It Is Not Possible To Rehabilitate The Los Alamos National Laboratory Characterization Well R-22 For Use As A Monitoring Well To Detect Groundwater Contamination by
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1. <u>Executive Summary</u>. The LANL characterization well R-22 is at an important location for the study of the groundwater contamination from MDA G / Area G, a 65-acre dump and landfill that has disposed of hazardous and radioactive waste for fifty years. Very toxic and highly mobile mixed wastes are buried in MDA G. Area G is currently used as an active landfill for the disposal of the LANL low-level radioactive waste. MDA G / Area G is displayed on Figure 1.

At the location of LANL characterization well R-22, the groundwater in the regional aquifer is contaminated with hazardous and radionuclide waste that was released from the unlined trenches and shafts at MDA G. The nature and extent of the groundwater contamination in the regional aquifer is not known because of the many mistakes in 1). the drilling, 2). the well construction and 3). the no-purge methods that were used for collecting water samples from the five screened intervals in the multiple-screen well.

The New Mexico Environment Department (NMED) Hazardous Waste Bureau (HWB) has ordered LANL to rehabilitate well R-22 by sealing off screens #1, #4 and #5, and installing a pumping system to produce water samples from screens #2 and #3. The expensive rehabilitation required by the NMED is unacceptable for the following reasons.
- 1. The rehabilitation does not meet the requirement of the Resource Conservation and Recovery Act (RCRA) to monitor the uppermost aquifer. RCRA requires the installation of a new monitoring well to characterize and monitor the contamination that was detected in the permeable strata near the water table where screen #1 was installed. A water sample collected when the borehole was drilled into the permeable aquifer strata was contaminated with tritium and chloride.

The type and amount of contamination in the permeable strata (e.g., the RCRA uppermost aquifer) is not known because 1). the water sample was not analyzed for many contaminants of concern and 2). the water sample was diluted by the water-based organic drilling fluids. Screen #1 was installed in the permeable strata that are the RCRA uppermost aquifer but this screen never produced reliable water samples because of 1). the new reactive mineralogy created from the organic drilling fluids, and 2). the Westbay^{R} no-purge sampling system that collected stagnant water samples from the zone with the new mineralogy.

The drilling operations did not seal off the contaminated groundwater at the top of the regional aquifer. Instead, the contaminated groundwater was allowed to drain down the open borehole. A large number of hazardous waste contaminants and also tritium were detected for many years in the water samples produced from screen #5, the deepest screen in well R-22. The tritium contamination is still detected in water samples from screen #5. The contamination in screen #5 is probably because the contaminated groundwater in the uppermost aquifer was allowed to drain down the open borehole.

RCRA requires the installation of a new monitoring well close to well R-22 to characterize the groundwater contamination known to be present in the permeable strata near the top of the regional aquifer at screen #1. The new single-screen monitoring well must be drilled with casing advance methods that use only air as a drilling fluid when drilling into the regional aquifer.

- 2. Screen #2 is unacceptable as a monitoring well for LANL contamination in the regional aquifer. The NMED HWB has ordered LANL to seal off screen #1 and use screen #2 for monitoring the groundwater contamination at the top of the regional aquifer. However, the information in the LANL reports[7,8,13] show that screen #2 is installed in basalt rock with very low permeability that does not produce groundwater from the permeable aquifer strata at screen #1. Screen #2 in well R-22 does not meet the requirement of RCRA to monitor the uppermost aquifer.

In fact, the well development record and the aquifer test performed in screen #2 are proof that the very low permeability in screen #2 is not sufficient to produce a continuous flow of groundwater. Screen #2 does not meet the requirement of RCRA or of the NMED Consent Order for pumping a continuous flow of groundwater to assure that samples of *in situ* formation groundwater are collected for the analytical suite.

- 3. Screen #3 in well R-22 is unacceptable as a monitoring well for LANL contamination in the regional aquifer. The reasons screen #3 is unacceptable as a monitoring well for the characterization and long-term monitoring of the groundwater contamination from MDA G / Area G are as follows:

- Screen #3 is installed at a depth of 390 feet below the water table of the regional aquifer. The screen is installed too deep below the water table and below four sections of aquifer strata with high permeability (including the strata at screen #1) that are important to monitor but are not monitored. See Figure 3.
- Screen #3 is installed in fine-grained sediments that have low permeability.
- The zone of filter pack sediments surrounding screen #3 (i.e., the screened interval) is too long because of a mistake during the construction of the well.
- The screened interval was invaded with organic drilling additives that created a new reactive mineralogy in the stagnant zone sampled by screen #3.
- The screened interval is contaminated with grout of bentonite clay and cement because of a mistake during the construction of the well.
- The well development methods cannot clean the new reactive mineralogy or the bentonite clay grout contamination from the screened interval.
- Indeed, the restrictive pipe-based design of the well screen well prevent the well rehabilitation from even cleaning the grout contamination from the well screen. Figure 5 is a picture of a pipe-based well screen.

<u>The stainless steel screens in LANL well R-22 are unacceptable</u>. It is well known in the technical literature that stainless steel screens corrode in the oxidizing chemistry of the regional aquifer below LANL. The corrosion prevents the monitoring wells from producing reliable groundwater samples for the detection and accurate measurement of LANL contaminants. The new monitoring wells must be constructed with screens made of materials that are inert and that will not corrode.

<u>The required action at LANL well R-22</u>. The only important use for well R-22 is for the measurement of water levels. LANL should stop collecting water samples

from this well except for the collection of water samples from screen #5 for tritium. Well R-22 is important for on-going measurements of water levels. LANL must install two new single-screen monitoring wells at locations close to but west of well R-22. One well must be installed in the permeable aquifer strata that are close to the water table of the regional aquifer. The second well must be installed in the first section of aquifer strata with high permeability that are present at a depth below the depth of screen #2 in well R-22. Pumping tests must be performed in the two wells to determine the hydraulic properties of the upper 200 feet of the regional aquifer. During the pumping tests it is very important to monitor water levels in the five screens installed in well R-22.

The two new monitoring wells must be drilled with air-rotary reverse circulation casing advance drilling methods that only use air as a drilling fluid for drilling into the regional aquifer. During drilling operations it is very important to collect water samples at the water table and from the discrete layers of permeable aquifer strata that are discovered during the drilling. The water samples must be analyzed for an appropriate suite of analytes for the hazardous and radionuclide contaminants of concern for the wastes buried at MDA G / Area G

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3. <u>Background</u>. The Los Alamos National Laboratory (LANL) installed the multiple-screen characterization well R-22 to study the subsurface geology and hydrology below Mesita del Buey, the mesa where the 65-acre dump and landfill known as Material Disposal Area G (MDA G) or Area G is located. The location of well R-22 approximately 500 feet east of MDA G is displayed on Figure 1. Figure 2 is the as-built construction of well R-22 with five screened intervals. Figure 3 is a summary of the findings from the Schlumberger^R geophysics measurements that were taken in the borehole for well R-22.

- A major mistake is that well R-22 was drilled with methods that invaded the five screened intervals with organic drilling fluids that caused chemical reactions which formed a new highly reactive mineralogy in the zone surrounding the well screens. The new mineralogy[1,2,3,4] have well-known strong properties to prevent the detection and accurate measurement of groundwater contamination from the large inventory of toxic radioactive and hazardous waste buried in unlined trenches and shafts at MDA G. Well R-22 is equipped with a Westbay^R no-purge sampling system that collects stagnant water samples from the zone of new mineralogy. The zone of new mineralogy is displayed in Figure 4. LANL now uses drilling methods that do not use organic fluids, organic foams or bentonite clay drilling muds when drilling into the regional aquifer.

- A second major mistake is that the drilling methods allowed the contaminated groundwater in the permeable aquifer strata at the water table to drain down the open borehole. The contamination measured in screen #5 in well R-22 is probably because of the cross-contamination that was allowed in the open borehole.

- A third major mistake is that three of the screens in well R-22 were not installed in the permeable aquifer strata in the regional aquifer that are important to monitor for contamination. Screen #1 is installed in permeable aquifer strata near the water table that must be monitored. The Resource Conservation and Recovery Act requires a reliable single-screen monitoring well to be installed in the uppermost aquifer at screen #1. However, the New Mexico Environment Department (NMED) Hazardous Waste Bureau (HWB) has ordered LANL to plug and abandon screen #1 without replacement with a new monitoring well.

