Str. cementation. Stratified. Moist Color 2.5Y 4/2			100% FULL
211.17 211.67	0745	SS	S01014-104A			M-D					SAND, >95% Sand <5% mud. Sand is mostly C-M. Wk-no Rx to HCl. Wk-no cementation. Moist color is 2.5Y 4/2			80% FULL PHOTO P0000379.JPG

W = Wet, M = Moist, D = Dry

1998/DCL/PROC/DBL/001

Pacific Northwest National Laboratory	**DAILY BOREHOLE LOG**	Boring/Well No S01014 (299-E33-45) Depth 217.20-219.70 Date 02/15/01 Location 241-BX-102 Project TANK FARM VZ CHAR.
Sheet 2 of 9		

Logged by GVL/AST

Reviewed by ______ Date ______

Lithologic Class. Scheme FOLK/WENTWORTH Procedure PNNL-99L-GVL-01 Rev 0

Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______

Drilling Contractor -

Driller

Rig/Method

Depth Control Point

DEPTH (FT)	TIME	SAMPLES		CONTAMINATION		MOISTURE	GRAPHIC LOG				LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H_2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
		TYPE	ID NUMBER	INSTR.	READING		C	Z	S	G				
217.20	0750	SS	S01014-110D			m					SAND 95% Sand 5% mud. Sand			95% FULL
218.20											is mostly M-F. No stratification or			PHOTO P0000380.JPG
											laminations (massive). Wk-no Rx to			
											HCl. Mod. cementation. Moist			
											color is 2.5Y 5/2.			
218.20	0808	SS	S01014-110C			m					SAND. 95% Sand 5% mud. Sand			100% FULL
218.70											grades to mostly Fine Sand just			
											above Silt. Wk Rx to HCl. Moist			
											color 2.5Y 4/2.			
											MUD. Wk Rx to HCl. Mod-str. Cementation			
218.70-	0816	SS	S01014-110B			m					MUD. Some F-VF Sand, some clay.			100% FULL
219.20											will roll, but breaks up easily. Wk			
											Rx to HCl. Mod. cemented. Color			
											2.5Y 4/2. Some lamination - possibly			
											due to drilling. Mostly massive.			
											HARD.			
219.20	0825	SS	S01014-110A			m					MUD. Not much sand, little clay.			70% FULL
219.70											same as above. looks massive -			
											homogeneous. Some color changes but			
											mostly 2.5Y 4/2. Hard. Mod-Str cementation.			
											Wk Rx to HCl.			

W = Wet, M = Moist, D = Dry

Pacific Northwest National Laboratory

DAILY BOREHOLE LOG

Boring/Well No S01019 (299-E33-45) Depth 220.00-222.00 Date 2/15/01
Location 241-BX-102 Project TANK FARM VZ CHAR
Sheet 3 of 9

Logged by GV LAST
Reviewed by Date
Lithologic Class. Scheme FOLK/WENTWORTH Procedure PNNL-99-GVL-01 Rev 0
Steel Tape/E-Tape / Field Indicator Equip. 1) 2)
Drilling Contractor
Driller
Rig/Method
Depth Control Point

DEPTH (FT)	TIME	SAMPLES		CONTAMINATION		MOISTURE	GRAPHIC LOG				LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H_2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
		TYPE	ID NUMBER	INSTR.	READING		C	Z	S	G				
220.00	10:45	SS	S01019-111D			M-D								80% FULL
220.50											SAND. ≥95% Sand <5% mud. Sand is			
											well sorted mostly M. Sand. No cementation.			
											Wk Rx to HCl. Moist color is 2.5Y5/2			
											1 clod of Mud from above.			
220.50	11:00	SS	S01014-111C			M-D					SAND, ≥95% Sand <5% mud. Mostly			102% FULL. USED EXTRACTOR.
221.00											M. Sand			
						M-D					MUD. Massive-concoidal fracturing. Maybe			
											some fine lamination. - Won't roll. Mod			
											cementation. Wk Rx Moist color 2.5Y 4/2 - 4/4			
221.00	11:15	SS	S01014-111B			M-D					MUD, Dry and Hard. Breaks up in disks.			100% FULL. USED EXTRACTOR.
221.50											No obvious laminations. Wk Rx to			
											HCl. Mod. cementation. Won't roll-			
											not much clay. Moist color 2.5Y 5/2. Very			
											compacted.			
221.50	11:35	SS	S01019-111A			M-D					MUD. Massive-concoidal fracturing. Some			80% FULL. USED EXTRACTOR
222.00											banding in color changes - reddish to brown.			PHOTO 396-398
											Moist color is 2.5Y 4/4. Won't roll- little			
											clay and/or too dry. Look finer & more			
											compact than above.- holds together.			

W = Wet, M = Moist, D = Dry

Pacific Northwest National Laboratory

DAILY BOREHOLE LOG

Boring/Well No S01014 (299-E33-45)
Depth 221.90-223.90
Date 2/15/01
Location 241-BX-102
Project TANK FARM VZ CHAR.
Sheet 4 of 9

Logged by G V LAST
Reviewed by
Date
Lithologic Class. Scheme FOLK/WENTWORTH
Procedure DPT81-99-GVL-01
Rev 0
Steel Tape/E-Tape /
Field Indicator Equip. 1) 2)
Drilling Contractor
Driller
Rig/Method
Depth Control Point

DEPTH (FT)	TIME	SAMPLES TYPE	SAMPLES ID NUMBER	CONTAMINATION INSTR.	CONTAMINATION READING	MOISTURE	GRAPHIC LOG C Z S G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H₂O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
221.90-	1155	SS	S01014-112D								50% FULL, SLUFF? POORLY
222.90											CONSOLIDATED - BROKEN UP -
											EASILY KNOCKED OUT OF SLEEVE
						m-D		MUD. WK. RX			
								MUDDY SAND. 2.5Y 4/2. WK RX. } SLUFF?			
								MUD			
222.90-	12:05	SS	S01014-112C			m-D		MUDDY SAND			100% FULL, USED EXTRACTOR
222.90								SILT, FAIRLY MASSIVE. HINT OF LAMINATIONS			
								NEAR TOP, SHARP CONTACT WITH MUDDY			
								SAND ABOVE.			
								MUDDY SAND. MOSTLY F-VF, Sand 2.5Y 4/2.			SAMPLES TAKEN OF MUDDY SAND.
								WK to Strg Rx to HCl.			
222.90	1230	SS	S01014-112B			m		MUDDY SAND MOSTLY F-VF SAND.			100% FULL, USED EXTRUDER.
223.40								LOOKS A LITTLE WETTER.			TOOK UFA SAMPLE.
								MUD. LAMINATED, WITH F-VF. SAND			
								2.5Y 4/2. WK-ST RX TO HCl. MOD-			
								WK CEMENTATION.			
223.40	1250	SS	S01014-112A			M-W		MUDDY SAND. HINTS OF LAMINATIONS.			100% FULL USED EXTRACTOR.
223.90								MOSTLY F-VF SAND.			
								MUD, FAIRLY MASSIVE, SOME MOTTLING IN			
								COLOR. 2.5Y 4/2 OVERALL WK. Rx to HCl.			
								MUDDY SAND. SAND MOSTLY F-VF.			
								WK-ST RX TO HCl.			

W = Wet, M = Moist, D = Dry

1998/DCL/PROC/DBL/001

Pacific Northwest National Laboratory	DAILY BOREHOLE LOG	Boring/Well No S01014 (299-E33-45) Location 241-BX-102	Depth 229.80-231.70 Date 2/15/01 Project TANK FARM VZ CHAR.	Sheet 5 of 9

Logged by GV LAST

Reviewed by ______ Date ______

Lithologic Class. Scheme FOLK/WENTWORTH Procedure DSTBI-99-GVL-01 Rev 0

Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______

Drilling Contractor -

Driller

Rig/Method

Depth Control Point

DEPTH (FT)	TIME	SAMPLES TYPE	SAMPLES ID NUMBER	CONTAMINATION INSTR.	CONTAMINATION READING	MOISTURE	GRAPHIC LOG C	GRAPHIC LOG Z	GRAPHIC LOG S	GRAPHIC LOG G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H_2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
229.20	1305	SS	S01014-116D			W								80% FULL. WATER CAME OUT WHEN
230.20											MUD. Silt to very fine sand. No structure-			OPENING CORE - FULLY SATURATED!
											homogeneous. Wk Rx to HCl. Moist			NO FILTER PAPER
	-										color is 2.5Y 4/2.			
230.20	13:50	SS	S01014-116C			W					MUDDY SAND. Sand most VF. No structure			100% FULL, SATURATED. WATER COMES
230.70											homogeneous. SANDIER THAN ABOVE.			TO SURFACE WHEN WORKING WITH IT.
											MOIST COLOR IS 2.5Y 4/2. WK to St.			NO FILTER PAPER. TOOK UFA
											Rx to HCl.			SAMPLE.
230.20	1405	SS	S01014-116B			W					MUDDY SAND. Sand is mostly VF.			100% FULL. SATURATED. HARD TO
231.20											Hint of some lamination. MOIST COLOR IS			KNOCK OUT OF SLEEVE. MUCH
											2.5Y 4/2. Wk to Str. Rx to HCl. Might be			HARDER THAN ABOVE.
											wetter at top, than bottom.			
231.20	1420	SS	S01014-116A			W					MUDDY SAND. Sand is mostly F-VF Sand.			80% FULL. USED EXTRUDER. CORE
231.70											Finely laminated. Wk to Str Rx to HCl.			CUT EASILY SHOW FINE LAMINATIONS.
											Moderate Cementation. Moist color 2.5Y 4/2			

W = Wet, M = Moist, D = Dry

Pacific Northwest National Laboratory	DAILY BOREHOLE LOG	Boring/Well No S01014 (299-E33-45) Location 241-BX-102	Depth 240.14 - 242.14 Date 2/15/01 Project TANK FARM VZ CHAR.	Sheet 6 of 9

Logged by GV LAST

Reviewed by ____________ Date ________

Lithologic Class. Scheme FOLK/WENTWORTH

Procedure PNBI-99-GL-01 Rev 0

Steel Tape/E-Tape ________ / ________ Field Indicator Equip. 1) ________ 2) ________

Drilling Contractor -

Driller

Rig/Method

Depth Control Point

DEPTH (FT)	TIME	SAMPLES TYPE	SAMPLES ID NUMBER	CONTAMINATION INSTR.	CONTAMINATION READING	MOISTURE	GRAPHIC LOG C Z S G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H_2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
240.14	1435	ss	S01014-122D			M-W		MUDDY SANDY GRAVEL. 50% GRAVEL, 35%			90% FULL LOOKS LIKE RINGOLD
240.64								sand. 15% mud. Sand is mostly VF			Gravels.
								sand. Small stringer of poorly sorted			
								M sand. Moist color is 2.5Y 4/4.			
								Str. Rx to HCl. Moderate Cementation			
								GRAVEL upto 40 mm - Subangular to Round			
240.64	1445	SS	S01014-122C			D		SANDY GRAVEL. >50% GRAVEL.			80% FULL
241.14								45% Sand, <5% mud. Not nearly			
								as muddy as above. Color changes			
								to 2.5Y 4/2. No Cementation. Gravels			
								broken to >50 mm. No Rx to HCl.			
241.14	1450	ss	S01014-122B			D		SANDY GRAVEL. >50% Gravel, 45%			80% FULL
241.64								Sand (mostly M). <5% mud. Gravels			
								upto 60 mm broken - quartzites, basalt.			
								Moist color of matrix is 2.5Y 4/2. No			
								Rx except caliche fragments. No			
								cementation.			
241.64	1455	SS	S01014-122A			D		SANDY GRAVEL. 30% Gravel, 65% Sand			70% FULL
242.14								<5% mud. Less Gravel than above.			
								Sand is poorly sorted. Most C-M.			
								Wk to No Rx to HCl. Moist color			
								is 2.5Y 4/2.			

W = Wet, M = Moist, D = Dry

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Pacific Northwest National Laboratory	**DAILY BOREHOLE LOG**	Boring/Well No S01014 (299-E33-45) Depth 243.5-245.5 Date 2/15/01 Location 241-BX-102 Project TANK FARM VZ CHAR

Sheet 7 of 9

Logged by G V LAST

Reviewed by ______ Date ______

Lithologic Class. Scheme FOLK/WENTWORTH Procedure DSRL-97-SUL-01 Rev 0

Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______

Drilling Contractor ______

Driller ______

Rig/Method ______

Depth Control Point ______

DEPTH (FT)	TIME	SAMPLES TYPE	SAMPLES ID NUMBER	CONTAMINATION INSTR.	CONTAMINATION READING	MOISTURE	GRAPHIC LOG C Z S G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H₂O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
243.5-	1500	SS	S01014-124D			D		Muddy Sandy GRAVEL. 40% Gravel			98% FULL, PALEOSOL?
244.0								50% Sand 10% mud. Sand is poorly			
								sorted. Gravel up to 50mm. Subround			
								to round when not broken. Some mod.			
								cemented olive colored zones. Wk to			
								Str. Rx to HCl. Overall color is 2.5Y 5/2			
244.0	1505	SS	S01014-124C			D		Muddy Sandy GRAVEL. 35% Gravel			100% FULL PALEOSOL?
244.5								55% Sand, 10% mud. Gravels are			
								smaller upto 20 mm. Lots of white			
								CaCO3? desseminated throughout only			
								Wk Rx to HCl. Mod. to Wk cementation.			
244.5	1510	SS	S01014-124B			D		Muddy Sandy GRAVEL. 50% gravel.			100% FULL
245								40% Sand, 10% silt (mud). Gravels upto			
								55mm at top. Color is 2.5Y 5/2-6/2.			
								Wk to Str Reaction to HCl. Mod to			
								wk cementation.			
245	1515	SS	S01014-124A			M-D		Muddy Sandy GRAVEL. 30% Gravel.			80% FULL.
245.5								60% Sand 10% mud (silt). Gravels upto			
								30 mm subround, lots of quartzite.			
								Color is 2.5Y 5/2. No cementation.			
								Sand is mostly Med.			

W = Wet, M = Moist, D = Dry

1996/DCL/PROC/DBL/001

Pacific Northwest National Laboratory	DAILY BOREHOLE LOG	Boring/Well No S01014 (299-E33-45) Location 241-BX-102	Depth 250.5 - 252 Date 2/15/01 Project TANK FARM YZ CHAR	Sheet 8 of 9

Logged by GV LAST

Reviewed by ______ Date ______

Lithologic Class. Scheme FOLK/WENTWORTH

Procedure DSTB-99-GVL-01 Rev 0

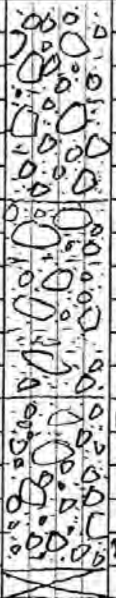
Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______

Drilling Contractor ______

Driller ______

Rig/Method ______

Depth Control Point ______

DEPTH (FT)	TIME	SAMPLES		CONTAMINATION		MOISTURE	GRAPHIC LOG C Z S G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H_2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
		TYPE	ID NUMBER	INSTR.	READING						
250.5-	1530	SS	S01014-128C			M-W		Muddy Sandy Gravel. 70% gravel.			95% FULL
251								20% Sand 10% mud. Lots of gravel.			
								up to 40 mm (broken) subround to rounded.			
								Most color is 2.5Y 4/2. Wk Rx to HCl			
								Wk to no cementation.			
251-	1535	SS	S01014-128B			M		Muddy Sandy GRAVEL. 70% Gravel			102% FULL Top looks like [illegible].
251.5								30% Sand 10% mud. Top is olive			PALEOSOL?
								brown 2.5Y 4/4 w/ Wk-Mod. Cemented.			
								Bottom is 2.5Y 4/2. Small streak of white			
								(rotten granite? - wk Rx).			
251.5	1540	SS	S01014-128A			M-W		Muddy Sandy Gravel. 80% Gravel. 15%			90% FULL.
252								Sand 5% mud. Darker color 2.5Y 4/2.			
								Some very dk 2.5Y 3/0 coloration.			
								Some yellowish coloration 2.5Y 7/4. Wk			
								Rx to HCl. wk cementation.			

W = Wet, M = Moist, D = Dry

1998/DCL/PROC/DBL/001

Pacific Northwest National Laboratory	**DAILY BOREHOLE LOG**	Boring/Well No S01014 (299-E33-45) Depth 251.9 - 253.9 Date 2/15/01 Location 241-BX-102 Project TANK FARM VZ CHAR.	Sheet 9 of 9

Logged by G V LAST

Reviewed by ______ Date ______

Lithologic Class. Scheme FOLK/WENTWORTH Procedure DSTBI-99-GVL-01 Rev 0

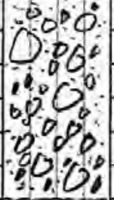
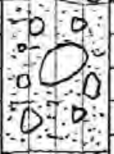
Steel Tape/E-Tape ______ / ______ Field Indicator Equip. 1) ______ 2) ______

Drilling Contractor ______

Driller ______

Rig/Method ______

Depth Control Point ______

DEPTH (FT)	TIME	SAMPLES		CONTAMINATION		MOISTURE	GRAPHIC LOG C Z S G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, etc.)	H_2O ADDED	CASING	DRILLING COMMENTS (drilling rate, down time, blow counts, water level, drill fluid, etc.)
		TYPE	ID NUMBER	INSTR.	READING						
251.9	1555	ss	S01014-129D			M-D		MUDDY SANDY GRAVEL. 75% Gravel			100% FULL. SLUFF AT TOP?
252.4								15% Sand, 10% mud. Wk Rx to			TRIED EXTRUDER BUT DID NOT
								HCl. most cemented (Mod.) to			STAY TOGETHER.
								bottom. Color is 2.5Y 4/2. No			
								cementation at top.			
252.4	1600	ss	S01014-129C			M-D		MUDDY SANDY GRAVEL. 80% Gravel			100% FULL.
252.9								15% Sand 5% mud. Wk to no Rx to			
								HCl. Mod to wk cementation.			
								MOIST COLOR IS 2.5Y 5/2. Gravel upto			
								30 mm subround to round.			
252.9	1605	ss	S01014-129B			M-D		MUDDY SANDY GRAVEL. 80% Gravel, 15%			102% FULL
253.4								SAND, 5% mud. Mod-wk cementation.			
								Wk to str. Rx to HCl. Moist color is			
								2.5Y 4/2 some yellowish coloration as			
								well 2.5Y 7/6. Gravel upto 35mm.			
253.4	1610	ss	S01014-129A			M		MUDDY SANDY GRAVEL. 60% Gravel.			75% FULL
253.9								40% Sand 10% mud Wk to no cementation.			
								Wk Rx to HCl. Sand is mostly C-M.			
								Color is 2.5Y 4/2 to 3/2. Gravel upto			
								50 mm.			

W = Wet, M = Moist, D = Dry

1998/DCL/PROC/DBL/001

Appendix B

Core Samples from Borehole 299-E33-45

Contents

Figures

Appendix B

Core Samples from Borehole 299-E33-45

B.1.0 Photographs of Sediment Samples from Borehole 299-E33-45

This appendix contains color photographs of almost all of the sediment samples obtained from emptying or extruding (for the cohesive fine-grained sediment) material from the 6-in. long stainless steel liners that were inside the splitspoon sampler.

The photographs are arranged from the shallowest to the deepest. The core liner sample identification (ID), depth interval, and assigned lithology are shown in the legends. The orientation of the sample is marked on the photograph (i.e., the left side of the picture indicates the upward direction or closest to the ground surface).

Figure B.1. Sample S01014-1A from Depth of 10.39 ft to 10.89 ft bgs in the H1-Upper Gravel Sequence

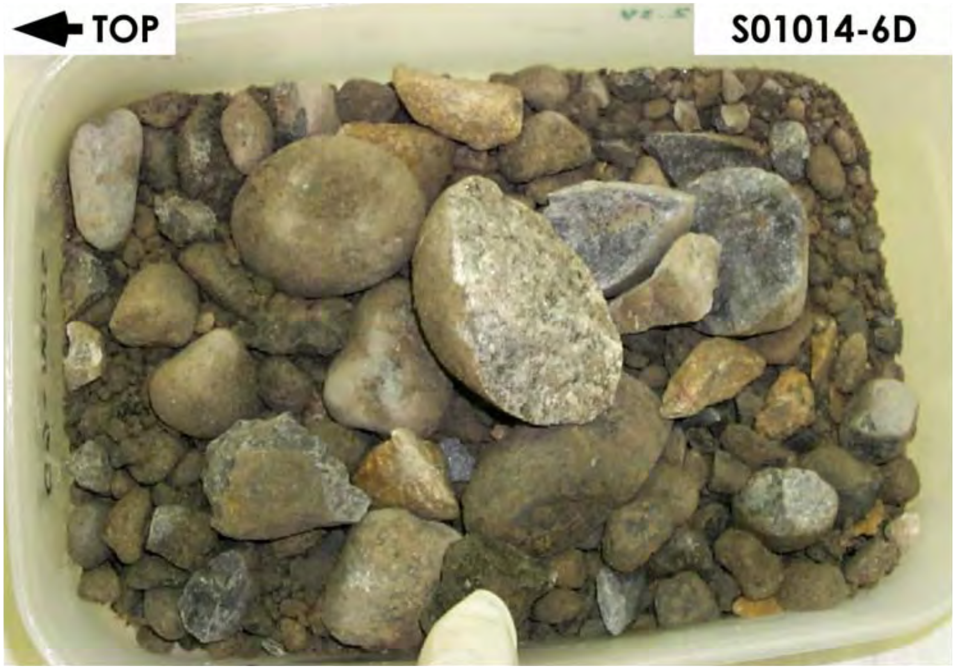


Figure B.2. Sample S01014-6D from a Depth of 19.09 ft to 19.59 ft bgs in the H1-Upper Gravel Sequence

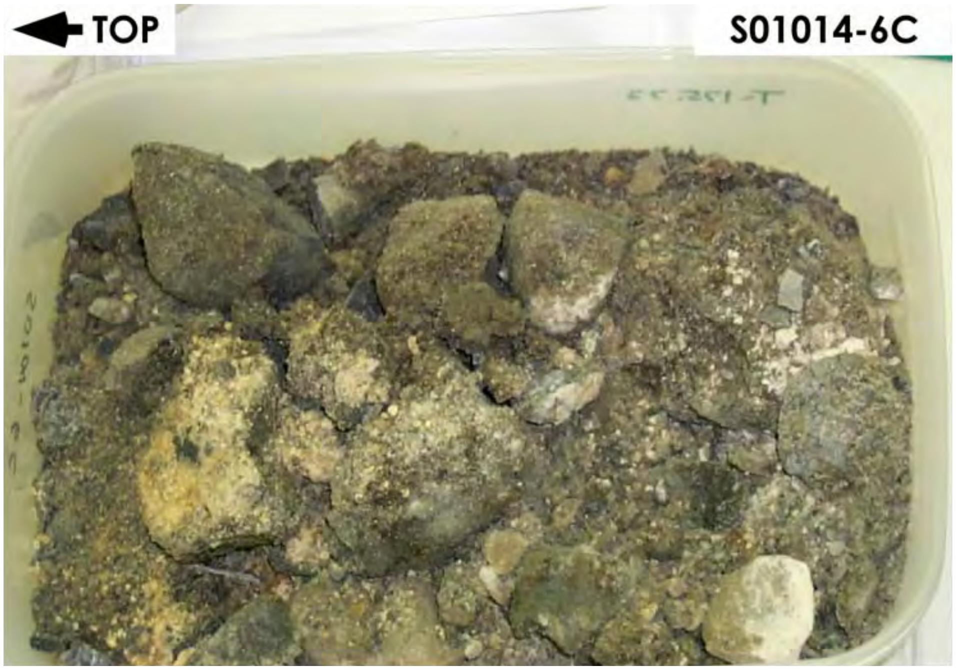


Figure B.3. Sample S01014-6C from a Depth of 19.59ft to 20.09 ft bgs in the H1-Upper Gravel Sequence

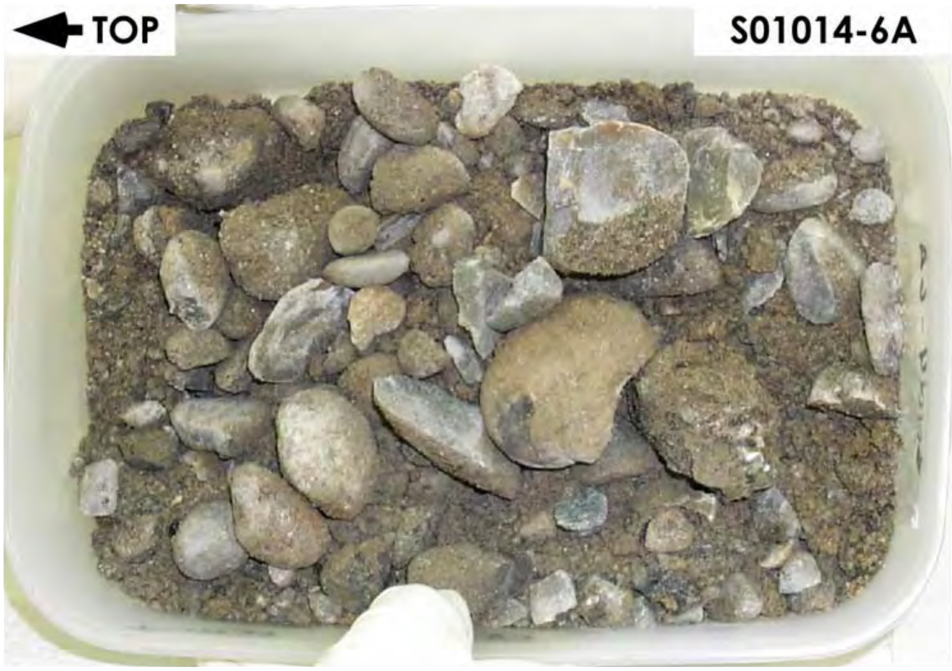


Figure B.4. Sample S01014-6A from a Depth of 20.59ft to 21.09 ft bgs in the H1-Upper Gravel Sequence

Figure B.5. Sample S01014-11D from a Depth of 30.19 ft to 30.59 ft bgs in the H1-Upper Gravel Sequence

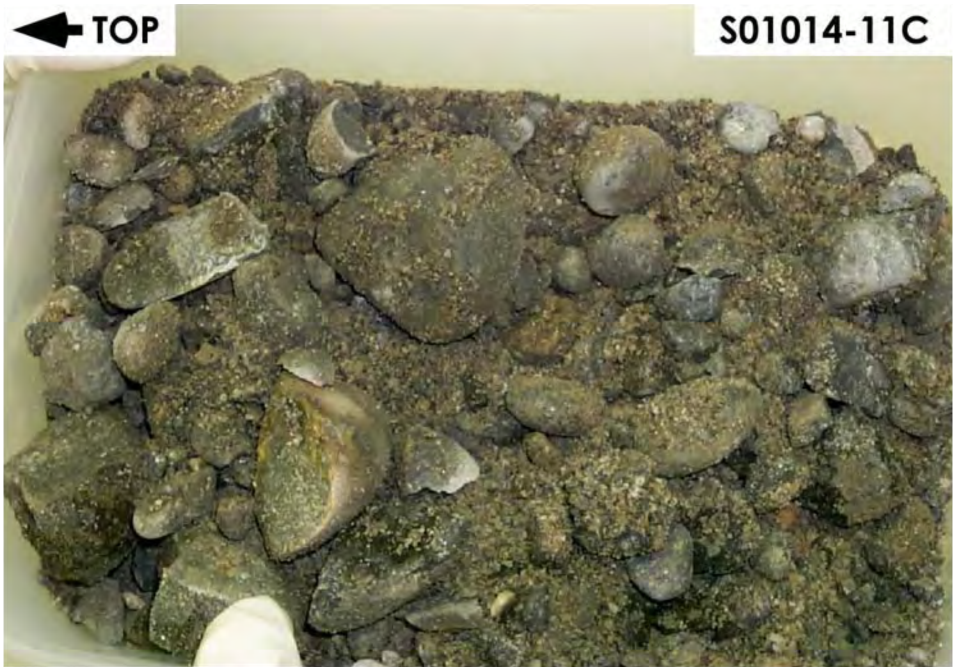


Figure B.6. Sample S01014-11C from a Depth of 30.59 ft to 31.09 ft bgs in the H1-Upper Gravel Sequence

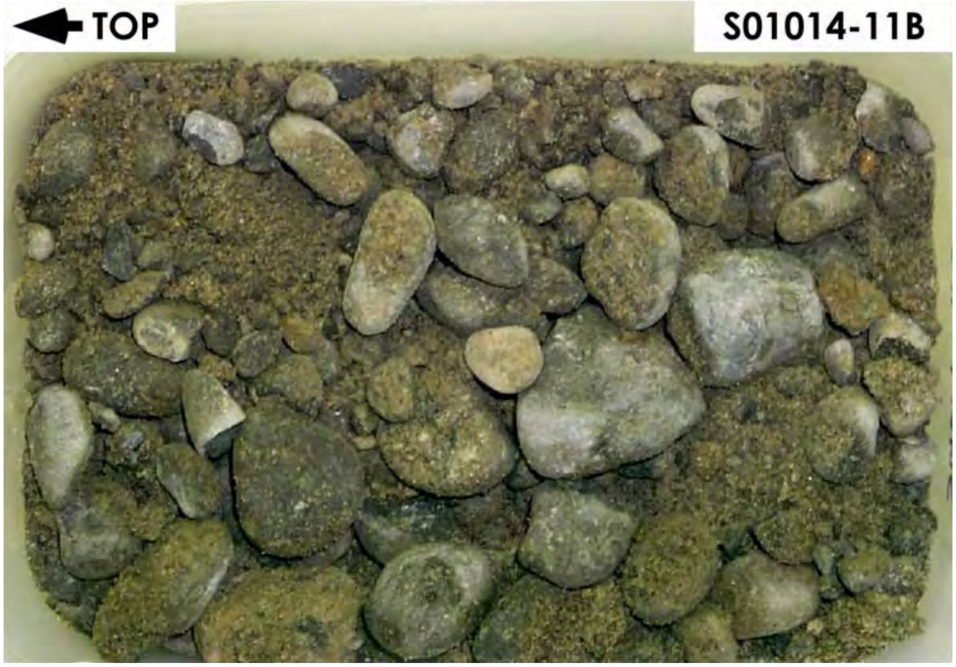


Figure B.7. Sample S01014-11B from a Depth of 31.09 ft to 31.59 ft bgs in the H1-Upper Gravel Sequence

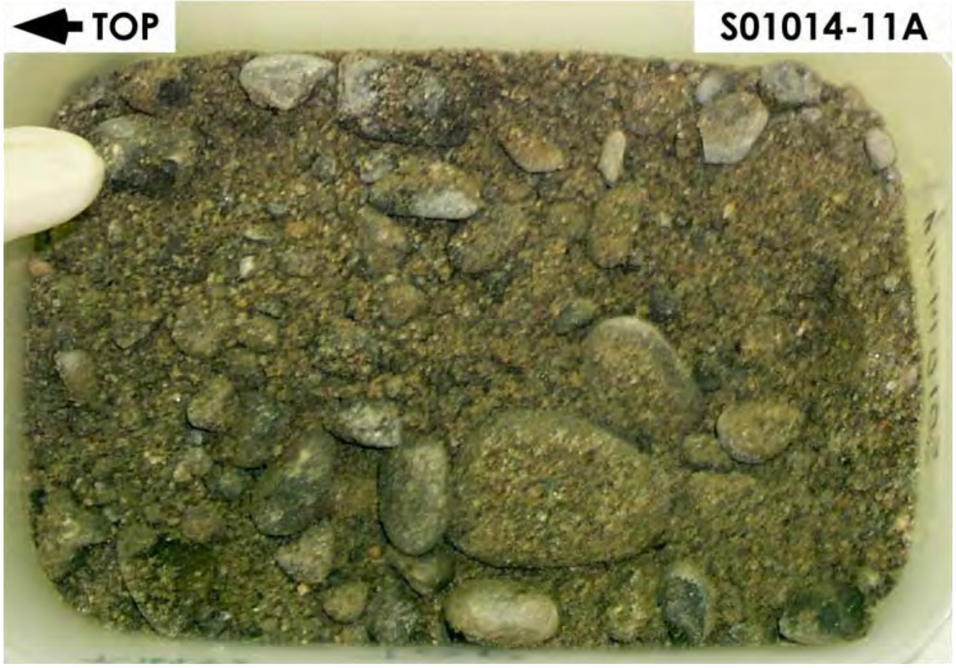


Figure B.8. Sample S01014-11A from a Depth of 31.59 ft to 32.09 ft bgs in the H1-Upper Gravel Sequence

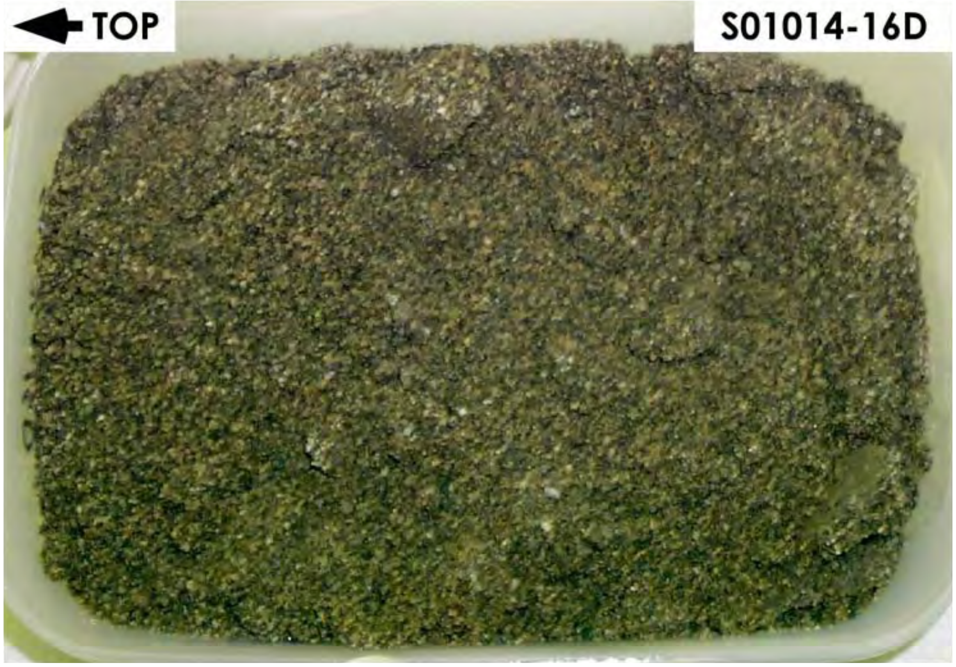


Figure B.9. Sample S01014-16D from a Depth of 40.29 ft to 40.79 ft bgs in the H2-Upper Sand and Gravel Sequence

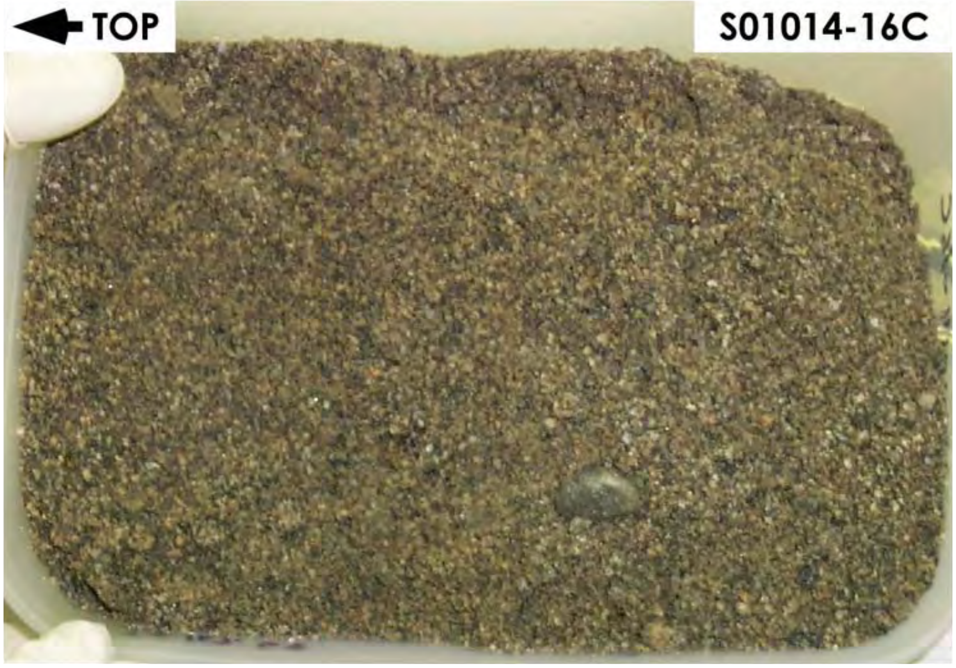


Figure B.10. Sample S01014-16C from a Depth of 40.79 ft to 41.29 ft bgs in the H2-Upper Sand and Gravel Sequence

