Los Alamos National Laboratory Legacy Contaminant Study at the Buckman Direct Diversion

Los Alamos County, New Mexico

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Forward

The mission of the New Mexico Environment Department DOE Oversight Bureau is to assure that activities at DOE facilities in New Mexico are protective of the public health and safety and the environment. The Bureau's activities are funded through a grant from the U.S. Department of Energy in accordance with the provisions set forth in the *Agreement-In-Principle between the State of New Mexico and the U.S. Department of Energy*. One of the primary objectives of the agreement is the development and implementation of a program of independent monitoring and oversight.

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Introduction

Early in 2007, the New Mexico Environment Department (NMED) DOE Oversight Bureau released a report identifying Los Alamos National Laboratory (LANL) legacy contaminants along the Rio Grande (Englert and others, 2007). The highest levels of these contaminants were found in an abandoned channel near Cañada Ancha. This channel is also in the vicinity of the proposed site for the Santa Fe community water-diversion project from the Rio Grande, the Buckman Direct Diversion (BDD). Flood materials, some originating from canyons at LANL, filled the channel during the 1950's and 1960's. They contained radionuclides and other wastes discharged into the Los Alamos watershed and spread by natural processes through the canyons and into the Rio Grande. The contaminant concentrations were reduced with time and distance from the sources.

During the week of May 5th, 2008, representatives from the Buckman Direct Diversion Board, the City of Santa Fe, Santa Fe National Forest Service, NMED, and LANL participated in characterization efforts at the Buckman Landing area. The Buckman Landing area description is used to identify the area of the proposed BDD infrastructure and the abandoned channel along the Rio Grande near the Cañada Ancha tributary. The scope of work was identified in a "Sediment Characterization Work Plan" in support of the Buckman Diversion Project (the Work Plan). Development of the Work Plan was initiated in January 2008 and developed through several revisions by LANL, the Buckman Direct Diversion Board, and NMED.

The purposes of our characterization efforts were: 1) to identify the downstream extent of the abandoned channel, characterized as a slough and described by Graf, 1994, and 2) determine whether planned construction activities would intercept the slough and the legacy contaminants in the sediments that filled it, or if minor realignment of the planned infrastructure could avoid such disturbance.

Geomorphic characterizations made from core holes drilled in February 1999, and February, April, and May of 2008, chemical analysis of samples collected from the May 2008 core holes, and evaluation of data from those analyses, identified and delineated the slough and LANL legacy contaminants contained within it. The samples were collected from sediment intervals most likely to contain legacy contaminants and were submitted to a commercial analytical laboratory for radiochemical and metal analysis.

The NMED and Buckman Direct Diversion representatives conclude that the southern extent of the slough is north of the areas to be disturbed by construction, and that the BDD infrastructure footprint is within Cañada Ancha tributary alluvium and not Rio

Grande origin alluvial sediments. The BDD construction plans are unlikely to disturb slough sediments containing legacy contaminants from the Laboratory.

Methods

The Work Plan identified preliminary drilling locations, and subsequent site visits and surveys provided adjustments to adequately characterize the site. The final Work Plan included a series of five boreholes spaced approximately equidistant along the planned northwest-southeast BDD pipeline excavation route and five boreholes along a northeast-southwest transect perpendicular to the pipeline.

An additional drilling site was selected based on previous boreholes made in February 2008 by NMED that provided additional geomorphic information, including the possible southern extent of the slough. This additional site is located below the terraces where the Buckman Well #1 is sited. It is about 500 feet north of the proposed Buckman Direct Diversion and associated pipeline.

The Work Plan indicated that the cores will penetrate at least the full depth of the planned excavations with an additional five foot buffer to incorporate possible over-excavation during construction. At some locations the boreholes were drilled even deeper to penetrate through the projected slough depth.

Figures 1 and 2 on the following pages identify the BDD footprint and borehole locations along the Rio Grande at the Buckman Landing. The maps were provided by the City of Santa Fe.

Figure 1. Footprint Plan of Buckman Direct Diversion at the Buckman Landing (note the north arrow in the upper right hand corner of map)

Figure 2. Borehole locations at Buckman Direct Diversion study area (north is at the top of the page)

Drilling

On May 7th, 2008 BDD project manager Rick Carpenter, BDD consulting engineer Norm Gaume, LANL geologist Steven Reneau, United States Forest Service Espanola District Ranger Sandy Hurlocker, NMED representative Dave Englert, and the AMEC Earth and Environmental, Inc. drilling crew drilled five boreholes (identified as DH-1 through DH-5) at least ten feet deep along the proposed raw water pump station and pipeline alignments at the Buckman Landing, and five boreholes (DH-6 though DH-10) in a perpendicular transect across the proposed infrastructure. Boreholes DH-5, DH-6, and DH-7 were drilled deeper to intercept the projected slough horizon. They were drilled to 15 feet, 15 feet, and 11 feet six inches respectively.

On May 8th, the NMED representative and the AMEC crew returned and completed two more bore holes. The AMEC crew drilled a 30 foot hole, for geotechnical investigation purposes at the proposed raw-water pump station, near DH-1. The State representative hand augured a ten foot borehole (DH-11) in an area that he predicted might be the southern extent of the slough. Earlier exploratory auger holes to the south and west of this location did not intercept the clay sediments we expected to find in the slough, except to the far northwest near the current Rio Grande channel and slightly above the same grade as the channel.

The geotechnical crew bored each borehole, DH-1 through DH-10, to a pre-determined depth using a 12 inch diameter hollow stem auger. At the projected sample depth drilling was paused and a sediment core was collected. In boreholes where sample horizons were relatively shallow, the drillers continued the holes to a total depth of at least ten feet.

The NMED representative hand augured the DH-11 borehole and exploratory holes with a 2.5 inch diameter by seven inch long auger at the end of five foot flight extensions. Thick Russian Olive and Tamarisk tree groves limited the drill rig access to DH-11 and many of the exploratory holes.

Cuttings from all boreholes were observed and logged by on-site geologists and/or engineers.

Figure 3. Hand augur operation and hollow stem drill rig

Sample Collection

Thirteen sediment samples were collected from the boreholes and submitted to a commercial analytical laboratory. The laboratory analyzed them for isotopic plutonium $^{238 \text{ and } 239/240}$ (Pu^{238} and $Pu^{239/240}$) uranium isotopes $^{234,\ 235, \text{ and } 238}$($U^{234}$, U^{235}, and U^{238}) americium^{241} (Am^{241}), cesium ^{137} (Cs^{137}), strontium ^{90} (Sr^{90}), neptunium^{237} (NP^{237}), 24 trace and heavy metals, and particle size distribution. For most radionuclides, the laboratory used high resolution methods. The increased resolution is acquired by using larger aliquot mass and longer spectroscopy count times.