- A fourth major mistake is that the NMED HWB issued a technically indefensible letter on April 5, 2007[5] that orders LANL to rehabilitate well R-22 for use as a monitoring well to investigate groundwater contamination from MDA G. The NMED has ordered the rehabilitation to be abandonment of screens #1, #4 and #5 and installation of a pumping system to provide for purging water from screens #2 and #3. However, the rehabilitation of either screen #2 or #3 will not be successful because of the following reasons:

- 1. Screen #2 is installed in basalt rock with very low permeability that does not produce groundwater from the uppermost aquifer where screen #1 is installed.

- 2. Screen #3 is installed too deep below the water table in a layer of fine-grained sediments with low permeability that were damaged by the organic drilling fluids and by contamination from bentonite clay grout because of a mistake during the construction of well R-22. The top of screen #3 is located 390 feet below the water table of the regional aquifer.

- 3. There are three thick permeable sections of aquifer strata located above screen #3 that are important to monitor for groundwater contamination but the layers of permeable strata are not monitored by well R-22. In fact, screens #1 and #5 are the only screens in well R-22 that are installed in permeable aquifer strata in the regional aquifer.

- 4. Screen #1 is installed in the contaminated highly permeable aquifer strata near the water table that the Resource Conservation and Recovery Act[6] (RCRA) requires to be monitored. However, the NMED HWB orders the abandonment of screen #1 because of the extensive damage to this screened interval that was caused by the new reactive mineralogy formed by the organic drilling fluids. The NMED HWB has not enforced the requirement of RCRA for the installation of a new monitoring well to characterize the groundwater contamination in the permeable aquifer strata at screen #1 (e.g. The RCRA uppermost aquifer).

- 5. Screen #5 is installed greater than 560 feet (ft) below the water table of the regional aquifer. The LANL Well R-22 Completion Report[7] documents the mistakes in the drilling of well R-22 that allowed the contaminated groundwater at the water table to drain down the borehole during the drilling. The NMED HWB has not enforced the requirement in the LANL Consent Order[10] for LANL to use drilling methods that prevent the cross-contamination of groundwater in boreholes. This requirement in the Consent Order is discussed on page 8 of this report. The uncontrolled downward flow of contaminated groundwater in the open borehole is probably responsible for the radioactive and hazardous contaminants that were measured in the water samples collected for many years from screen #5. This contamination is discussed further in Section 7 beginning on page 13 of this report.

- 6. The attempt to rehabilitate well R-22 would require removing the Westbay[R] sampling system from the well. The Westbay[R] system has inflatable packers that seal off the flow of groundwater between the screened intervals. Removing the Westbay[R] system is unacceptable because the strong downward hydraulic gradient below Mesita del Buey will once again drain the contaminated groundwater at the water table of the regional aquifer down the open well.

The available information is that the basalt strata in the upper 125 ft of the regional aquifer at the location of well R-22 contain laterally extensive layers with very low permeability (known as aquitards) that naturally prevent the downward flow of groundwater. The aquitards may be present below MDA G. The presence of aquitards near the top of the regional aquifer below MDA G will prevent the downward travel of contamination from MDA G to deep into the regional aquifer below MDA G. The aquitards will cause the lateral flow of contaminated groundwater in the permeable aquifer strata (e.g., the RCRA uppermost aquifer) above the aquitards and possibly lateral flow in the direction of the slope on the surface of the aquitards.

Accurate knowledge of the hydrogeology below MDA G is essential to the installation of a reliable network of monitoring wells and to making correct decisions on the required remedy for MDA G in the New Mexico Environment Department (NMED) Consent Order.[10] The required knowledge does not exist at the present time and the requirement of the NMED HWB[5] for the technically indefensible attempt to rehabilitate well R-22 is actually a step backwards in gaining the required knowledge.

4. <u>Screen #2 in well R-22 cannot be rehabilitated</u>. There is much information that shows screen #2 is installed in layers of basalt rock that have very low permeability and will only produce small amounts of groundwater. In fact, the available information indicates that screen #2 is located inside the 90-ft thick interval in the basalt over the depth interval of 928 - 1018 ft below ground surface (bgs) that serves as an aquitard to prevent the downward flow of contaminated groundwater in the regional aquifer at the location of well R-22 and perhaps below MDA G.

Screen #2 has a length of 42 ft in the depth interval of 947 - 989 ft bgs. The filter pack sediments that surround screen #2 have a length of 70 ft in the depth interval of 937 - 1007 ft bgs. The very low permeability of the basalt in 70-ft thick interval where screen #2 is installed is shown by the fact that water could not be pumped from the zone during well development (page 9 in the well R-22 completion report[7]).

The hydraulic properties of the 70-ft screened interval surrounding screen #2 were measured by an injection test. The measured permeability was a very low value of 0.04 ft/day[8]. For comparison, the permeability values measured in some of the LANL monitoring wells are greater than 100 ft/day and up to 150 ft/day[8]. In addition, the very low permeability measured in screen #2 is proof that screen #2 is sealed off from the permeable aquifer strata near the water table at screen #1 that are very important to monitor for groundwater contamination.

5. <u>The need to replace screen #1 in well R-22 with a new monitoring well</u>.

The plan of the NMED HWB[5] to seal off screen #1 in well R-22 and use screen #2 to monitor for groundwater contamination at the water table in the regional aquifer is unacceptable because 1). screen #2 is not in hydraulic communication with the permeable aquifer strata at screen #1 and 2). groundwater contamination is present in the aquifer strata at screen #1 based on a water sample collected from the permeable strata during the drilling of the borehole for well R-22. The water sample collected from the R-22 borehole was contaminated with tritium and chloride.

The concentrations measured in the water sample collected a short distance below the water table of the regional aquifer from the R-22 borehole[7] on October 11, 2000 are compared to the background concentrations in the LANL *Groundwater Background Investigation Report - Revision 3* [9] (GBIR-3) as follows:

	- Contamination in Well R-22 Borehole Water Sample	- Background Water Quality in GBIR-3 (Table 4.3-2c) Background Screening Value
- tritium (pCi/L)	109.2 pCi/L	0.32 pCi/L
- chloride (mg/L)	21 mg/L	3.57 mg/L

The actual amount of tritium and chloride contamination in the *in situ* groundwater at the top of the regional aquifer in the RCRA uppermost aquifer will be much higher than the measured concentrations because the water sample collected from the borehole was diluted by the water-based drilling fluids. The well R-22 well completion report acknowledged that the water sample collected from the borehole was diluted and other wise compromised by the organic drilling fluids. The pertinent excerpt from page 32 of the well R-22 report[7] is pasted below:

> - "Because of the presence of EZ-MUD®, QUIK-FOAM®, and other drilling fluids, these borehole water samples are not representative of groundwater. Consequently, these data are used only for screening purposes to assist drilling

decisions. Groundwater samples will be collected and analyzed for major ions, trace metals, stable isotopes, organic compounds, selected radionuclides, and other chemicals during characterization sampling."

However, screen #1 in well R-22 never produced reliable and representative water samples for the above chemical constituents, RCRA hazardous waste contaminants, radionuclide contaminants and stable isotopes because of 1). the drilling mistakes that drained the groundwater at the water table down the open borehole, 2). the new reactive mineralogy formed by the organic drilling fluids, and 3). the Westbay[R] no-purge sampling system that collected stagnant water samples that were in contact with the new reactive mineralogy for a long period of time.

Nevertheless, the tritium and chloride contamination in the water sample collected from the RCRA uppermost aquifer during the drilling of the R-22 borehole are proof that contamination has traveled from the wastes buried in MDA G to the regional aquifer at the location of well R-22. It is mandatory under RCRA 40 CFR §264 Subpart F[6] to install a new monitoring well near the location of well R-22 to characterize the groundwater contamination in the permeable aquifer strata that are close to the water table. The permeable strata near the water table may be the source for the technetium-99 and tritium contamination and the large number of hazardous waste contaminants detected in water samples collected from the screened intervals in well R-22 that are below screen #1. The drilling mistakes allowed the contamination near the water table to travel down the borehole and contaminate the deeper screened intervals. The cross-contamination is discussed further in Section 7 of this report.

Unfortunately, LANL did not perform a pumping test to measure the flow of groundwater from screen #1. Measuring the hydraulic properties of screen #1 was a requirement of RCRA. However, 1). the geologic log for well R-22, 2). the Schlumberger[R] geophysics measurements, and 3). the description of drilling through the zone where screen #1 is installed are all evidence that screen #1 is installed in permeable aquifer strata that will produce a sufficient flow of water to operate a submersible pump.