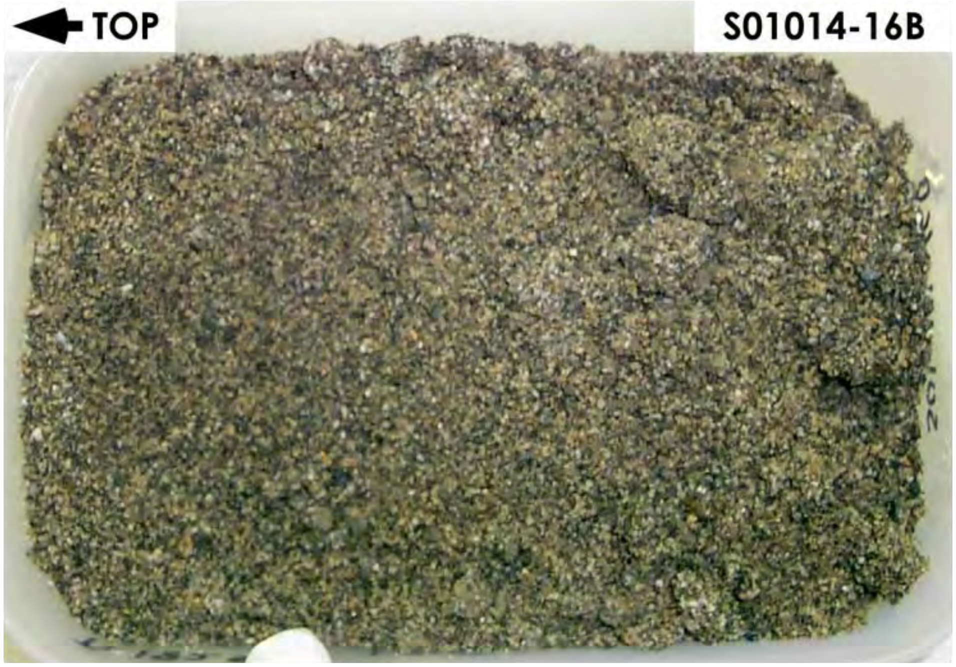


Figure B.11. Sample S01014-16B from a Depth of 41.29 ft to 41.79 ft bgs in the H2-Upper Sand and Gravel Sequence

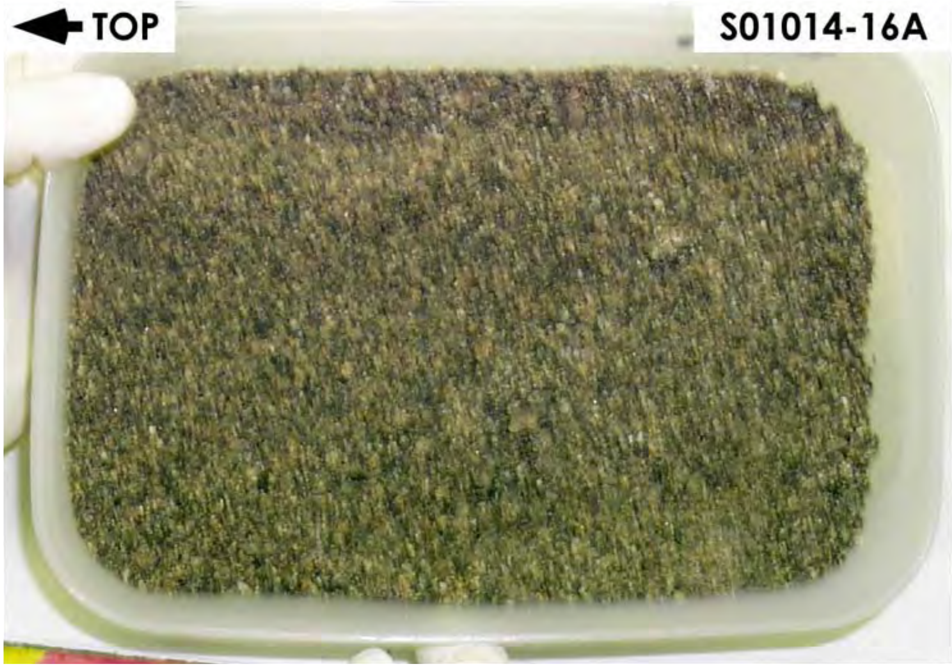


Figure B.12. Sample S01014-16A from a Depth of 41.79 ft to 42.29 ft bgs in the H2-Upper Sand and Gravel Sequence

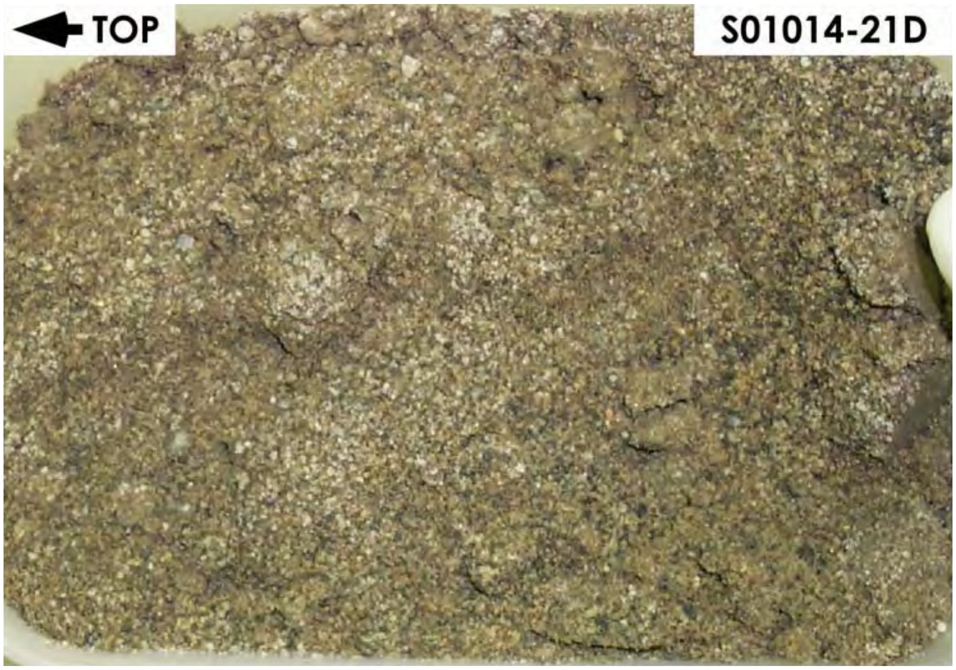


Figure B.13. Sample S01014-21D from a Depth of 49.89 ft to 50.39 ft bgs in the H2-Upper Sand and Gravel Sequence

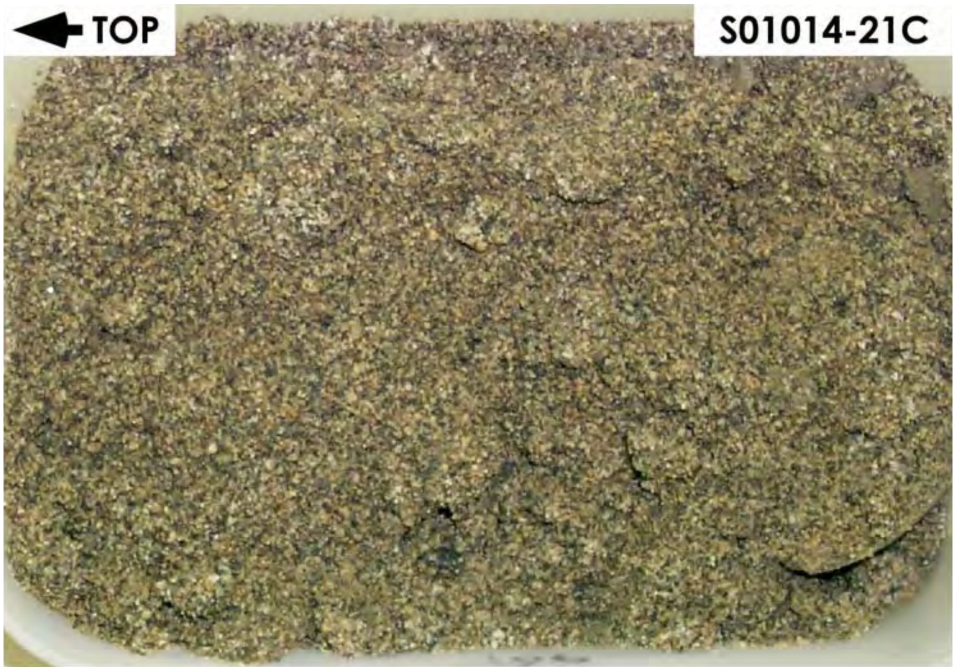


Figure B.14. Sample S01014-21C from a Depth of 50.39 ft to 50.89 ft bgs in the H2-Upper Sand and Gravel Sequence

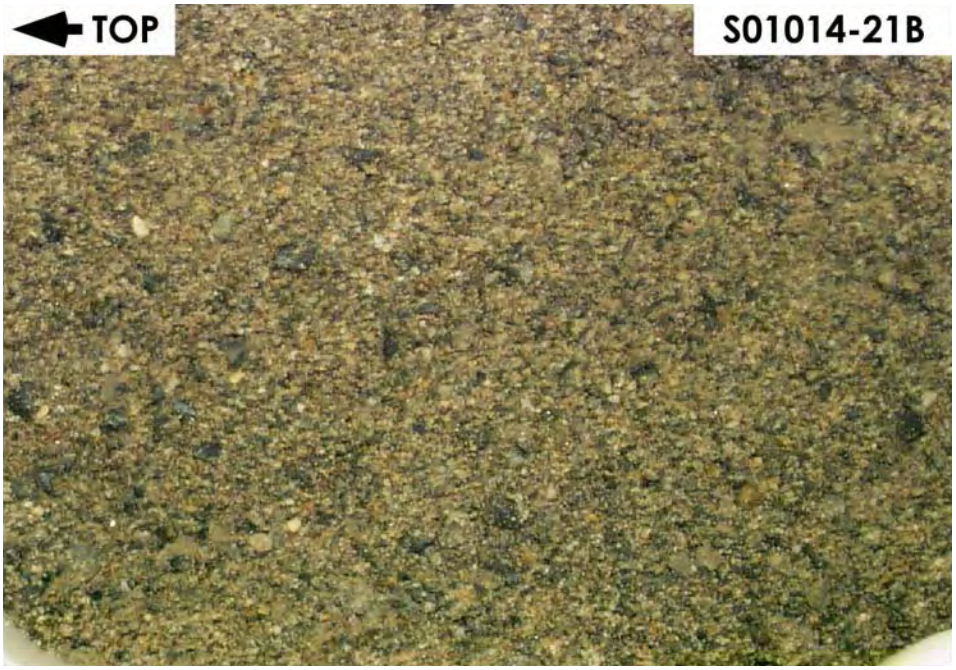


Figure B.15. Sample S01014-21B from a Depth of 50.89 ft to 51.39 ft bgs in the H2-Upper Sand and Gravel Sequence

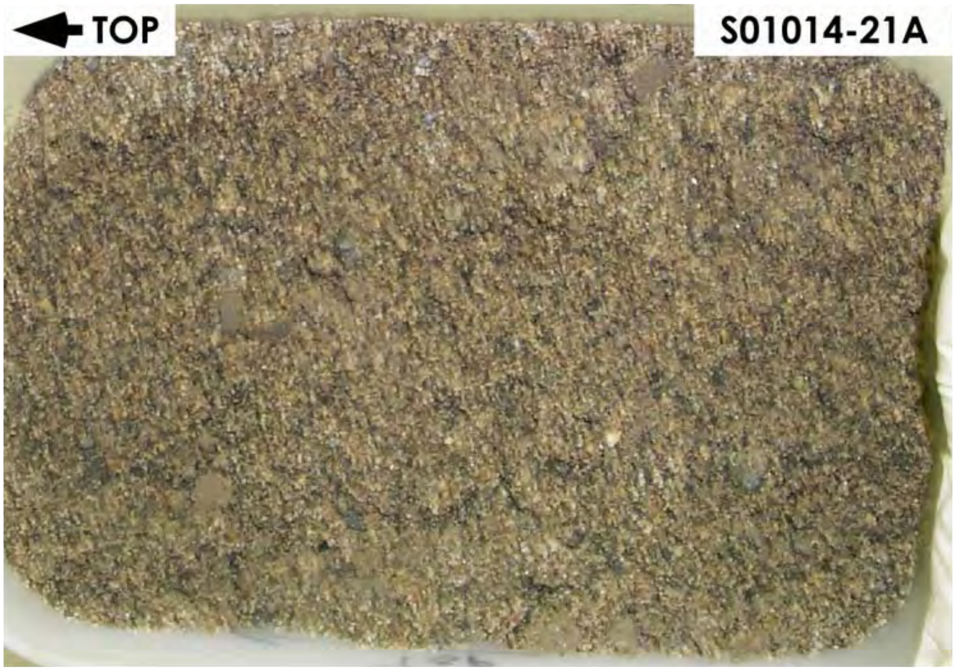


Figure B.16. Sample S01014-21A from a Depth of 51.39 ft to 51.89 ft bgs in the H2-Upper Sand and Gravel Sequence

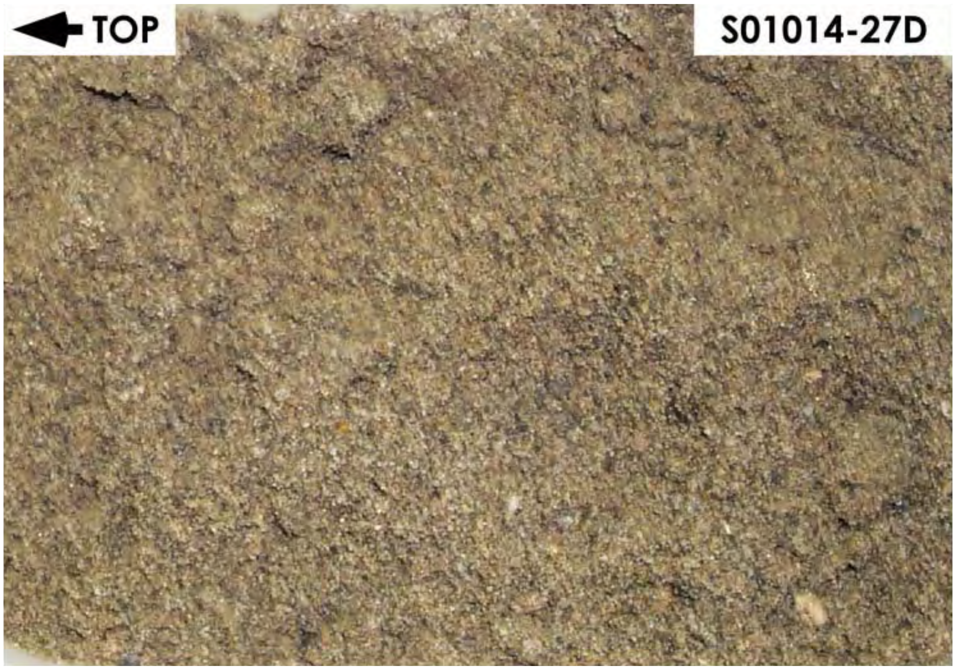


Figure B.17. Sample S01014-27D from a Depth of 61.24 ft to 61.74 ft bgs in the H2-Upper Sand and Gravel Sequence

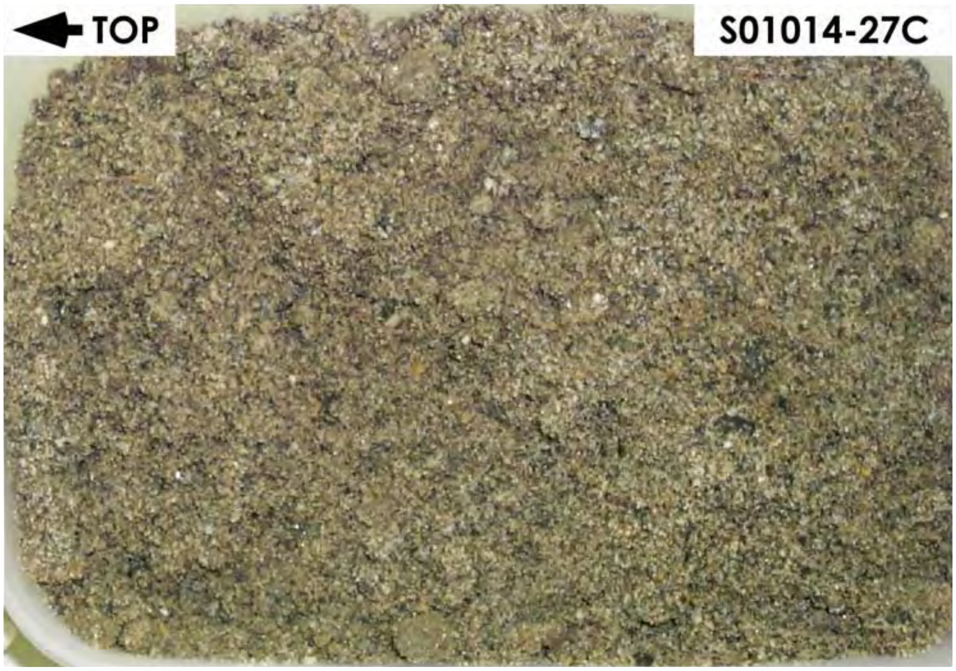


Figure B.18. Sample S01014-27C from a Depth of 61.74 ft to 62.24 ft bgs in the H2-Upper Sand and Gravel Sequence

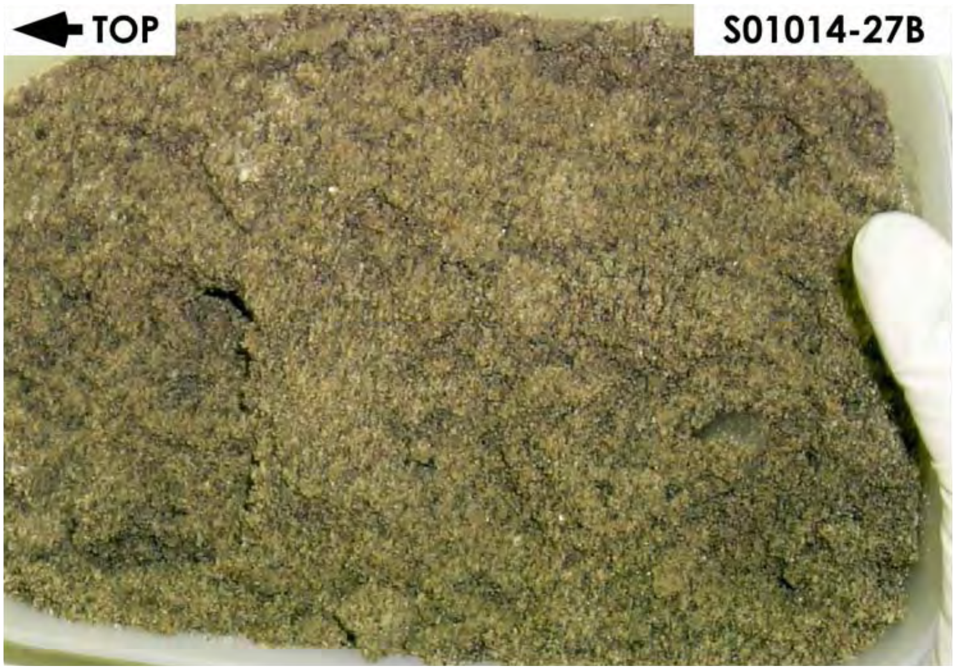


Figure B.19. Sample S01014-27B from a Depth of 62.24 ft to 62.74 ft bgs in the H2-Upper Sand and Gravel Sequence

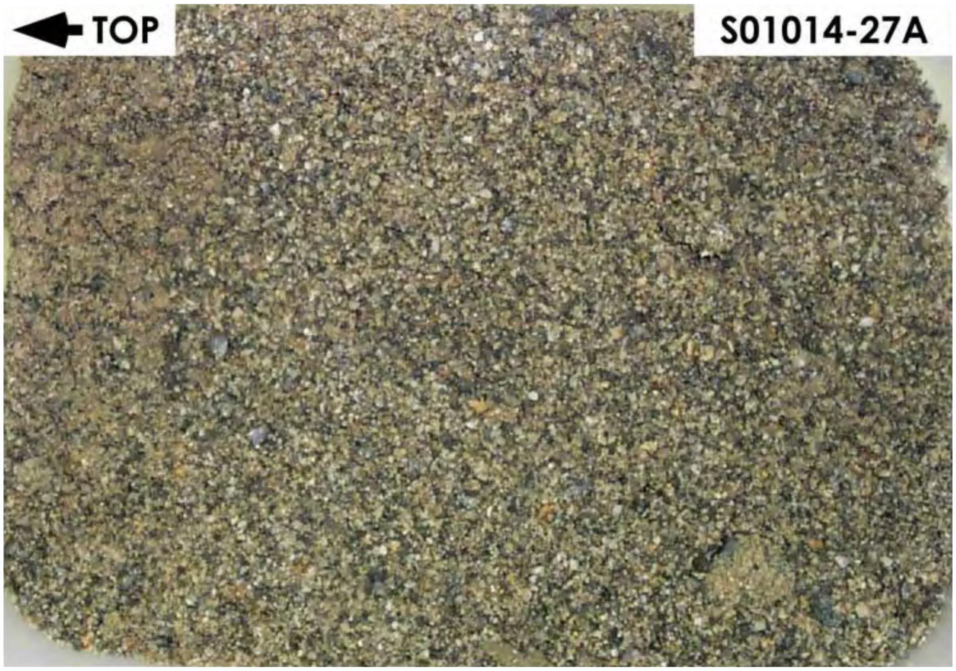


Figure B.20. Sample S01014-27A from a Depth of 62.74 ft to 63.24 ft bgs in the H2-Upper Sand and Gravel Sequence

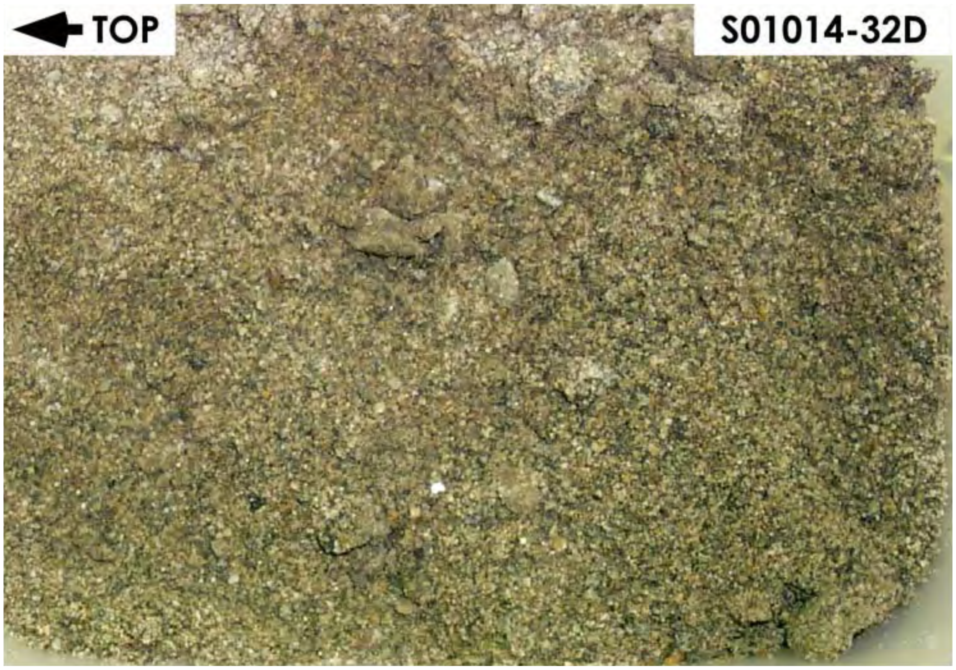


Figure B.21. Sample S01014-32D from a Depth of 69.49 ft to 69.99 ft bgs in the H2-Upper Sand and Gravel Sequence

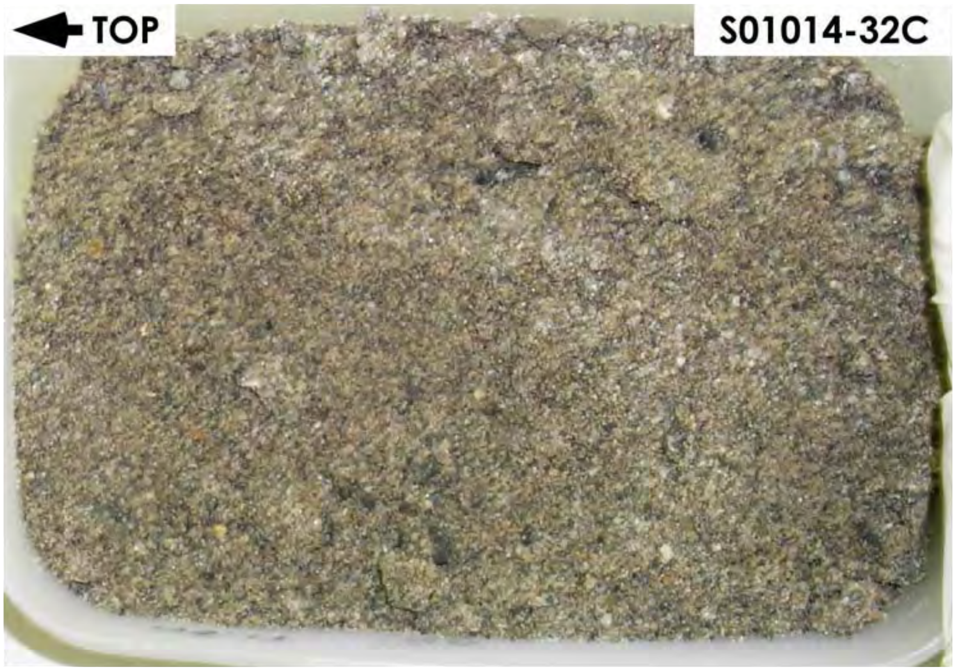


Figure B.22. Sample S01014-32C from a Depth of 69.99 ft to 70.49 ft bgs in the H2-Upper Sand and Gravel Sequence

Figure B.23. Sample S01014-32B from a Depth of 70.49 ft to 70.99 ft bgs in the H2-Upper Sand and Gravel Sequence

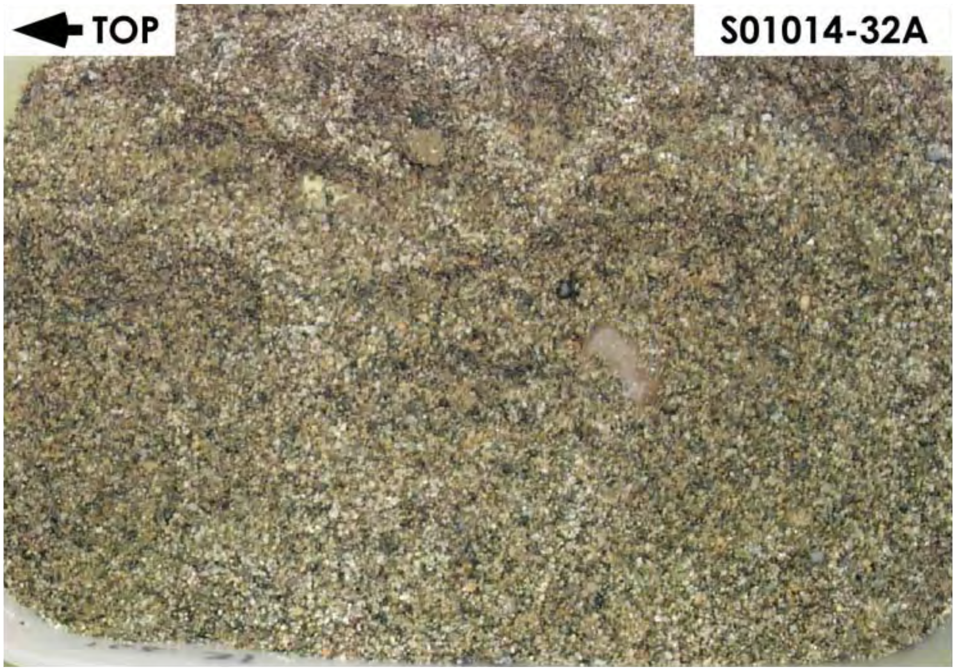


Figure B.24. Sample S01014-32A from a Depth of 70.99 ft to 71.49 ft bgs in the H2-Upper Sand and Gravel Sequence

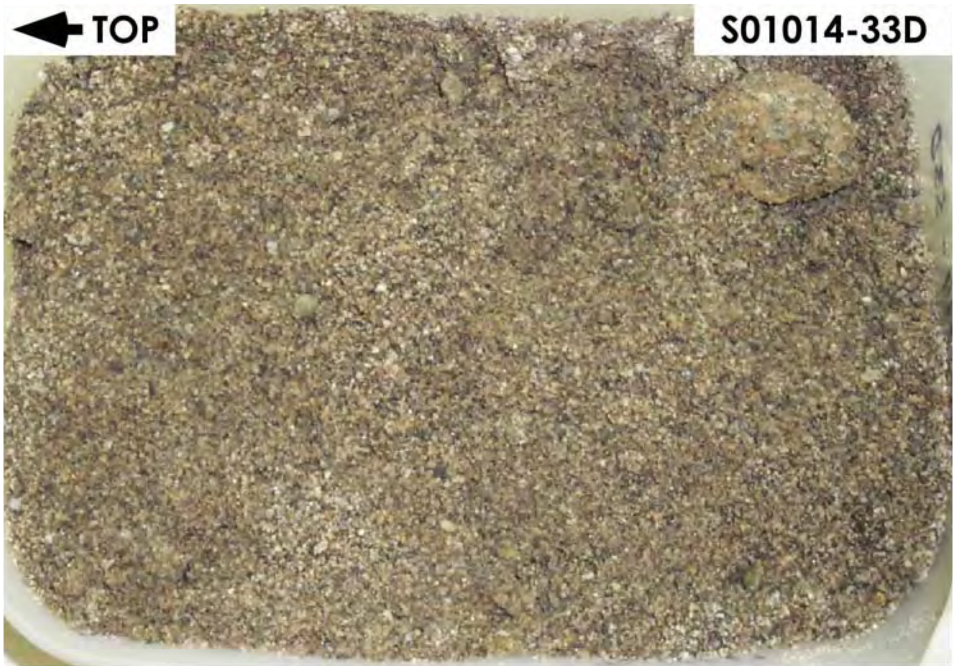


Figure B.25. Sample S01014-33D from a Depth of 71.64 ft to 72.14 ft bgs in the H2-Upper Sand and Gravel Sequence

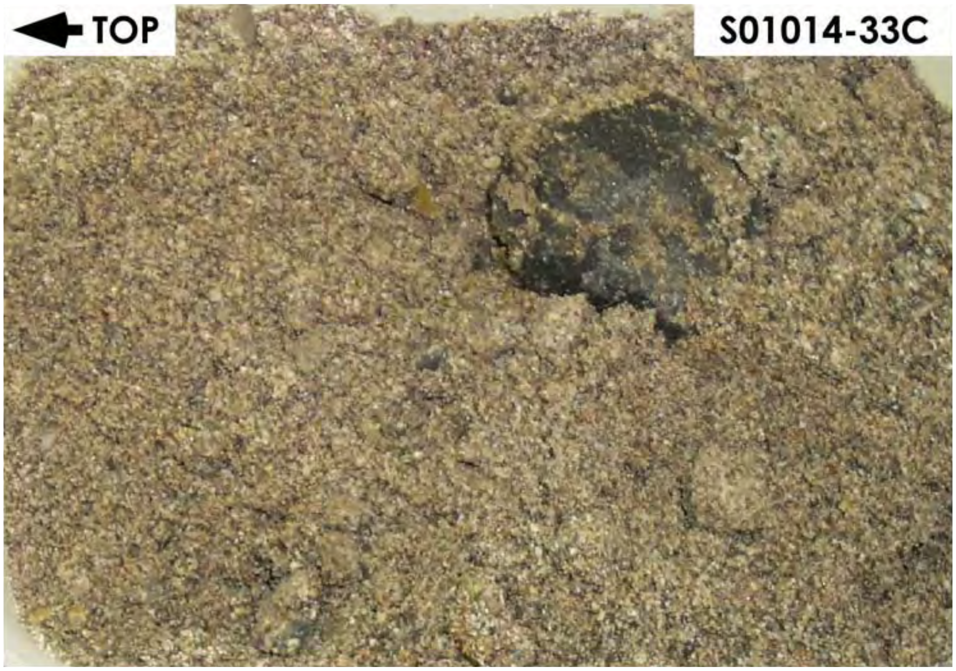


Figure B.26. Sample S01014-33C from a Depth of 72.14 ft to 72.64 ft bgs in the H2-Upper Sand and Gravel Sequence

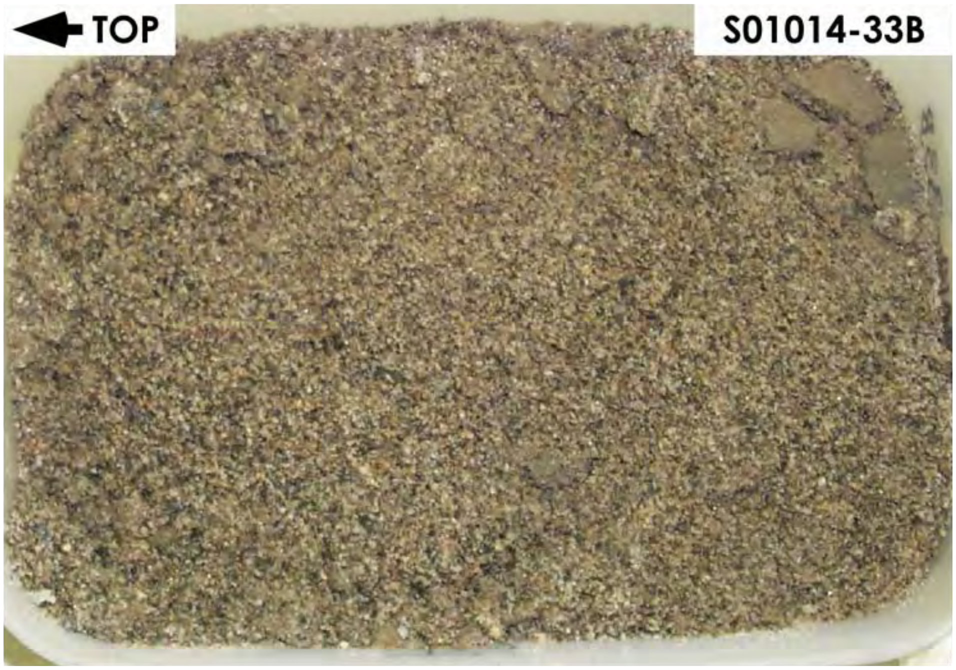


Figure B.27. Sample S01014-33B from a Depth of 72.64 ft to 73.14 ft bgs in the H2-Upper Sand and Gravel Sequence

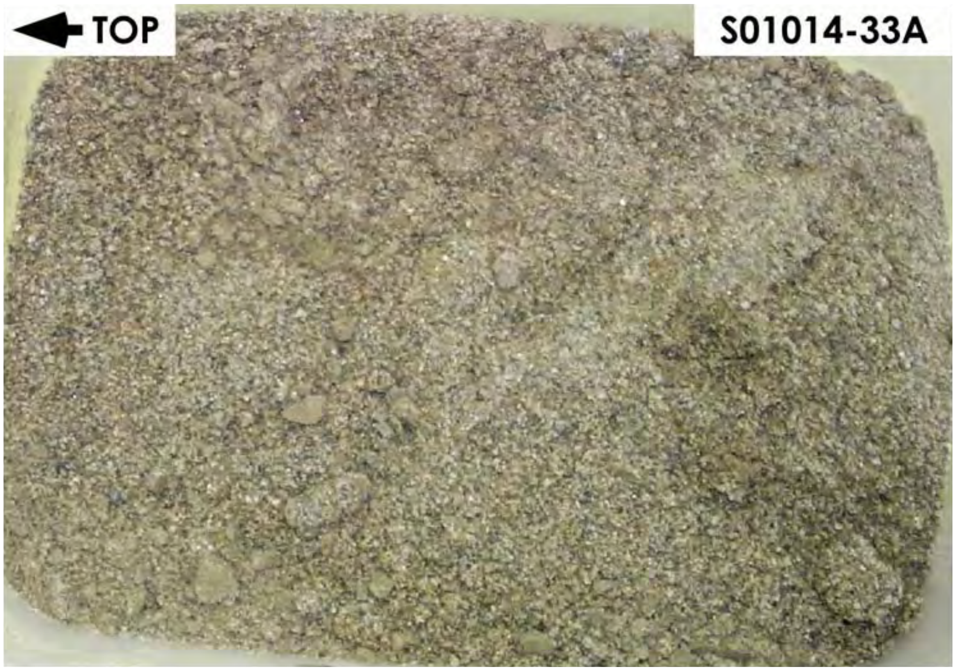


Figure B.28. Sample S01014-33A from a Depth of 73.14 ft to 73.64 ft bgs in the H2-Upper Sand and Gravel Sequence