A commingled surface sediment sample was collected from zero to one foot at boreholes DH-1 through DH-5 with a hand auger.

At a projected sample depth for each borehole, the geo-technicians inserted an 18 inch long, three inch diameter "C" ring sampler, similar to a split spoon tool, into the hollow stem flight and hammered it through the horizon of interest to acquire sediments for each sample. The NMED representative removed the sediments from the "C" ring core or auger bore and placed them into a stainless steel bowl to be thoroughly mixed. Collection of fine-grained materials at the projected horizon of the slough was prioritized.

At DH-8, DH-9, and DH-10, five inch, six inch, and six inch intervals respectively, were selected because they contained finer silts and sands. At DH-11, clay materials from the top nine inches and bottom 16 inches of a 33 inch interval of clay were collected. Each sample was then split into (two) one-gallon freezer zip-lock baggies and labeled with the sample identification, location, date, and time. One bag was reserved for LANL observation and possible duplicate analysis at a later time.

All equipment, including the "C" ring core, hand auger, and stainless steel bowl and spoon, which contacted the sample intervals were de-contaminated between samples with a laboratory grade detergent wash and a distilled water rinse.

Sample Horizon Identification

We identified the sample depths at each site by projecting the elevation of the slough clay lens described in the April, 2007 NMED report. That borehole is located approximately 0.3 miles (1,600 feet) north of construction area. The top of the clay interval elevation in that borehole is approximately 5,465 feet. The clay lens is three feet thick. NMED made a ground elevation survey at each borehole, or a bench mark near the predicted borehole, in February, 2008 and a subsequent visit in April. The difference in the ground elevation and the projected elevation then became the predicted sample depth. The river gradient or linear distance between each borehole was not considered. We determined that samples would be collected at the approximate predicted sample depth or at any interval near that depth that was comprised of silts or clays.

The total depth (TD) of boreholes, predicted sample depth interval, interval depths sampled for each borehole, and the textural classes of the sampled material are listed in Table 1.

Table 1. Borehole depths and sample intervals

Sample ID	Total Depth (TD)	Predicted Sample Interval	Sampled Interval	Sample Material
Surface DH-1 to DH-5	surface to 1'	surface to 1'	surface to 1'	coarse sand
DH-1	10'	5' - 6' 6"	5' - 6' 6"	coarse sand
DH-2	10'	7' - 8' 6"	7' - 8' 6"	coarse sand
DH-3	10'	7' - 8' 6"	7' - 8' 6"	medium to coarse sand
DH-4	10'	8' - 9' 6"	8' - 9' 6"	medium to coarse sand
DH-5	15'	12' 9" - 14' 3"	13' 9" - 14' 3"	sandy loam
DH-6	15'	11' 6" - 13'	11' 6" - 13'	medium to coarse sand
DH-7	11' 6"	10' - 11' 6"	10' - 11' 6"	coarse sand
DH-8	10'	6' - 7' 6"	7' - 7' 5"	loamy sand
DH-9	10'	5' - 6' 6"	5' 6" - 6'	sandy loam
DH-10	10'	4' - 5' 6"	4' 6" - 5'	very fine sand to silt loam
DH-11a	10'	6' - 9'	4' 3" - 5'	silty clay
DH-11b	10'	6' - 9'	5' 8" - 7'	silty clay

Other than the silty sands and clay intervals described in boreholes DH-5, -8, -9, -10, and -11, the borehole materials along and adjacent to the construction alignment (DH-1 through DH-7) were generally non-uniform coarse grained sands with gravel indicative of the Cañada Ancha wash (tributary alluvium) sediments.

We found a six inch sandy loam interval at DH-5 between 13 feet nine inches to 14 feet three inches covered by medium to coarse sands. A five inch loamy sand at DH-8 was identified between seven feet to seven feet five inches sandwiched between medium grained sands. The coarser grained sands draping over the fines at DH-5 and sandwiching DH-8 are Cañada Ancha wash sands.

We also identified a six inch sandy loam interval at DH-9 sandwiched between fine sands. The entire section at DH-10 was comprised of very fine sands to silt loam. We interpret the fine grained borehole materials found in DH-5, -8, -9, and -10 as well sorted sands or developing soils of Rio Grande alluvial origin deposited on flood plains or the mid-channel bar separating the slough from the present day channel.

Coordinate Acquisition

On May 8th, 2008 NMED also collected the location coordinates for each borehole with a Trimble® Geographic Positioning System. The satellite timed data acquired by this device are capable of being differentially corrected with data acquired at a level three survey location. This allows recorded coordinate accuracies within a few feet per location. The locations can also be electronically plotted onto maps.

Conclusions based on Geomorphic Characteristics

Boreholes located along the proposed Buckman Diversion and pipeline, DH-1 through DH-5 and DH-6 and DH-7, are comprised of non-uniform coarse-grained sands with gravel indicative of the Cañada Ancha wash (tributary alluvium) sediments. The alluvium also contained fragments and boulders originating upstream from the Cerros del

Rio basalt flows. These basalt fragments also exist in the Rio Grande channel but are largely absent from the slough.

The three foot thick clay horizon at DH-11 is similar in nature to the original 1999 borehole drilled in the upstream northern section of the slough. The DH-11 location is approximately 500 feet north of the proposed Buckman Diversion and pipeline. The sediment texture and vegetative cover indicates the slough begins 3,000 feet upstream from the proposed Buckman infrastructure and extends approximately 2,500 feet south and downstream before turning abruptly west into the existing Rio Grande channel. The slough was approximately 150 feet wide and at least three feet deep. The slough sediments were subsequently covered by pre-atmospheric testing Holocene terrace materials essentially clean of fission products.

The silty fine sediments sampled at DH-5, and DH-8, DH-9, and DH-10 may be Rio Grande flood plain or over-bank deposits relative to the active period of the slough and might contain atmospheric testing contaminants or legacy materials indistinguishable from background. These sediments probably comprise the southern bank of the slough and were draped over by the Cañada Ancha wash sediments. Boreholes DH-8 through DH-10 are north of and beyond the proposed pipeline, and the interval at DH-5 is significantly (eight feet) deeper than the proposed excavation depth.

Chemical Evaluation

The following section describes the methods used to evaluate the data and discusses our conclusions. We compared individual radiochemical measurements to reference values that reflect background. In this case background refers to an environment not impacted from past or present LANL activities but may contain contaminant fallout from atmospheric testing of nuclear weapons. The US, USSR, UK, China, and France tested nuclear weapons in the atmosphere from 1943 to 1963. French and Chinese testing continued into the 1980's.