The fluid-assisted drilling method circulated a steady flow of water in the drilling system. However, the drillers noted an increase in the flow of water from the discharge line while drilling through the depth interval of 890 to 900 ft bgs (page 30 in well R-22 completion report[7]). Drilling was stopped at the depth of 900 ft bgs to observe water levels which stabilized at a depth of 883 ft bgs - the water table of the regional aquifer.

The water table of the regional aquifer is at the depth of 883 ft bgs and screen #1 in well R-22 is installed across the water table in the depth interval of 872 - 914 ft bgs. The well R-22 geologic log[7] describes the basalt as follows:

- 780 - 893 ft bgs: massive basalt
- 893 - 903 ft bgs: <u>no sample recovery</u> *(this is evidence of a permeable zone)*
- 903 - 928 ft bgs: basalt with local fractures
- 928 - 958 ft bgs: massive basalt with no mention of fractures

The 10 foot interval with no sample recovery is evidence of a zone in the basalt with high permeability. This is because the reverse circulation drilling method produced drill cuttings of high quality because the cuttings traveled directly from the drill bit up a small diameter pipe to land surface. If no cuttings are produced with this drilling method, then this is evidence that the zone has high permeability with large dimensions of open porosity for accepting the cuttings. The Schlumberger[R] Water Filled Porosity log in Figure 3 shows a high porosity for the interval of no sample returns. In addition, for the entire borehole, the Schlumberger[R] Permeability log in Figure 3 assigns the highest permeability to the interval of no sample recovery at screen #1. For comparison, note the very low permeability on the Shlumberger[R] permeability log for most of the interval surrounding screen #2.

The well R-22 report[7] describes that the location for screen #2 was picked only because the static water level in the R-22 borehole was at 955 ft bgs when the borehole was drilled to the total depth of 1489 ft bgs. The 72 ft drop in static water level from 883 ft bgs to 955 ft bgs was because the borehole penetrated an aquitard in the Cerros del Rio Basalt. The drilling operations at well R-22 did not install cemented casing to prevent the contaminated groundwater at the water table from flowing down the open borehole.

The water table was restored to the depth of 883 ft bgs after the Westbay[R] sampling system was installed in the multiple-screen well. The Westbay[R] system sealed off water flow between the screened intervals. Removing the Westbay[R] system for the technically indefensible attempt to rehabilitate well R-22 will allow the groundwater at the water table to once-again cross-contaminate the deeper screened intervals in well R-22 and this must be prevented. The drainage will also prevent accurate knowledge of groundwater contamination at the water table of the regional aquifer because the drainage will draw in water from all directions radially around screen #1 where the basalt aquifer strata are present.

In fact, the NMED LANL Consent Order[10] describes the importance for LANL to use drilling methods and well construction practices that prevent the borehole and the well from being a conduit for cross-contamination. The pertinent excerpt from page 189 of the Consent Order is pasted below:

> - **X.B DRILLING METHODS**
>
> Groundwater monitoring wells and piezometers must be designed and constructed in a manner which will yield high quality samples, ensure that the well will last the duration of the project, and ensure that the well will not serve as a conduit for contaminants to migrate between different stratigraphic units or aquifers [emphasis added].
>
> • Contamination and cross-contamination of groundwater and aquifer materials during drilling shall be avoided [emphasis added].

For well R-22, the drilling mistakes allowed cross-contamination of groundwater during the drilling and well construction activities. The design of well R-22 ensures that the well will serve as a conduit for contaminants to migrate between different stratigraphic units if the Westbay[R] packer system is removed from the well. The NMED HWB is not enforcing the drilling and well construction requirements in the Consent Order.

6. Screen #3 in well R-22 cannot be rehabilitated. The reasons that screen #3 in well R-22 cannot be rehabilitated include the following:

- The screen is installed too deep below the water table and below layers of aquifer strata with high permeability that are important to monitor but are not monitored.

- The screen is installed in fine-grained sediments that have low permeability.
- The zone of filter pack sediments surrounding the screen (i.e., the screened interval) is too long.
- The screened interval was invaded with organic drilling additives that formed a new reactive mineralogy in the stagnant zone sampled by screen #3.
- The screened interval is contaminated with grout of bentonite clay and cement because of a mistake during the construction of the well.
- The methods that will be used for well rehabilitation cannot clean the new reactive mineralogy or the grout contamination from the screened interval.
- Indeed, the restrictive pipe-based design of the well screen will prevent the rehabilitation from even cleaning the grout contamination from the well screen.

Screen #3 is installed 390 feet below the water table of the regional aquifer and below thick intervals of permeable aquifer strata that are important to monitor for groundwater contamination. The permeable aquifer strata that are not monitored are discussed below in Sections 7 and 8.

Screen #3 has a short length of only 6.7 ft at a depth from 1272.2 to 1278.9 ft bgs. However, because of a mistake in well construction, the screen is installed inside a 49.5 ft long interval of filter pack sediments in the depth interval of 1234.5 - 1284 ft bgs. The standard industry practice is to limit the zone of filter pack sediments to not greater than five feet above and below the screen.

The LANL Hydrogeologic Workplan[11] that was approved by the NMED required the LANL characterization wells to be constructed with the zone of filter pack sediments not greater than two feet above or below the screen. However, for screen #3, the zone of filter pack sediments extends a distance of 37.7 feet above the screen and 5.1 feet below the screen. See Figure 2 for the as-built construction of well R-22.

The Well R-22 geologic log[7] shows that screen #3 was installed in an interval of fine-grained sediments that have a low permeability. The geologic log is pasted below:

- 1237 - 1258 ft bgs: gravel with fine to very coarse-grained sand
- 1258 - 1263 ft bgs: fine sand to pebble gravel
- 1263 - 1268 ft bgs: very fine to fine sand with 10% pebbles
- 1268 - 1273 ft bgs: very coarse sand with 10% pebbles
- 1273 - 1278 ft bgs: <u>very fine silty sand to pebble gravel</u>
- [1272.2 - 1278.9 ft bgs - - depth interval of screen #3]
- 1278 - 1288 ft bgs: medium to very coarse sand - minor amount of small pebbles

The reverse circulation drilling method produced drill cuttings of high quality because the cuttings travel directly from the drill bit up a small diameter pipe to land surface. The drill cuttings show that screen #3 was installed in silty, poorly sorted sediments with low effective porosity and low permeability. However, the geologic log shows that coarse sand sediments with a much higher effective porosity and permeability are located immediately above and below screen #3. In fact, the Schlumberger[R] geophysics logs in Figure 3 also show that sediments with markedly higher permeability and water- filled porosity are located immediately above and below screen #3.

A LANL aquifer test[8] measured a low permeability of only 0.32 ft/day for screen #3. This low value is expected for the description of the poorly sorted fine-grained sediments that surround the screen. The low permeability value is also expected because of the plugging properties of the new mineralogy in the screened interval that was formed by the organic drilling additives and the bentonite clay grout contamination.

An additional reason why screen #3 cannot be rehabilitated is that the screened interval was invaded with the bentonite clay/cement grout backfill materials because of a mistake during the construction of the well. The pertinent excerpt from page 8 of the well R-22 completion report[7] is pasted below:

> - "Initial development [of well R-22] consisted of scrubbing the inside of the casing and screens with a brush installed on drill pipe. After scrubbing was completed, muddy fluid and settled solids were bailed from the well. The initial high turbidity, pH, and conductivity readings were likely due to cement-tainted fluids that apparently entered through screen #3 during backfilling."

The **"***cement-tainted fluids that apparently entered through screen #3 during backfilling***"** are evidence of a large amount of contamination in the filter pack sediments surrounding screen #3 with the bentonite clay/cement grout that was used to seal the annular space between the well casing and the borehole wall during the construction of well R-22. The grout contamination cannot be cleaned from the screened interval. In fact, the restrictive design of the pipe-based screens installed in well R-22 prevents the grout contamination from being cleaned even from the well screen. The pipe-based design of the well screens is displayed in Figure 5. A pipe is installed inside the stainless steel well screen. The only access to clean screen #3 is by surging water through holes drilled in the pipe. The holes only provide access to only 5% to 10% of the surface area of the wire-wrapped well screen.

The extreme difficulty in removing the residual drilling fluids, the new reactive mineralogy, and the grout contamination from pipe-based well screens was described in a August 30, 2005 report by the NMED Oversight Bureau (OB) [12] as follows:

1. Because of their configuration, pipe-base screens may not have been appropriate. <u>Pipe-base screens tend to trap drilling fluid material, fine-grained drilling flower, etc., making development procedures extremely difficult. V-wire and/or rod-base screens should have been utilized</u> [emphasis added]. Pipe-base screens installed at R-7 (LANL, 2002a), R-19 (LANL, 2001a) and R-22 (LANL, 2002b), and possibly other Westbay wells, were constructed by drilling holes in solid well casing and welding a wire wrap over the perforated interval. Note that rod-base screens were used at R-12 (2001b) and R-25 (LANL, 2002c); slotted screens were used at R-31 (LANL, 2002d).