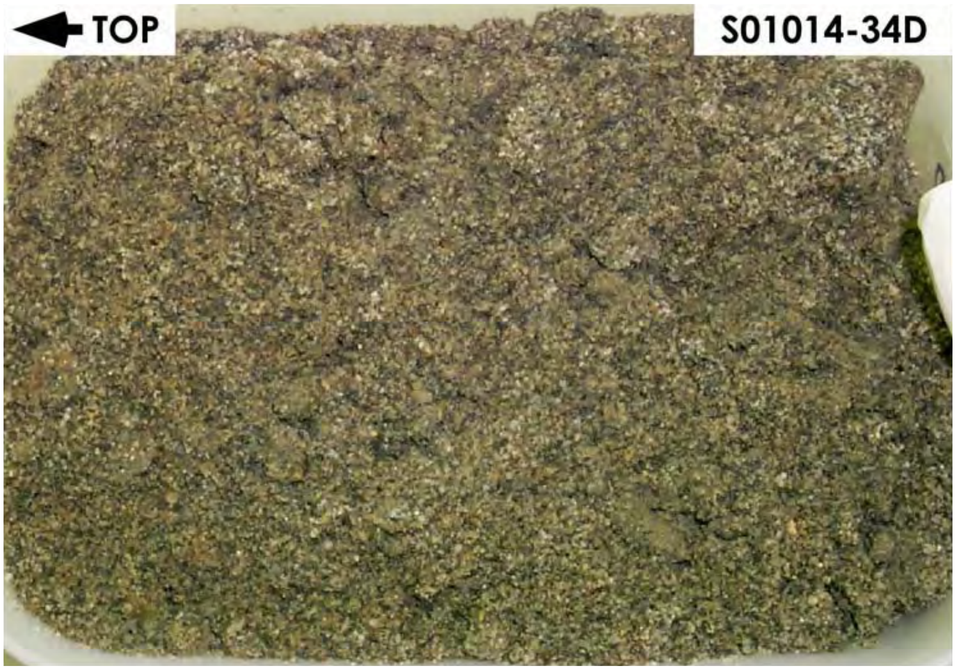


Figure B.29. Sample S01014-34D from a Depth of 73.90 ft to 74.40 ft bgs in the H2-Upper Sand and Gravel Sequence

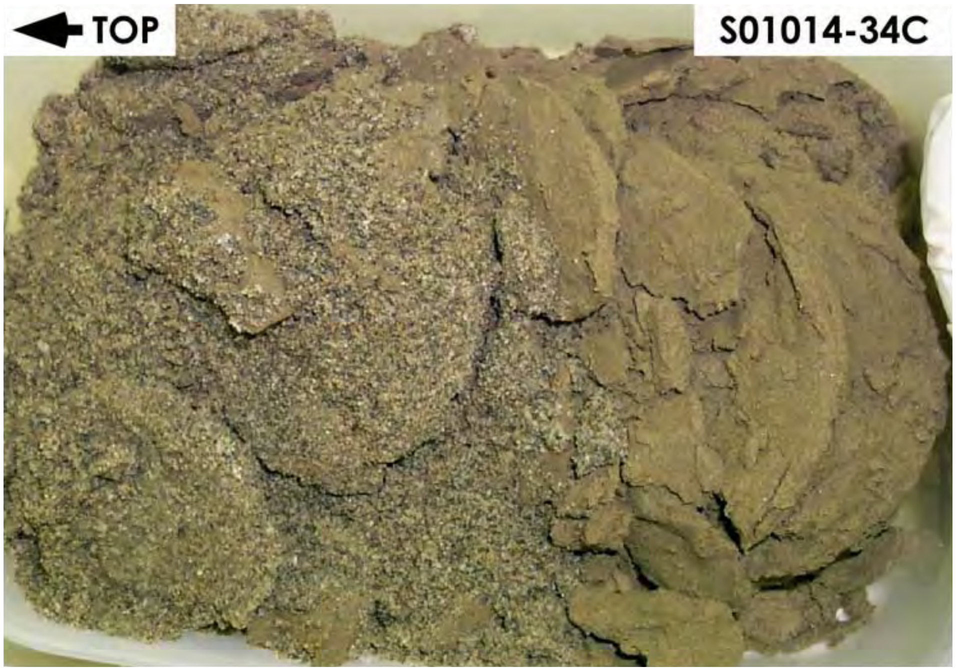


Figure B.30. Sample S01014-34C from a Depth of 74.40 ft to 74.90 ft bgs in the H2-Upper Sand and Gravel Sequence - Contact - H2- Muddy Very Fine to Fine Sand Layer

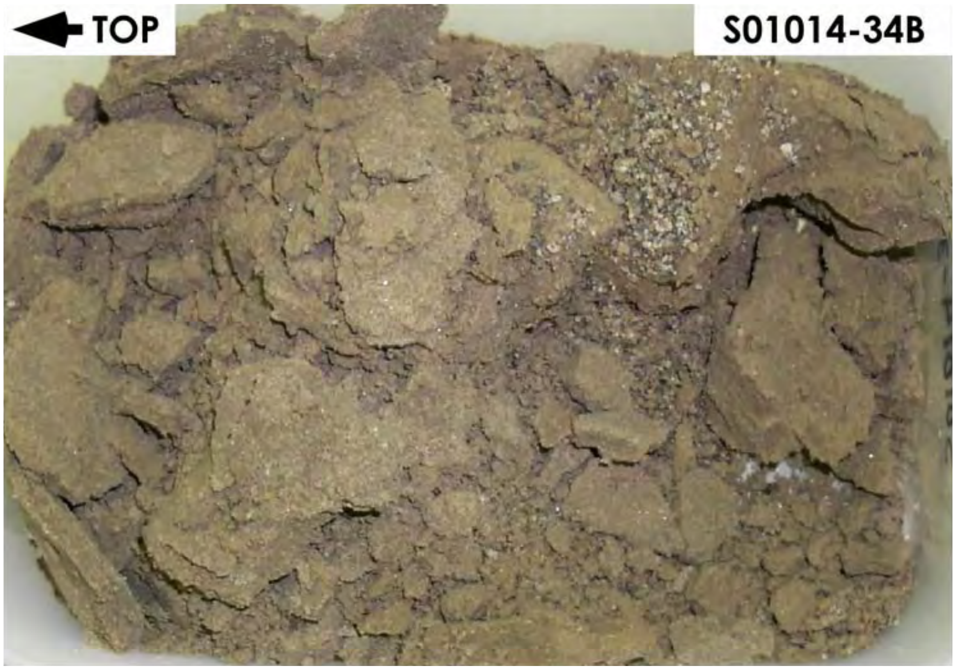


Figure B.31. Sample S01014-34B from a Depth of 74.90 ft to 75.40 ft bgs in the H2- Muddy Very Fine to Fine Sand Layer

Figure B.32. Sample S01014-34A from a Depth of 75.40 ft to 75.90 ft bgs in the H2- Sand Sequence

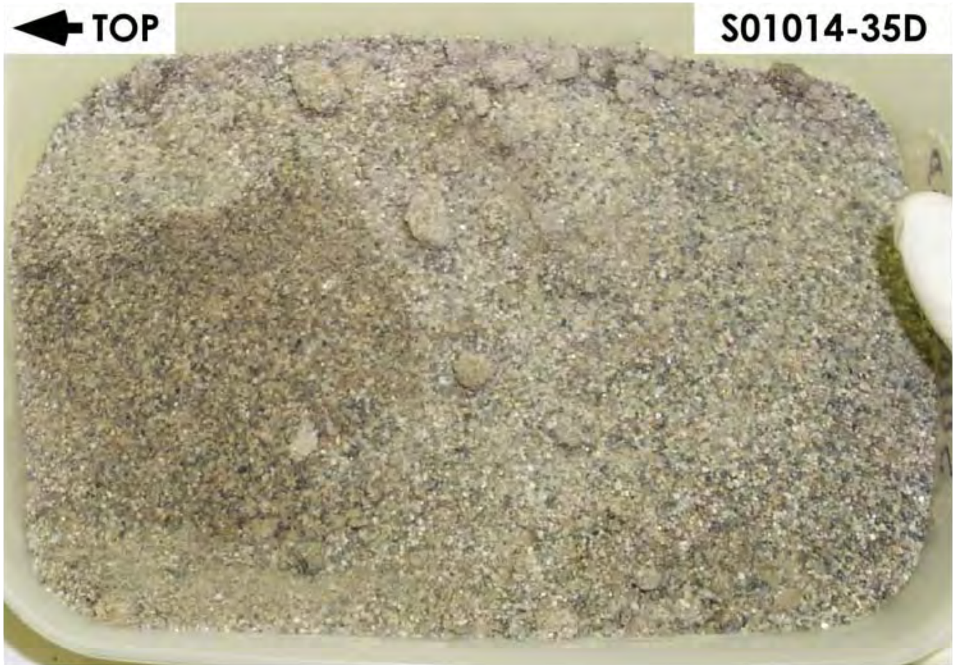


Figure B.33. Sample S01014-35D from a Depth of 76.44 ft to 76.94 ft bgs in the H2-Sand Sequence

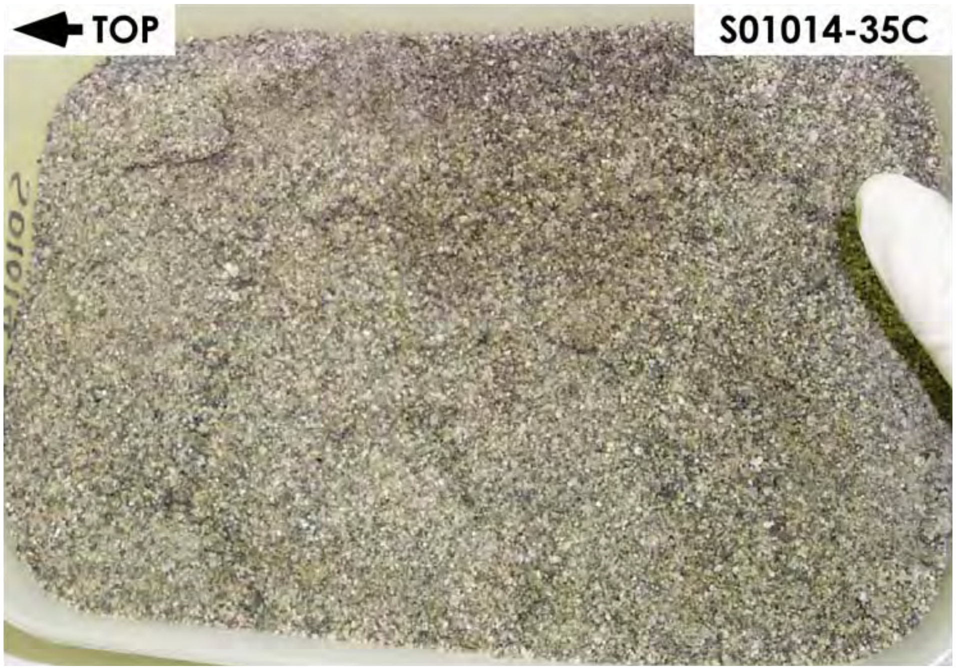


Figure B.34. Sample S01014-35C from a Depth of 76.94 ft to 77.44 ft bgs in the H2-Sand Sequence

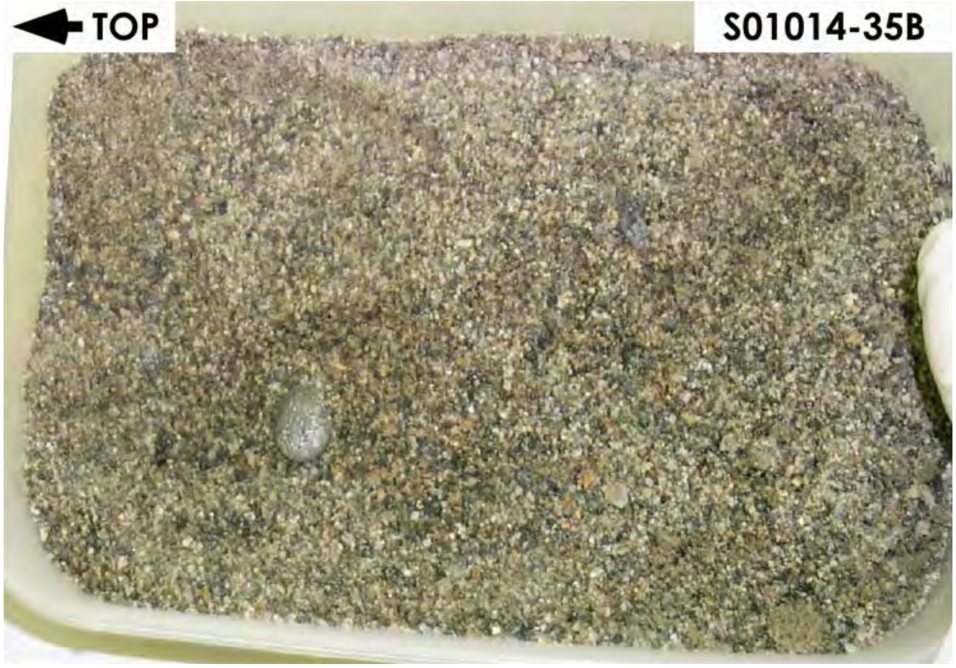


Figure B.35. Sample S01014-35B from a Depth of 77.44 ft to 77.94 ft bgs in the H2-Sand Sequence

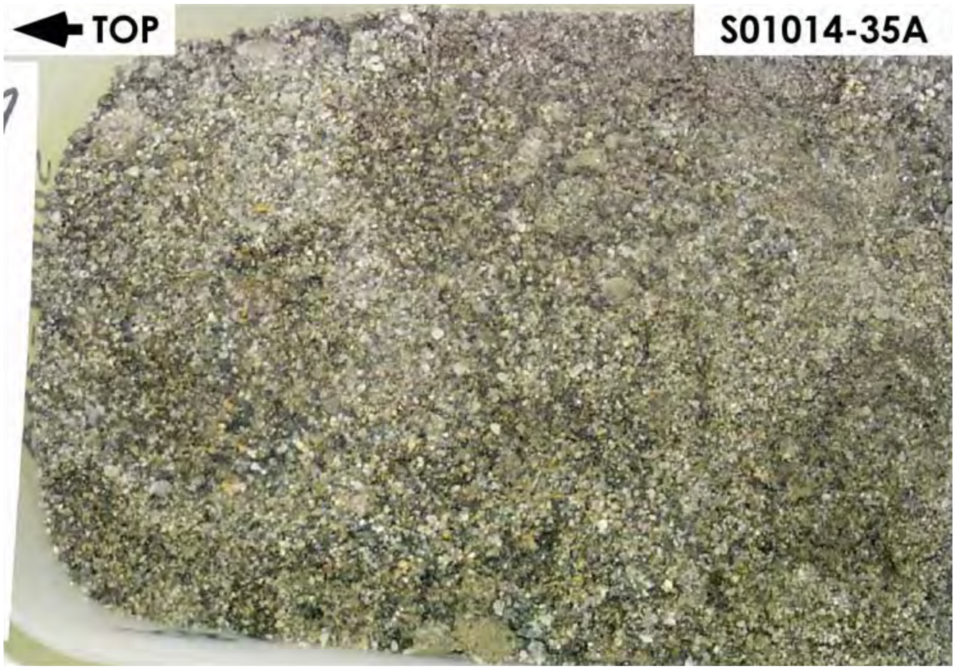


Figure B.36. Sample S01014-35A from a Depth of 77.94 ft to 78.44 ft bgs in the H2-Sand Sequence

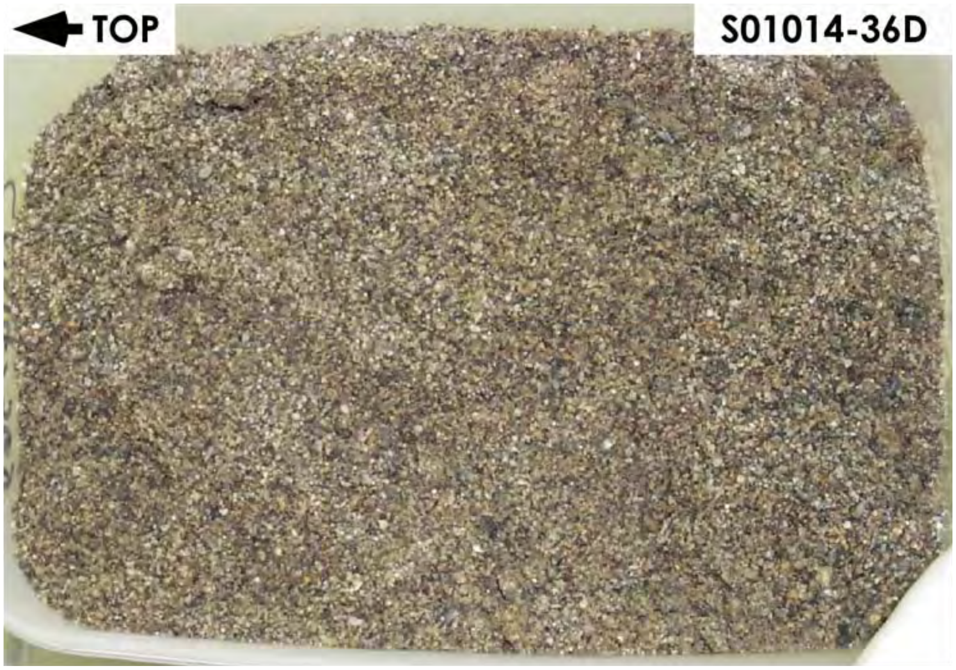


Figure B.37. Sample S01014-36D from a Depth of 77.59 ft to 78.09 ft bgs in the H2-Sand Sequence

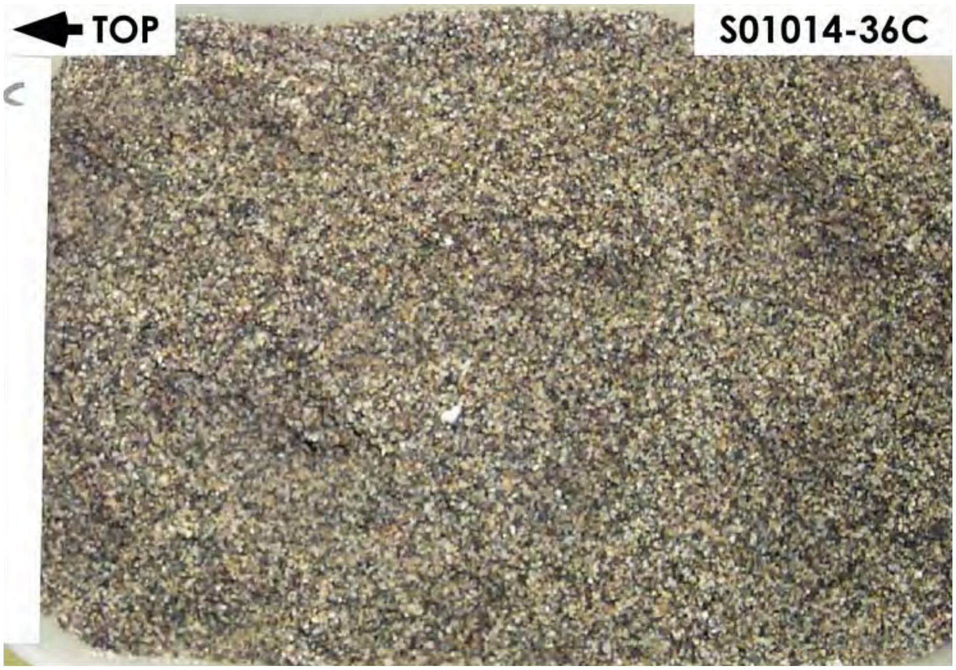


Figure B.38. Sample S01014-36C from a Depth of 78.09 ft to 78.59 ft bgs in the H2-Sand Sequence

Figure B.39. Sample S01014-36B from a Depth of 78.59 ft to 79.09 ft bgs in the H2-Sand Sequence

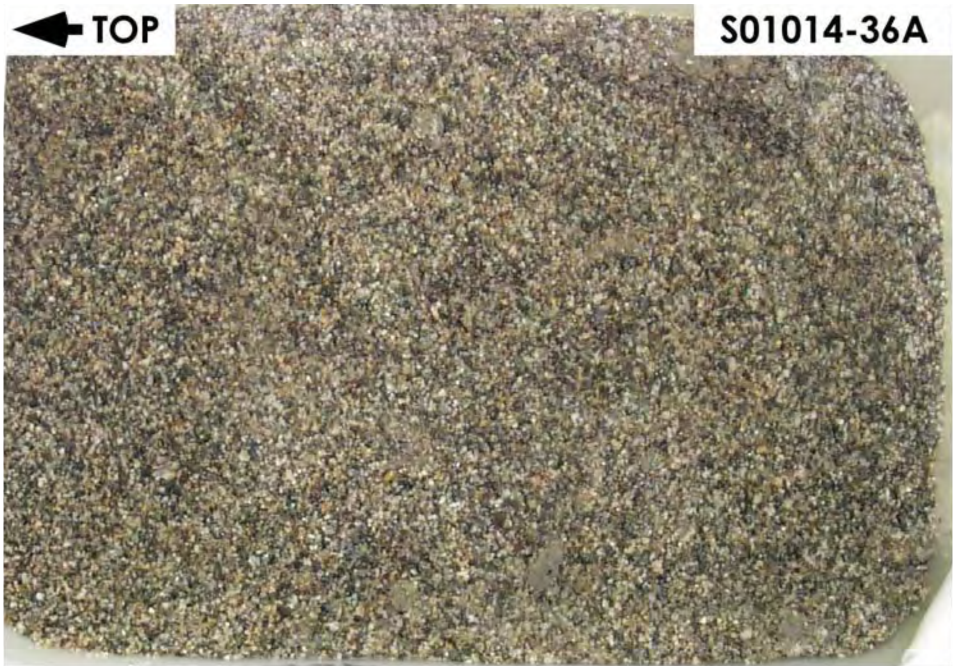


Figure B.40. Sample S01014-36A from a Depth of 79.09 ft to 79.59 ft bgs in the H2-Sand Sequence

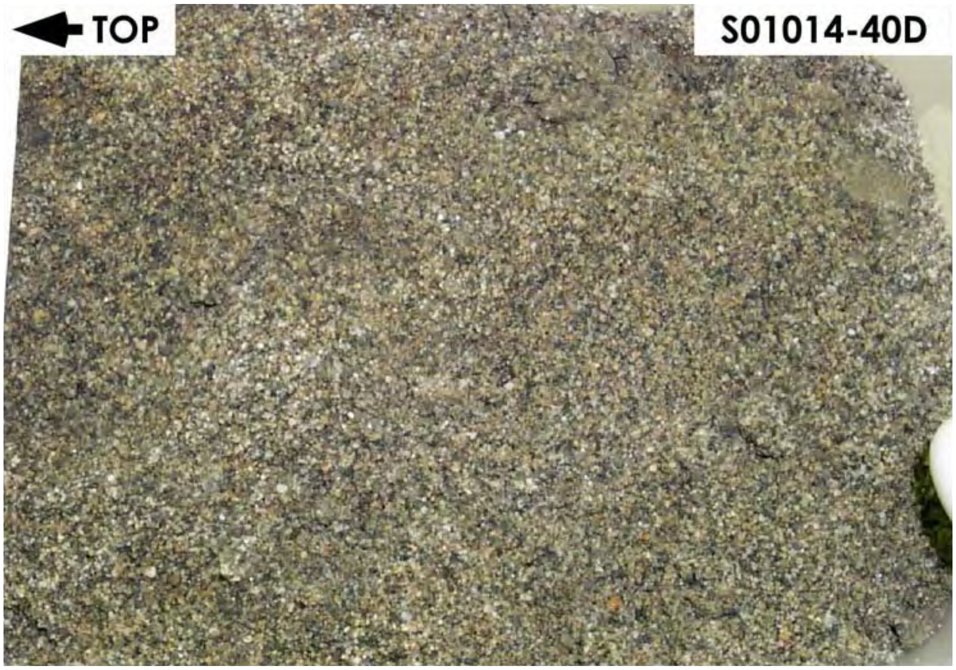


Figure B.41. Sample S01014-40D from a Depth of 86.90 ft to 87.40 ft bgs in the H2-Sand Sequence

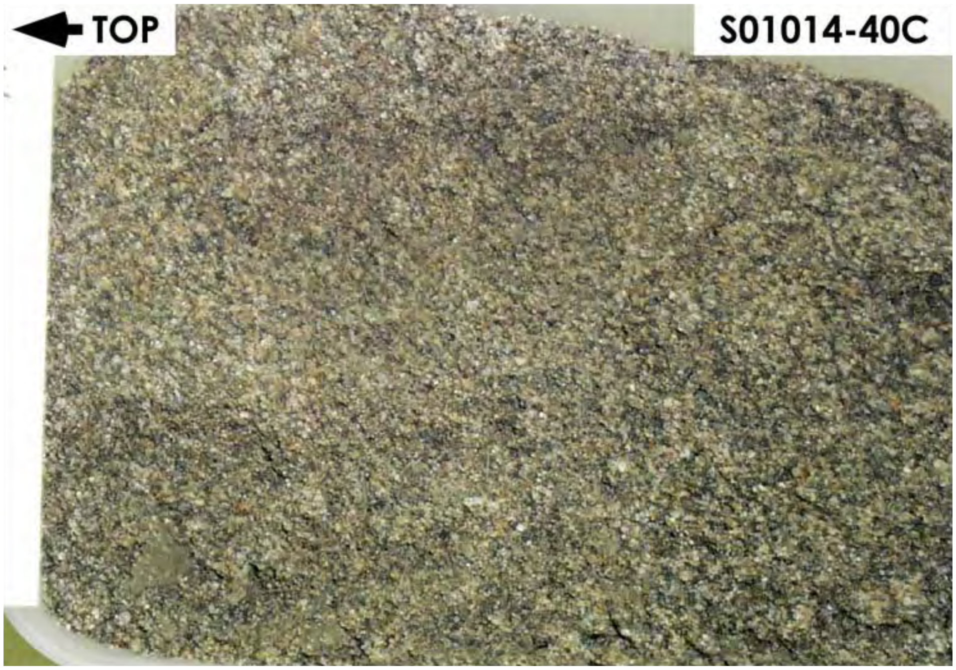


Figure B.42. Sample S01014-40C from a Depth of 87.40 ft to 87.90 ft bgs in the H2-Sand Sequence

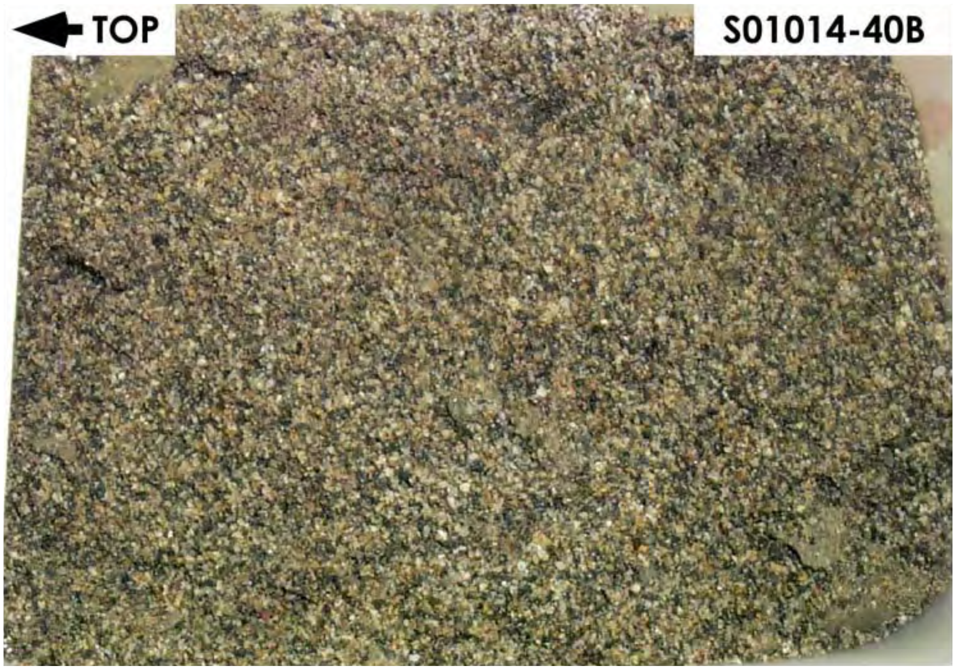


Figure B.43. Sample S01014-40B from a Depth of 87.90 ft to 88.40 ft bgs in the H2-Sand Sequence

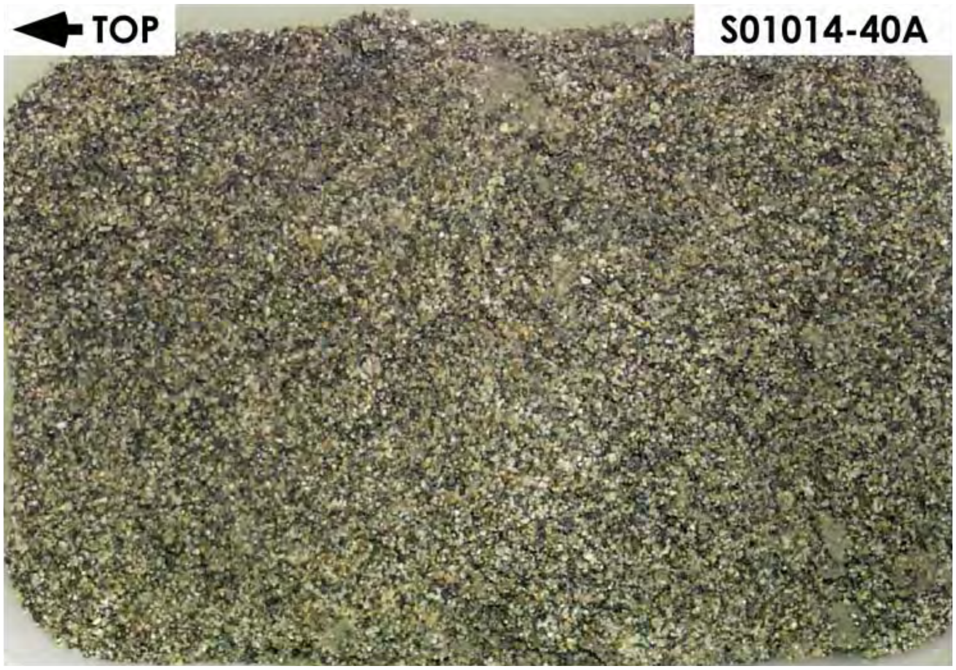


Figure B.44. Sample S01014-40A from a Depth of 88.40 ft to 88.90 ft bgs in the H2-Sand Sequence

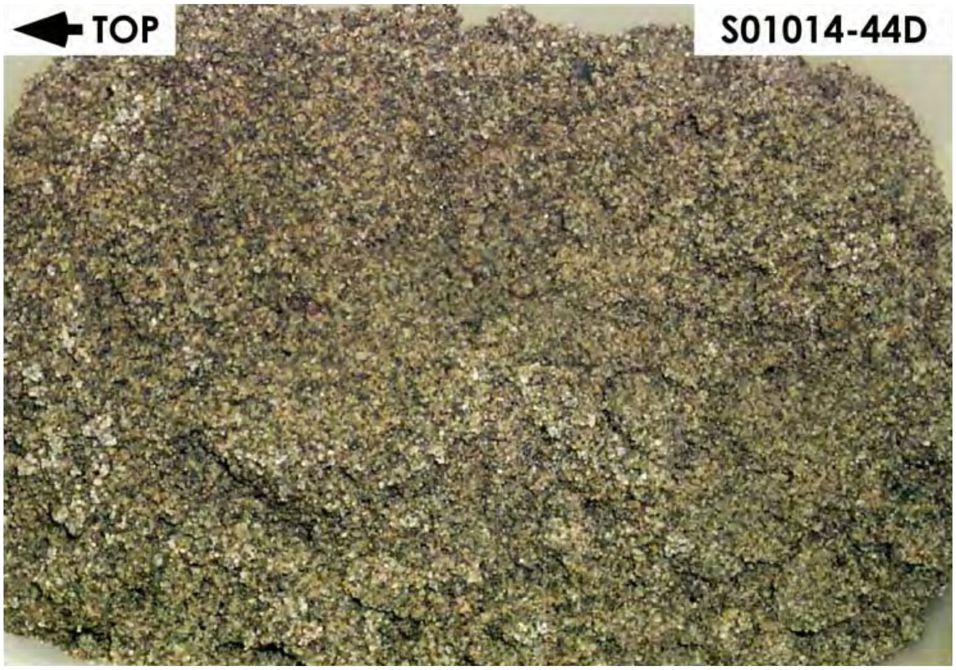


Figure B.45. Sample S01014-44D from a Depth of 98.34 ft to 98.84 ft bgs in the H2-Sand Sequence

Figure B.46. Sample S01014-44C from a Depth of 98.84 ft to 99.34 ft bgs in the H2-Sand Sequence

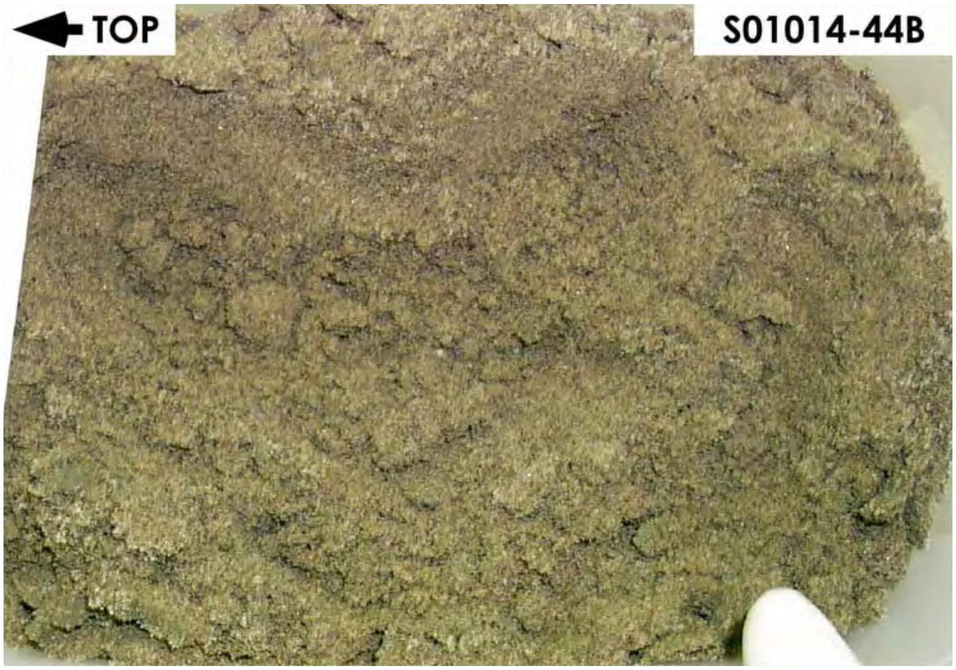


Figure B.47. Sample S01014-44B from a Depth of 99.34 ft to 99.84 ft bgs in the H2-Sand Sequence

Figure B.48. Sample S01014-44A from a Depth of 99.84 ft to 100.34 ft bgs in the H2-Sand Sequence

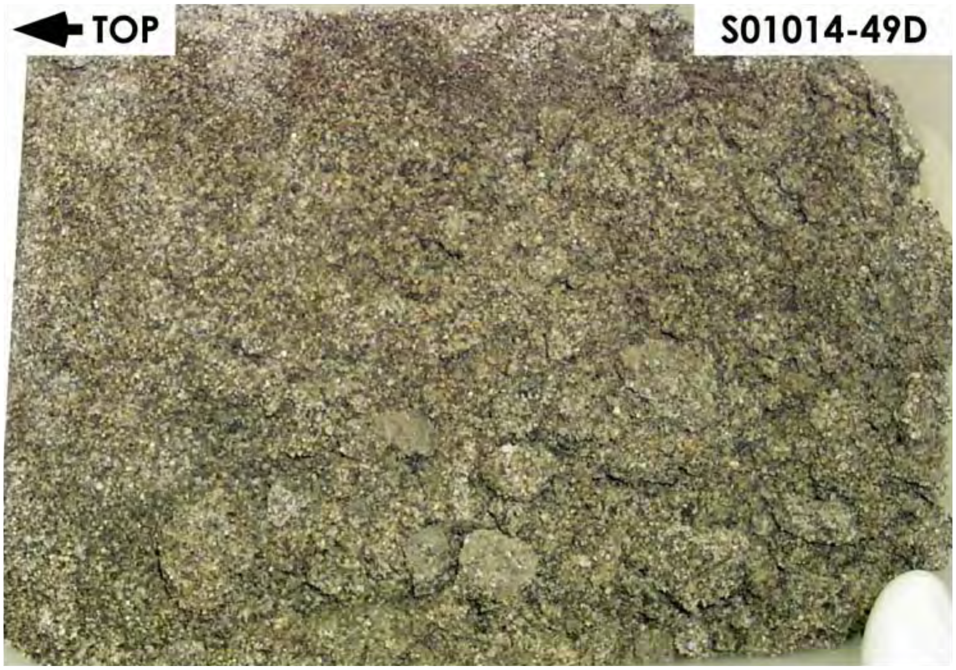


Figure B.49. Sample S01014-49D from a Depth of 109.39 ft to 109.89 ft bgs in the H2-Sand Sequence