We found that three sample populations may exist:

1) Cañada Ancha wash materials consisting of coarse grained sands with few or no radiochemical measurements above a detectable value,
2) fine grained sands that may be flood plain or overbank materials deposited when the slough was active, and contain radiochemical values indistinguishable from background, and
3) clay materials found in the slough, identified in the NMED 2007 report as containing LANL legacy contaminants.

We evaluated the potential Laboratory impacts at Cañada Ancha and the BDD infrastructure area by comparing individual radiochemical concentrations in the sampled sediments to LANL derived upper limits for background (BGULs) (McLin and Lyons, 2002) and the means and medians of their data set. These reference values were derived from historical measurements of sediments collected in Northern New Mexico beyond potential LANL impacts. If an individual measurement in an environmental sample is reported above its sample specific detection level and exceeds its reference value, assumptions are made that the contaminant is LANL derived. If it is less than the reference, we assume it is indistinguishable from background and derived from depositional fallout from atmospheric testing of nuclear weapons. Background sediments also contain naturally occurring levels of uranium and most metals.

With the exception of Np^{237}, the LANL BGULs published in "Background Radioactivity in River and Reservoir Sediments near Los Alamos, New Mexico" (McLin and Lyons, 2002) are refined background estimates from a previous study by Purtyman and others (1987). They were developed to reflect upstream reservoir sediments, and upstream and downstream river sediments. These references were derived from measurements acquired between 1974 and 1997, collected in areas well beyond the influence of the Laboratory. They reflect upper tolerance levels, or the probable largest value that might be measured in background. The reference value for each parameter was determined at the 0.95 (two tailed) quantile of McLin's data set.

A commercial analytical laboratory reported measurements for 13 samples and associated duplicates. They were measured for Pu^{238}, $Pu^{239/240}$, Am^{241}, Np^{237}, U^{234}, U^{235}, U^{238}, Sr^{90}, and Cs^{137} in sediment samples. The alpha and beta radiochemical count times varied from 160 minutes to 1,000 minutes for two to five gram sample aliquots. Gamma measurements were also counted for 1,000 minutes. Extended count times provide lower detection limits with less uncertainty. Uranium is naturally occurring in most sediment at levels easily distinguished with shorter 160 minute counts, while fallout products often require long 1,000 minute counts to identify and quantify them.

The sediments were collected from drill holes in the BDD area at an interval predicted to be at the same elevation as that of a slough described by Graf, 1996, and Englert and others, 2007. The slough contains LANL legacy contaminants washed into the Rio Grande from Los Alamos Canyon during the 1940's through the 1960's by storm water.

The chemical and physical parameters measured by commercial analytical laboratories are found in Tables 2 through 4. Table 2 presents the radiochemical data, Table 3 contains the metal results, and Table 4 the particle size distribution. The radiochemical values are reported along with their analytical uncertainty at two sigma (0.95 p) (total propagated uncertainty (TPU)), the sample specific minimum detection concentrations (MDAs), and any data qualifier.

All radiochemical measurements contain uncertainty associated with the random nature of radioactive decay and the analytical measurement error. This uncertainty is reported as a statistical interval around the reported value. At two sigma, the reported value plus or minus the TPU, describes a range of values which will contain the true value at a 95% confidence level. Multiple laboratory quality control samples, including blank, spiked, and duplicate samples are measured to quantify and control this variance.

Table 2. Radionuclide measurements for sediments in Buckman Direct Diversion study area

		Americium-241				Plutonium-238				Plutonium-239/240				Neptunium-237				Cesium-137			
Sample ID	**Date**	**Result**	**TPU**	**MDA**	**Qual**	**Result**	**TPU**	**MDA**	**Qual**	**Result**	**TPU**	**MDA**	**Qual**	**Result**	**TPU**	**MDA**	**Qual**	**Result**	**TPU**	**MDA**	**Qual**
Surface DH1-DH5	5/7/2008	0.0011	0.0046	0.003	U	0.0015	0.0046	0.0071	U	-0.00072	0.0046	0.0071	U	0.0034	0.01	0.018	U	0.043	0.013	0.019	LT
Surface DH1-DH5 duplicate						0.0025	0.0044	0.0068	U	0.0024	0.0044	0.0068	U								
DH-1	5/7/2008	0.0014	0.0049	0.011	U	-0.0022	0.0046	0.01	U	-0.0022	0.0046	0.01	U	0.0038	0.011	0.02	U	0.032	0.011	0.015	LT
DH-1 duplicate		0.0043	0.0045	0.0029	LT													0.042	0.013	0.017	LT
DH-2	5/7/2008	0.01	0.0069	0.003	LT	0.001	0.0042	0.0027	U	0.002	0.0042	0.0027	U	-0.00024	0.011	0.022	U	0.0074	0.007	0.011	U
DH-3	5/7/2008	0.0037	0.0038	0.0025	LT	0	0.0043	0.0028	U	0.0052	0.006	0.0095	U	0.0039	0.011	0.021	U	0.0061	0.013	0.022	U
DH-4	5/7/2008	0.0051	0.0046	0.0028	LT	0.0021	0.0043	0.0028	U	0.0059	0.0059	0.0084	U	0.0019	0.011	0.016	U	0.016	0.011	0.017	U
DH-4 duplicate														0.004	0.012	0.021	U				
DH-5	5/7/2008	0.0072	0.0058	0.0063	LT	-0.00068	0.0043	0.0067	U	0.0082	0.006	0.0028	LT	-0.0011	0.012	0.017	U	0.16	0.027	0.024	G
DH-6	5/7/2008	0.0048	0.0052	0.0071	U	0.0014	0.0042	0.0066	U	0.0037	0.005	0.0082	U	-0.0023	0.011	0.026	U	0.014	0.0093	0.014	U
DH-7	5/7/2008	0.0015	0.0046	0.0071	U	0.0014	0.0043	0.0067	U	0.00035	0.0043	0.0067	U	0.0056	0.013	0.019	U	0.01	0.013	0.021	U
DH-7 duplicate		0.0078	0.0066	0.009	U																
DH-8	5/7/2008	0.0064	0.005	0.0025	LT	0.00099	0.0041	0.0027	U	0.0099	0.0065	0.0027	LT	-0.0022	0.012	0.021	U	0.21	0.039	0.04	G
DH-9	5/7/2008	0.006	0.0071	0.012	U	-0.0056	0.0056	0.016	U	0.0071	0.0064	0.0085	U	0.0032	0.01	0.024	U	0.16	0.034	0.04	G
DH-9 duplicate						-0.0015	0.0038	0.0094	U	0.0089	0.0065	0.0074	LT	0.0061	0.01	0.018	U				
DH-10	5/7/2008	0.0091	0.007	0.0084	LT	-0.0015	0.0039	0.0096	U	0.0084	0.0058	0.0025	LT	-0.0034	0.016	0.038	U	0.27	0.042	0.033	G
DH-10 duplicate																		0.28	0.047	0.043	G
DH-11a	5/8/2008	0.026	0.014	0.0042	LT	0.0007	0.0043	0.0083	U	0.1	0.027	0.0095		0.016	0.017	0.019	U	1.7	0.21	0.051	M3,G
DH-11b	5/8/2008	0.016	0.011	0.011	LT	0.0029	0.004	0.0026	LT	0.027	0.011	0.0077	LT	0.0083	0.014	0.024	U	0.41	0.057	0.032	G