The NMED HWB ordered the rehabilitation of well R-22 despite the position of the NMED OB that the pipe-based screens would make the rehabilitation extremely difficult. In fact, the pipe-based screens are one factor that will make rehabilitation impossible.

The on-going effects of 1). the residual drilling fluids and 2). the grout contamination on the chemistry of water samples produced from screen #3 in well R-22 was described in the LANL report LA-UR-04-6777 (Sept 2004)[13]. The pertinent excerpts from page 29 of the report are pasted below:

- **"Screen 3:** Elevated concentrations of sodium, strontium and sulfate [in the water samples collected from screen 3] indicate residual bentonite is present [in the screened interval]."

- "[Water samples collected from] (S}creens 1,3, 4 and 5 [in well R-22] are not yet representative, although residual drilling fluid is breaking down through oxidation reactions and concentrations of sulfate are returning above detection."

The LANL report[13] does not inform the reader of the well-known strong adsorption properties of bentonite clay[1,2,3,4] to remove many of the LANL contaminants from the water samples collected from screen #3. In addition, the LANL report does not inform the reader that the organic drilling fluids have formed a new reactive mineralogy[1,2,3,4] in the screened interval with well-known strong adsorption properties to remove many of the LANL contaminants from the water samples collected from screen #3. In the above report and in many other reports, the LANL scientists make the mistake to claim that when the expected oxidizing background chemistry returns to the water samples, then the screened intervals have *"cleaned up"* and produce reliable and representative water samples. This *"assumption"* is not true as was pointed out in Langmuir,1997[1], the author's 2004 report[2], in the two reports in 2006 by the Environmental Protection Agency (EPA) Kerr Research Laboratory[3,4], and even in a Sept. 18, 2006 Notice of Disapproval (NOD) by the NMED[14] (see discussion of the NMED NOD below).

Nevertheless, despite the above reports, the LANL scientists *still* rely on only the return of an oxidizing chemistry to the water samples produced from the impacted wells for the decision that the screens have cleaned up and produce reliable and representative water samples. Nevertheless, despite the above reports, the NMED HWB in a letter dated May 25, 2007[15], approved of the LANL ***technically indefensible decision*** that an oxidizing chemistry indicates the wells have cleaned up and are well-suited for use as monitoring wells. The approval by the NMED HWB on May 25, 2007 is in contradiction with the technical assessment in the NMED NOD of September 18, 2006.[14]

In fact, the NMED NOD of September 18, 2006 shows that NMED was aware that the new reactive mineralogy would still be present *after* the wells produced water samples with an oxidizing chemistry. The pertinent excerpt from the NMED NOD is pasted below:

- "The presence of residual drilling fluids may not only turn groundwater from aerobic into anaerobic water, but also cause composition changes in aquifer solid materials adjacent to well screens. For example, the availability of organic compounds contained in drilling fluids likely stimulates sequential microbial metabolism, including iron and sulfate reduction. As a result, it is likely that iron sulfides are produced as precipitates, thereby enhancing the reactivity of the aquifer solids adjacent to impacted screens. It has been well-documented that iron sulfides are able to reductively transform organics such as chlorinated solvents, and some oxidizing metals and ions (e.g., hexavalent chromium, perchlorate, nitrate). In addition, the change of mineralogical compositions may also increase the adsorption capability of aquifer materials adjacent to where aerobic conditions [i.e., oxidizing groundwater] have been re-established after rehabilitation may still produce biased concentrations for certain contaminants in comparison to formation water" [emphasis added].

To prevent the formation of the new reactive mineralogy in screened intervals of the LANL monitoring wells, the NMED LANL Consent Order[10] that was signed into law on March 1, 2005 required the use of chemicals to destroy the organic drilling additives before the well was developed. The pertinent excerpt from page 191 of the Consent Order is pasted below:

- "Drilling muds provide greater borehole stabilization than water alone. There are several types of mud presently available, including bentonite, barium sulfate, organic polymers, cellulose polymers, and polyacrylamides. While drilling muds enhance the stability of the borehole and allow for drilling in formations not appropriate to other methods, they can adversely affect the hydrologic properties and geochemistry of the aquifer. For example, drilling fluid invasion and the buildup of borehole filter cake may reduce the effective porosity of the aquifer in the vicinity of the borehole [and form a stagnant zone] [emphasis added]. In addition, bentonite drilling muds may affect the pH of groundwater and organic polymer drilling muds have been observed to facilitate bacterial growth, which reduces the reliability of sampling results. If polymer emulsions are to be used in the drilling program at the Facility, polymer dispersion agents shall be used at the completion of the drilling program to remove the polymers from the boreholes. For example, if EZ Mud® is used as a drilling additive, a dispersant (e.g., BARAFOS® or five percent sodium hypochlorite) shall be used to disperse and chemically breakdown the polymer prior to developing and sampling the well" [emphasis added].

EZ Mud® was a drilling additive in the water-based drilling fluids that were used for drilling into the regional aquifer in the borehole for well R-22. However, no chemicals were used to disperse and chemically breakdown the organic polymer prior to developing and sampling the screened intervals in well R-22. In fact, until 2007, organic polymer drilling additives were used for drilling practically all boreholes into the regional aquifer but the NMED HWB never enforced the requirement in the Consent Order for the use of chemicals to destroy the organic polymers. The 2007 Final Report[16] of the National Academy of Sciences (NAS) described the importance to use chemicals to destroy the organic drilling additives. The pertinent excerpt from page 56 of the NAS report is pasted below:

- "The [NMED LANL] Consent Order allows mud rotary drilling while providing cautions about changes in the near-borehole environment that can be caused by bentonite and ionic or organic polymer fluids. In addition, the Consent Order recognizes that a polyacrylamide mud, such as EZ-Mud®, can be used appropriately if it is followed with a dispersant, such as BARAFOS®, to facilitate the breakdown and removal of the polymer. If the appropriate dispersant is applied, there should be reasonable success in recovering the dispersed and degraded EZ-Mud®."

In addition, the 2007 NAS Final Report described the importance of using drilling methods that prevented the invasion of drilling mud or additives into the monitoring zone. The pertinent excerpt from page 70 of the NAS report is pasted below:

> - ***Recommendation:*** *LANL should design and install new monitoring wells with the following attributes:*
> *• A borehole drilled through the monitoring zone without the introduction of drilling muds or additives (i.e., use air or water),*
> *• One screened interval that targets a single saturated zone, and*
> *• A carefully planned design (length and depth) of the well screen, which is confirmed with information collected in the drilling process.*

- **The three bulleted recommendations by the National Academy of Sciences are the same recommendations that the author made to LANL, DOE and NMED in 1998. The author's recommendations were not followed with the result being an estimated misspending of more than $250 million over the past ten years and the misspending continues at the present time with the technically indefensible attempt to rehabilitate the damaged LANL characterization wells as one example.**

7. The thick layers of permeable aquifer strata above screen #3 that are not monitored. There are three thick sections of permeable aquifer strata located below screen #2 and above screen #3 in well R-22 that are not monitored. The available information indicates the three sections will produce large supplies of groundwater. RCRA requires the installation of monitoring wells in the permeable aquifer strata to investigate groundwater contamination from the three RCRA "regulated units" waste disposal facilities known as MDA G, MDA H and MDA L. MDA L and MDA H are located atop Mesita del Buey west of MDA G.

Two of the thick layers of permeable aquifer strata are in the basalt and were identified by both the geologic log for well R-22 and the Schlumberger^{R} geophysics. The third layer is a thick interval of river gravels located below the basalt but above screen #3. The layer of river gravels is described in Section 8.

The two thick layers of aquifer strata in the basalt are described below. The upper layer is a thick deposit of scoria. The lower layer is a thick interval of volcanoclastic deposits between two basalt flows. For comparison, the depth of the screened interval for screen #3 below the two layers of aquifer strata is from 1244 -1284 ft bgs.

Scoria Layer. 1033 - 1063 ft bgs, 30-foot thick interval of scoria strata

- 1033 - 1038 ft bgs. Basalt, similar to above but including scoria
- 1038 - 1043 ft bgs. Basalt, dominantly porphyritic scoria
- 1043 - 1048 ft bgs. Basalt, 80 - 85% basalt particles, possibly scoria-bearing sediments
- 1048 - 1063 ft bgs. Basalt, dominantly basalt fragments and scoria

Basalt scoria are well known in the technical literature to be permeable aquifer strata that produce large supplies of groundwater.