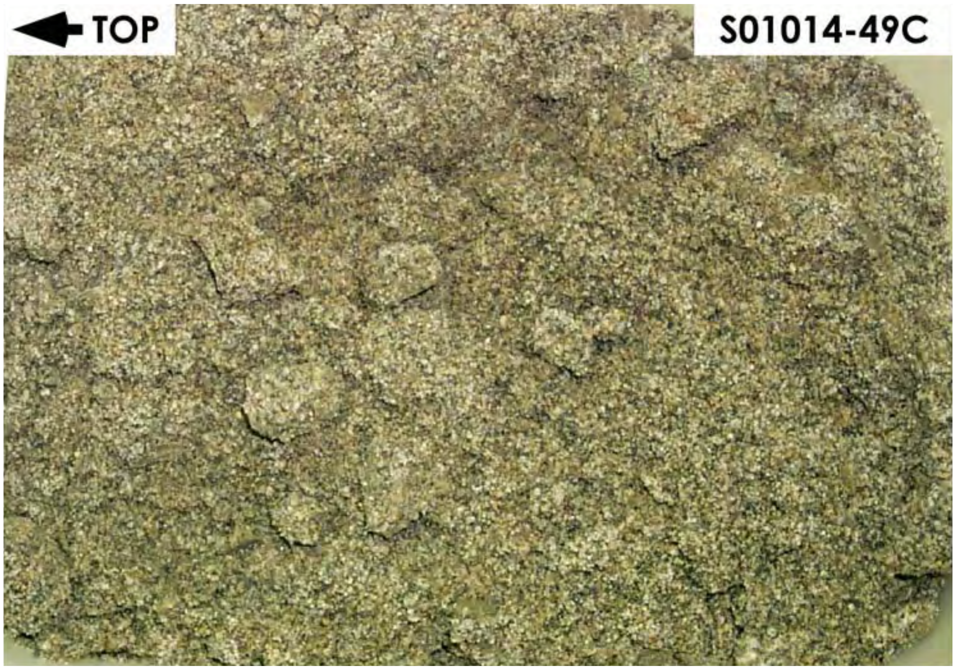


Figure B.50. Sample S01014-49C from a Depth of 109.89 ft to 110.39 ft bgs in the H2-Sand Sequence

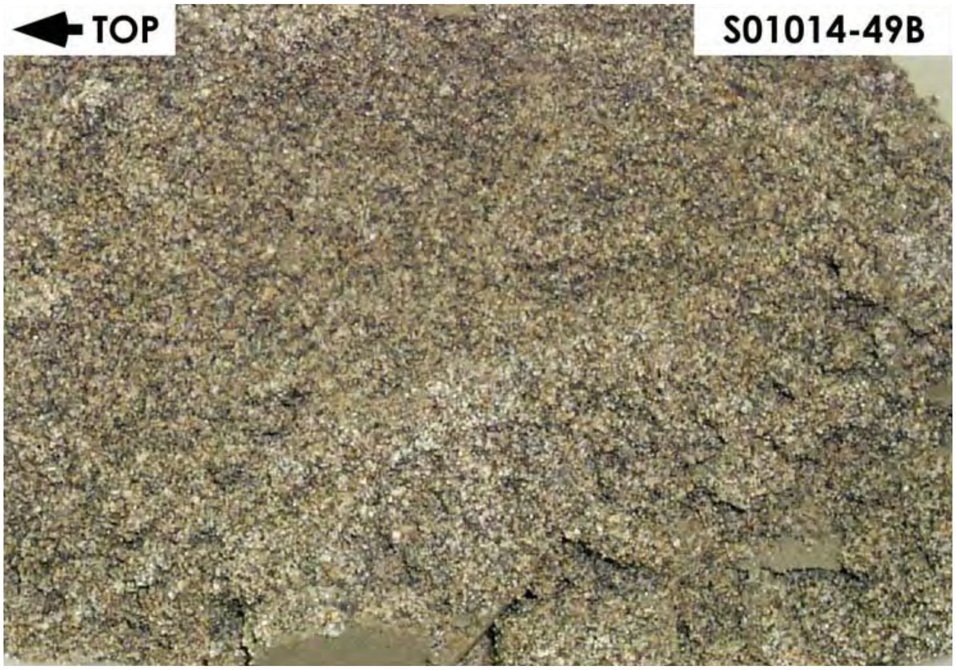


Figure B.51. Sample S01014-49B from a Depth of 110.39 ft to 110.89 ft bgs in the H2-Sand Sequence

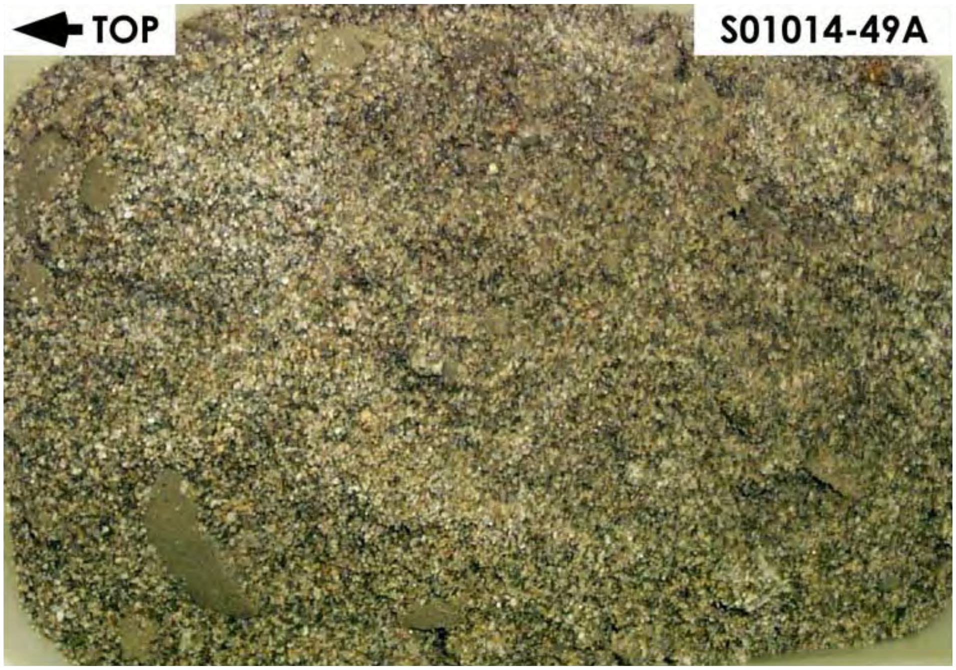


Figure B.52. Sample S01014-49A from a Depth of 109.89 ft to 111.39 ft bgs in the H2-Sand Sequence

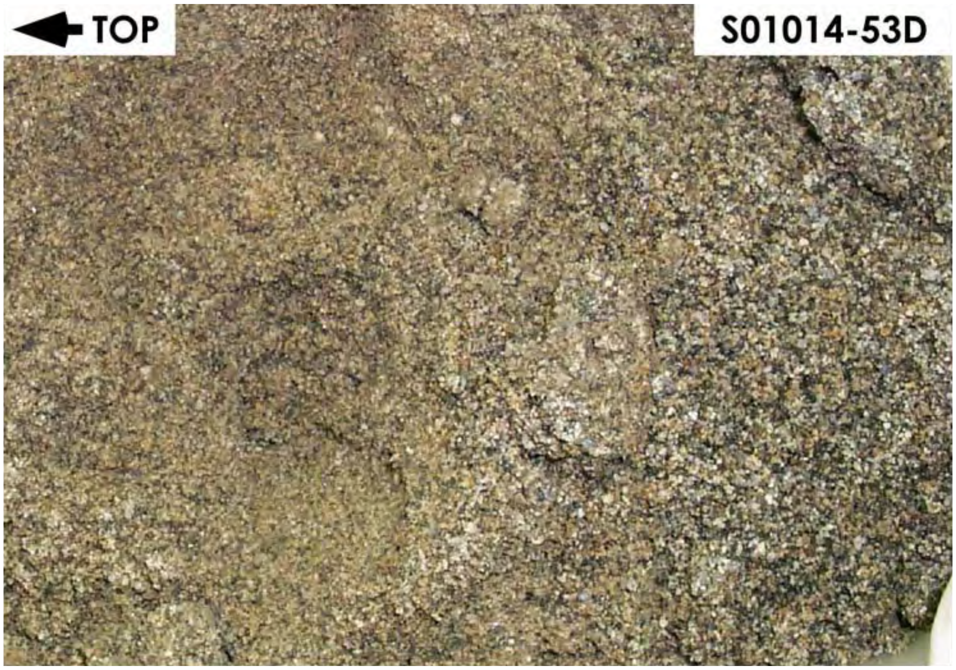


Figure B.53. Sample S01014-53D from a Depth of 117.29 ft to 117.79 ft bgs in the H2-Sand Sequence

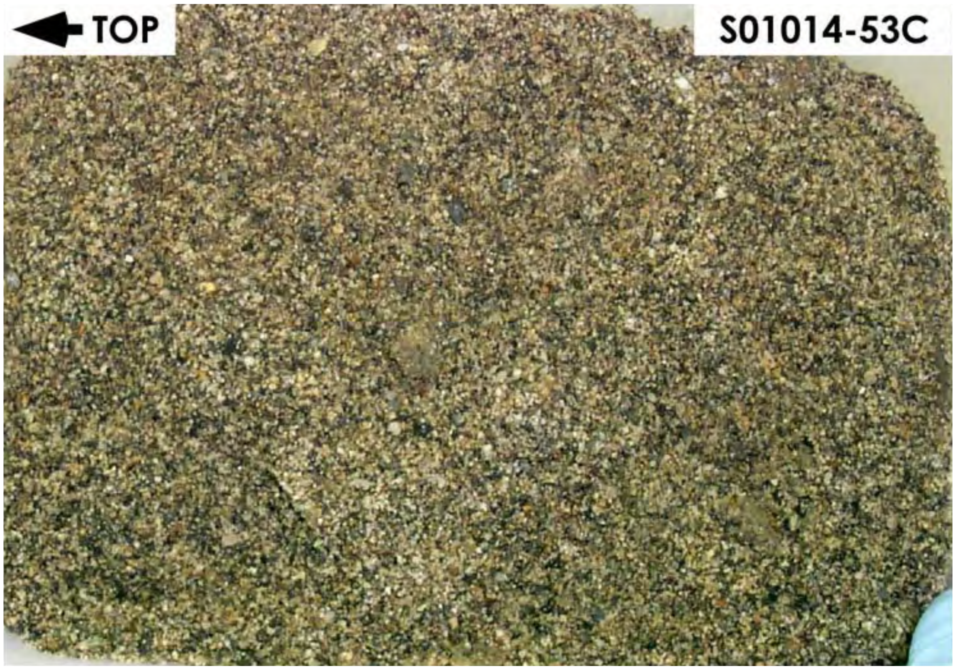


Figure B.54. Sample S01014-53C from a Depth of 117.79 ft to 118.29 ft bgs in the H2-Sand Sequence

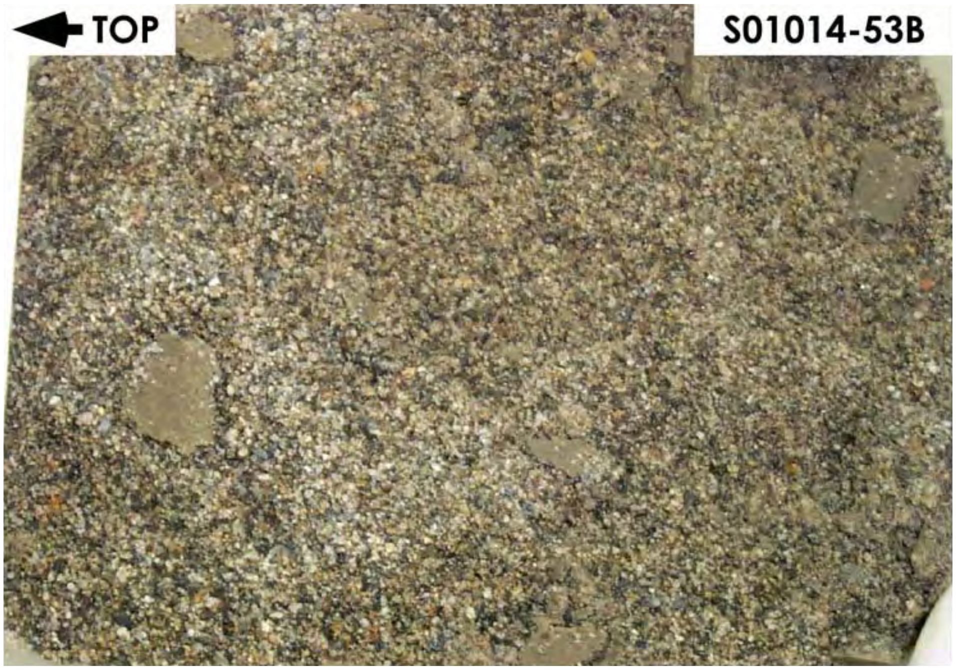


Figure B.55. Sample S01014-53B from a Depth of 118.29 ft to 118.79 ft bgs in the H2-Sand Sequence

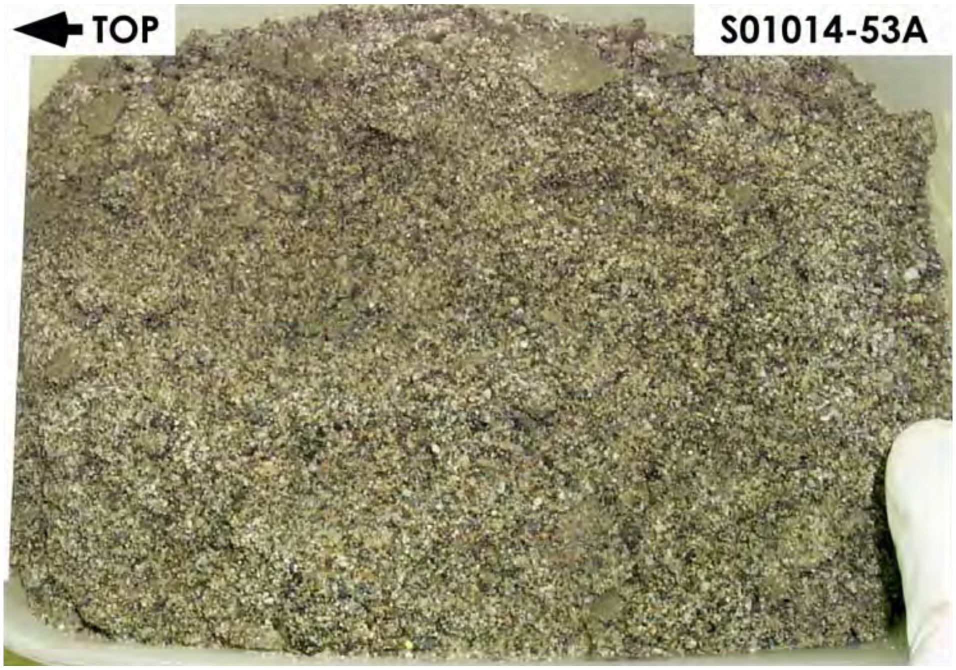


Figure B.56. Sample S01014-53A from a Depth of 118.79 ft to 119.29 ft bgs in the H2-Sand Sequence

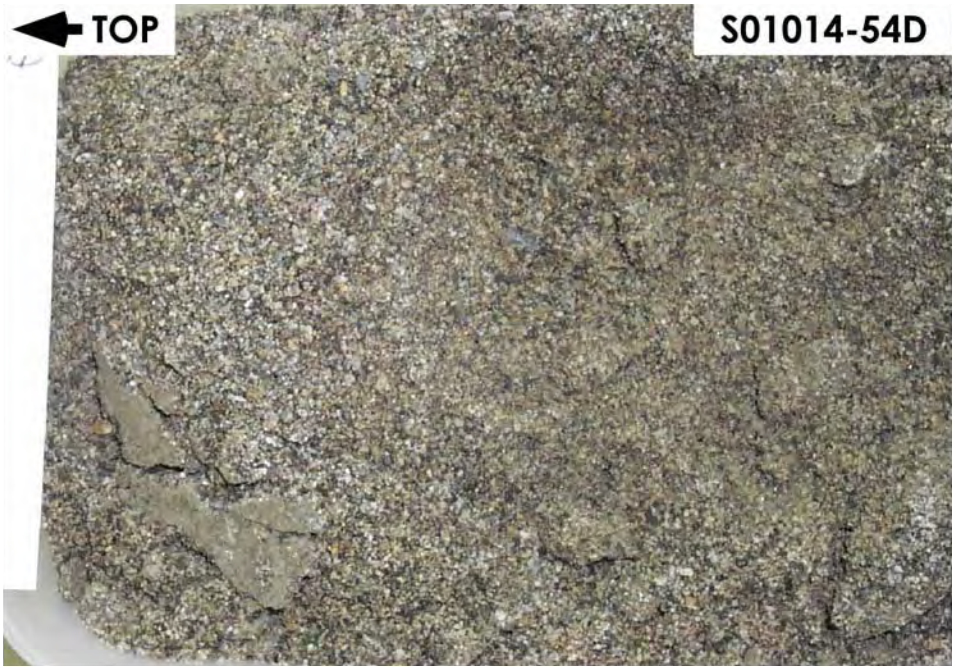


Figure B.57. Sample S01014-54D from a Depth of 119.14 ft to 119.64 ft bgs in the H2-Sand Sequence

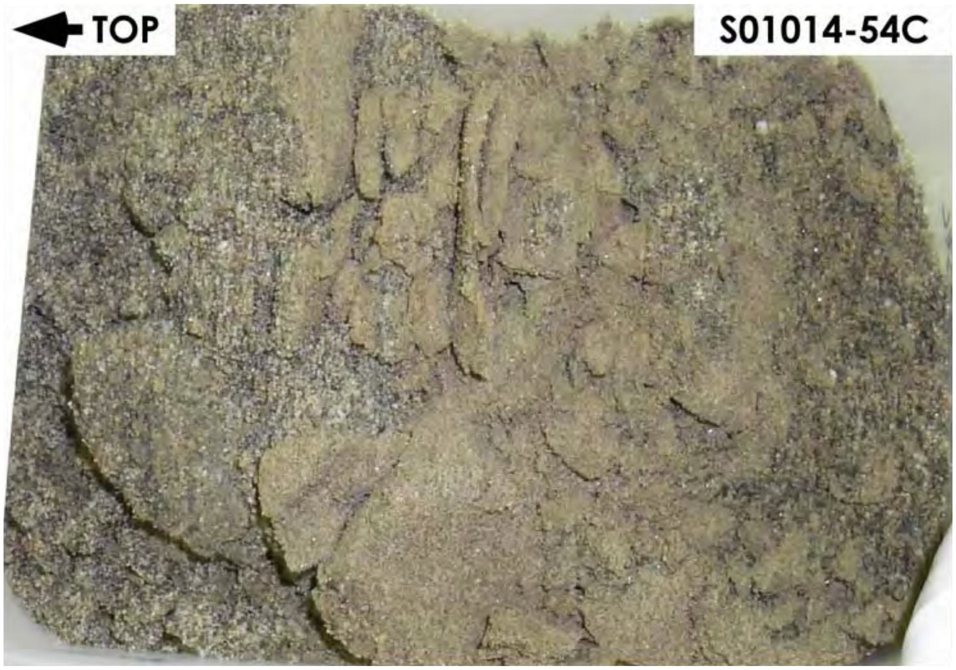


Figure B.58. Sample S01014-54C from a Depth of 119.64 ft to 120.14 ft bgs in the H2-Sand Sequence

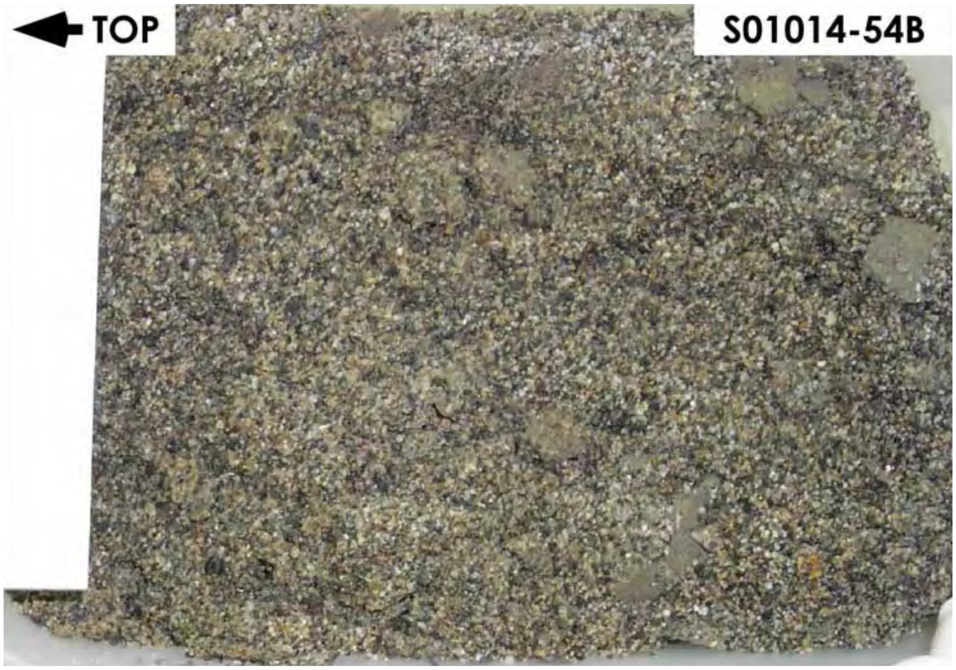


Figure B.59. Sample S01014-54B from a Depth of 120.14 ft to 120.64 ft bgs in the H2-Sand Sequence

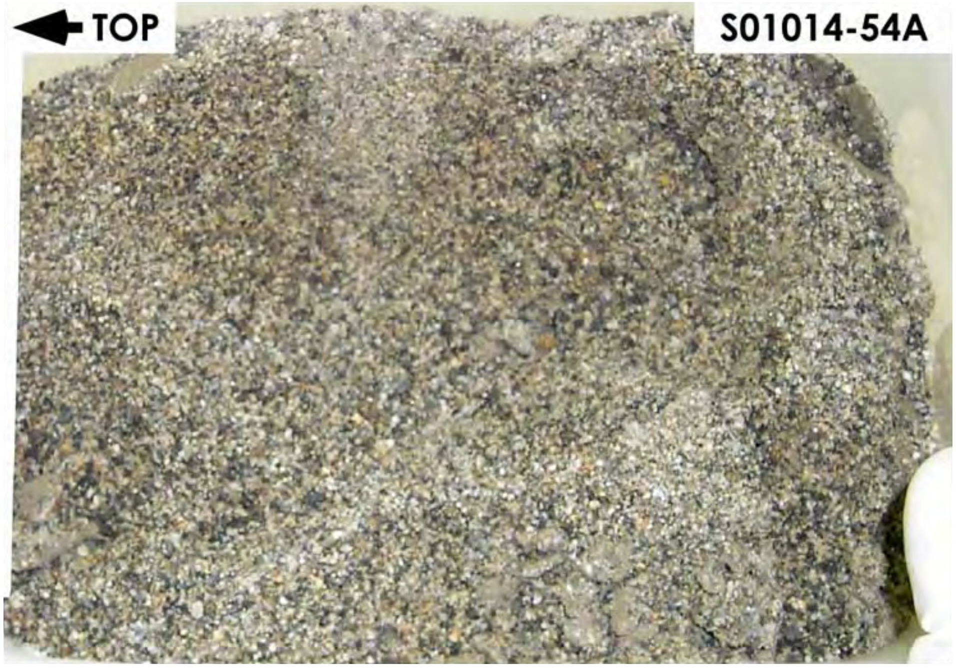


Figure B.60. Sample S01014-54A from a Depth of 120.64 ft to 121.14 ft bgs in the H2-Sand Sequence

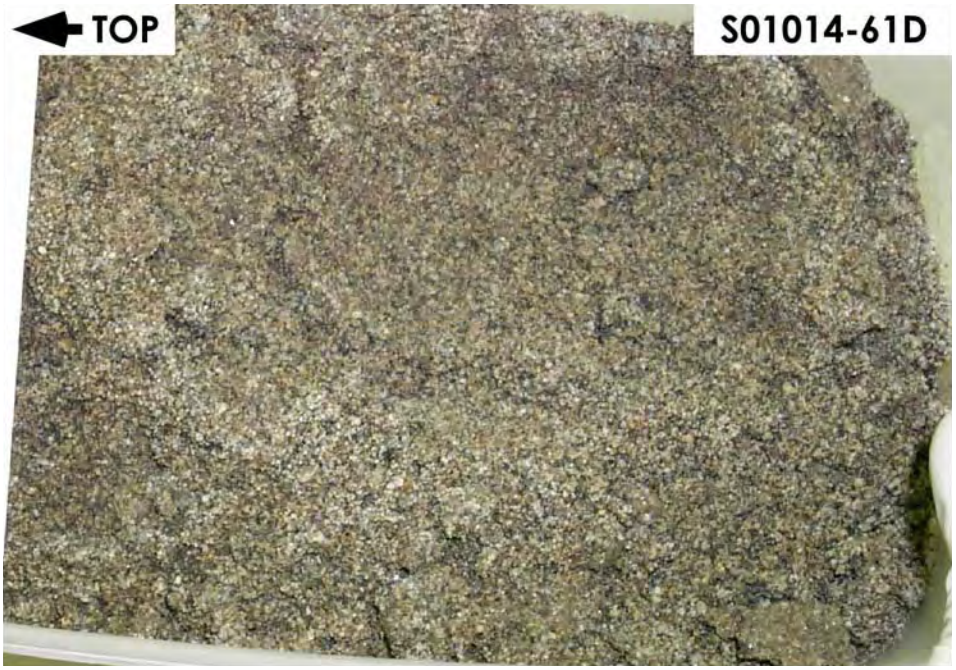


Figure B.61. Sample S01014-61D from a Depth of 129.20 ft to 129.70 ft bgs in the H2-Sand Sequence

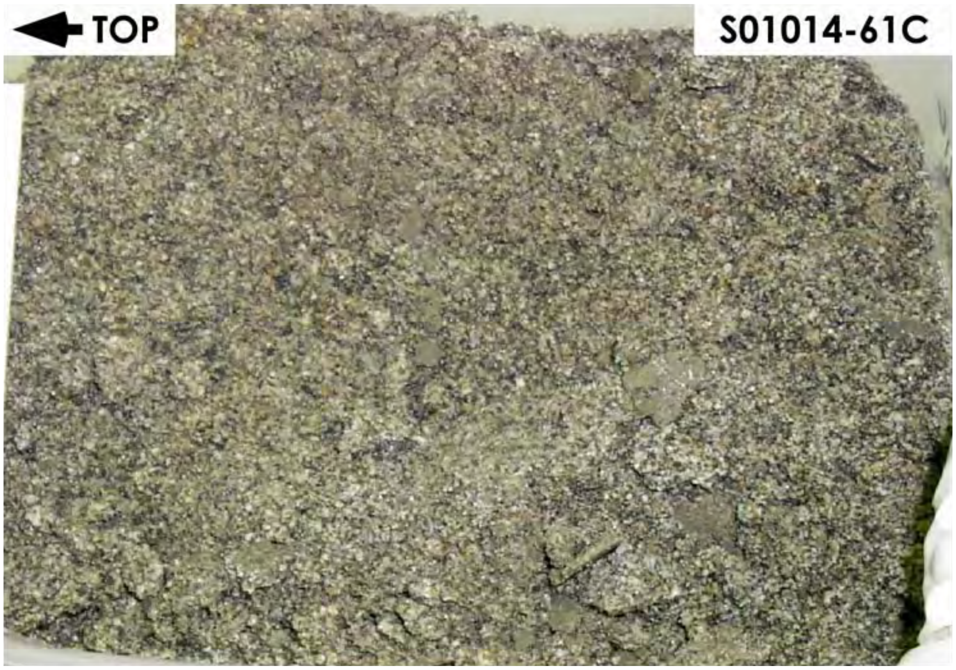


Figure B.62. Sample S01014-61C from a Depth of 129.70 ft to 130.20 ft bgs in the H2-Sand Sequence

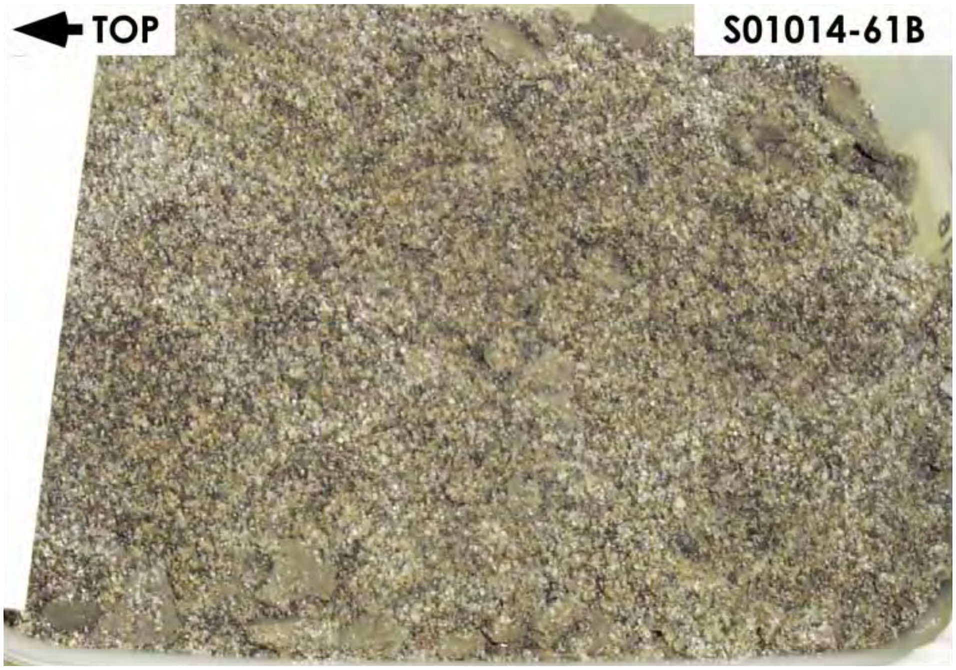


Figure B.63. Sample S01014-61B from a Depth of 130.20 ft to 130.70 ft bgs in the H2-Sand Sequence

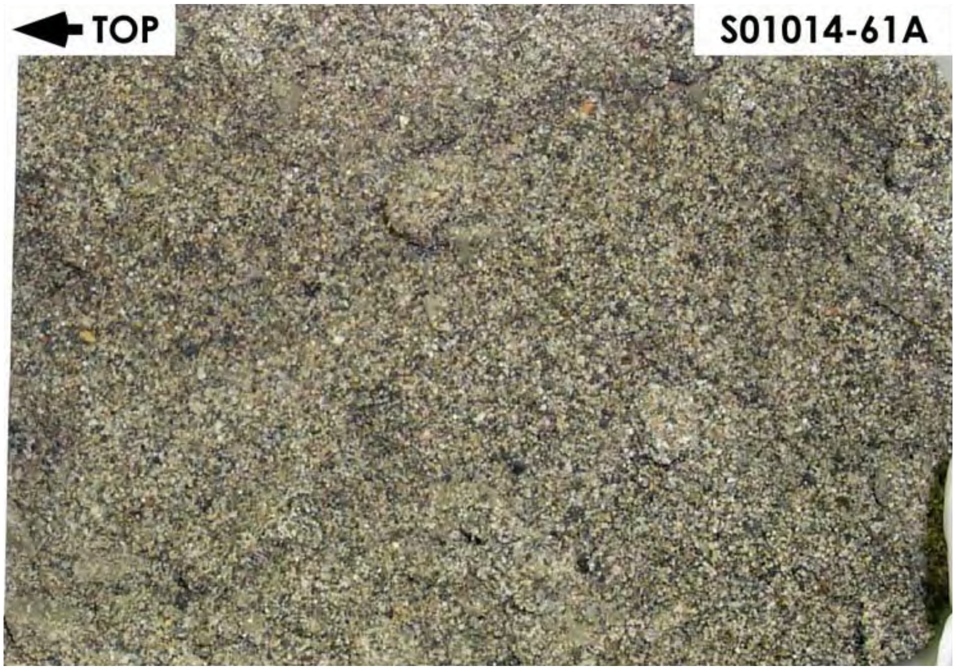


Figure B.64. Sample S01014-61A from a Depth of 130.70 ft to 131.20 ft bgs in the H2-Sand Sequence

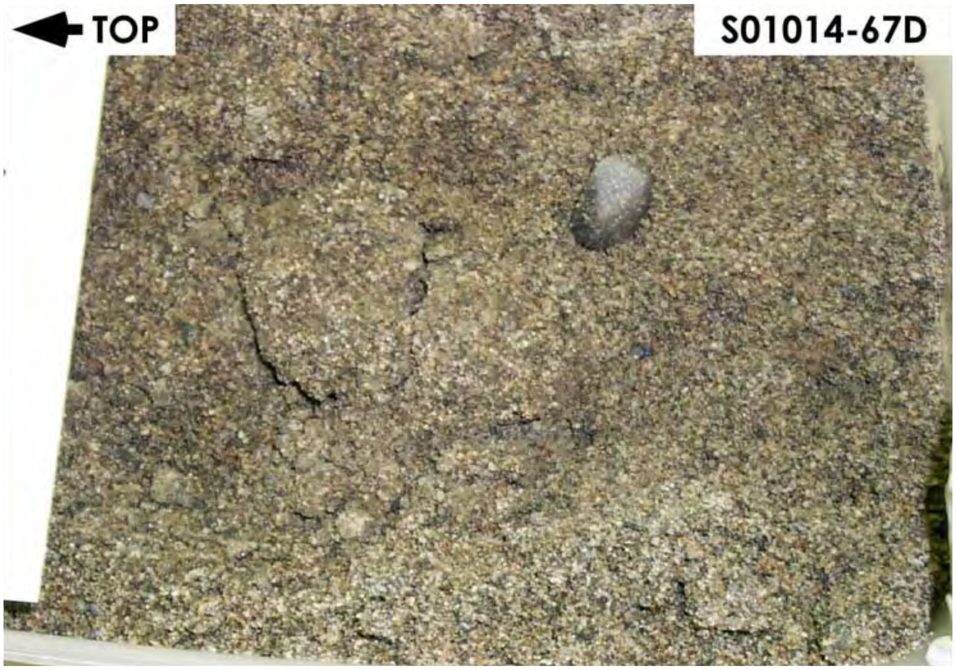


Figure B.65. Sample S01014-67D from a Depth of 139.50 ft to 140.00 ft bgs in the H2-Sand Sequence

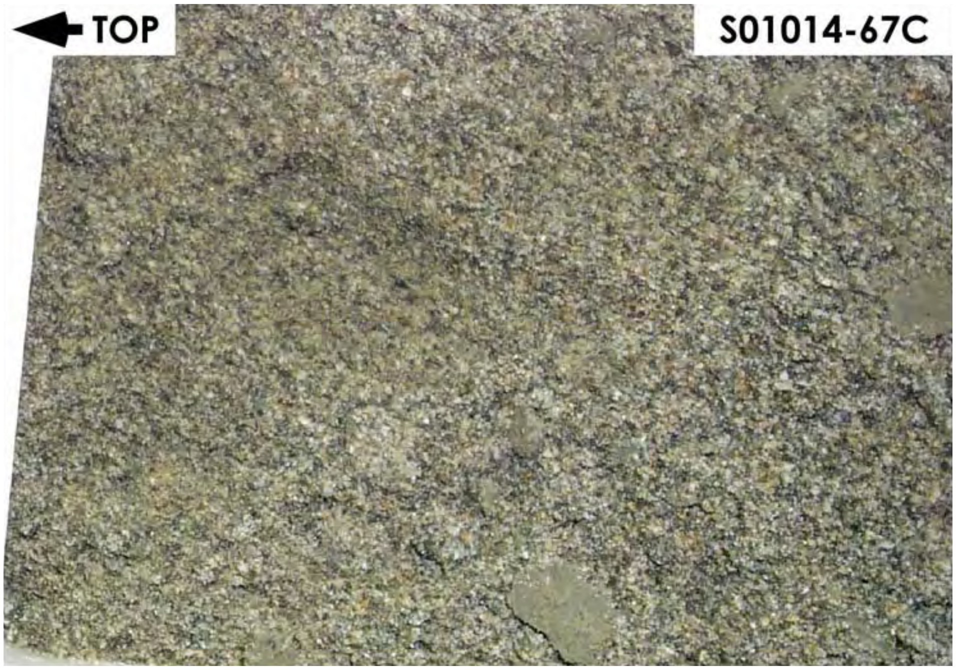


Figure B.66. Sample S01014-67C from a Depth of 140.00 ft to 140.50 ft bgs in the H2-Sand Sequence

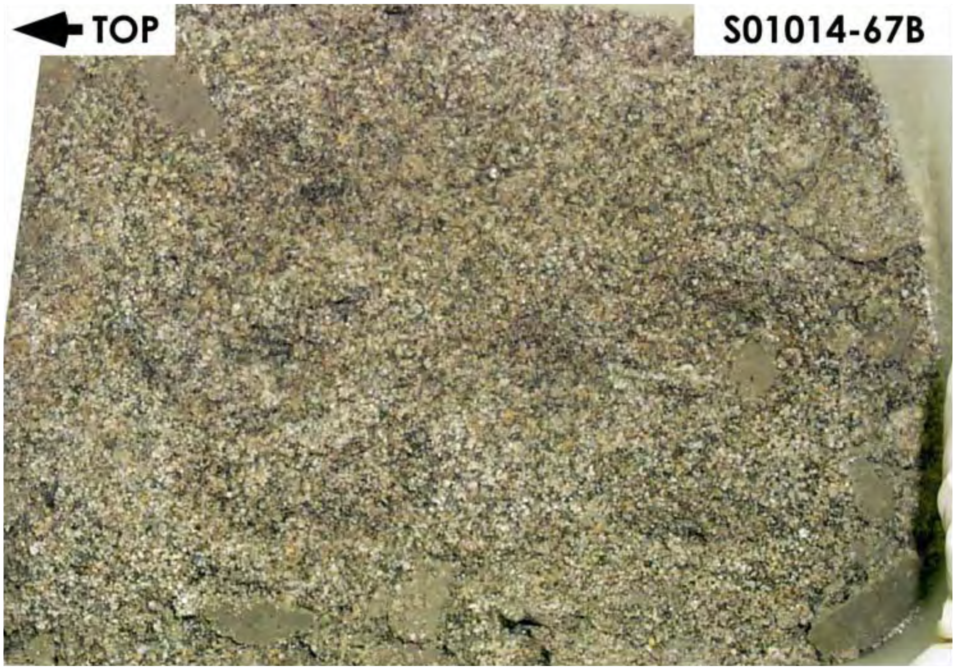


Figure B.67. Sample S01014-67B from a Depth of 140.50 ft to 141.00 ft bgs in the H2-Sand Sequence