		Uranium-234				Uranium-235				Uranium-238				Strontium-90			
Sample ID	**Date**	**Result**	**TPU**	**MDA**	**Qual**	**Result**	**TPU**	**MDA**	**Qual**	**Result**	**TPU**	**MDA**	**Qual**	**Result**	**TPU**	**MDA**	**Qual**
Surface DH1-DH5	5/7/2008	0.35	0.088	0.02		0.021	0.019	0.021	LT	0.39	0.094	0.0087		0.12	0.047	0.061	M3
DH-1	5/7/2008	0.38	0.094	0.032	W	0.018	0.017	0.018	LT	0.33	0.085	0.023	W	0.033	0.036	0.057	U
DH-1 duplicate		0.66	0.14	0.018		0.027	0.021	0.01	LT	0.6	0.13	0.015					
DH-2	5/7/2008	0.43	0.1	0.02		0.023	0.02	0.018	LT	0.38	0.094	0.018		0.051	0.038	0.059	U
DH-2 duplicate														0.099	0.044	0.06	
DH-3	5/7/2008	0.35	0.085	0.0081		0.017	0.016	0.017	LT	0.4	0.094	0.0081		0.066	0.034	0.049	
DH-4	5/7/2008	0.42	0.1	0.027		0.014	0.017	0.028	U	0.33	0.088	0.024		0.034	0.029	0.045	U
DH-5	5/7/2008	0.8	0.16	0.036		0.016	0.016	0.019	U	0.74	0.15	0.029		0.13	0.044	0.05	
DH-6	5/7/2008	0.43	0.1	0.022		0.026	0.021	0.021	LT	0.35	0.088	0.029		0.091	0.044	0.062	M3
DH-7	5/7/2008	0.35	0.088	0.02		0.014	0.016	0.021	U	0.34	0.086	0.018		0.055	0.034	0.052	LT
DH-7 duplicate		0.51	0.12	0.018		0.039	0.025	0.01	LT	0.38	0.093	0.015					
DH-8	5/7/2008	0.42	0.098	0.019		0.018	0.017	0.017	LT	0.51	0.11	0.0084		0.08	0.042	0.06	M3
DH-9	5/7/2008	0.59	0.13	0.016		0.018	0.018	0.022	U	0.63	0.14	0.019		0.077	0.043	0.063	M3
DH-10	5/7/2008	0.66	0.14	0.023		0.042	0.026	0.01	LT	0.72	0.15	0.02		0.16	0.055	0.064	M3
DH-11a	5/8/2008	1.1	0.22	0.016		0.078	0.038	0.022	LT	1.2	0.23	0.016		0.51	0.13	0.071	M3
DH-11b	5/8/2008	1.1	0.22	0.022		0.061	0.034	0.019	LT	1.1	0.22	0.0095		0.27	0.081	0.076	M3

TPU - Total Propagated Uncertainty, reported at two sigma
MDA - Minimum Detectable Concentration
Qual - Laboratory qualifier
U - Result is less than the sample specific MDA
LT - Result is less than the requested MDC, greater than the sample specific MDA
W - The Duplicate Error Ratio is greater than the 1.42 warning limit
G - Sample density differs more than 15% of Laboratory Control Sample density
M3 - The requested MDA was not met, but the reported activity is greater than the reported MDC

The sample specific minimum detection concentration or MDA identifies the sensitivity or capability of an analytical process to measure or detect radionuclides. This value indentifies a radiological counting level that can expected to be seen with a fixed level of statistical certainty. This decision level also differentiates between the possibility of falsely reporting detection when there is not, or falsely reporting a non-detect when in fact a measurement is a detection. Measurements reported below the detection level contain diminishing confidence and an increasing chance of falsely reporting a positive value.

On occasion, individual radiochemical values are reported lower than the minimum detectable concentration (MDA) of the analytical technique or in negative numbers. These values are net values from the counting process. Analytical laboratories report net values in which the analytical and instrument background activities are subtracted from the sample measurements. Terms for minimum detection concentrations, limits, values, or levels are interchangeable in this report.

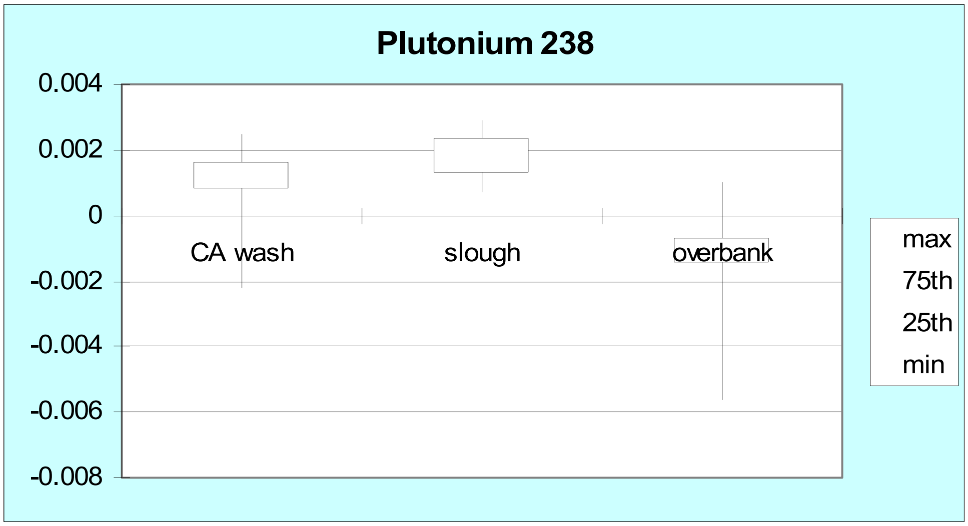
Data Descriptions

The following sections describe the radionuclide evaluation. After each narrative a graph is presented that demonstrates the relative differences between; 1) the Cañada Wash tributary sediments, 2) the slough that contains LANL legacy contaminants, and 3) the overbank or floodplain deposited during the time frame the slough was present and subsequently buried by terrace materials found above and east of these units. The maximum and minimum values are identified by the ends of the whisker lines, and the 25^{th} and 75^{th} quantiles are represented by the open box. The y axis represents the activity values in pCi/g. The x axis identifies the three populations described above.