Figure 3 shows that the Schlumberger^{R} geophysics measured an interval of high water-filled porosity, high permeability and low density for the layer of scoria. The

Schlumberger[R] geophysics measurements and the geologic log show the layer of scoria to be a thick interval of aquifer strata that are capable of producing large supplies of groundwater. The productive layer of scoria is not monitored by well R-22.

Interflow Layer. 1088 - 1138 ft bgs - 50-foot thick layer of productive aquifer strata

- 1088 - 1133 ft bgs. Basalt, no sample recovery (45-ft interval)
- 1133 - 1138 ft bgs. Basalt, 20% pebble gravel (5-ft interval)

Figure 3 shows that the Schlumberger[R] geophysics measured an interval of high water-filled porosity, high permeability and low density for the 45-ft interval of no sample recovery in the interflow layer. The geophysics measurements and the drilling record indicate the interflow deposits are capable of producing large supplies of groundwater.

The above excerpt from the geologic log in the well R-22 completion report shows that there was a 45-ft thick interval of no sample recovery that is above a 5-ft interval that contains a large amount of pebble gravel. The information indicates that the 50-ft thick layer is an interval of water-laid coarse sediments that were deposited between two separate basalt flows. It is well known in the technical literature for the interflow deposits to be highly permeable and to produce large supplies of groundwater. The fact that the reverse circulation drilling method did not produce any drill cuttings over a 45-ft interval is evidence of a productive aquifer. As described on page 7-8 of this report, when no cuttings are produced with this drilling method, then this is evidence that the zone has high permeability with large dimensions of open porosity for accepting the cuttings.

In summary, the Schlumberger[R] geophysics measurements and the geologic log show the inter-flow deposits to be a thick interval of aquifer strata that are capable of producing large supplies of groundwater. This thick layer of productive aquifer strata is not monitored by well R-22.

8. The permeable river gravel aquifer strata above screen #3 that are not monitored. At well R-22, the LANL scientists expected a thick interval of river gravels in an ancestral valley of the Rio Grande to be present in the 46-ft thick depth interval from 1191 - 1237 ft bgs where there was "no sample recovery." The formal stratigraphic name for the river gravels is the Totovi River Gravels. The pertinent section from the well R-22 geologic log[7] is pasted below:

- 1188 - 1191 ft bgs. Puye Formation, gravel with coarse sand (3-ft interval)
- 1191 - 1237 ft bgs. Puye Formation, no sample recovery (46-ft interval)
- 1237 - 1258 ft bgs. Puye Formation, gravel with fine to very coarse sand (21-ft interval)

Indeed, the LANL scientists speculated in the well R-22 completion report that the Totavi River Gravels were in the 46-ft interval of no sample recovery. The pertinent excerpt from page 38 of the well R-22 report[7] is pasted below:

> "Beneath the Cerros del Rio lavas [i.e., basalt], the predicted stratigraphy included two units that were not encountered– axial river gravels of the Puye Formation (“Totavi” river gravels) and sediments of the Santa Fe Group. The as-drilled stratigraphy at R-22 owes its peculiarities to several features. First and most important is the exceptional thickness of Cerros del Rio lavas and cinder, indicating fill within a paleocanyon. The absence of quartzite-rich axial river gravels at the base of this Cerros del Rio volcanic series suggests that this

> paleocanyon was not the path of a through-going drainage ancestral to the modern Rio Grande. It is important to note, however, that cuttings were not returned from ~51 ft of key intervals beneath the Cerros del Rio lavas. (No cuttings were returned at the 1178- to 1183-ft depth or at the 1191- to 1237-ft depth.) It is thus possible that quartzite-rich gravels may have been present within 5 ft of the base of the Cerros del Rio but were not sampled. As a result, it is uncertain whether the orientation of the paleocanyon may be more east-west (carved by flow from the volcanic highlands) than north-south (carved by rift-controlled flow)."

It was a mistake to drill through the 46-ft interval of "no sample recovery" without taking special measures to acquire geologic samples of the interval. Changes to the drilling procedures to enable collection of cuttings from the reverse circulation drilling system are simple to implement. The procedure is to turn off the circulation of drilling fluids and drill a distance of only several inches to a foot. Then when the circulation system is turned on, the drill cuttings will be delivered to land surface. If this simple method doesn't deliver cuttings, then the alternative is to remove the drilling system from the borehole and install a coring system to collect samples of the sediments. It is a serious mistake that care was not taken to acquire accurate knowledge of the hydrologic properties of the regional aquifer below Mesita del Buey at hydrogeologic characterization well R-22 at a location 500 feet east of MDA G and Area G, the LANL active waste disposal facility for radioactive waste.

9. The hazardous and radionuclide contamination measured in the water samples collected from well R-22. The large suite of radioactive and hazardous waste contaminants that were detected for many years from the screened intervals in well R-22 were listed in the three LANL reports LA-13893-MS (February 2002) [7], LA-13986-MS (September 2002) [17] and LA-UR-04-677 (September 2004).[13] The contamination is summarized in the list below:

- Contaminants detected in groundwater samples collected from well R-22.

– Contaminants listed in the LANL Well R-22 Completion Report [7]
– tritium - 109 picocuries per liter (pCi/L) at the water table of the regional aquifer
– chloride - 21 mg/L at the water table of the regional aquifer

– Contaminants listed in the LANL Well R-22 Geochemistry Report.[17]
– tritium - many detections
– technetium-99 (4.3 and 4.9 pCi/L)
– *****pentachlorophenol (6.2 parts per billion (ppb))
– *****chloroform (0.94 ppb)
– *****phenol (19 and 32 ppb)
– *****4-methylphenol (44 to 210 ppb)
– *****2-butanone (6.9 to 8.9 ppb)
– *****diethylphthalate (1.3 ppb)
– benzo(a)pyrene (0.24 ppb)
– benzoic acid (3 to 12.5 ppb)
– butyl benzyl phthalate (9.8 ppb)
– toluene (0.2 to 0.76 ppb)
– methylene chloride (0.62 and 2.2 ppb)
– bis(2-ethylhexyl)phthalate (1.0 and 3.9 ppb)

– Several substituted benzene compounds including
– isopropylbenzene (0.16 to 0.54 ppb), and
– 1,4-dichlorobenzene (0.16 to 0.23 ppb).

- Tritium and technetium-99 are radionuclide contaminants that are highly mobile. Large amounts of both contaminants are buried in unlined pits and shafts at MDA G and Area G. The detection of the two contaminants in water samples collected from well R-22 are evidence of groundwater contamination from MDA G and Area G.

- *****The six hazardous waste contaminants with asterisks in the above list are highly mobile in groundwater and all are commonly found in groundwater beneath hazardous waste dumps. There are large amounts of these contaminants in the mixed wastes buried in MDA G. The measurement of these contaminants in the water samples produced from well R-22 is evidence of groundwater contamination below MDA G. The nature and extent of the contamination is not known but must be investigated.

A LANL report – (LA-UR-04-6777, September 2004) [13] recognized the on-going contamination detected in the water samples produced from well R-22 as follows:

- "Thirty-one volatile and semi-volatile organic compounds have also been detected in water from well R-22. Only two of these, pentachlorophenol (1 detection, 6.2 ppb, MCL = 1 ppb) and benzo(a)pyrene (2 detections, 0.24 ppb, MCL = 0.2 ppb) were present at concentrations above the MCL. Monitoring for organic compounds at well R-22 will continue" [MCL means Maximum Contaminant Level allowed in the EPA Drinking Water Standards].

A large number of organic chemical contaminants were repeatedly detected in the water samples collected from screen #5 in well R-22. Table 1 on page 19 presents the organic chemicals detected in screen #5 for the sampling event on December 10, 2001. The contamination detected in screen #5 is an important reason for not plugging and abandoning the screen. The contamination in screen #5 is probably from the cross-contamination that was allowed in the borehole for well R-22. Until the source of the contamination is understood, screen #5 needs to be kept available for sampling. In the future, it may be necessary to install a submersible pump in screen #5 so that a large volume of groundwater may be purged from the screened interval during the collection of time-series water samples in an attempt to collect *in situ* groundwater samples that are not impacted by the cross-contamination or by the new reactive mineralogy in the zone surrounding screen #5.