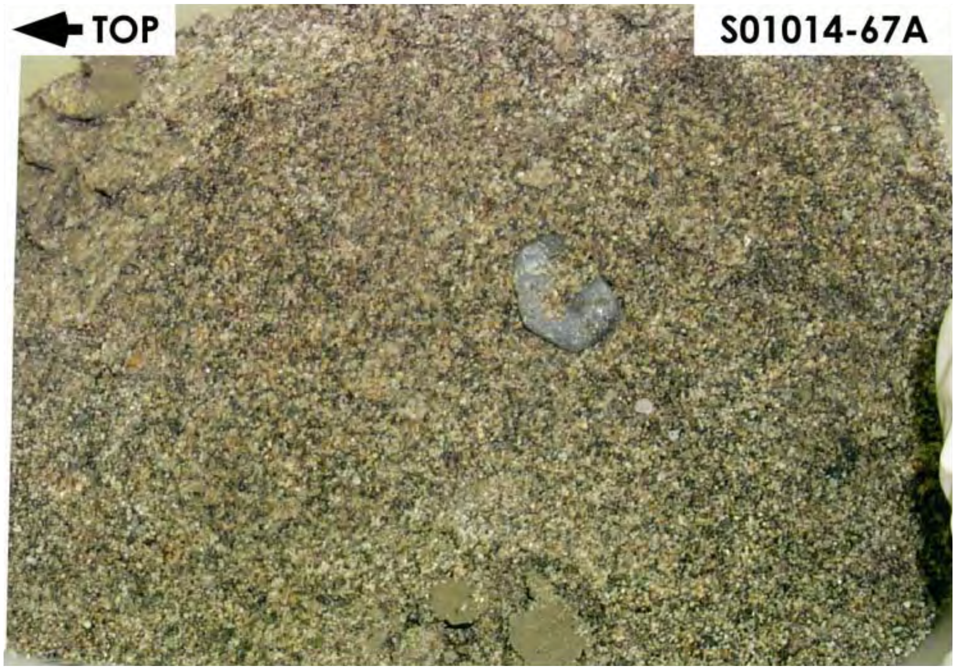


Figure B.68. Sample S01014-67A from a Depth of 141.00 ft to 141.50 ft bgs in the H2-Sand Sequence

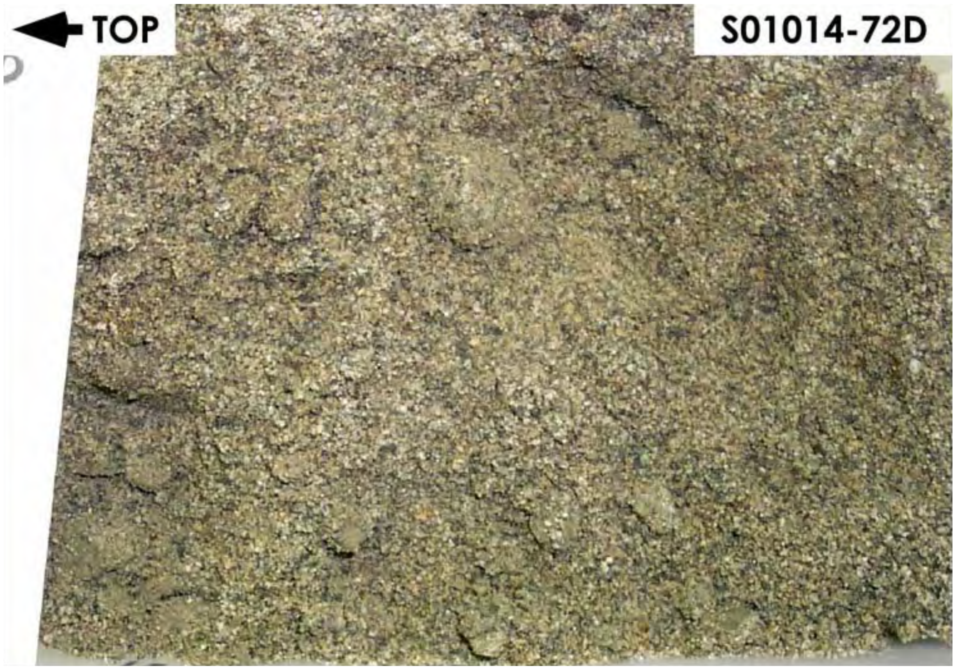


Figure B.69. Sample S01014-72D from a Depth of 149.80 ft to 150.30 ft bgs in the H2-Sand Sequence

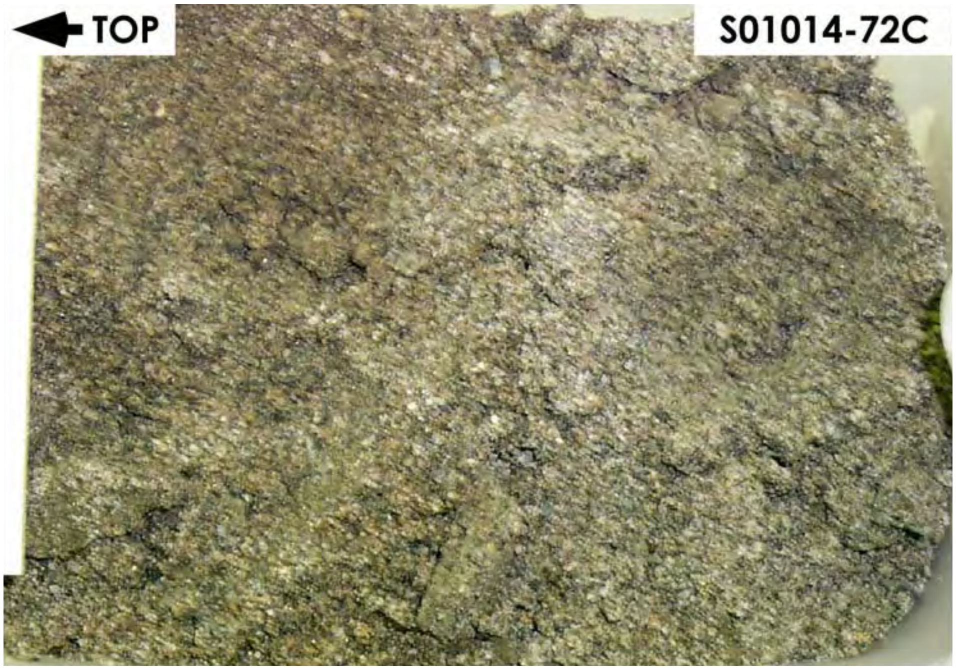


Figure B.70. Sample S01014-72C from a Depth of 150.30 ft to 150.80 ft bgs in the H2-Sand Sequence

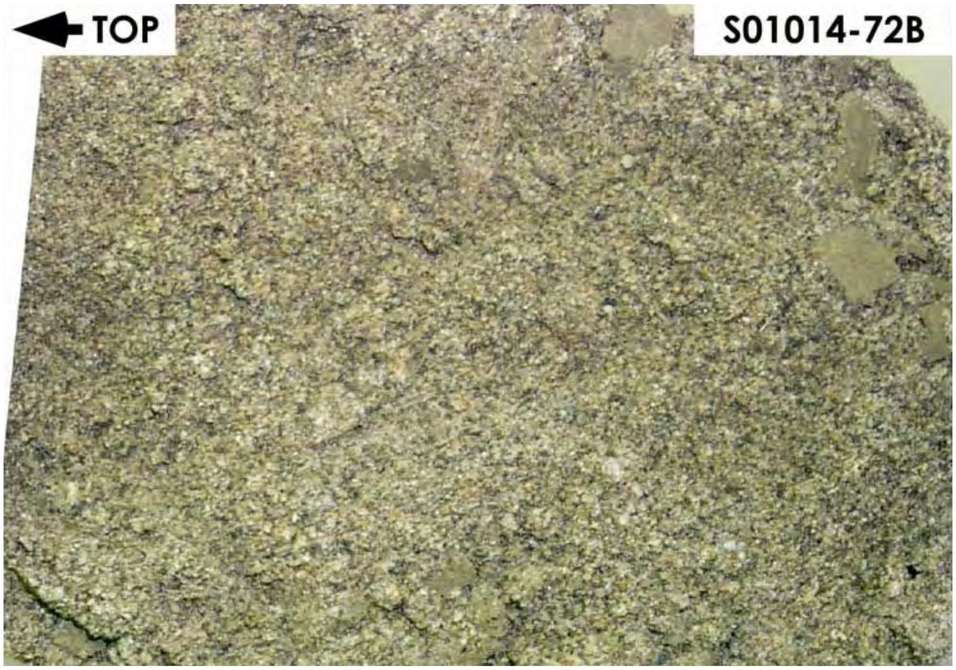


Figure B.71. Sample S01014-72B from a Depth of 150.80 ft to 151.30 ft bgs in the H2-Sand Sequence

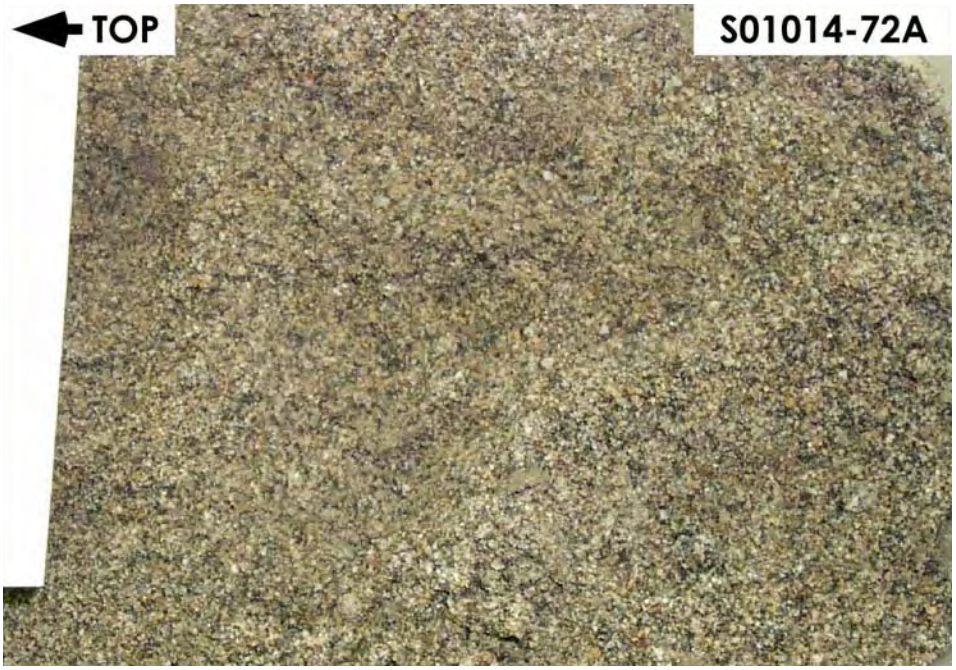


Figure B.72. Sample S01014-72A from a Depth of 151.30 ft to 151.80 ft bgs in the H2-Sand Sequence

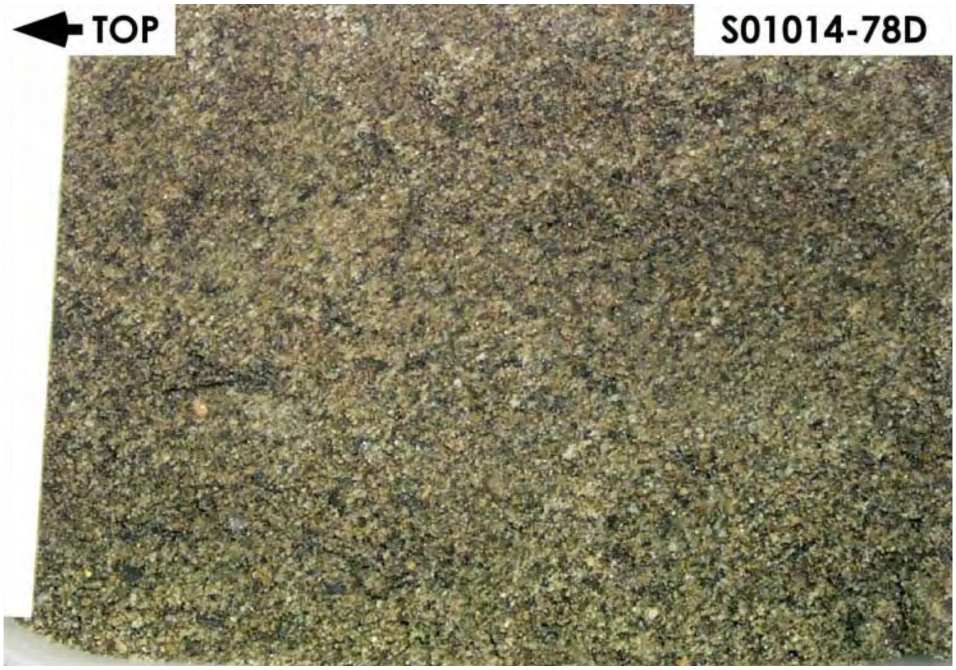


Figure B.73. Sample S01014-78D from a Depth of 159.10 ft to 159.60 ft bgs in the H2-Sand Sequence

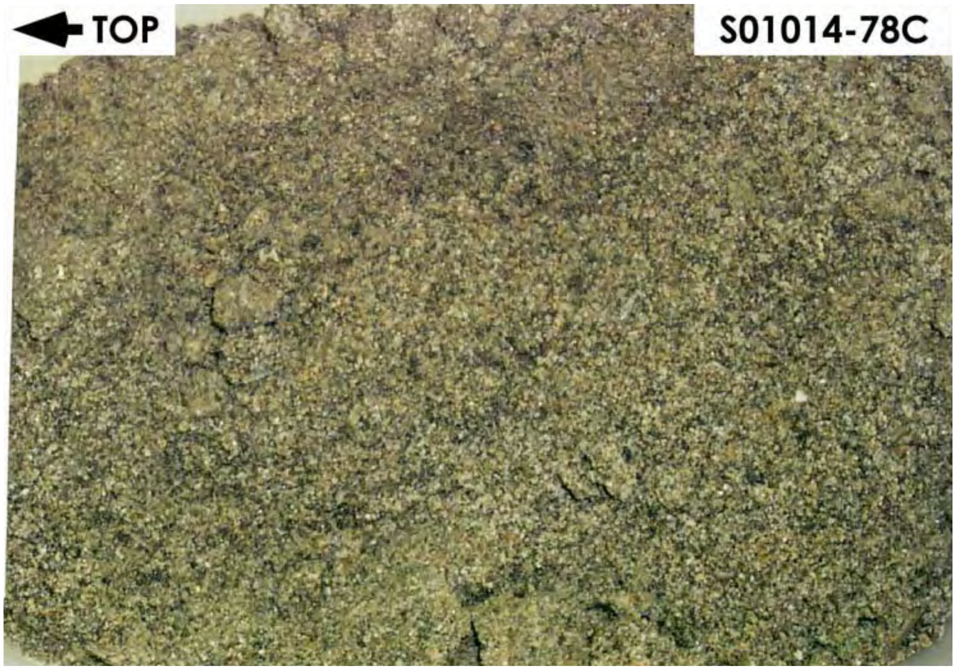


Figure B.74. Sample S01014-78C from a Depth of 159.60 ft to 160.10 ft bgs in the H2-Sand Sequence

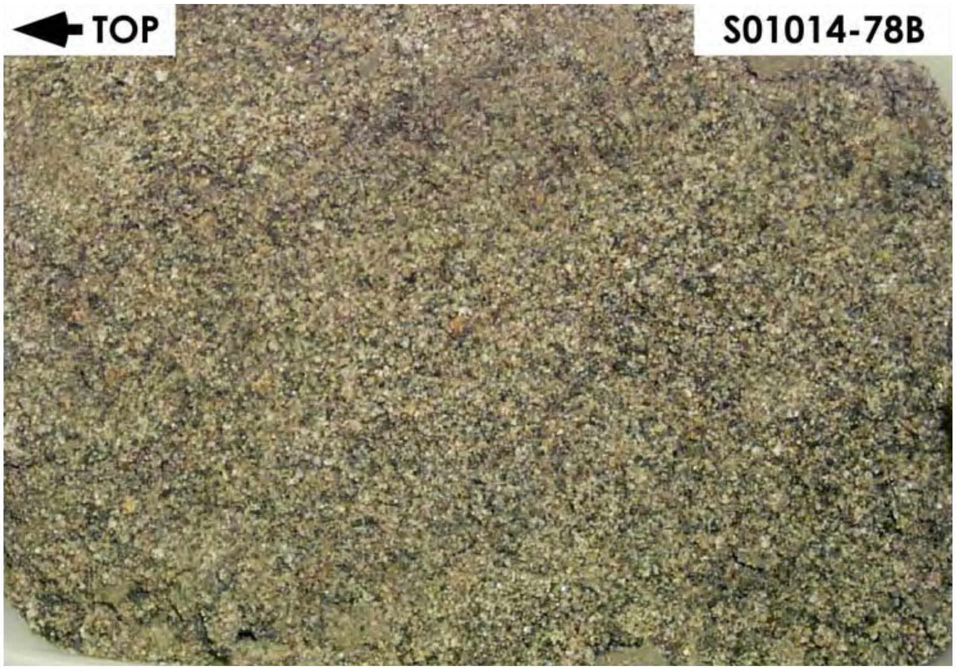


Figure B.75. Sample S01014-78B from a Depth of 160.10 ft to 160.60 ft bgs in the H2-Sand Sequence

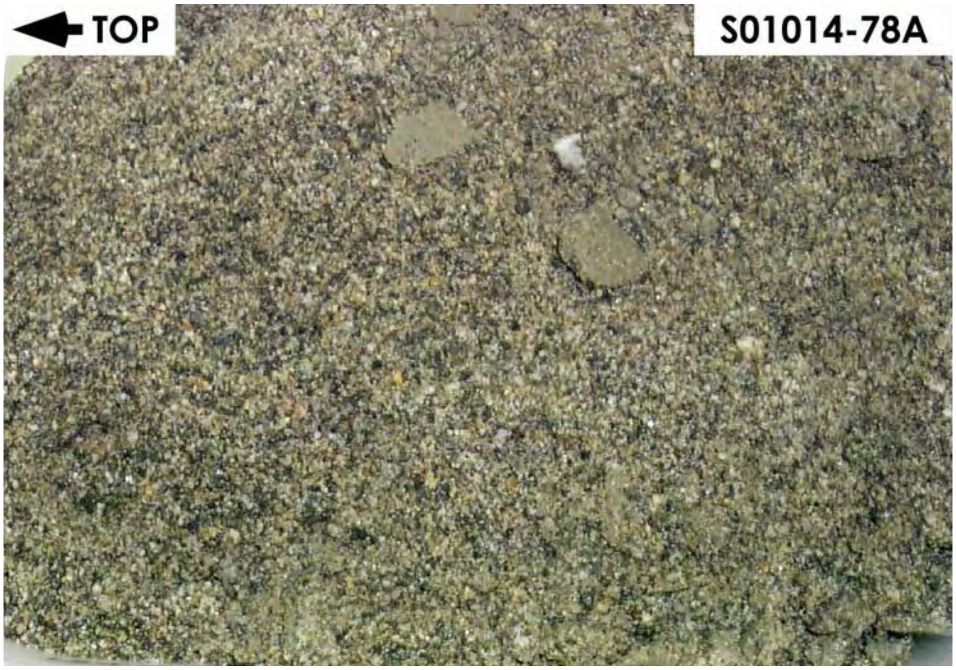


Figure B.76. Sample S01014-78A from a Depth of 160.60 ft to 161.10 ft bgs in the H2-Sand Sequence

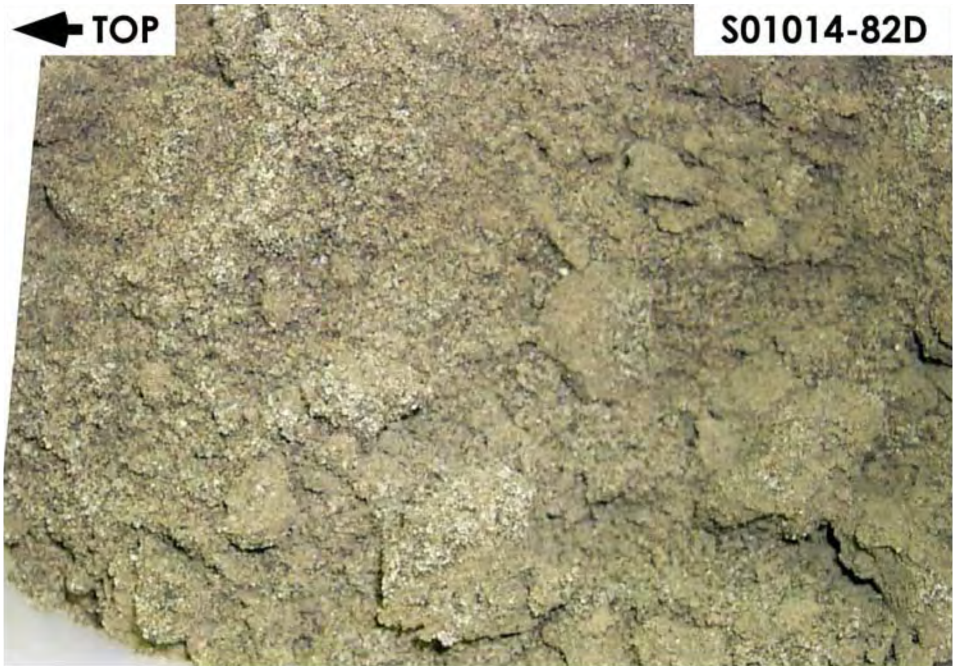


Figure B.77. Sample S01014-82D from a Depth of 166.90 ft to 167.40 ft bgs in the H2-Sand Sequence

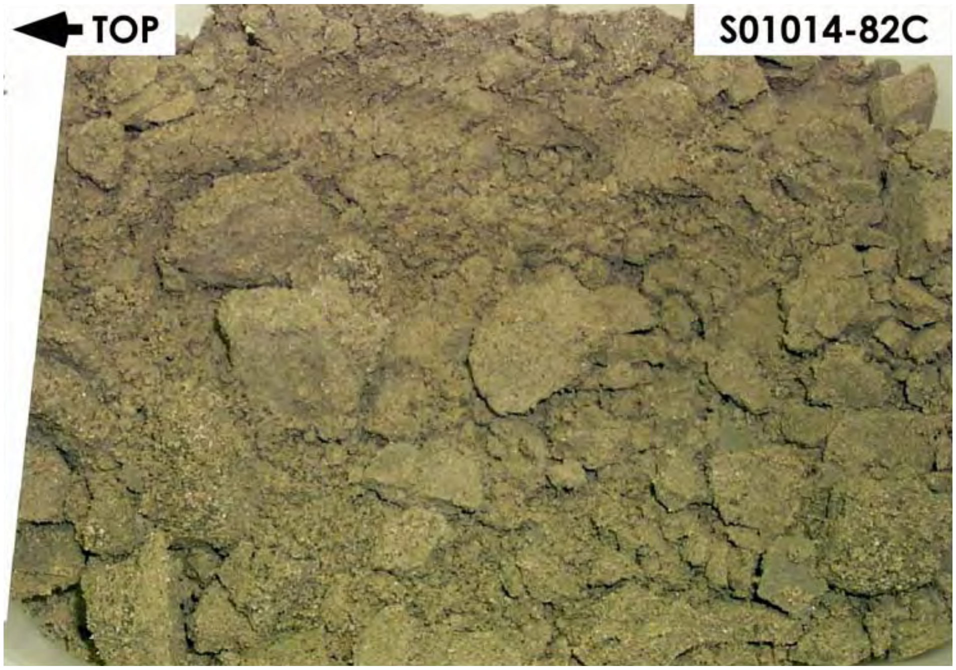


Figure B.78. Sample S01014-82C from a Depth of 167.40 ft to 167.90 ft bgs in the H2- Fine to Very Fine Sand Layer

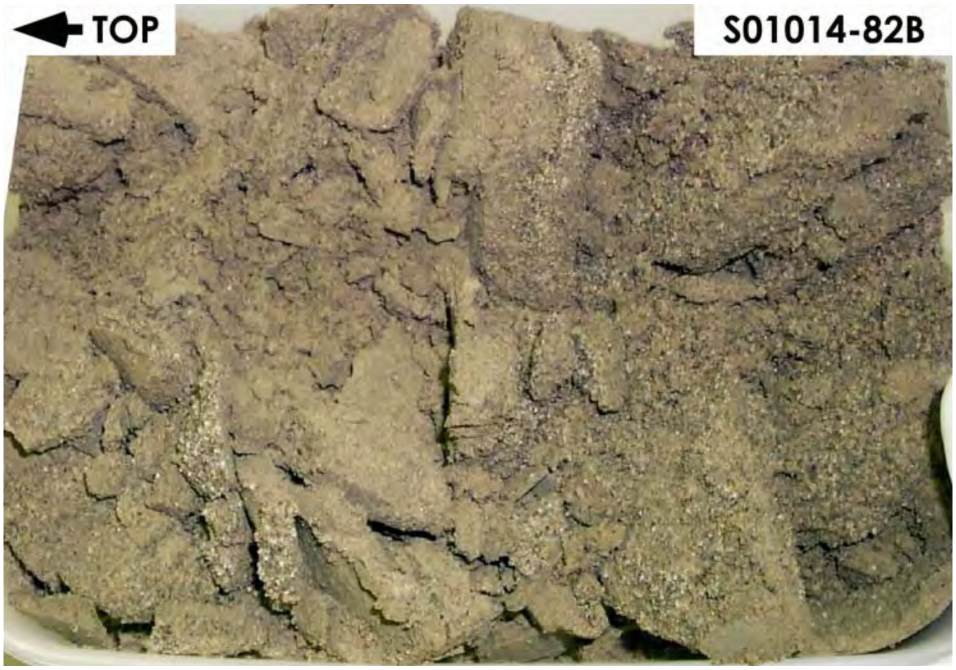


Figure B.79. Sample S01014-82B from a Depth of 167.90 ft to 168.40 ft bgs in the H2- Fine to Very Fine Sand Layer - Contact - Sand Sequence

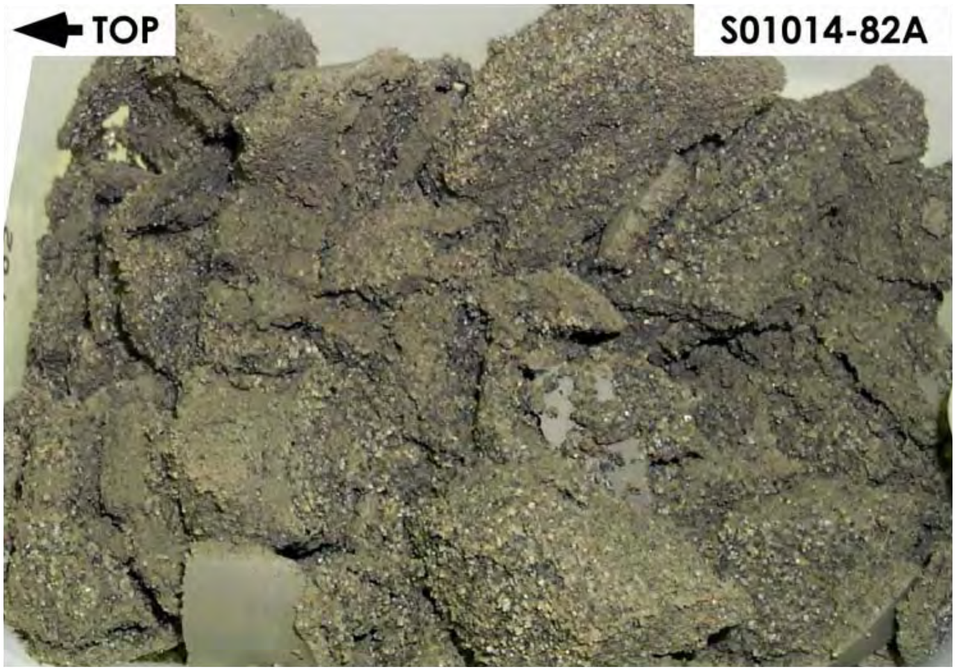


Figure B.80. Sample S01014-82A from a Depth of 168.40 ft to 168.90 ft bgs in the H2-Sand Sequence

Figure B.81. Sample S01014-83D from a Depth of 169.30 ft to 169.80 ft bgs in the H2-Sand Sequence

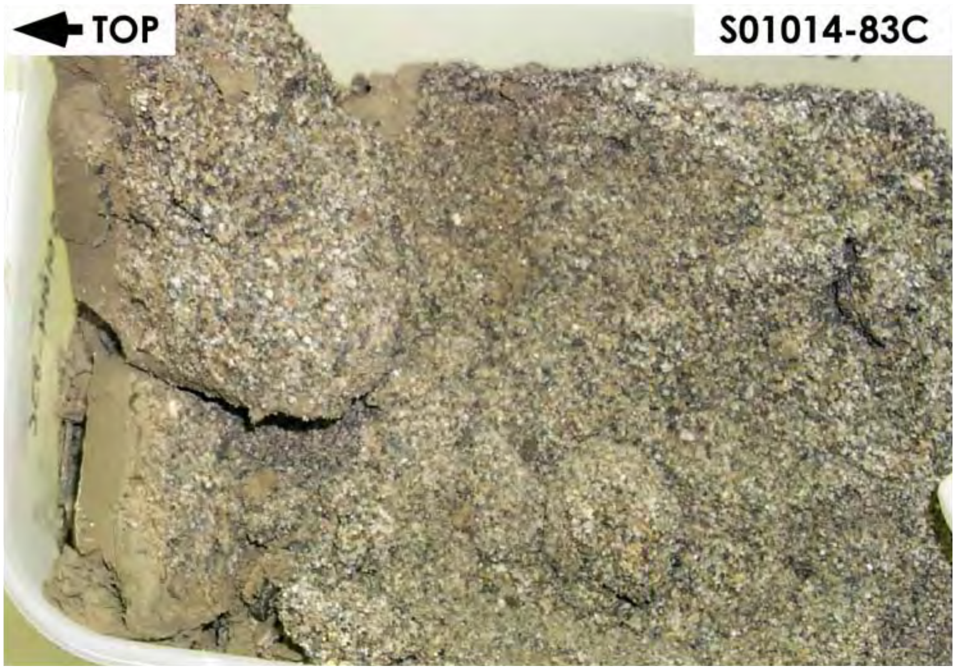


Figure B.82. Sample S01014-83C from a Depth of 169.80 ft to 170.30 ft bgs in the H3-Lower Sand and Gravel Sequence

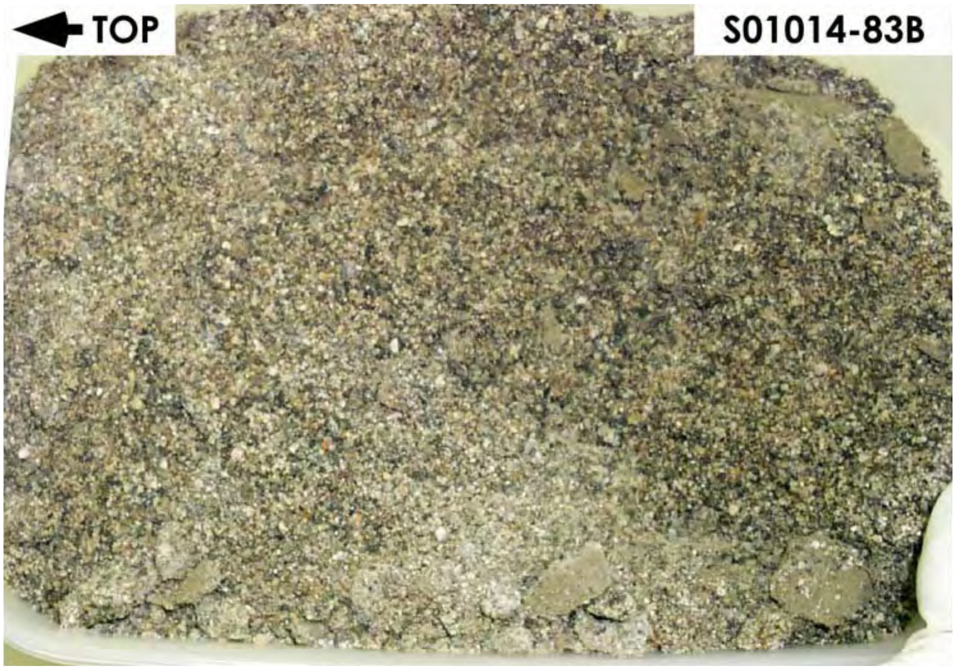


Figure B.83. Sample S01014-83B from a Depth of 170.30 ft to 170.80 ft bgs in the H3-Lower Sand and Gravel Sequence

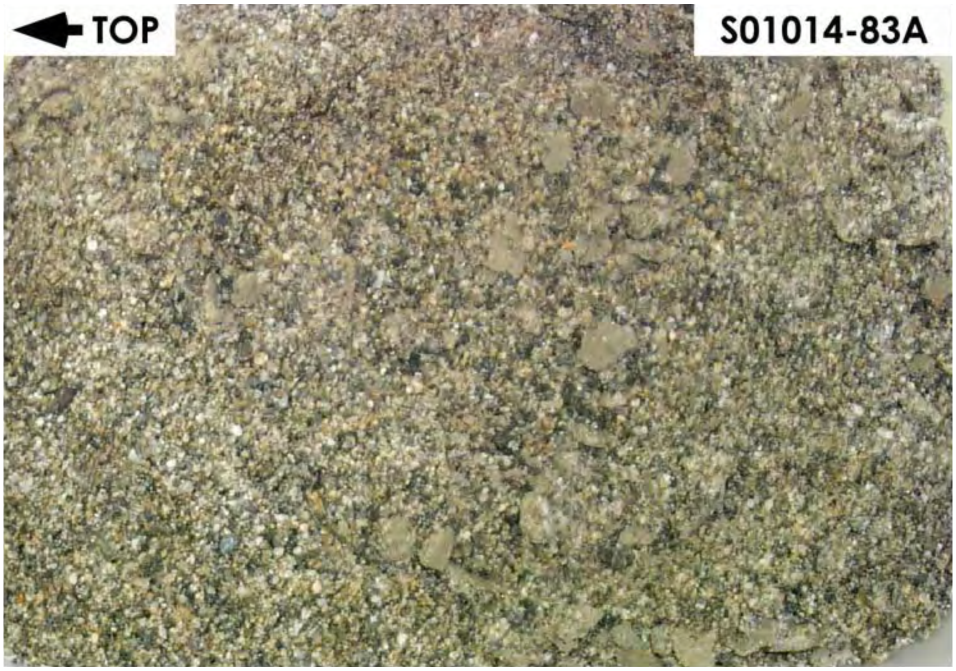


Figure B.84. Sample S01014-83A from a Depth of 170.80 ft to 171.30 ft bgs in the H3-Lower Sand and Gravel Sequence

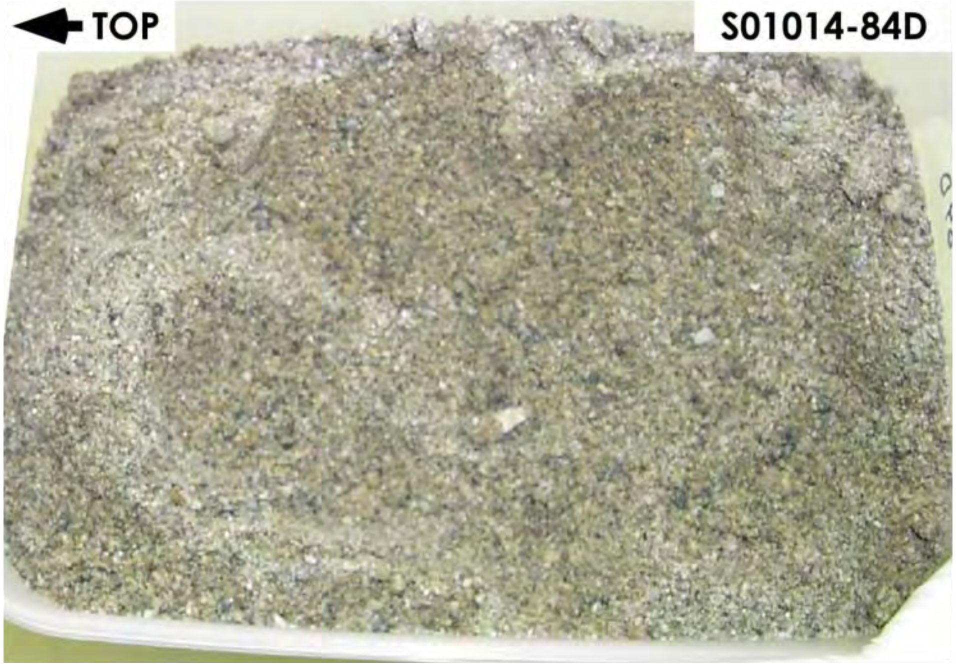


Figure B.85. Sample S01014-84D from a Depth of 171.60 ft to 172.10 ft bgs in the H3-Lower Sand and Gravel Sequence