All reported laboratory measurements are included in the graphs for completeness, and to show the consistent pattern of contaminates absent in Canada Wash sediments, background levels of contamination in the overbank sediments, and the presence of LANL legacy contaminants in the buried slough. It is emphasized, however, that analytical results reported less than their minimum detectable concentration represents values reported below a pre-determined 95% level of confidence.

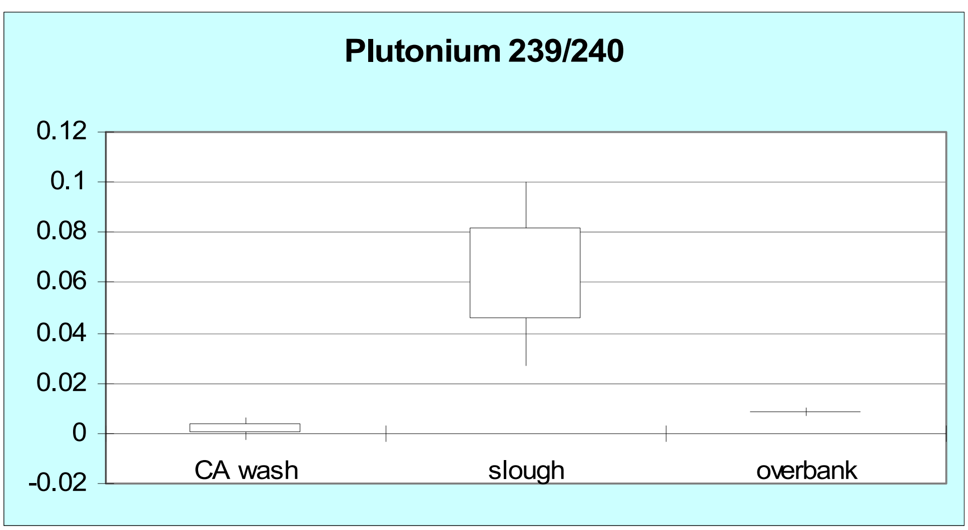
Plutonium Isotopes

All Pu^{238} values were less than their sample specific detection limits except one measurement at DH-11. DH-11 has been identified to be from the slough containing LANL legacy contaminants. The reported value is 0.0029 pCi/g, slightly greater than its detection limit of 0.0026 pCi/g; it is less than the 0.0087 pCi/g BGUL but three times greater than the mean and median of 111 measurements from the LANL background data set. The average detection level for this data set is 0.0067 pCi/g.



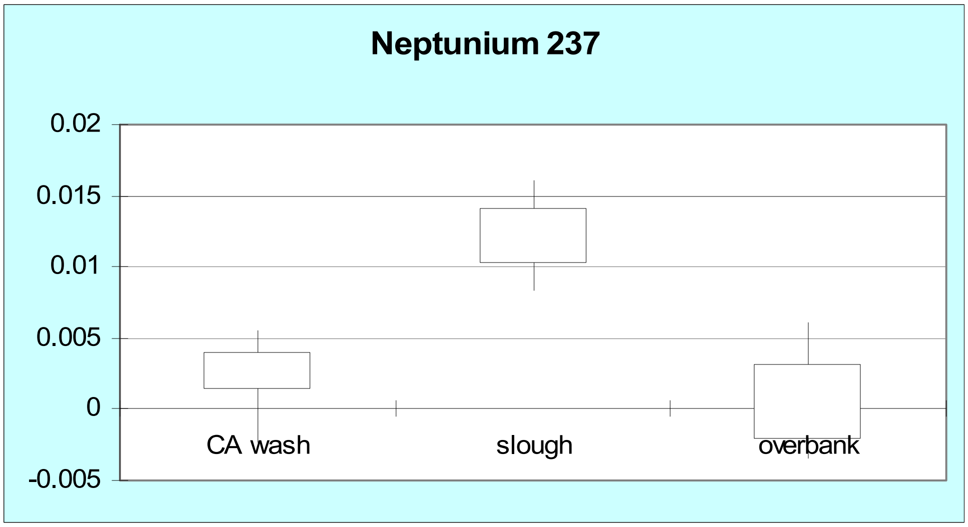
The Pu$^{239/240}$ values for samples identified as Cañada Ancha wash sediments, are less than their detection limits. The average detection limit is 0.0074 pCi/g. All of the reported values in the sediments identified as overbank or floodplain materials are greater than their detection limits, which average 0.0048 pCi/g, but are less than the 0.013 pCi/g LANL BGUL. We conclude these values are indistinguishable from background.

The Pu$^{239/240}$ values measured in two samples from the slough, Borehole DH-11, are up to eight times greater than the BGUL and 30 to 50 times greater than the mean and medians of the original LANL background data set. The maximum value is 0.10 pCi/g relative to the original 1999 slough measurement of 0.067 pCi/g. We conclude these plutonium values identify LANL legacy contaminants.



Neptunium ^{237}

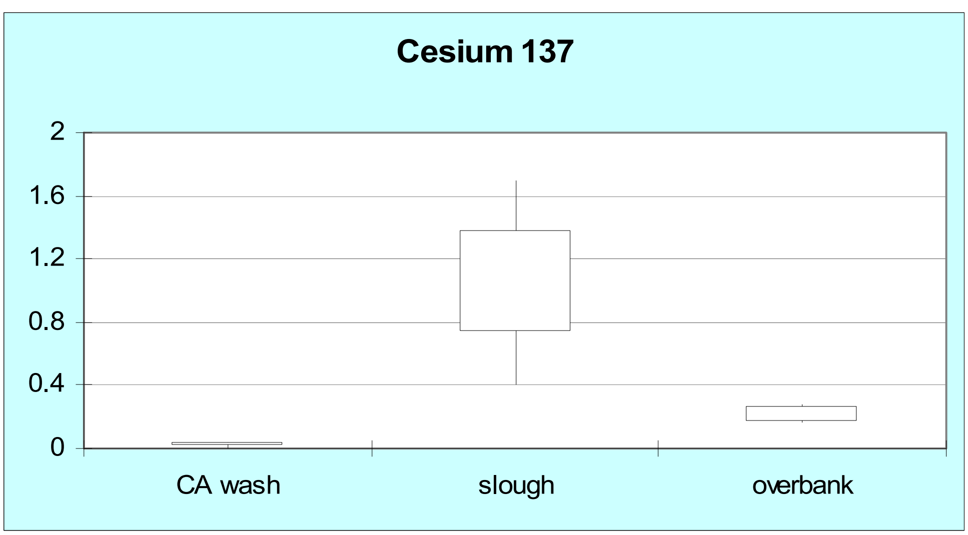
All Np^{237} values are less than their sample specific detection levels. The average detection level is 0.022 pCi/g.