The tritium contamination measured in the groundwater samples collected from screen #5 are presented in the list below. For comparison, the background screening concentration listed in the LANL GBIR-3[9] for tritium in the regional aquifer is 0.32 pCi/L.

Sample Date	Tritium concentration
- 06-26-2000	14 pCi/L
- 12-07-2001	17 pCi/L
- 03-07-2002	15 pCi/L
- 07-10-2002	13 pCi/L
- 11-21-2003	12.5 pCi/L
- 07-05-2005	11.1 pCi/L
- 08-21-2006	8.7 pCi/L
- 12-06-2006	7.8 pCi/L

- Sample Date   Tritium concentration (continued)
  - 03-22-2007   8.1 pCi/L
  - 07-10-2007   7 pCi/L
  - 09-07-2007   7 pCi/L
  - 12-18-2007   7 pCi/L
  - 03-05-2008   3 pCi/L
  - 06-23-2008   6 pCi/L
  - 09-16-2008   7 pCi/L

Under RCRA, the contamination detected in well R-22 is ***"statistically significant evidence of contamination."*** Accordingly, DOE is required to comply with the requirement in RCRA 40 CFR §264.98 for a Compliance Monitoring Program at MDAs G, H and L. The pertinent excerpts from §264.98 are pasted below:

> §264.98 (f) The owner or operator must determine whether there is statistically significant evidence of contamination for any chemical parameter of hazardous constituent specified in the permit pursuant to paragraph (a) of this section at a frequency specified under paragraph (d) of this section.
>
> (1) In determining whether statistically significant evidence of contamination exists, the owner or operator must use the method(s) specified in the permit under §264.97(h). These method(s) must compare data collected at the compliance point(s) to the background ground-water quality data.
>
> (2) The owner or operator must determine whether there is statistically significant evidence of contamination at each monitoring well as the compliance point within a reasonable period of time after completion of sampling. The Regional Administrator will specify in the facility permit what period of time is reasonable, after considering the complexity of the statistical test and the availability of laboratory facilities to perform the analysis of ground-water samples.
>
> (g) If the owner or operator determines pursuant to paragraph (f) of this section that there is statistically significant evidence of contamination for chemical parameters or hazardous constituents specified pursuant to paragraph (a) of this section at any monitoring well at the compliance point, he or she must:
>
> (1) Notify the Regional Administrator of this finding in writing within seven days. The notification must indicate what chemical parameters or hazardous constituents have shown statistically significant evidence of contamination;

(2) Immediately sample the ground water in all monitoring wells and determine whether constituents in the list of appendix IX of this part are present, and if so, in what concentration. However, the Regional Administrator, on a discretionary basis, may allow sampling for a site-specific subset of constituents from the Appendix IX list of this part and other representative/related waste constituents.

(3) For any appendix IX compounds found in the analysis pursuant to paragraph (g)(2) of this section, the owner or operator may resample within one month or at an alternative site-specific schedule approved by the Administrator and repeat the analysis for those compounds detected. If the results of the second analysis confirm the initial results, then these constituents will form the basis for compliance monitoring. If the owner or operator does not resample for the compounds in paragraph (g)(2) of this section, the hazardous constituents found during this initial appendix IX analysis will form the basis for compliance monitoring.

(4) Within 90 days, submit to the Regional Administrator an application for a permit modification to establish a compliance monitoring program meeting the requirements of §264.99. The application must include the following information:

(i) An identification of the concentration of any appendix IX constituent detected in the ground water at each monitoring well at the compliance point;

(ii) Any proposed changes to the ground-water monitoring system at the facility necessary to meet the requirements of §264.99;

(iii) Any proposed additions or changes to the monitoring frequency, sampling and analysis procedures or methods, or statistical methods used at the facility necessary to meet the requirements of §264.99;

The Department of Energy and the prime contractor Los Alamos National Security (LANS) have not complied with the requirements in RCRA for the groundwater contamination that was measured in well R-22. Furthermore, the NMED HWB is well aware of the groundwater contamination but has not enforced the requirements under RCRA 40 CFR §264.99 for a Compliance Monitoring Program at MDAs G, H and L.

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12. NMED OB (New Mexico Environment Department Oversight Bureau), August 30, 2005. NMED DOE Oversight Bureau Evaluation of LANL Westbay Monitoring Wells: Well Construction, Completion, and Development, August 30, 2005

13. LANL (Los Alamos National Laboratory), September 2004. "Response to Concerns About Selected Regional Aquifer Wells at Los Alamos National Laboratory," Los Alamos National Laboratory document LA-UR-04-6777, Los Alamos, New Mexico. (LANL 2004, 088420)

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15. NMED (New Mexico Environment Department), May 25, 2007. Notice of Approval for the Los Alamos National Laboratory *"Well Screen Analysis Report - Revision 2."*

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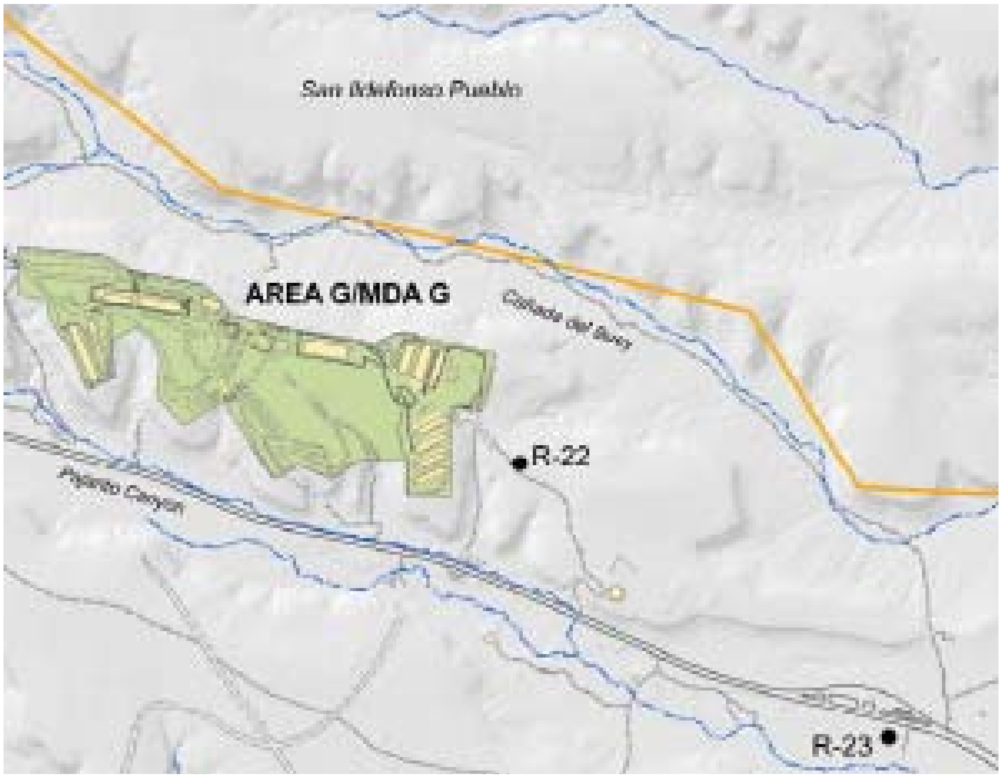
17. Longmire, P., October 2002. "Characterization Well R-22 Geochemistry Report," Los Alamos National Laboratory report LA-13986-MS, Los Alamos, New Mexico.