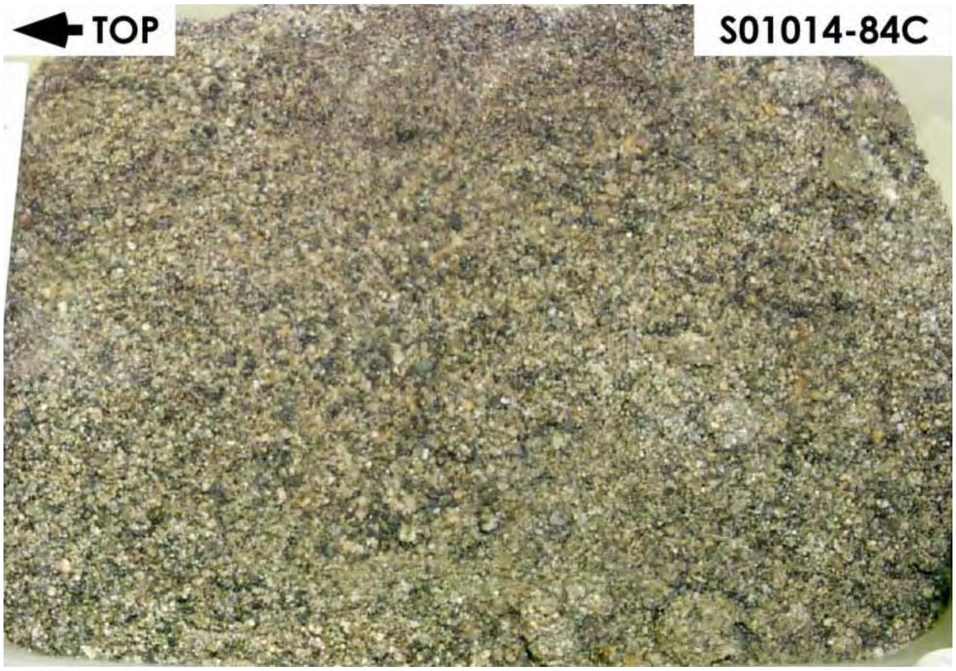


Figure B.86. Sample S01014-84C from a Depth of 172.10 ft to 172.60 ft bgs in the H3-Lower Sand and Gravel Sequence

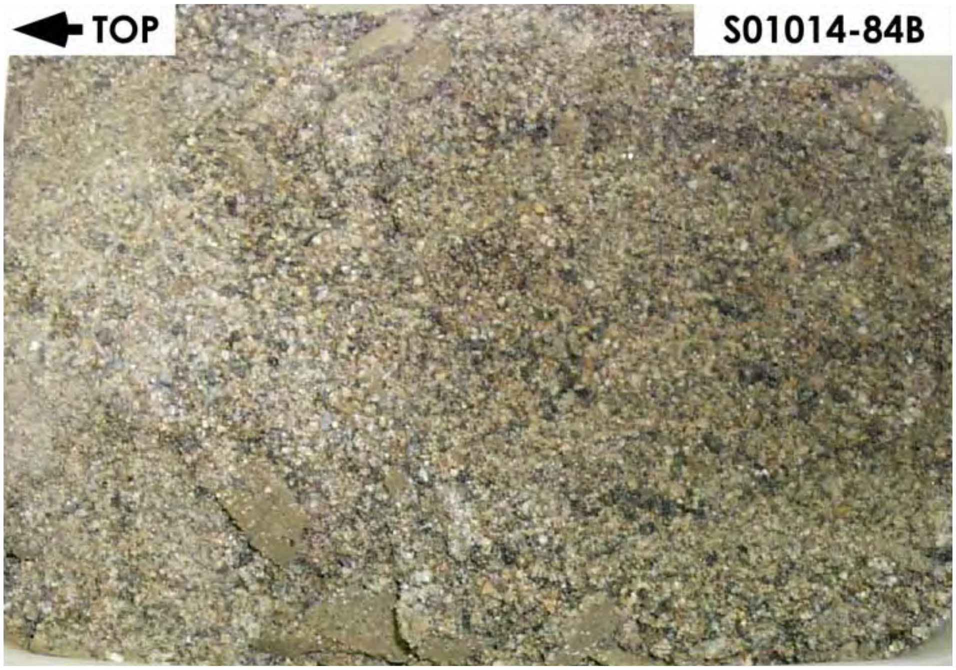


Figure B.87. Sample S01014-84B from a Depth of 172.60 ft to 173.10 ft bgs in the H3-Lower Sand and Gravel Sequence

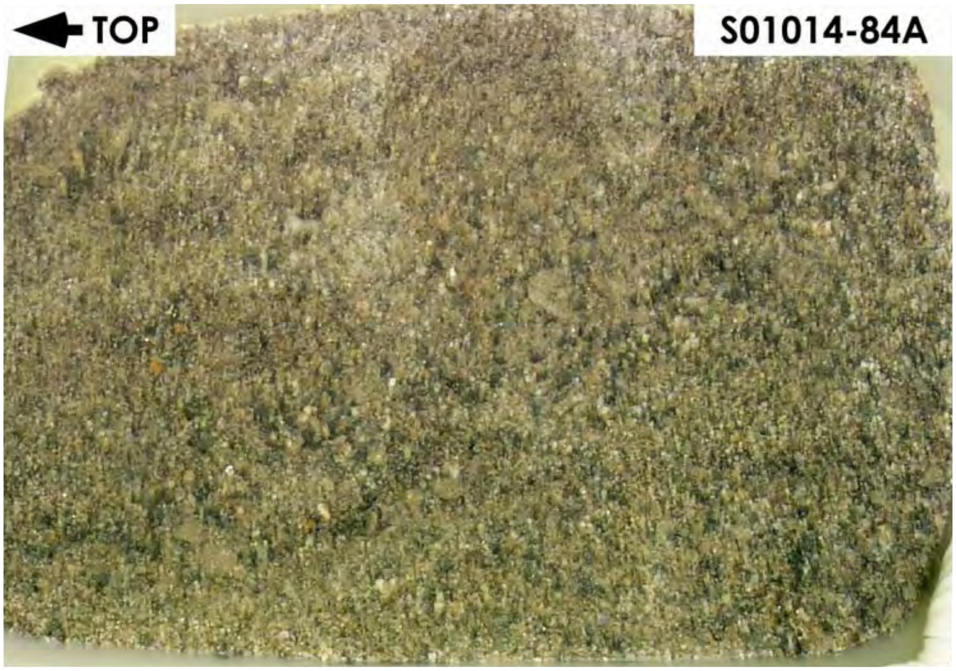


Figure B.88. Sample S01014-84A from a Depth of 173.10 ft to 173.60 ft bgs in the H3-Lower Sand and Gravel Sequence

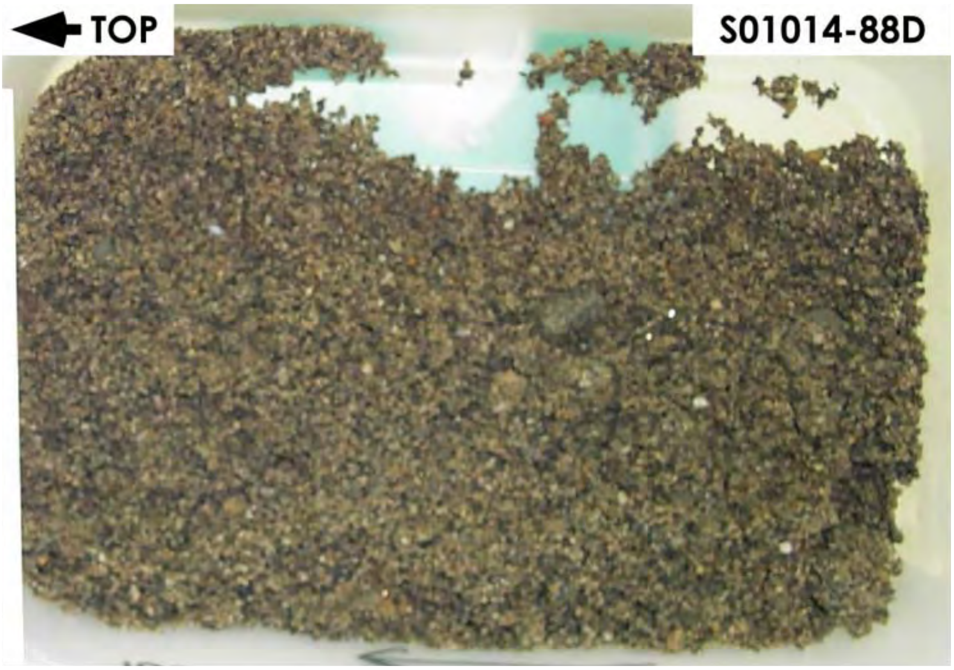


Figure B.89. Sample S01014-88D from a Depth of 179.90 ft to 180.40 ft bgs in the H3-Lower Sand and Gravel Sequence

Figure B.90. Sample S01014-88C from a Depth of 180.40 ft to 180.90 ft bgs in the H3-Lower Sand and Gravel Sequence

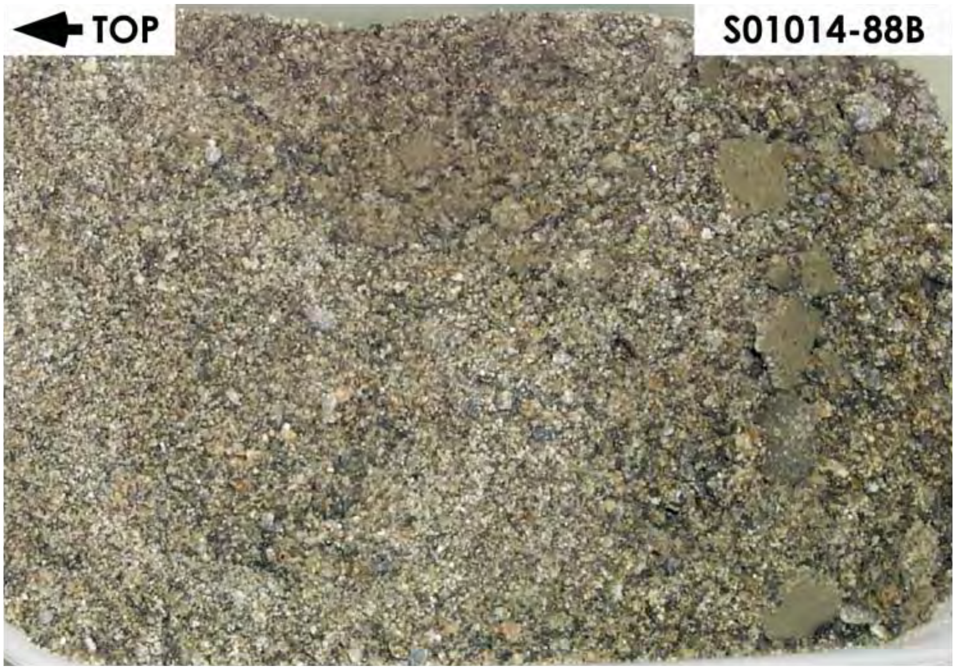


Figure B.91. Sample S01014-88B from a Depth of 180.90 ft to 181.40 ft bgs in the H3-Lower Sand and Gravel Sequence

Figure B.92. Sample S01014-88A from a Depth of 181.40 ft to 181.90 ft bgs in the H3-Lower Sand and Gravel Sequence

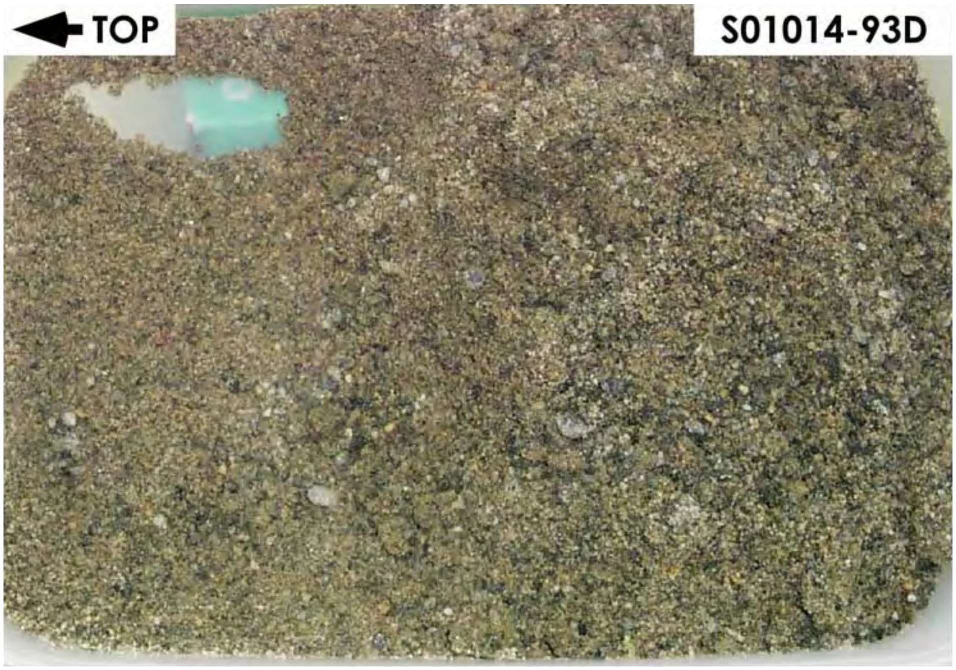


Figure B.93. Sample S01014-93D from a Depth of 188.90 ft to 189.40 ft bgs in the H3-Lower Sand and Gravel Sequence

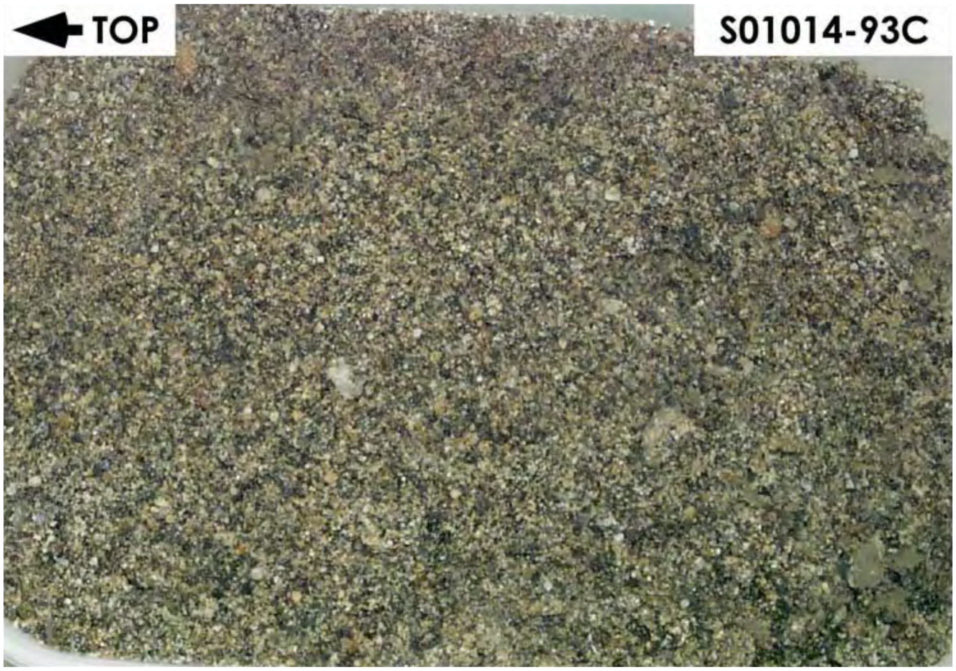


Figure B.94. Sample S01014-93C from a Depth of 189.40 ft to 189.90 ft bgs in the H3-Lower Sand and Gravel Sequence

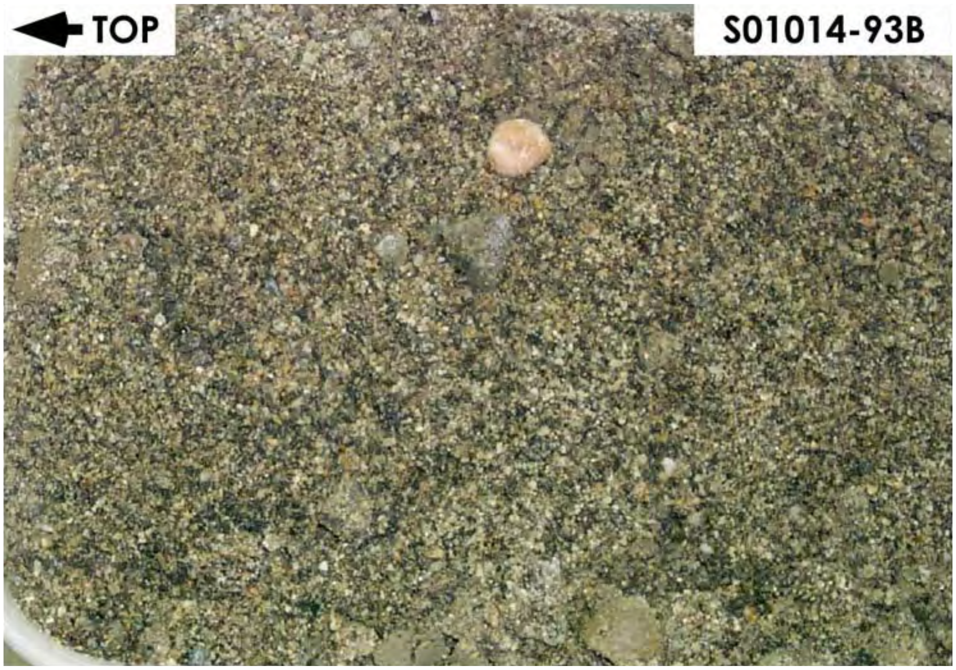


Figure B.95. Sample S01014-93B from a Depth of 189.90 ft to 190.40 ft bgs in the H3-Lower Sand and Gravel Sequence

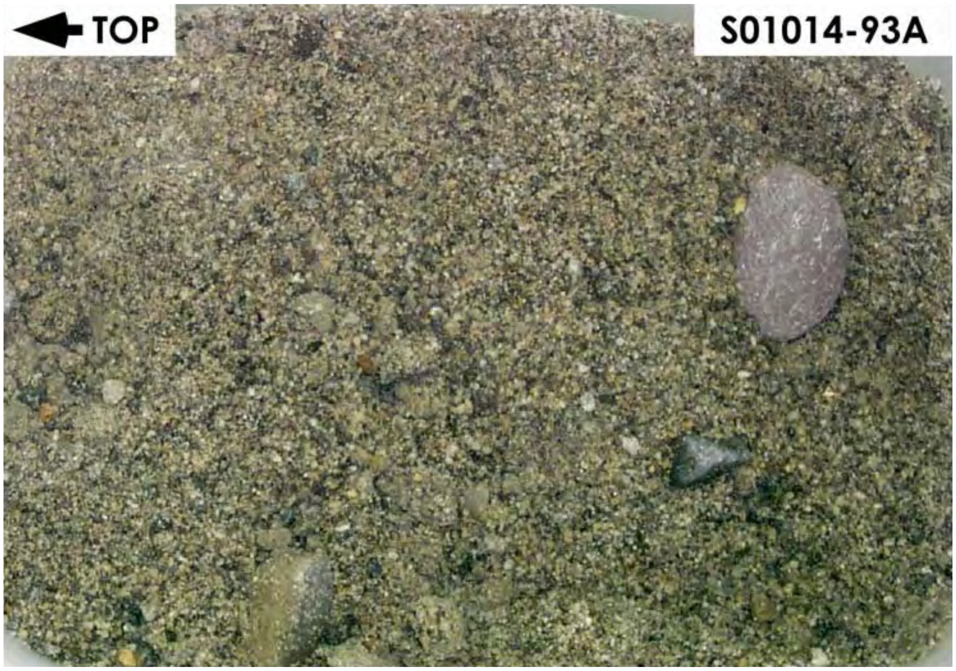


Figure B.96. Sample S01014-93A from a Depth of 190.40 ft to 190.90 ft bgs in the H3-Lower Sand and Gravel Sequence

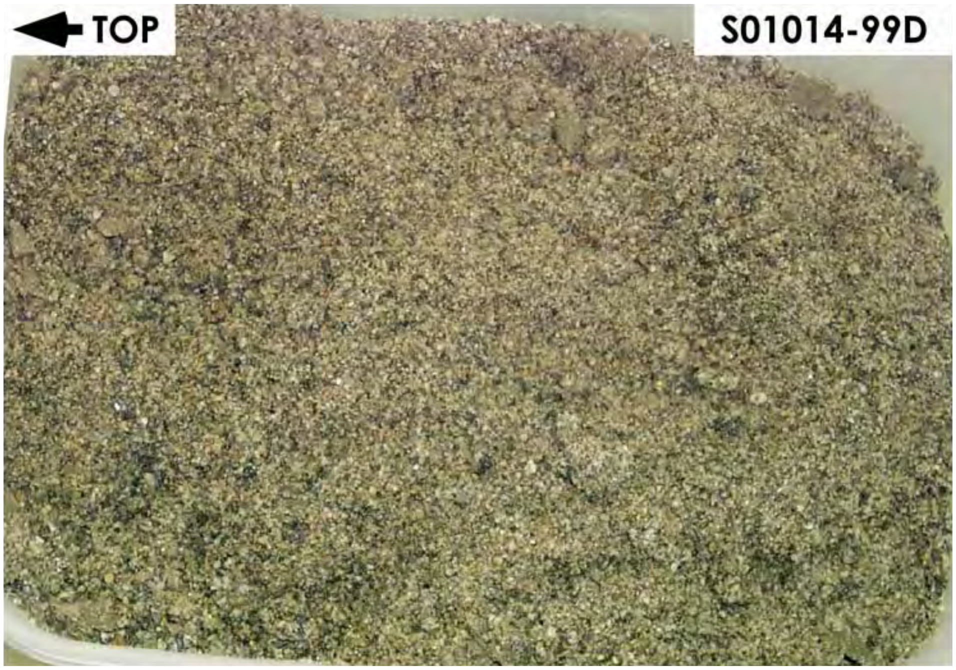


Figure B.97. Sample S01014-99D from a Depth of 199.60 ft to 200.10 ft bgs in the H3-Lower Sand and Gravel Sequence

Figure B.98. Sample S01014-99C from a Depth of 200.10 ft to 200.60 ft bgs in the H3-Lower Sand and Gravel Sequence

Figure B.99. Sample S01014-99B from a Depth of 200.60 ft to 201.10 ft bgs in the H3-Lower Sand and Gravel Sequence

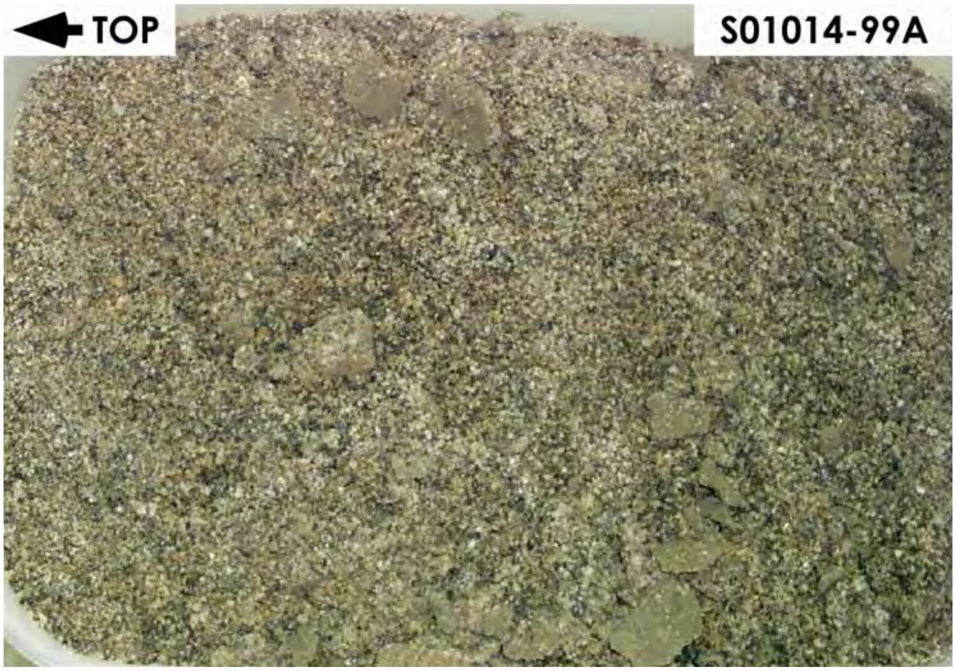


Figure B.100. Sample S01014-99A from a Depth of 201.10 ft to 201.60 ft bgs in the H3-Lower Sand and Gravel Sequence

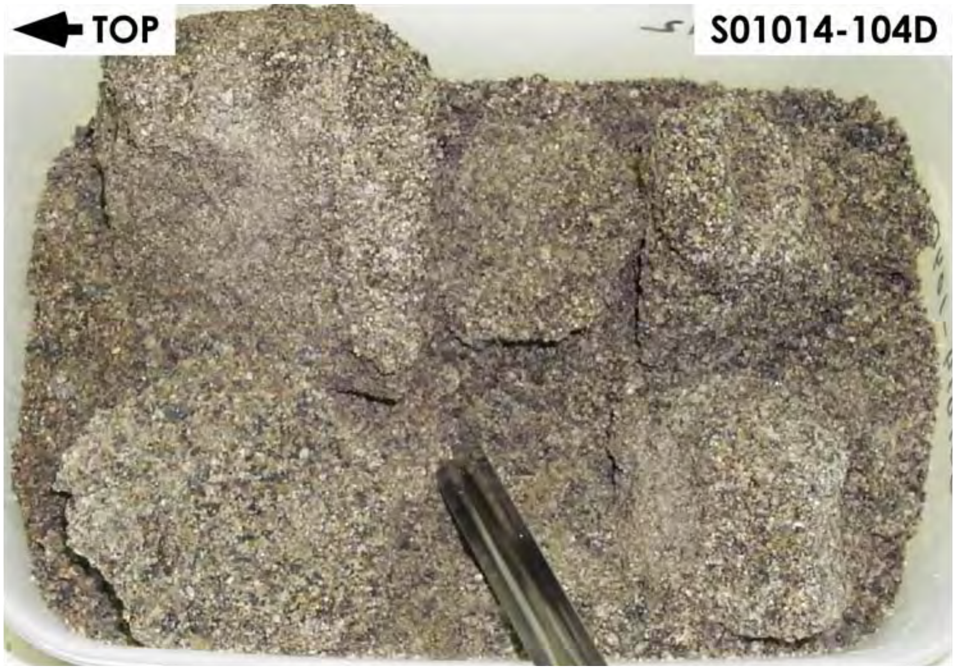


Figure B.101. Sample S01014-104D from a Depth of 209.67 ft to 210.17 ft bgs in the H3-Lower Sand and Gravel Sequence

Figure B.102. Sample S01014-104C from a Depth of 210.17 ft to 210.67 ft bgs in the H3-Lower Sand and Gravel Sequence

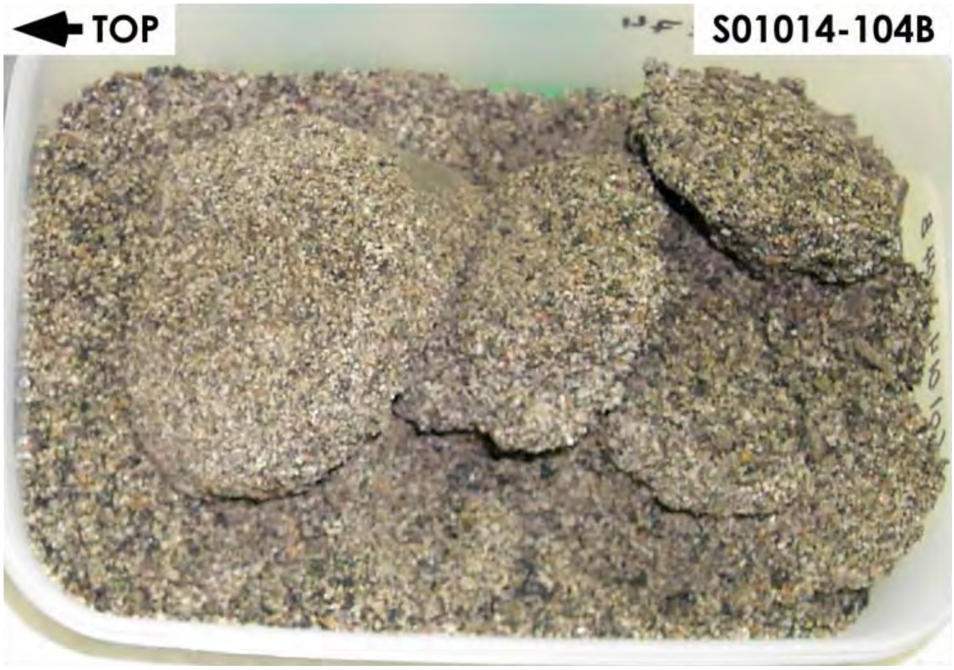


Figure B.103. Sample S01014-104B from a Depth of 210.67 ft to 211.17 ft bgs in the H3-Lower Sand and Gravel Sequence

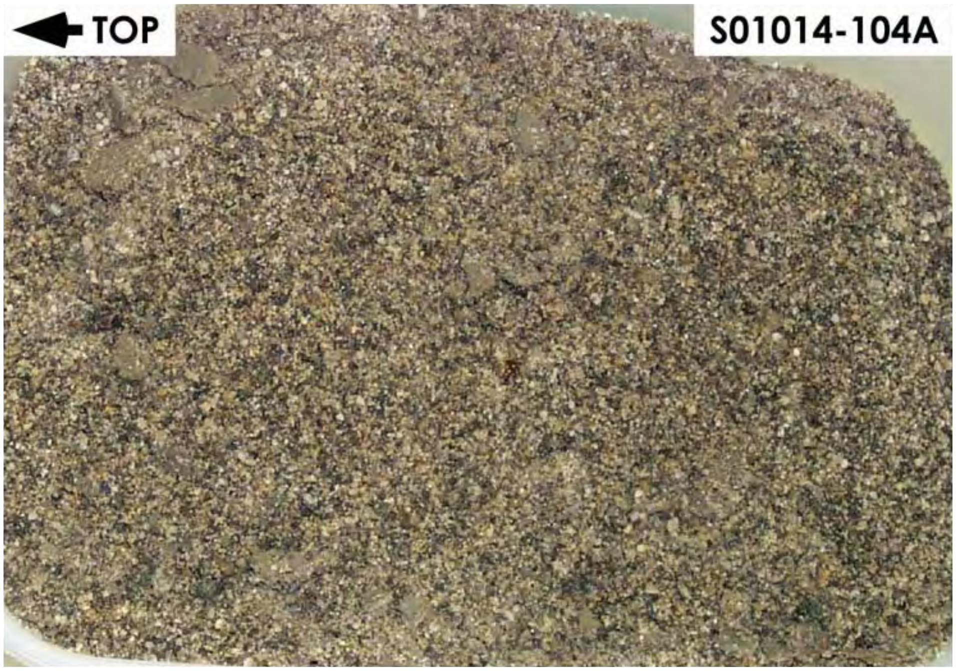


Figure B.104. Sample S01014-104A from a Depth of 211.17 ft to 211.67 ft bgs in the H3-Lower Sand and Gravel Sequence

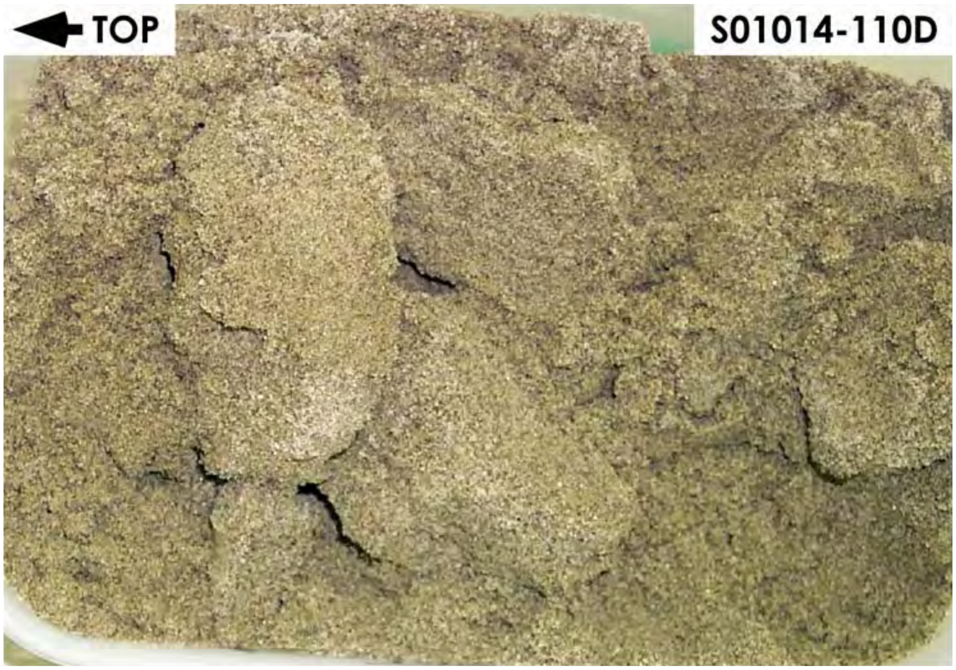


Figure B.105. Sample S01014-110D from a Depth of 217.70 ft to 218.20 ft bgs in the Hanford/Plio-Pleistocene (?) Unit

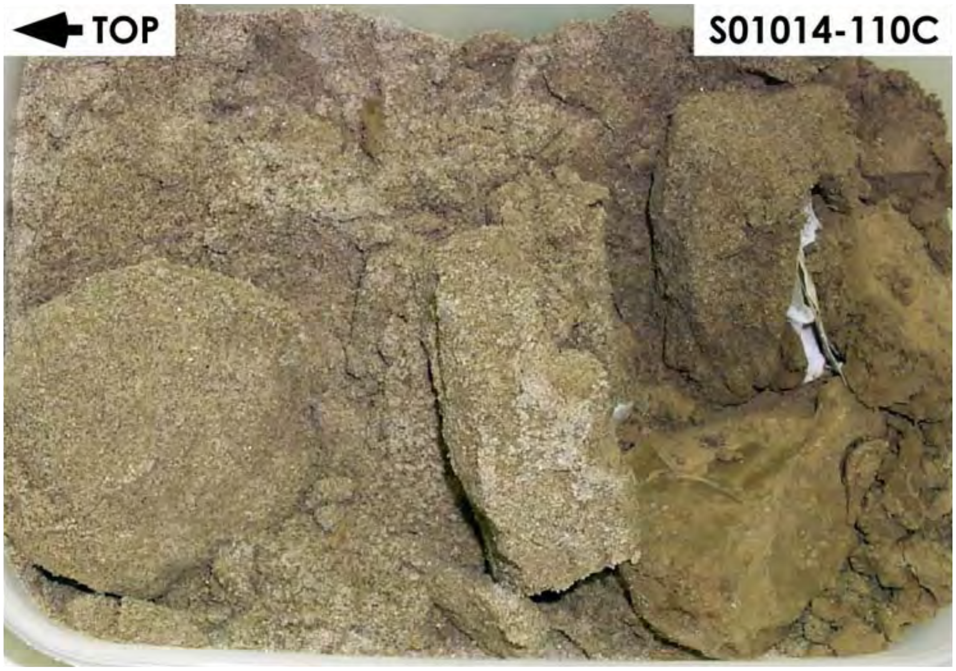


Figure B.106. Sample S01014-110C from a Depth of 218.20 ft to 218.70 ft bgs in the Plio-Pleistocene Silt Unit (PPlz)

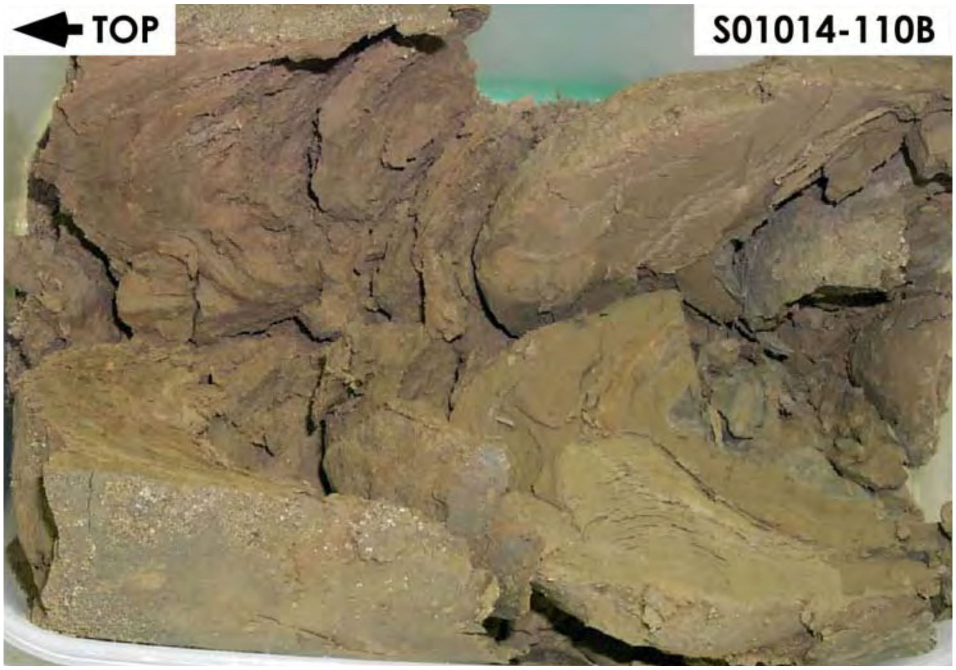


Figure B.107. Sample S01014-110B from a Depth of 218.70 ft to 219.20 ft bgs in the Plio-Pleistocene Silt Unit (PPlz)