Cesium ^{137}

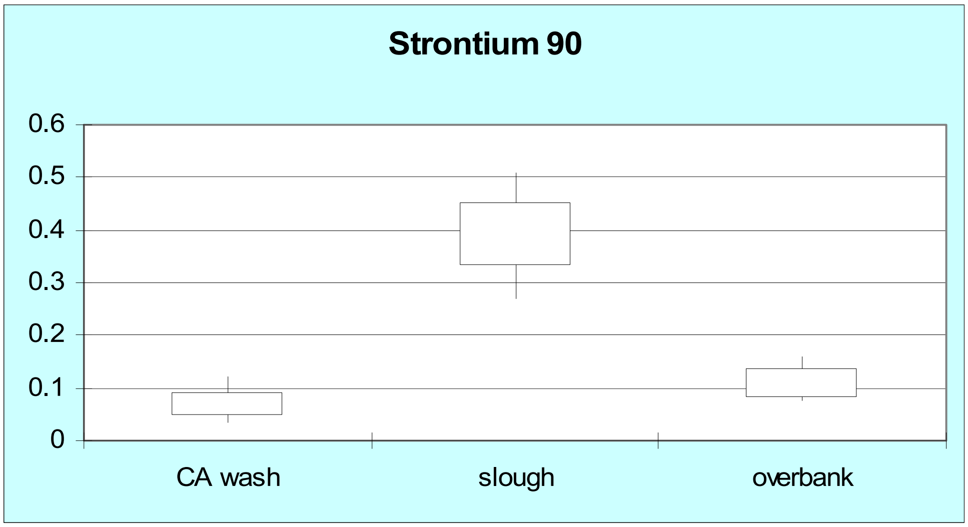
Most Cs^{137} values in the Cañada Ancha wash sediments are less than their detection levels which average 0.017 pCi/g. The exceptions are results from the composite DH-1 through DH-5 surface sample (0.043 pCi/g) and from a subsurface sample at DH-1 (0.032 pCi/g). Both detections are less than the 0.56 pCi/g background reference. The overbank and floodplain measurements, averaging 0.20 pCi/g, were all above their sample specific detection levels, but within the background reference range.

The Cs^{137} values within the slough deposits were 1.7 pCi/g and 0.41 pCi/g, up to three times greater than the LANL BGUL reference and 11 to 14 times greater than the mean and median of LANL's background data set. These values identify LANL legacy contaminants in the slough.



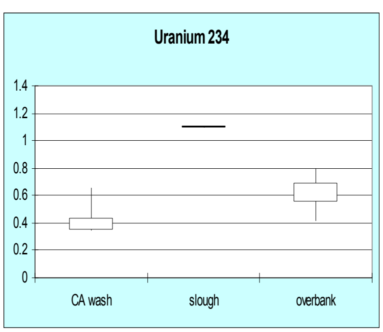
Strontium ^{90}

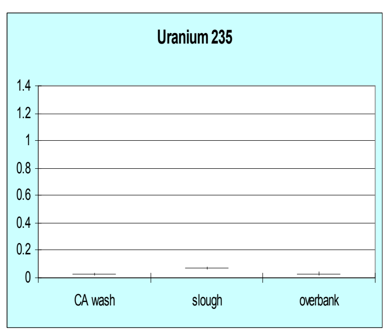
All Sr^{90} values were measured above their detection levels except three samples from the Cañada Ancha wash sediments. And all values were less than the 1.02 pCi/g background reference value. The sediments within the slough had values of 0.51 and 0.27 pCi/g. These values are up to five times the mean and median of the LANL data set, although noteworthy, these findings are not conclusive.

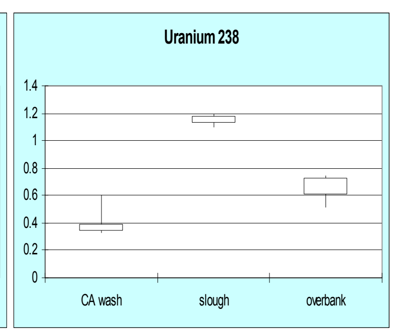


Uranium Isotopes

Almost all uranium $^{234,\ 235,}$ and ^{238} isotope measurements were quantifiable, except four U^{235} measurements reported below their detection limits, which averaged 0.02 pCi/g. Uranium is a natural occurring element in the environment, and all values are within the background values established by the Laboratory. Natural, as well as depleted and enriched uranium was and is used extensively at the Laboratory. Although below the Laboratory references for background, the levels found within the slough deposits are two to three times all the measurements found within the Cañada Ancha sediments and overbank deposits. Although noteworthy, this observation is inconclusive regarding the source of the element.



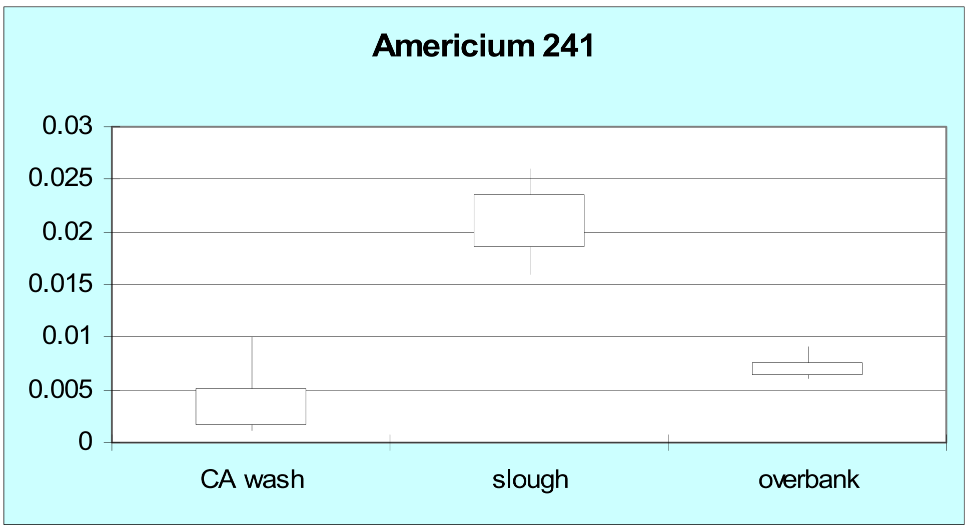




Americium^{241}

Most of the Am^{241} measurements in the Cañada Ancha wash and one measurement in the overbank deposits are non-detects, and all values are within the background range. The detection level average is 0.006 pCi/g, and the background reference value is 0.076 pCi/g.