Table 1. Data summary for detected organic chemicals in the groundwater sample collected on January 10, 2001 from screen #5 in LANL characterization well R-22.
Source: Table A-40 *in* LANL Well R-22 Geochemistry Report

Analyte	Screen	Depth (ft)[a]	Collection Date	Field Preparation	Number of Analyses	Number of Detects	Detected Value (µg/L)	Non-detected Value (µg/L)	Drinking Water MCL[b] (µg/L)
Acenaphthene	5	1448	12/10/01	NF[e]	1	1	0.42	—[f]	—
Acenaphthylene	5	1448	12/10/01	NF	1	1	0.4	—	—
Anthracene	5	1448	12/10/01	NF	1	1	0.36	—	—
Benzo(a)pyrene	5	1448	12/10/01	NF	1	1	0.24	—	0.2
Benzo(b)fluoranthene	5	1448	12/10/01	NF	1	1	0.41	—	—
Benzo(k)fluoranthene	5	1448	12/10/01	NF	1	1	0.38	—	—
Bis(2-ethylhexyl)phthalate	5	1448	12/10/01	NF	1	1	1	—	6
Chloronaphthalene[2-]	5	1448	12/10/01	NF	1	1	0.46	—	—
DDT[4,4'-]	5	1448	12/10/01	NF	1	1	0.024	—	—
Diethylphthalate	5	1448	12/10/01	NF	1	1	1.3	—	—
Fluoranthene	5	1448	12/10/01	NF	1	1	0.38	—	—
Fluorene	5	1448	12/10/01	NF	1	1	0.42	—	—
Methylnaphthalene[2-]	5	1448	12/10/01	NF	1	1	0.42	—	—
Pentachlorophenol	5	1448	12/10/01	NF	1	1	6.2	—	1
Phenanthrene	5	1448	12/10/01	NF	1	1	0.4	—	—
Pyrene	5	1448	12/10/01	NF	1	1	0.49	—	—
Toluene	5	1448	12/10/01	NF	1	1	0.76	—	1000
Total Organic Carbon	5	1448	12/10/01	NF	1	1	4880	—	—

[a] The static water level for the regional aquifer at R-22 was 883 ft when the well was drilled.
[b] MCL = Maximum contaminant level. US Environmental Protection Agency (EPA) MCLs are from *National Primary Drinking Water Regulations*, 40 CFR *Secondary Drinking Water Regulations*, 40 CFR Part 143. State of New Mexico MCLs are from *Drinking Water Regulations*, 20 NMAC 7.1.
[c] NMED = New Mexico Environment Department.
[d] State of New Mexico groundwater standards are from *New Mexico Water Quality Control Commission Regulations, Ground and Surface Water Protect*
[e] NF = Nonfiltered.
[f] — = Not available or not applicable.

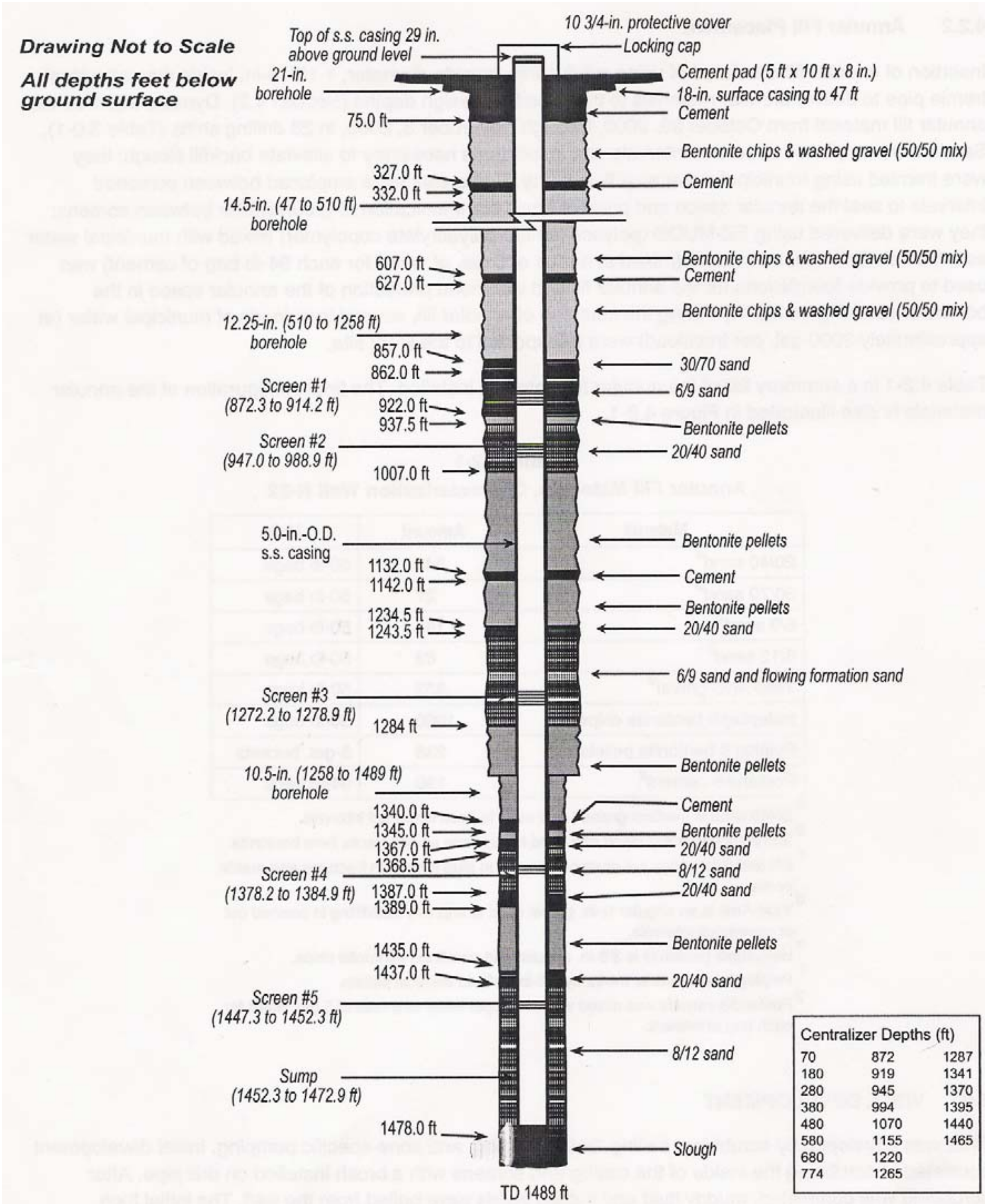
Figure 1. The locations of LANL characterization wells R-22 and R-23 east of the LANL 63-acre landfill and waste dump Area G/MDA G.



scale 0 - - - - - - - - 1000 feet

- **The orange line north of MDA G marks the boundary of LANL with the San Ildefonso Pueblo.**
- **Wells R-22 and R-23 are installed in the regional aquifer to monitor groundwater contamination from MDA G. The distances from the eastern boundary of MDA G to wells R-22 and R-23 are 500 feet and 3,300 feet, respectively.**
- **The direction of groundwater flow at the water table below MDA G is from west to east toward the Rio Grande. The travel time for contaminated groundwater below MDA G to reach wells R-22 and R-23 is not known.**
- **The 2008 LANL Environmental Surveillance Report states that the speed of lateral groundwater travel in the regional aquifer below LANL is generally 30 feet per year. Accordingly, the time for contaminated groundwater in the regional aquifer below MDA G to reach wells R-22 and R-23 is as follows:**
  - **eastern boundary of MDA G to well R-22 = 15 years**
  - **middle of MDA G to well R-22 = 65 years**
  - **western boundary of MDA G to well R-22 = 130 years**
  - **eastern boundary of MDA G to well R-23 = 110 years**
  - **middle of MDA G to well R-23 = 165 years**
  - **western boundary of MDA G to well R-23 = 225 years**

Figure 2. The as-built construction of LANL characterization well R-22.



Note: 1. The screen interval lists the footage of the pipe perforations, not the top and bottom of screen joints.
2. Pipe-based screen: 4.5-in. I.D., 5.563-in. O.D. 304 stainless steel with s.s. wire wrap: 0.010-in. slot.

Source for Figure 1: LANL Characterization Well R-22 Completion Report, (LA-13893-MS, February 2002).

Figure 3. Summary of Schlumberger[R] Geophysics for LANL Well R-22.
Source: LANL Report LA-UR-04-677 (September 2004)