Figure B.108. Sample S01014-110A from a Depth of 219.20 ft to 219.70 ft bgs in the Plio-Pleistocene Silt Unit (PPlz)

Figure B.109. Sample S01014-111D from a Depth of 220.00 ft to 220.50 ft bgs in the Plio-Pleistocene Silt Unit (PPlz)

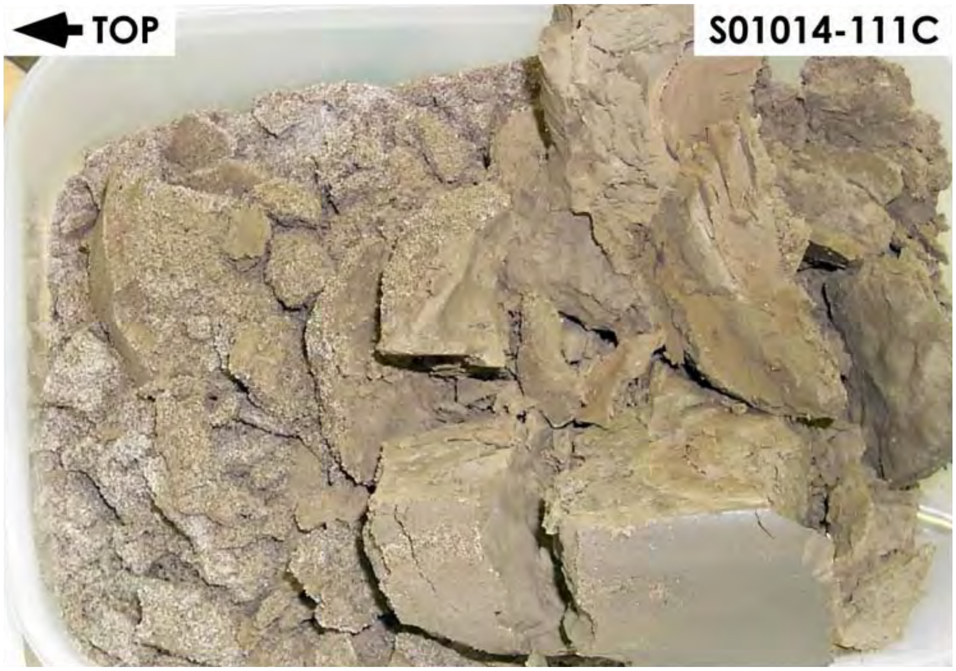


Figure B.110. Sample S01014-111C from a Depth of 220.50 ft to 221.00 ft bgs in the Plio-Pleistocene Silt Unit (PPlz)

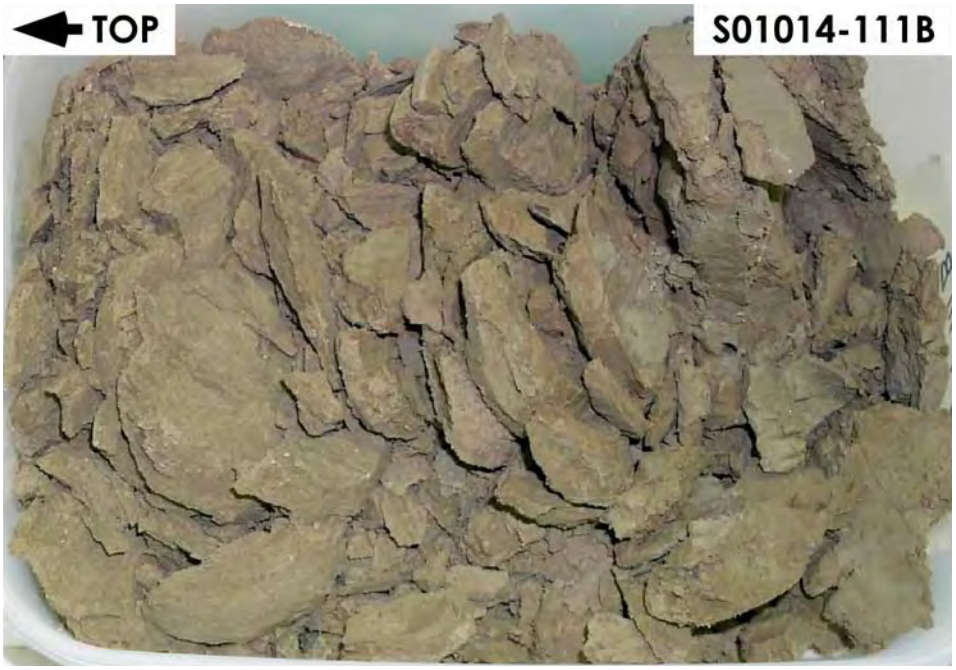


Figure B.111. Sample S01014-111B from a Depth of 221.00 ft to 221.50 ft bgs in the Plio-Pleistocene Silt Unit (PPlz)

Figure B.112. Sample S01014-111A from a Depth of 221.50 ft to 222.00 ft bgs in the Plio-Pleistocene Silt Unit (PPlz)

Figure B.113. Sample S01014-112D from a Depth of 221.90 ft to 222.40 ft bgs in the Plio-Pleistocene Silt Unit (PPlz)

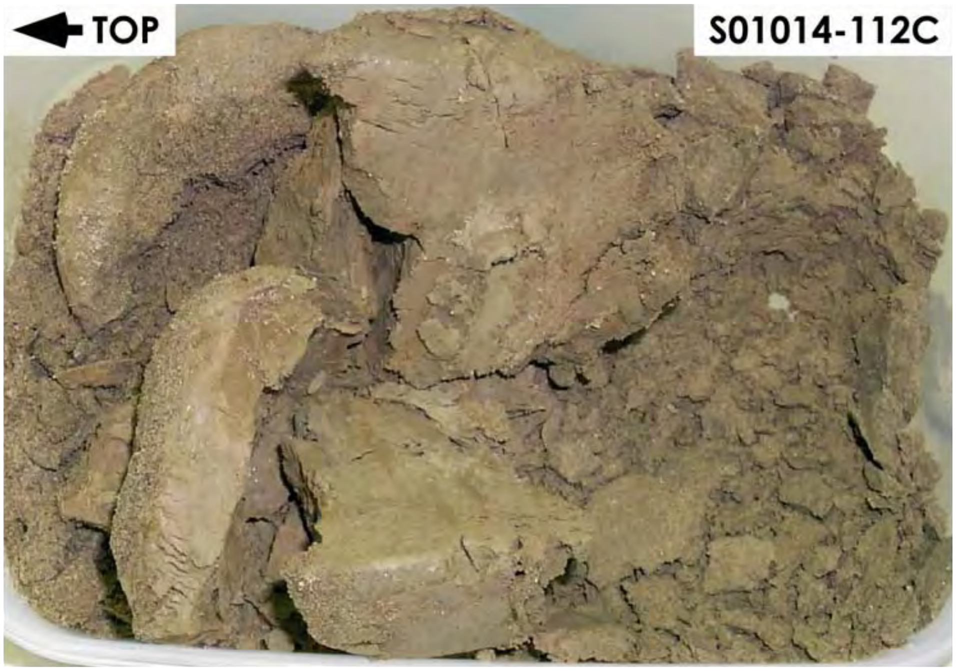


Figure B.114. Sample S01014-112C from a Depth of 222.40 ft to 222.90 ft bgs in the Plio-Pleistocene Silt Unit (PPlz)

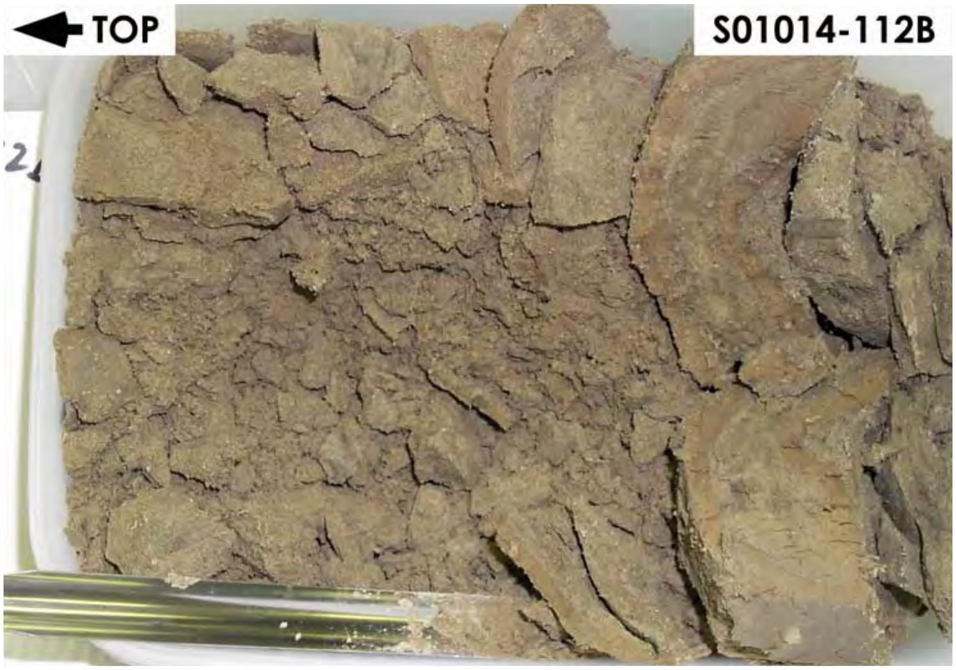


Figure B.115. Sample S01014-112B from a Depth of 222.90 ft to 223.40 ft bgs in the Plio-Pleistocene Silt Unit (PPlz)

Figure B.116. Sample S01014-112A from a Depth of 223.40 ft to 223.90 ft bgs in the Plio-Pleistocene Silt Unit (PPlz)

Figure B.117. Sample S01014-116D from a Depth of 229.70 ft to 230.20 ft bgs in the Plio-Pleistocene Silt Unit (PPlz)

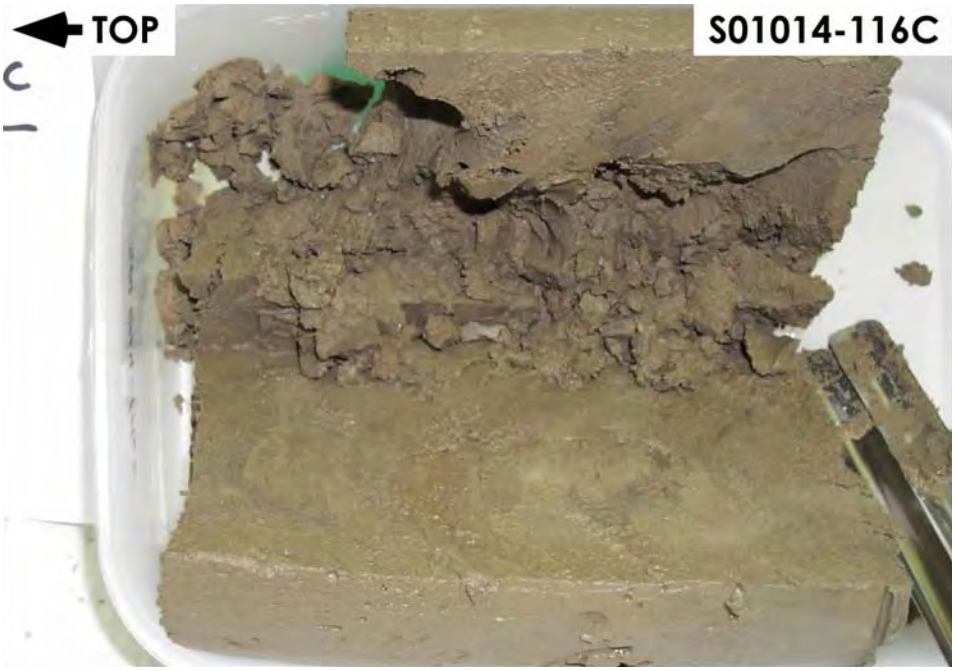


Figure B.118. Sample S01014-116C from a Depth of 230.20 ft to 230.70 ft bgs in the Plio-Pleistocene Silt Unit (PPlz)

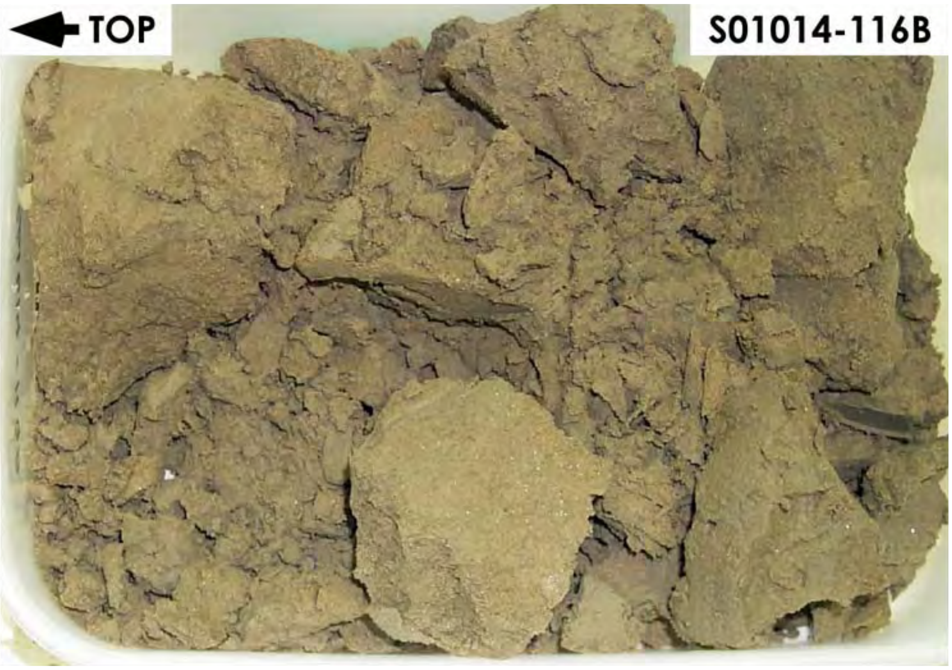


Figure B.119. Sample S01014-116B from a Depth of 230.70 ft to 231.20 ft bgs in the Plio-Pleistocene Silt Unit (PPlz)

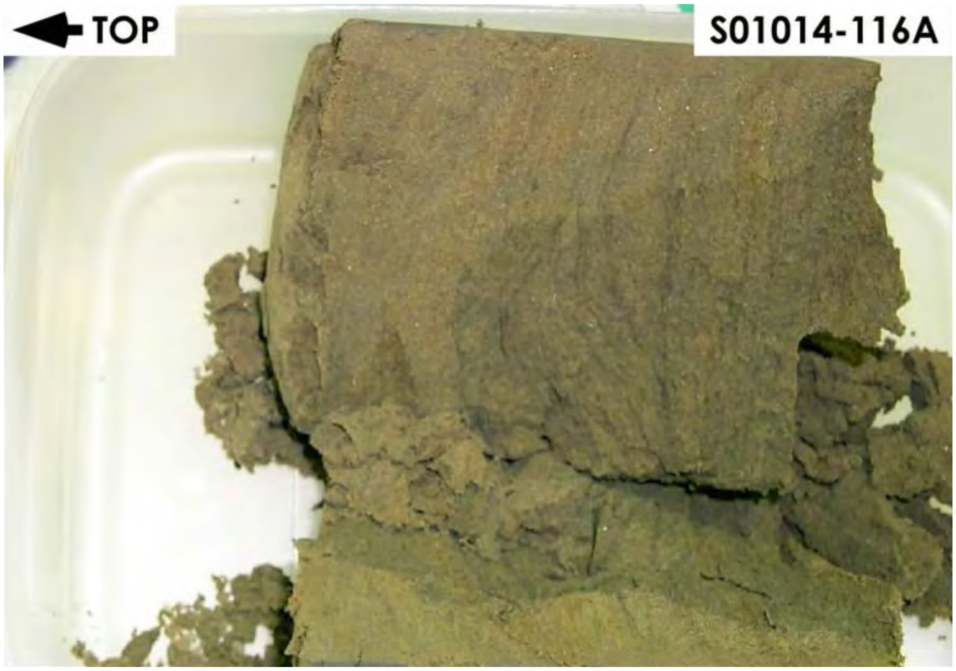


Figure B.120. Sample S01014-116A from a Depth of 231.20 ft to 231.70 ft bgs in the Plio-Pleistocene Silt Unit (PPlz)

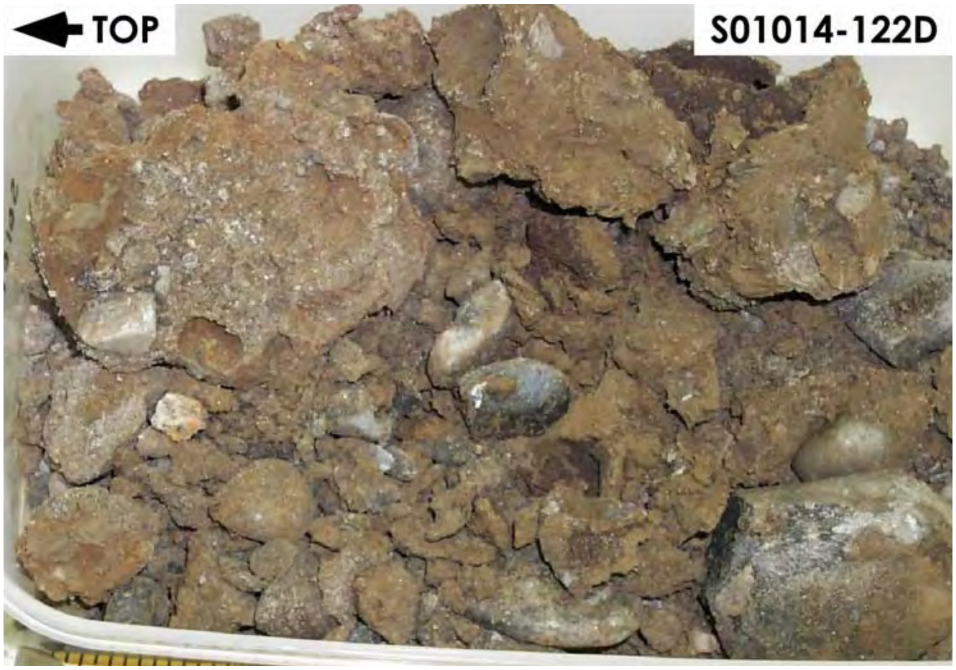


Figure B.121. Sample S01014-122D from a Depth of 240.14 ft to 240.64 ft bgs in the Plio-Pleistocene Gravel Unit (PPlg)

Figure B.122. Sample S01014-122C from a Depth of 240.64 ft to 241.14 ft bgs in the Plio-Pleistocene Gravel Unit (PPlg)

Figure B.123. Sample S01014-122B from a Depth of 241.14 ft to 241.64 ft bgs in the Plio-Pleistocene Gravel Unit (PPlg)

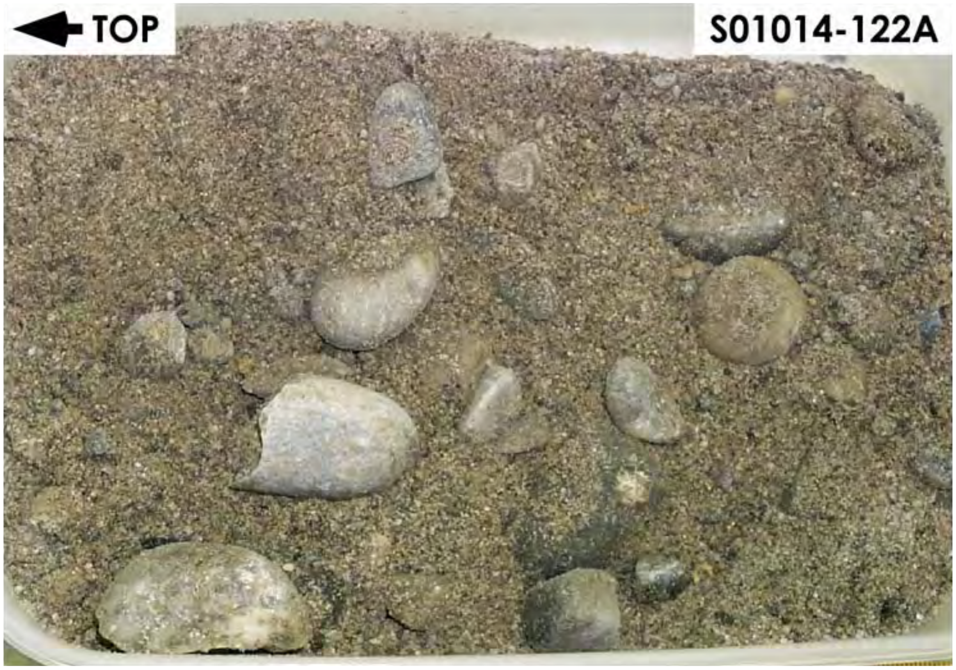


Figure B.124. Sample S01014-122A from a Depth of 241.64 ft to 242.14 ft bgs in the Plio-Pleistocene Gravel Unit (PPlg)

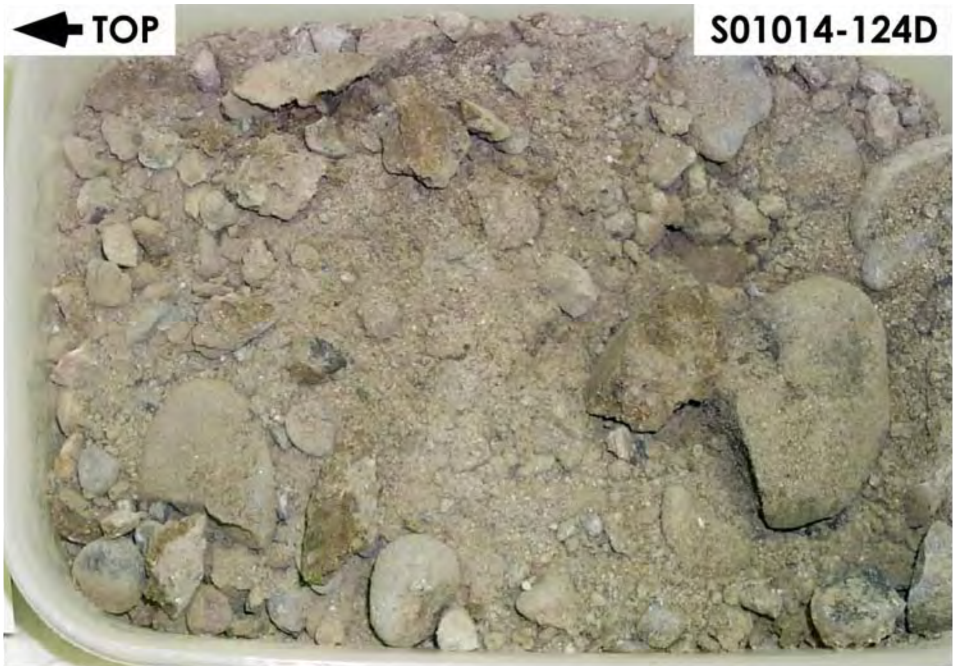


Figure B.125. Sample S01014-124D from a Depth of 243.50 ft to 244.00 ft bgs in the Plio-Pleistocene Gravel Unit (PPlg)

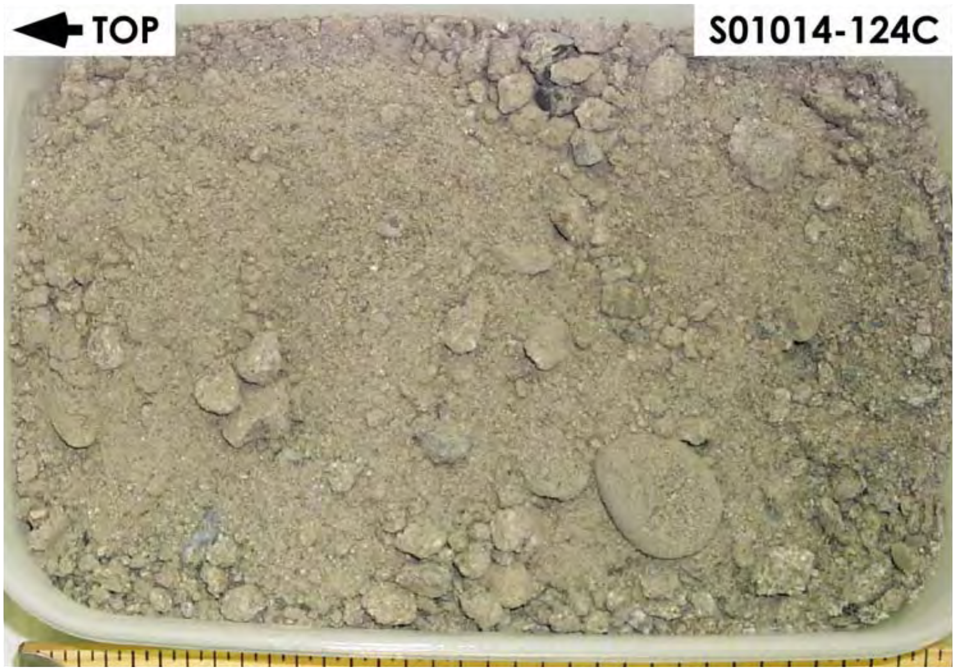


Figure B.126. Sample S01014-124C from a Depth of 244.00 ft to 244.50 ft bgs in the Plio-Pleistocene Gravel Unit (PPlg)

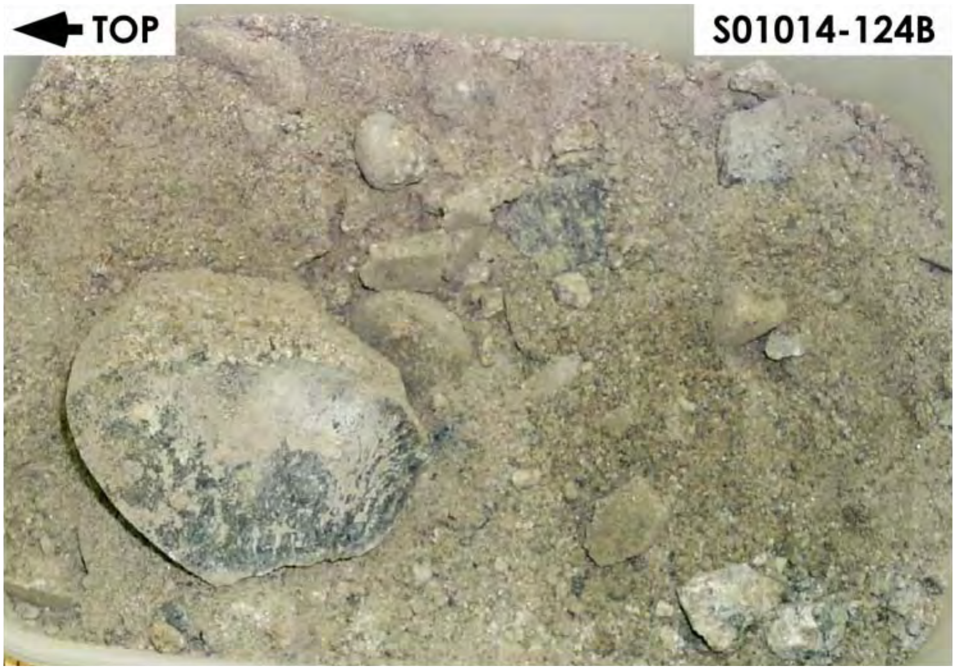


Figure B.127. Sample S01014-124B from a Depth of 244.50 ft to 245.00 ft bgs in the Plio-Pleistocene Gravel Unit (PPlg)

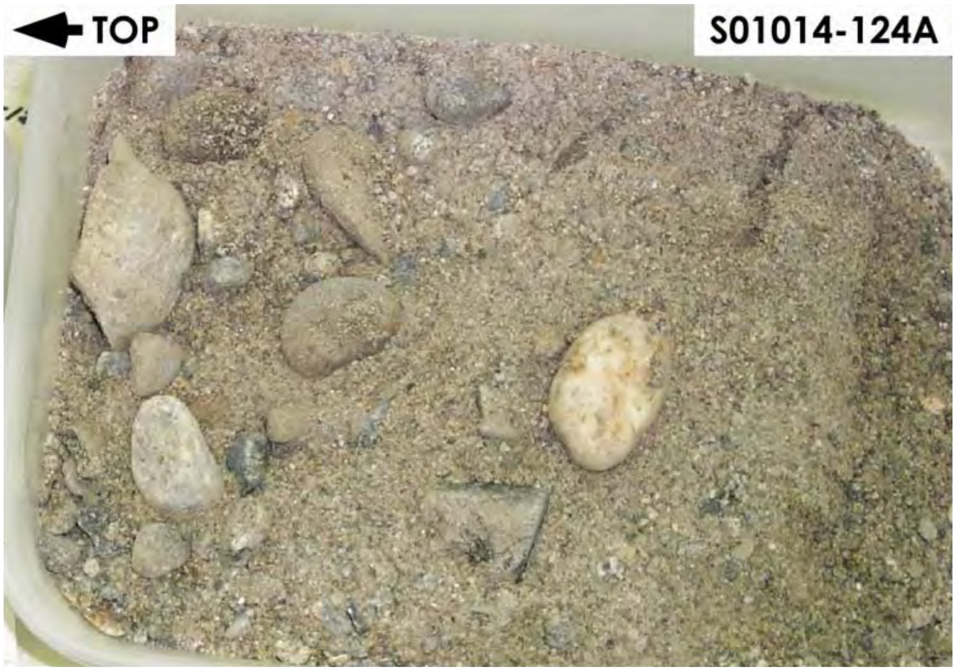


Figure B.128. Sample S01014-124A from a Depth of 245.00 ft to 245.50 ft bgs in the Plio-Pleistocene Gravel Unit (PPlg)

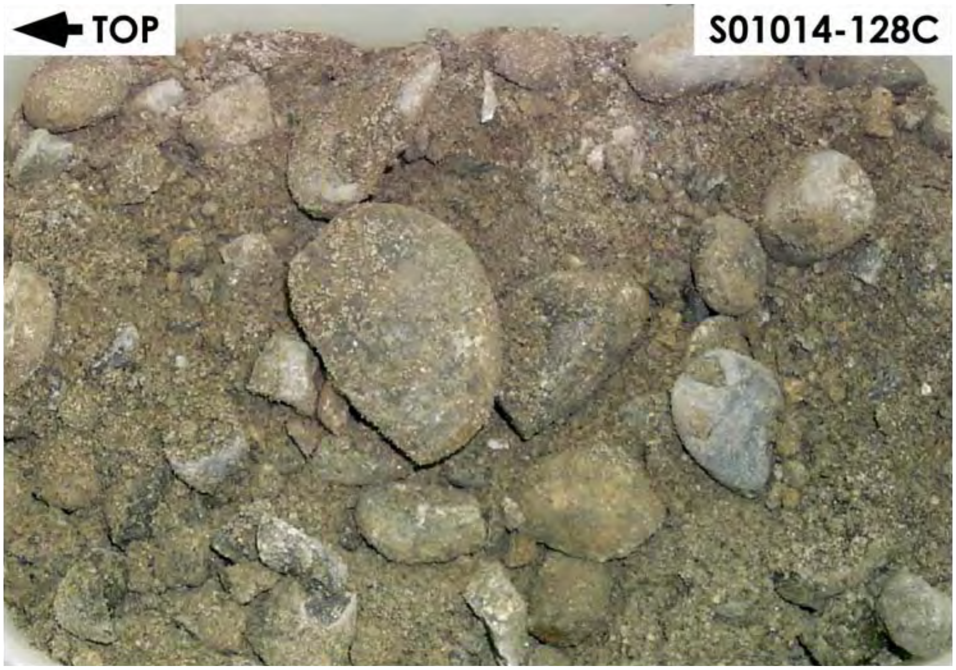


Figure B.129. Sample S01014-128C from a Depth of 250 ft to 251 ft bgs in the Plio-Pleistocene Gravel Unit (PPlg)

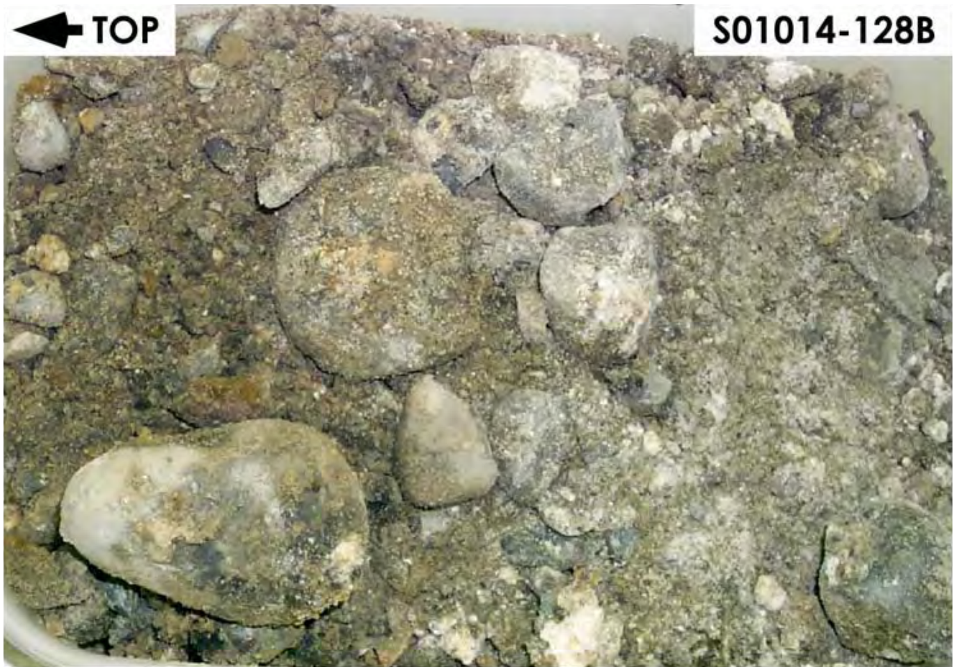


Figure B.130. Sample S01014-128B from a Depth of 251 ft to 251.5 ft bgs in the Plio-Pleistocene Gravel Unit (PPlg)

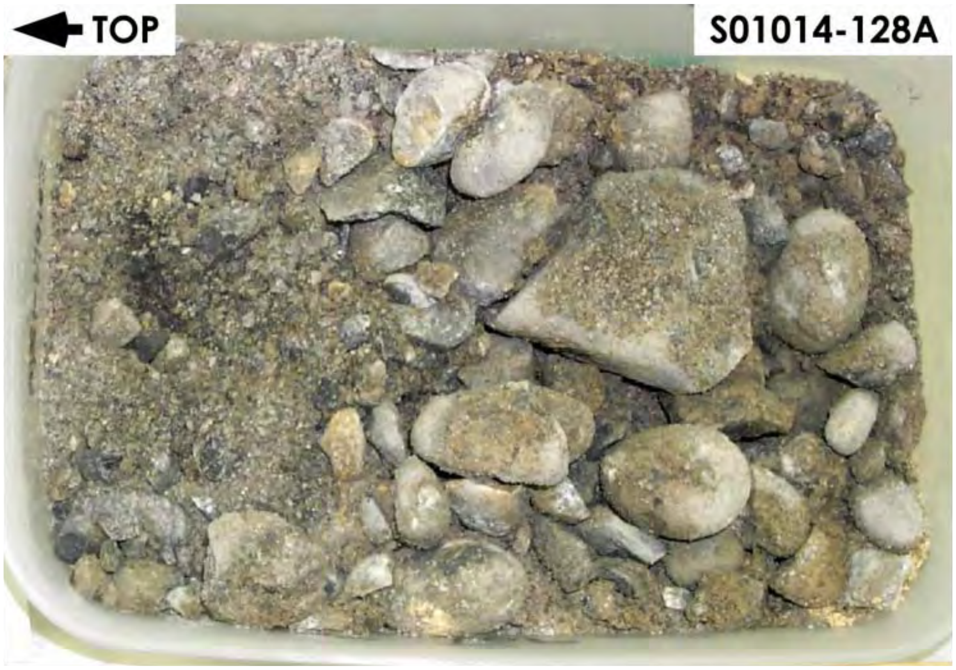


Figure B.131. Sample S01014-128A from a Depth of 251.5 ft to 252 ft bgs in the Plio-Pleistocene Gravel Unit (PPlg)