The values in the slough sediments, 0.026 pCi/g and 0.016 pCi/g, are less than background, but are an order of magnitude greater than the 0.003 pCi/g median or the -0.1005 pCi/g mean of LANL's background data set and all other measurements reported for this study area. Although noteworthy, these values do not conclusively identify the source.



Metals

We submitted all borehole sediments to a commercial laboratory and had them analyzed for 24 trace and heavy metals. Table 3 contains the analytical data for metals. Like the radionuclide measurements, several metal analyses exhibited larger values in the slough sediment horizon than background references. Thirteen metal measurements exceeded background-sediment reference levels for metals, including aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, manganese, nickel, vanadium, and zinc. In this case, the background reference levels for metals in sediments are plateau specific (Ryti and others, 1998). Arsenic, barium, vanadium, and zinc were also measured above background levels in sediments from DH-10, as well as barium in DH-9 and vanadium in DH-5.

All metal values were then compared to the State Soil Screening Levels (SSLs) (NMED, 2006) for residential, industrial/occupational, and construction worker receptors. This exercise is done to identify the relative nature of the metal concentrations in the subsurface slough sediments. It is important to note that the SSLs were developed assuming exposure to distinct soil horizons for each receptor, residential and industrial receptors are generally exposed to surface soils (0 – 2 feet) while construction workers typically have exposures to subsurface soils. The SSLs were also developed upon chronic long-term exposures.

Aluminum and arsenic exceed the residential SSLs in the slough sediments found in borehole DH-11. Arsenic also exceeds the residential SSL in borehole DH-10. Manganese exceeds the construction worker exposure pathway in boreholes DH-5, -9, -10, and -11. The residential SSL for aluminum is 7780 mg/kg, and the measurements in DH-11 were 19,000 mg/kg and 16,000 mg/kg. The residential SSL for arsenic is 3.9 mg/kg, and 7.4 mg/kg and 4.2 mg/kg measurements were found in DH-11, and 4.2 mg/kg in DH-10. The construction worker SSL for manganese is 150 mg/kg, compared to 160 mg/kg in DH-5, 210mg/kg in DH-9, 250 mg/kg in DH-10, 700 mg/kg and 640 mg/kg in DH-11. All of these measured values are for sub-surface intervals associated with the slough, covered by clean terrace sediments, and beyond the planned construction activities associated with the BDD.

Table 3. Heavy and Trace Metal measurements for sediments at the Buckman Direct Diversion study area

Sample ID	Date	Aluminum		Antimony		Arsenic		Barium		Berylium		Cadmium		Calcium		Chromium		Cobalt		Copper		Iron		Lead	
		Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Surface DH1-DH5	5/7/2008	2300		0.053		1.3		50		0.31		0.052		7600		6		2.5		2.9		11000		3.4	
DH-1	5/7/2008	1500		0.028	B	0.99		33		0.23		0.033		5600		2.8		1.8		3.7		5700		1.9	
DH-2	5/7/2008	1200		0.031		1.1		26		0.19		0.029		5700		2.7		1.5		2.3		4800		2	
DH-3	5/7/2008	1300		0.029	B	1.3		28		0.2		0.027		5400		3.1		1.5		2.4		5600		1.9	
DH-4	5/7/2008	1600		0.036		1.4		37		0.2		0.034		6000		3.6		2.2		2.9		6900		2.5	
DH-5	5/7/2008	5300		0.056		2.3		120		0.5		0.15		20000		6.7		4		6		9500		6	
DH-6	5/7/2008	1200		0.042		1.6		22		0.2		0.028		4400		3.4		1.5		2.1		6400		2.1	
DH-7	5/7/2008	1800		0.048	N	2.3		32		0.23		0.04		7900		4.4		1.9		3		5560		2.3	
DH-8	5/7/2008	3100		0.051		1.9		72		0.32		0.092		15000		5		2.6		3.4		7200		3.6	
DH-9	5/7/2008	4800		0.068		2.5		130		0.43		0.12		18000		6.4		3.8		5.1		9400		5.5	
DH-10	5/7/2008	6200		0.079		4.2		170		0.53		0.17		22000		8.4		4.7		7.9		12000		6.9	
DH-11a	5/8/2008	19000		0.13		7.4		400		1.5		0.54		43000		14		11		20		20000		19	
DH-11b	5/8/2008	16000		0.082		4.2		570		1.3		0.3		40000		12		10		13		17000		12	

Sample ID	Date	Magesium		Manganese		Mercury		Nickel		Potassium		Selenium		Silver		Sodium		Thallium		Uranium		Vanadium		Zinc	
		Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual	Result	Qual
Surface DH1-DH5	5/7/2008	1200		110		0.0051	B	4.8		600		0.042	B	0.053		55		0.033		0.42		18		0.12	
DH-1	5/7/2008	1000		88		0.0047	B	3.4		320		0.04	B	0.035		84		0.025		0.3		9.6		7.5	
DH-2	5/7/2008	830		79		0.0042	B	3.3		280		0.04	U	0.036		68		0.027		0.27		9.5		7.7	
DH-3	5/7/2008	900		79		0.004	B	3.8		300		0.04	U	0.029		45	B	0.024		0.28		10		8	
DH-4	5/7/2008	1100		99		0.0045	B	4.5		350		0.04	U	0.037		79		0.028		0.33		12		9.3	
DH-5	5/7/2008	2400		160		0.008	B	7		1500		0.077	B	0.069		270		0.072		1.1		20		19	
DH-6	5/7/2008	820		79		0.0043	B	3.5		280		0.04	U	0.032		54		0.026		0.3		12		8.7	
DH-7	5/7/2008	1200		90	N	0.0039	B	4.1		360		0.039	U	0.032		72	E	0.026		0.37		12		11	
DH-8	5/7/2008	1600		150		0.0052	B	5.2		760		0.044	U	0.047		130		0.051		0.46		15		18	
DH-9	5/7/2008	2200		210		0.0067	B	7.1		1200		0.045	U	0.064		150		0.076		0.53		19		11	
DH-10	5/7/2008	3000		250		0.0084	B	9.3		1600		0.077	B	0.086		580		0.094		0.74		23		27	
DH-11a	5/8/2008	6800		700		0.034		18		4200		0.17		0.25		1600		0.2		1.8		34		48	
DH-11b	5/8/2008	6500		640		0.019		15		3500		0.12	B	0.12		1900		0.15		1.7		32		34	

Qual - Qualifier
B - The reported value was obtained from a reading that was less than the Practical Quantitaion Limit but greater than or equal to the Instrument Detection Limit.
N - Spiked sample recovery not within control limits. A post spike is analyzed for all ICP analyses when the matrix spike and or spike duplicate fail and the native sample concentration is less than four times the spike added concentration.
U - The analyte was analyzed but not detected.
E - The reported value is estimated because of the presence of interference. An explanatory note may be included in the narrative.

Particle Size Distribution

The following Table 4 contains the particle size distribution of the sediments sampled at the study site. The textural classification is based on the textural triangle and size class scales provided by the Desert Research Institute with the data results.

Table 4. Particle Size Distribution

					Sand Fractions					Silt Fractions					
ID	Collection Date	Collection Time	Soil Moisture (g/g)	% wt. Gravel	2.0-1.0 mm %wt.	1.0-0.5 mm %wt.	0.5-0.25 mm %wt.	0.25-0.125 mm %wt.	0.125-0.0625 mm %wt.	Fine Silt %wt.	Co. Silt %wt.	Total Sand %wt.	Total Silt %wt.	Clay %wt.	Textural Class
Surface, DH1-DH5	5/7/08	1255	0.01	24.0	22.3	24.5	22.7	12.5	8.6	1.2	5.3	90.7	6.5	2.8	sand
DH-1	5/7/08	1010	0.01	35.5	36.5	26.7	17.6	7.2	5.2	0.5	4.2	93.1	4.7	2.2	sand
DH-2	5/7/08	1050	0.01	16.3	19.3	27.3	31.3	12.2	4.4	0.9	3.1	94.7	4.0	1.3	sand
DH-2 D			*NA*	*NA*	*18.2*	*28.4*	*31.4*	*11.8*	*4.6*	*0.4*	*3.4*	*94.5*	*3.9*	*1.7*	sand
DH-3	5/7/08	1130	0.01	30.7	25.1	28.6	27.0	9.8	3.8	0.8	2.6	94.6	3.4	2.0	sand
DH-4	5/7/08	1150	0.02	16.4	20.6	29.3	27.6	11.4	5.0	1.7	3.0	93.9	4.7	1.5	sand
DH-5	5/7/08	1310	0.07	0.0	0.2	0.7	3.2	23.6	34.7	4.7	23.5	62.2	28.2	9.6	sandy loam
DH-6	5/7/08	1550	0.01	41.4	35.4	30.1	18.2	7.7	3.3	0.9	2.4	94.7	3.3	2.0	sand
DH-7	5/7/08	1635	0.02	25.6	10.3	21.6	39.6	16.6	5.8	0.4	3.9	93.8	4.2	2.0	sand
DH-8	5/7/08	1400	0.13	6.0	5.1	6.6	22.6	23.3	18.6	2.4	16.4	76.1	18.9	5.0	loamy sand
DH-9	5/7/08	1445	0.17	0.0	0.7	2.8	10.6	18.4	34.7	3.8	23.6	67.3	27.4	5.3	sandy loam
DH-10	5/7/08	1510	0.09	0.0	0.1	0.3	0.5	3.9	28.6	6.7	51.9	33.4	58.6	8.0	silt loam
DH-11a	5/8/08	1230	0.31	0.0	0.0	0.1	0.2	0.3	1.8	25.7	19.1	2.2	44.7	53.0	silty clay
DH-11b	5/8/08	1300	0.40	64.7*	0.3	0.4	0.5	1.1	6.5	24.5	23.8	8.7	48.3	43.0	silty clay

*Laboratory re-evaluating, Lab prep did not completely grind sample and large particles of clay were meaasured as gravel

Samples from DH-11 were identified as silty clays. We believe these materials were deposited from receding flood waters that occasionally filled the abandoned channel during storm water events in watersheds along the Rio Grande. These storm water events occasionally occurred from within the Los Alamos watershed. The horizon is approximately three feet thick, lies over medium grained channel sands, and is covered by silty fine grained sands originating from the Holocene terraces along the east bank of the Rio Grande.

Loam materials from boreholes DH-5, -8, -9, and -10 have been interpreted to be overbank deposits of flood materials or developing soils on the flood plain along the slough or the bar separating the abandoned channel and the existing main course of the Rio Grande. The loams found in DH-5 and DH-8 are sandwiched by the coarse sands identified as sediments from the tributaries draining the uplands along the east bank of the Rio Grande.

Other than the silty sands and clay intervals described above, the borehole materials along and adjacent to the construction alignment (DH-1 through DH-7) were generally non-uniform coarse grained sands with gravel indicative of the Cañada Ancha wash (tributary alluvium) sediments.

Summary

From February to May of 2008, representatives from the City of Santa Fe, the Buckman Direct Diversion Board, Santa Fe National Forest Service, NMED, and LANL participated in characterization efforts at the Buckman Landing along the Rio Grande to determine whether planned construction activities of the Buckman Direct Diversion would intercept an abandoned Rio Grande channel that contains LANL legacy contaminants.

We found that three sample populations may exist, 1) Cañada Ancha coarse grained sands, which exhibit few or no radiochemical measurements above a detectable value, or heavy metal values above background references, 2) flood plain or overbank fine-grained sands, deposited when the slough was active, which contain radiochemical and most trace metal levels indistinguishable from background, and 3) clay materials found in a slough, an abandoned channel that had been active only during flooding. The slough was filled with fine-grained sediments from receding flood waters during the 1940's to 1967, some originating from the canyons at LANL. The fine-grained sediments, silts and clays, contain LANL legacy contaminants.

Chemical analyses of samples collected from a borehole approximately 500 feet north of the construction area and near the southern extent of the slough, identify LANL legacy contaminants. The contaminant concentrations are similar to those reported by Englert and others, 2007, for sediments collected from boreholes drilled in 1999 and originally used to characterize the slough. The contaminant sediments are buried beneath more than four feet of sediments that contain only background levels of contamination.

The NMED and Buckman Direct Diversion Board representatives conclude that the southern extent of the slough is north of the areas to be disturbed by the BDD construction. These conclusions are based on geomorphic and the chemical characterization of sediments in the BDD study area. The planned construction activities for the BDD are unlikely to disturb slough sediments containing legacy contaminants from the Laboratory.

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