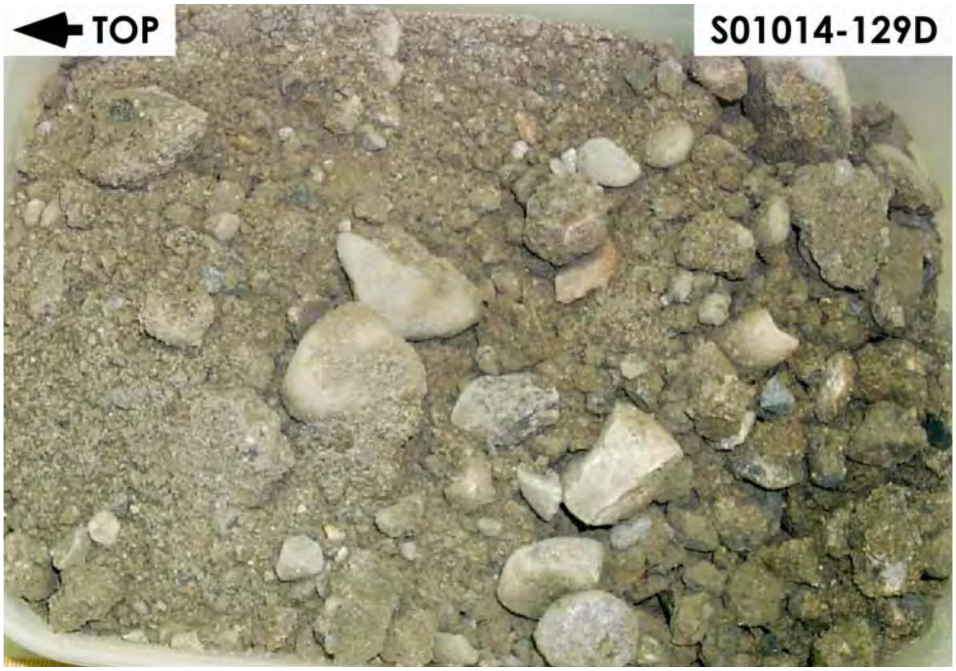


Figure B.132. Sample S01014-129D from a Depth of 251.9 ft to 252.4 ft bgs in the Plio-Pleistocene Gravel Unit (PPlg)

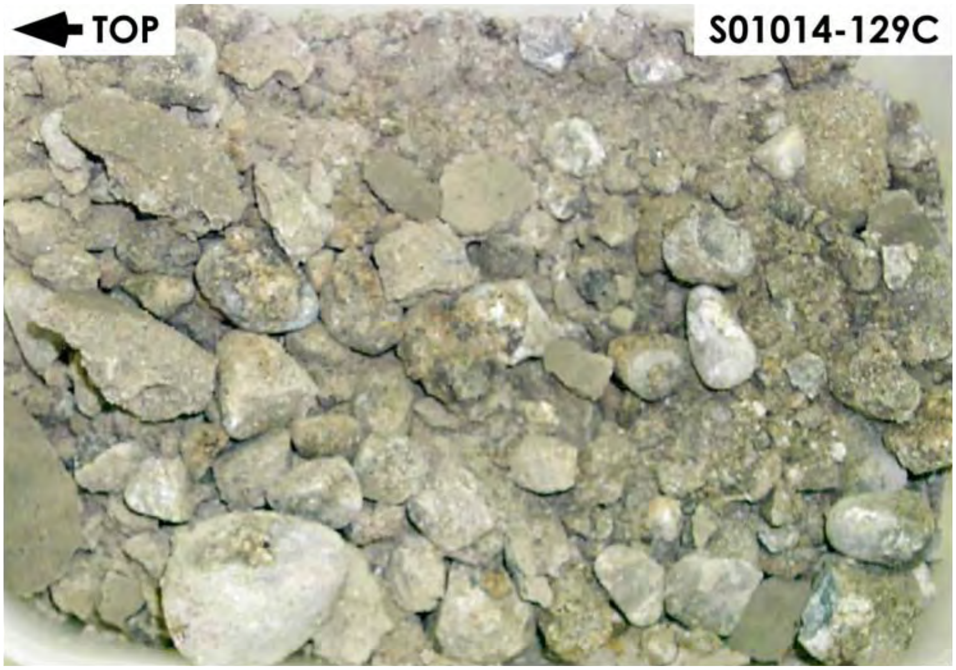


Figure B.133. Sample S01014-129C from a Depth of 252.4 ft to 252.9 ft bgs in the Plio-Pleistocene Gravel Unit (PPlg)

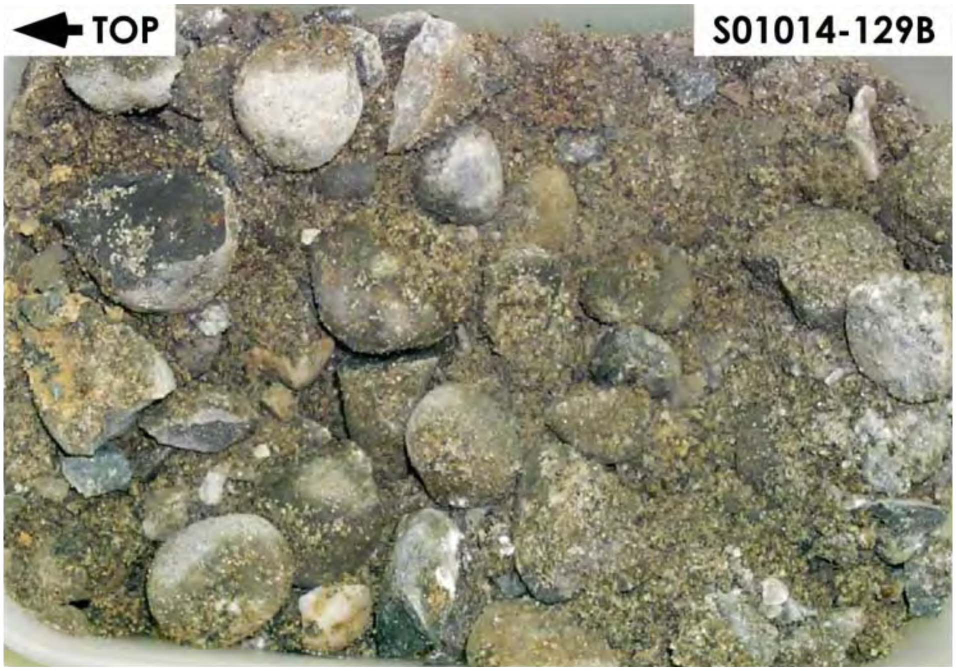


Figure B.134. Sample S01014-129B from a Depth of 252.9 ft to 253.4 ft bgs in the Plio-Pleistocene Gravel Unit (PPlg)

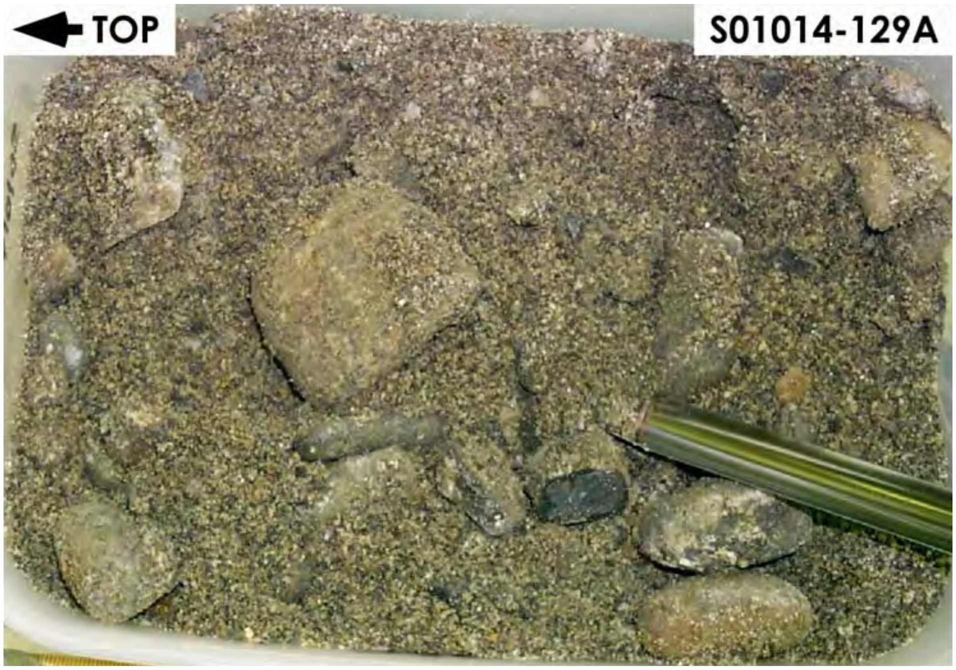


Figure B.135. Sample S01014-129A from a Depth of 253.4 ft to 253.9 ft bgs in the Plio-Pleistocene Gravel Unit (PPlg)

Appendix C

Particle Size Data From Nearby Boreholes

Contents

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Appendix C

Particle Size Data From Nearby Boreholes

C.1.0 Particle Size Data from Nearby Boreholes

To aid the geologic interpretation of the samples obtained from borehole 299-E33-45, available particle size data from surrounding boreholes that were used in the past to construct cross-sections and assign lithology/stratigraphy were tabulated. All this information was used to assign the samples from borehole 299-E33-45 a consistent lithologic designation to aid cross-sections to be prepared for the transport and risk modeling found in the Waste Management Area B-BX-BY field investigation report[1].

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[1] Knepp AJ. 2002. *Field Investigation Report for Waste Management Area B-BX-BY.* RPP-10098, CH2M HILL Hanford Group, Inc., Richland, Washington.

Table C.1. Physical Properties of Sediments from Borehole In and Near Waste Management Area B-BX-BY (4 pages)

Well No.	Depth (ft)	Drill Sample Method[(a)]	Hydrogeologic Unit[(b)]	Gravel (2 mm) ( )	Sand (0.05-2 mm) ( )	Corrected Sand [(c)]	Silt (0.002-0.05 mm) ( )	Corrected Silt [(c)]	Clay (0.002 mm) ( )	Corrected Clay [(c)]	Corrected Totals
299-E33-4	10-15	Cable Tool / Hard Tool	Backfill	44.6	66.5	36.8	27.5	15.2	6	3.3	100.0
	25-30	Cable Tool / Hard Tool	H1	13.2	76	66.0	17.2	14.9	6.8	5.9	100.0
	65-70	Cable Tool / Hard Tool	H2	5	74.9	71.2	21.4	20.3	3.7	3.5	100.0
	90	Cable Tool / Hard Tool	H2	7.7	84	77.5	12.9	11.9	3.1	2.9	100.0
	110	Cable Tool / Hard Tool	H2	3.9	82	78.8	15.5	14.9	2.5	2.4	100.0
	130	Cable Tool / Hard Tool	H2	5.3	91	86.2	7.8	7.4	1.2	1.1	100.0
	150	Cable Tool / Hard Tool	H2	24.5	78.4	59.2	16.3	12.3	5.3	4.0	100.0
	170	Cable Tool / Hard Tool	H2	15.6	85.6	72.2	13.3	11.2	1.1	0.9	100.0
	190	Cable Tool / Hard Tool	H3	13.7	96.8	83.5	3.2	2.8	0		100.0
	210	Cable Tool / Hard Tool	H3	70	67.2	20.2	26	7.8	4.8	1.4	99.4
	225	Cable Tool / Hard Tool	H3	43.8	61.4	34.5	31.6	17.8	7	3.9	100.0
299-E33-9	20	Cable Tool / Hard Tool	Backfill	6.8	84	78.3	11.3	10.5	4.7	4.4	100.0
	50	Cable Tool / Hard Tool	H1	18.6	87.9	71.6	7.9	6.4	4.2	3.4	100.0
	80	Cable Tool / Hard Tool	H2	2.3	87.3	85.3	8.7	8.5	4	3.9	100.0
	110	Cable Tool / Hard Tool	H2	3.7	88.8	85.5	7.8	7.5	3.4	3.3	100.0
	140	Cable Tool / Hard Tool	H2	2.4	90.1	87.9	5.9	5.8	3.9	3.8	99.9

Table C.1. Physical Properties of Sediments from Borehole In and Near Waste Management Area B-BX-BY (4 pages)

Well No.	Depth (ft)	Drill Sample Method[(a)]	Hydrogeologic Unit[(b)]	Gravel (2 mm) ( )	Sand (0.05-2 mm) ( )	Corrected Sand [(c)]	Silt (0.002-0.05 mm) ( )	Corrected Silt [(c)]	Clay (0.002 mm) ( )	Corrected Clay [(c)]	Corrected Totals
299-E33-9 continued	160	Cable Tool / Hard Tool	H2	18.1	69.9	57.2	23.7	19.4	6.4	5.2	100.0
	180	Cable Tool / Hard Tool	H2	22	81	63.2	13.4	10.5	5.6	4.4	100.0
	200	Cable Tool / Hard Tool	H2	42.1	70.1	40.6	23.4	13.5	6.5	3.8	100.0
	220	Cable Tool / Hard Tool	H3	55.8	65.7	29.0	27.7	12.2	6.6	2.9	100.0
	230	Cable Tool / Hard Tool	H3	50.6	64	31.6	29.3	14.5	6.7	3.3	100.0
299-E33-12	25	Cable Tool / Hard Tool	H2	11.5	81.1	71.8	12.7	11.2	6.18	5.5	100.0
	50	Cable Tool / Hard Tool	H2	1.8	78.4	77.0	14.1	13.8	7.53	7.4	100.0
	80	Cable Tool / Hard Tool	H2	2.2	73.4	71.8	19.3	18.9	7.34	7.2	100.0
	100	Cable Tool / Hard Tool	H2	13.3	5.5	4.8	85.2	73.9	9.3	8.1	100.0
	150	Cable Tool / Hard Tool	H2	2.8	5.6	5.4	78.3	76.1	16.1	15.6	100.0
	170	Cable Tool / Hard Tool	H2	19.8	5.5	4.4	83.4	66.9	11.1	8.9	100.0
	180	Cable Tool / Hard Tool	H2	17.9	5.9	4.8	84.5	69.4	9.6	7.9	100.0
	200	Cable Tool / Hard Tool	H3		6.8	6.8	81.3	81.3	11.9	11.9	100.0
	225	Cable Tool / Hard Tool	H3	10.7	92.6	82.7	7.3	6.5	0.5	0.4	100.4
	230	Cable Tool / Hard Tool	H3	61.1	84.5	32.9	6.8	2.6	0.8	0.3	96.9

Table C.1. Physical Properties of Sediments from Borehole In and Near Waste Management Area B-BX-BY (4 pages)

Well No.	Depth (ft)	Drill Sample Method[a]	Hydrogeologic Unit[b]	Gravel (2 mm) ( )	Sand (0.05-2 mm) ( )	Corrected Sand [c]	Silt (0.002-0.05 mm) ( )	Corrected Silt [c]	Clay (0.002 mm) ( )	Corrected Clay [c]	Corrected Totals
299-E33-13	20	Cable Tool / Hard Tool	299-E33-17H1	6.8	84	78.3	11.3	10.5	4.7	4.4	100.0
	50	Cable Tool / Hard Tool	H2	18.6	87.9	71.6	7.9	6.4	4.2	3.4	100.0
	80	Cable Tool / Hard Tool	H2	2.3	87.3	85.3	8.7	8.5	4	3.9	100.0
	110	Cable Tool / Hard Tool	H2	3.7	88.8	85.5	7.8	7.5	3.4	3.3	100.0
	140	Cable Tool / Hard Tool	H2	2.4	90.1	87.9	5.9	5.8	3.9	3.8	99.9
	160	Cable Tool / Hard Tool	H2	18.1	69.9	57.2	23.7	19.4	6.4	5.2	100.0
	180	Cable Tool / Hard Tool	H2	22	81	63.2	13.4	10.5	5.6	4.4	100.0
	200	Cable Tool / Hard Tool	H3	42.1	70.1	40.6	23.4	13.5	6.5	3.8	100.0
	220	Cable Tool / Hard Tool	H3	55.8	65.7	29.0	27.7	12.2	6.6	2.9	100.0
	230	Cable Tool / Hard Tool	H3	50.6	64	31.6	29.3	14.5	6.7	3.3	100.0
299-E33-17	15	Cable Tool / Hard Tool	H1	36.7	61.8	39.1	30.5	19.3	7.7	4.9	100.0
	30	Cable Tool / Hard Tool	H2	0	85.3	85.3	13.4	13.4	1.3	1.3	100.0
	50	Cable Tool / Hard Tool	H2	12	84	73.9	11.9	10.5	4.1	3.6	100.0
	80	Cable Tool / Hard Tool	H2	8.7	85	77.6	11.5	10.5	3.5	3.2	100.0
	110	Cable Tool / Hard Tool	H2	6.3	73.6	69.0	17.7	16.6	8.7	8.2	100.0
	150	Cable Tool / Hard Tool	H2	0	87.5	87.5	9	9.0	3.5	3.5	100.0

Table C.1. Physical Properties of Sediments from Borehole In and Near Waste Management Area B-BX-BY (4 pages)

Well No.	Depth (ft)	Drill Sample Method(a)	Hydrogeologic Unit(b)	Gravel (2 mm) ( )	Sand (0.05-2 mm) ( )	Corrected Sand (c)	Silt (0.002-0.05 mm) ( )	Corrected Silt (c)	Clay (0.002 mm) ( )	Corrected Clay (c)	Corrected Totals
299-E33-17 continued	170	Cable Tool / Hard Tool	H3	25.3	71.1	53.1	25.9	19.3	3	2.2	100.0
	200	Cable Tool / Hard Tool	H3	0.8	92.3	91.6	5.9	5.9	1.8	1.8	100.0
	230	Cable Tool / Hard Tool	H/PP/R?	35.4	63.6	41.1	28.8	18.6	7.6	4.9	100.0
	240	Cable Tool / Hard Tool	H/PP/R?	51.7	61.5	29.7	30.3	14.6	8.2	4.0	100.0
299-E33-30	39-40	Cable Tool / Hard Tool			70.37	70.4	20.33	20.3	9.31	9.3	100.0
	139-140	Cable Tool / Drive Barrel(d)									

(a) From Hanford Well Information System (http://www.rl.gov/~eis/wells/wellhome.htm)
(b) Based on Lindsey et al. 2001
(c) Corrected by adjusting for % gravel
(d) Confirmed via geologists logs (PNNL Well Library)

Table C.2. Moisture, Calcium Carbonate, and Cation Exchange Capacity of Sediment Taken from Same Boreholes (4 pages)

Well No.	Depth (ft)	Drill Sample Method[(a)]	Hydrogeologic Unit[(b)]	Sand Silt Clay Ratio	Silt Clay Ratio	Rocsan Class	pH	15-Atmosphere Moisture Content ( )	CaC 3 ( )	CEC (Me . 100 g)	Reference
299-E33-4	10-15	Cable Tool / Hard Tool	Backfill	2.0	4.6	msG	8.4	3.46	0.8	12	McHenry 1957
	25-30	Cable Tool / Hard Tool	H1	3.2	2.5	mgS	8.2	2.58	0.8	9.2	McHenry 1957
	65-70	Cable Tool / Hard Tool	H2	3.0	5.8	mS	8.5	2.43	1.2	5.2	McHenry 1957
	90	Cable Tool / Hard Tool	H2	5.3	4.2	(gm)S	8.3	1.95	1.3	4.4	McHenry 1957
	110	Cable Tool / Hard Tool	H2	4.6	6.2	(m)S	8.6	1.8	1.4	4.7	McHenry 1957
	130	Cable Tool / Hard Tool	H2	10.1	6.5	(g)S	8.5	1.38	0.9	4.8	McHenry 1957
	150	Cable Tool / Hard Tool	H2	3.6	3.1	mgS	8.3	2.62	0.7	8.9	McHenry 1957
	170	Cable Tool / Hard Tool	H2	5.9	12.1	(m)gS	8.4	1.95	0.7	7.1	McHenry 1957
	190	Cable Tool / Hard Tool	H3	30.3		gS	8.4	1.3	0.8	5.4	McHenry 1957
	210	Cable Tool / Hard Tool	H3	2.2	5.4	msG	8.2	2.21	0.3	7.4	McHenry 1957
	225	Cable Tool / Hard Tool	H3	1.6	4.5	msG	8.3	2.38	0.3	9.6	McHenry 1957
299-E33-9	20	Cable Tool / Hard Tool	Backfill	5.3	2.4	(gm)S	8.7	1.48	0.5	5.2	McHenry 1957
	50	Cable Tool / Hard Tool	H1	7.3	1.9	(m)gS	8.65	1.37	0.4	7.1	McHenry 1957
	80	Cable Tool / Hard Tool	H2	6.9	2.2	(m)S	8.7	1.45	0.5	6	McHenry 1957
	110	Cable Tool / Hard Tool	H2	7.9	2.3	(m)S	8.85	1.15	0.6	6.5	McHenry 1957

Table C.2. Moisture, Calcium Carbonate, and Cation Exchange Capacity of Sediment Taken from Same Boreholes (4 pages)

Well No.	Depth (ft)	Drill Sample Method[(a)]	Hydrogeologic Unit[(b)]	Sand Silt Clay Ratio	Silt Clay Ratio	Rocsan Class	pH	15-Atmosphere Moisture Content ( )	CaC $_3$ ( )	CEC (Me . 100 g)	Reference
299-E33-9 continued	140	Cable Tool / Hard Tool	H2	9.2	1.5	S	8.7	1.31	0.4	5.3	McHenry 1957
	160	Cable Tool / Hard Tool	H2	2.3	3.7	mgS	8.45	1.88	0.6	6.8	McHenry 1957
	180	Cable Tool / Hard Tool	H2	4.3	2.4	(m)gS	8.5	2.08		7.1	McHenry 1957
	200	Cable Tool / Hard Tool	H2	2.3	3.6	msG	8.4	2.58	0.2	7.1	McHenry 1957
	220	Cable Tool / Hard Tool	H3	1.9	4.2	msG	7.85	2.15	0.3	5.6	McHenry 1957
	230	Cable Tool / Hard Tool	H3	1.8	4.4	msG	7.8	2.34	0.3	6.5	McHenry 1957
299-E33-12	25	Cable Tool / Hard Tool	H2	4.3	2.1	(m)gS	8.6	1.5	0.5	5.4	McHenry 1957
	50	Cable Tool / Hard Tool	H2	3.6	1.9	mS	8.8	1.83	0.6	4.7	McHenry 1957
	80	Cable Tool / Hard Tool	H2	2.8	2.6	mS	8.7	2.04	0.6	5.7	McHenry 1957
	100	Cable Tool / Hard Tool	H2	0.1	9.2	gM	8.8	1.38	0.4	5.2	McHenry 1957
	150	Cable Tool / Hard Tool	H2	0.1	4.9	M	8.7	1.5	0.5	5	McHenry 1957
	170	Cable Tool / Hard Tool	H2	0.1	7.5	gM	8.7	1.1	0.4	5.2	McHenry 1957
	180	Cable Tool / Hard Tool	H2	0.1	8.8	gM	8.7	0.77	0.4	5.9	McHenry 1957
	200	Cable Tool / Hard Tool	H3	0.1	6.8	M					McHenry 1957
	225	Cable Tool / Hard Tool	H3	11.9	14.6	gS	7.9	0.98	0.3	4.2	McHenry 1957
	230	Cable Tool / Hard Tool	H3	11.1	8.5	sG	7.7	1.26	0.3	5.4	McHenry 1957

Table C.2. Moisture, Calcium Carbonate, and Cation Exchange Capacity of Sediment Taken from Same Boreholes (4 pages)

Well No.	Depth (ft)	Drill Sample Method[(a)]	Hydrogeologic Unit[(b)]	Sand Silt Clay Ratio	Silt Clay Ratio	Rocsan Class	pH	15-Atmosphere Moisture Content ( )	CaC $_3$ ( )	CEC (Me . 100 g)	Reference
299-E33-13	20	Cable Tool / Hard Tool	H1	5.3	2.4	(gm)S	8.7	1.48	0.5	5.2	McHenry 1957
	50	Cable Tool / Hard Tool	H2	7.3	1.9	(m)gS	8.65	1.37	0.4	7.1	McHenry 1957
	80	Cable Tool / Hard Tool	H2	6.9	2.2	(m)S	8.7	1.45	0.5	6	McHenry 1957
	110	Cable Tool / Hard Tool	H2	7.9	2.3	(m)S	8.85	1.15	0.6	6.5	McHenry 1957
	140	Cable Tool / Hard Tool	H2	9.2	1.5	S	8.7	1.31	0.4	5.3	McHenry 1957
	160	Cable Tool / Hard Tool	H2	2.3	3.7	mgS	8.45	1.88	0.6	6.8	McHenry 1957
	180	Cable Tool / Hard Tool	H2	4.3	2.4	(m)gS	8.5	2.08		7.1	McHenry 1957
	200	Cable Tool / Hard Tool	H3	2.3	3.6	msG	8.4	2.58	0.2	7.1	McHenry 1957
	220	Cable Tool / Hard Tool	H3	1.9	4.2	msG	7.85	2.15	0.3	5.6	McHenry 1957
	230	Cable Tool / Hard Tool	H3	1.8	4.4	msG	7.8	2.34	0.3	6.5	McHenry 1957
299-E33-17	15	Cable Tool / Hard Tool	H1	1.6	4.0	msG	8.55	3.28	0.6	8.9	McHenry 1957
	30	Cable Tool / Hard Tool	H2	5.8	10.3	(m)S	8.8	1.29	1.4	4.5	McHenry 1957
	50	Cable Tool / Hard Tool	H2	5.3	2.9	(m)gS	8.8	1.27	1.3	5	McHenry 1957
	80	Cable Tool / Hard Tool	H2	5.7	3.3	(gm)S	8.65	1.42	1	4.8	McHenry 1957
	110	Cable Tool / Hard Tool	H2	2.8	2.0	(gm)S	8.95	2.28	1.5	6	McHenry 1957
	150	Cable Tool / Hard Tool	H2	7.0	2.6	(m)S	8.95	1.38	1	5	McHenry 1957

Table C.2. Moisture, Calcium Carbonate, and Cation Exchange Capacity of Sediment Taken from Same Boreholes (4 pages)

Well No.	Depth (ft)	Drill Sample Method[(a)]	Hydrogeologic Unit[(b)]	Sand Silt Clay Ratio	Silt Clay Ratio	Rocsan Class	pH	15-Atmosphere Moisture Content ( )	CaC 3 ( )	CEC (Me . 100 g)	Reference
299-E33-17 continued	170	Cable Tool / Hard Tool	H3	2.5	8.6	mgS	8.3	1.92	1.3	7.1	McHenry 1957
	200	Cable Tool / Hard Tool	H3	12.0	3.3	S	8.65	1.1	0.8	4.3	McHenry 1957
	230	Cable Tool / Hard Tool	H/PP/R?	1.7	3.8	msG	7.9	2.33	0.5	6	McHenry 1957
	240	Cable Tool / Hard Tool	H/PP/R?	1.6	3.7	msG	7.7	2.6	0.5	7.7	McHenry 1957
299-E33-30	39-40	Cable Tool / Hard Tool		2.4	2.2	mS				3.6	Shramke 1988; Ames and Serne 1991
	139-140	Cable Tool / Drive Barrel[(c)]								2.5	Shramke 1988; Ames and Serne 1992

(a) From Hanford Well Information System (http://www.rl.gov/~eis/wells/wellhome.htm)

(b) Based on Lindsey et al. 2001

(c) Confirmed via geologists logs (PNNL Well Library)

Table C.3. Summary Statistics for All Samples Based on Designated Geologic Units (Samples) from Table C.1

All Samples					
Silt		*Clay*		*Silt/Clay Ratio*	
Max	81.3	Max	15.6	Max	14.6
Min	2.6	Min	0.3	Min	1.5
Median	12.3	Median	3.8	Median	3.7
SD	18.9	SD	2.8	SD	2.9
Backfill					
Silt		*Clay*		*Silt/Clay Ratio*	
Max	15.2	Max	4.4	Max	4.6
Min	10.5	Min	3.3	Min	2.4
Median	12.9	Median	3.9	Median	3.5
SD	3.3	SD	0.7	SD	1.5
All Hanford Formations					
Silt		*Clay*		*Silt/Clay Ratio*	
Max	81.3	Max	15.6	Max	14.6
Min	2.6	Min	0.3	Min	1.5
Median	12.2	Median	3.8	Median	3.7
SD	19.9	SD	2.9	SD	3.0
Hanford H1					
Silt		*Clay*		*Silt/Clay Ratio*	
Max	19.3	Max	5.9	Max	4.0
Min	6.4	Min	3.4	Min	1.9
Median	12.7	Median	4.6	Median	2.5
SD	5.6	SD	1.0	SD	0.9
Hanford H2					
Silt		*Clay*		*Silt/Clay Ratio*	
Max	76.1	Max	15.6	Max	12.1
Min	5.8	Min	0.9	Min	1.5
Median	11.6	Median	3.9	Median	3.0
SD	21.1	SD	2.9	SD	2.8
Hanford H3					
Silt		*Clay*		*Silt/Clay Ratio*	
Max	81.3	Max	11.9	Max	14.6
Min	2.6	Min	0.3	Min	3.3
Median	12.2	Median	2.9	Median	4.4
SD	20.3	SD	3.0	SD	3.2
H/PP/R?					
Silt		*Clay*		*Silt/Clay Ratio*	
Max	18.6	Max	4.9	Max	3.8
Min	14.6	Min	4.0	Min	3.7
Median	16.6	Median	4.4	Median	3.7
SD	2.8	SD	0.7	SD	0.1

C.2.0 References

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Appendix D

X-Ray Diffraction Patterns for Selected Core Samples

Figures

Appendix D

X-Ray Diffraction Patterns for Selected Core Samples

D.1.0 Additional X-Ray Diffraction Data for Bulk Sediment and Clay Fractions

This appendix contains x-ray diffraction (XRD) patterns for the bulk and clay-sized particles for the 12 core samples that were characterized for particle size and mineralogy. All the patterns for the bulk and clay-sized samples are shown on one figure each arranged by sample depth, from shallowest to deepest sample. Details on XRD methods are found in Section 3.3.10. All samples were analyzed on a Scintag x-ray diffraction unit equipped with a Pelter thermoelectrically cooled detector and a copper x-ray tube. Slides of preferentially oriented clay were scanned from 2 to 45 degrees 2θ, and randomly oriented powder mounts were scanned from 2 to 75 degrees 2θ. The bulk samples were prepared by crushing approximately 0.5 gram of sample to a fine powder that was then packed into a small circular holder. After air-drying approximately 0.5 gram of the clay slurry, a random mount was prepared and analyzed from 2 to 75 degrees 2θ.

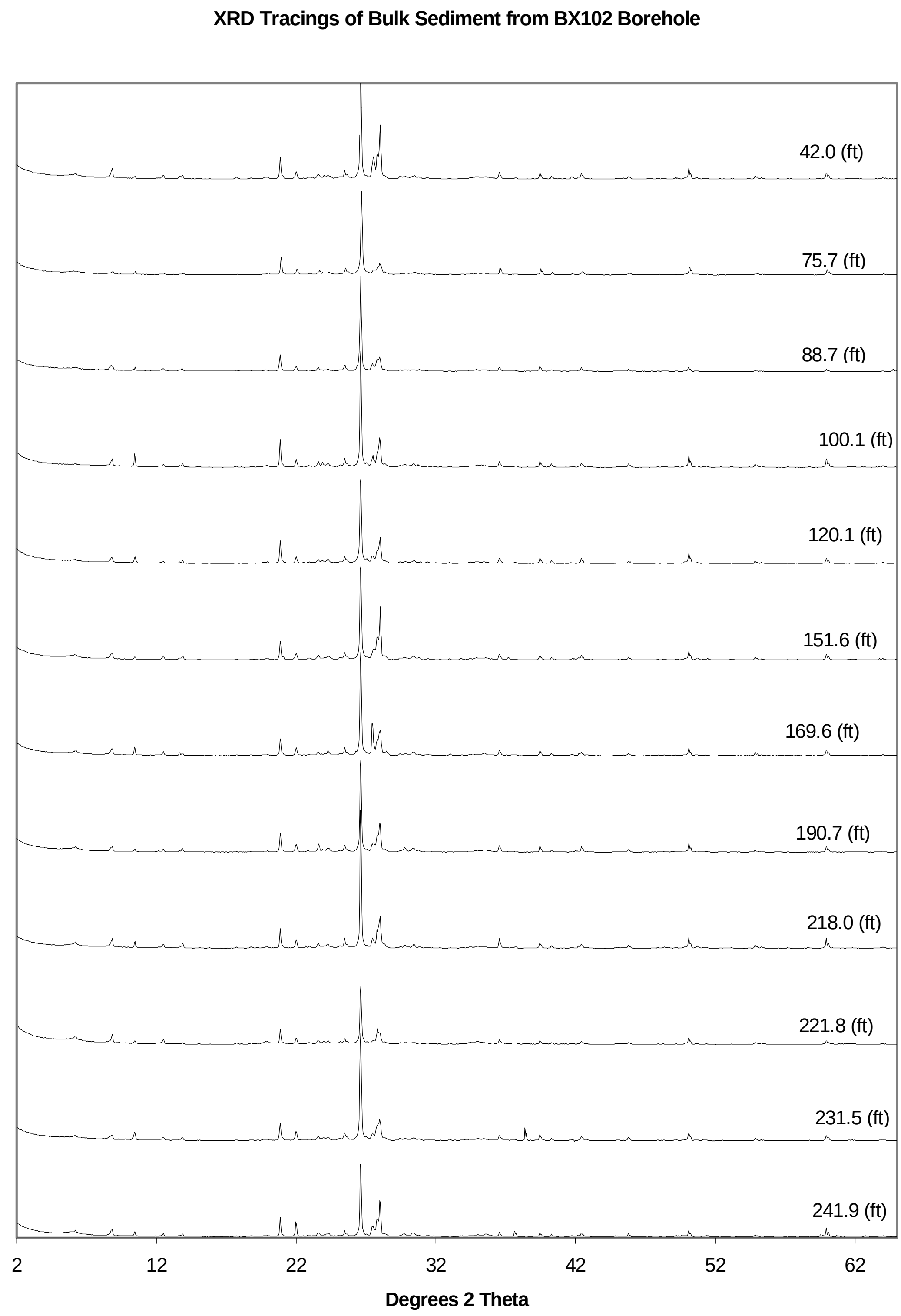

Figure D.1. X-Ray Diffraction Data for Bulk Sample

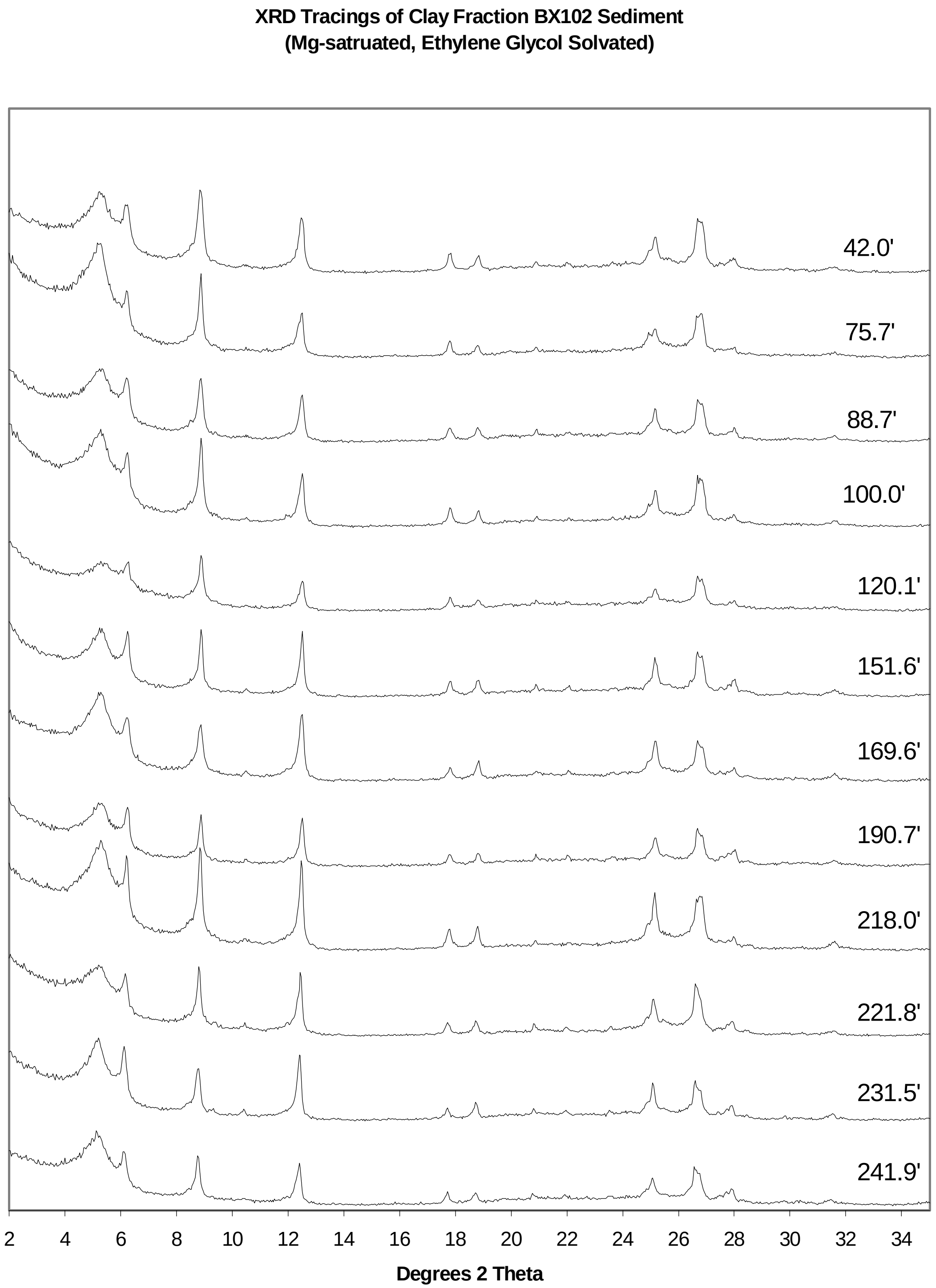

Figure D.2. X-Ray Diffraction Data for Clay Fraction

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