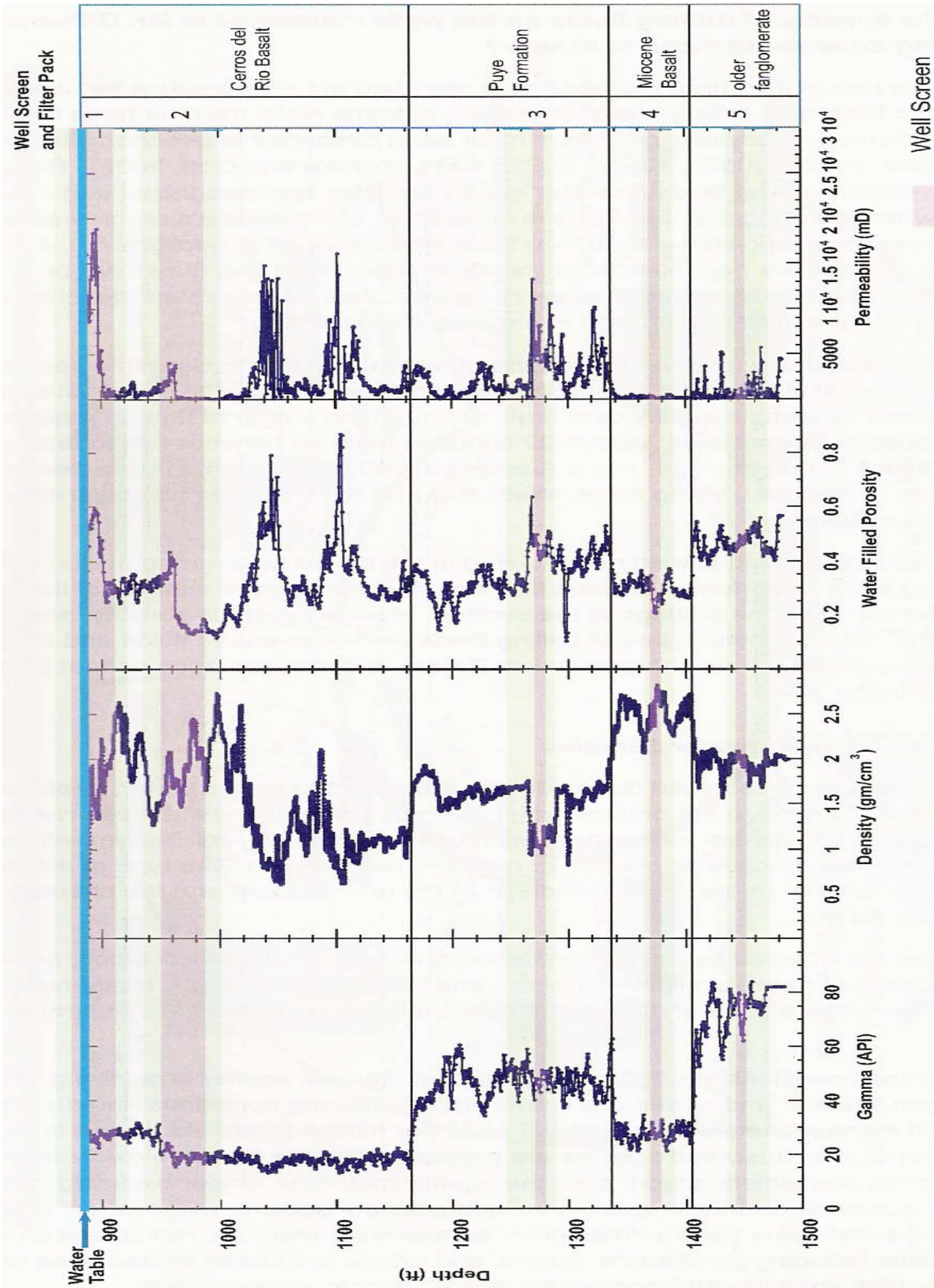
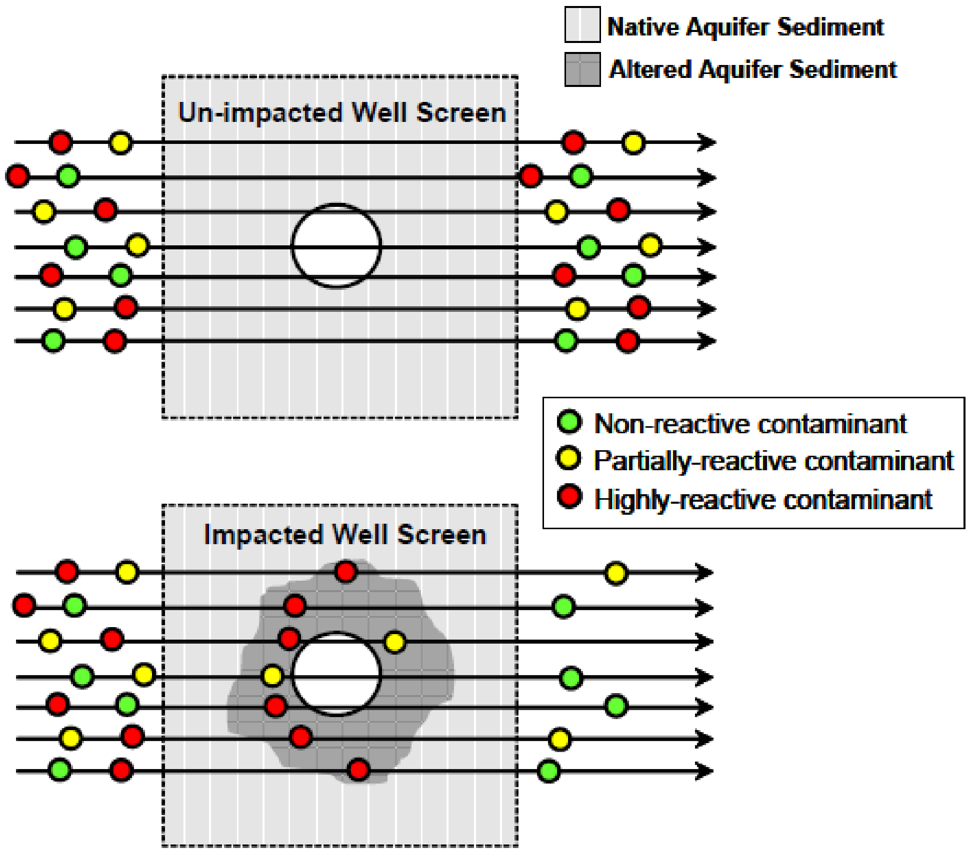


Figure 4. Conceptual schematic illustrating differential transport behavior of contaminants within the impacted zone adjacent to a well screen influenced by biodegradation of organic-based drilling fluids.
Source: EPA Kerr Lab report on LANL monitoring well construction practices



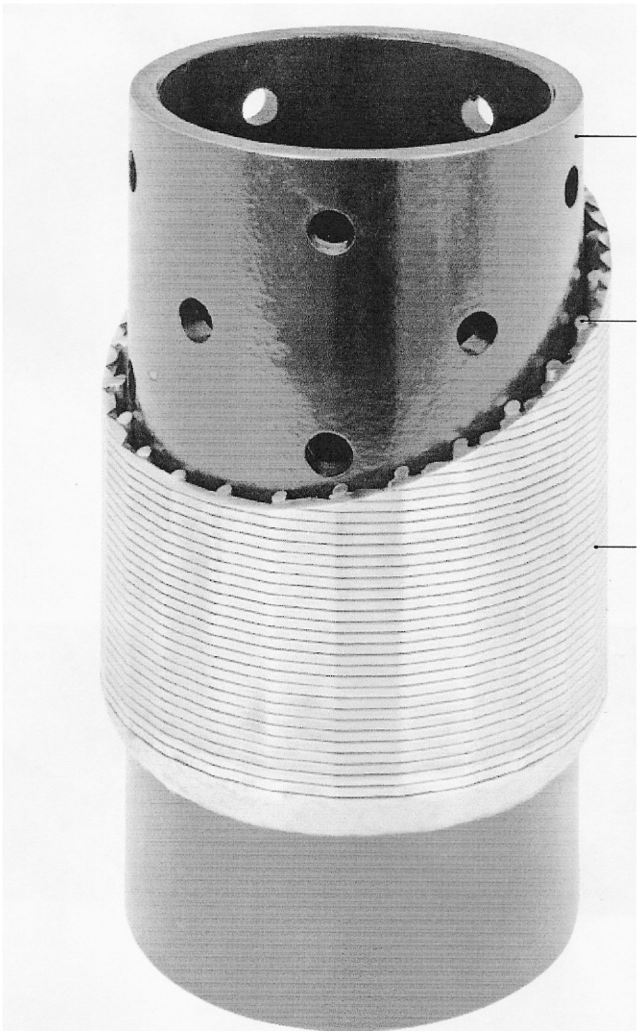
- Examples of non-reactive contaminants are tritium and chloride.

- Examples of partially-reactive contaminants are hexavalent chromium and uranium.

- Examples of highly-reactive contaminants are the LANL radioactive contaminants plutonium, americium, cerium and cesium, and the trace metals lead, zinc and cadmium.

- During the period of time that an anaerobic chemistry is present in the impacted zone, the new mineralogy will efficiently destroy the LANL organic contaminants including volatile organic compounds, semi-volatile organic compounds and high explosives.

Figure 5. Schematic of the pipe-based wire-wrap stainless steel well screens installed in many of the LANL characterization wells including LANL well R-22.



- The restrictive design of the pipe-based screens prevented the efforts at well rehabilitation from even cleaning residual drilling additives and clays from the wire wraps of the well screens. Cleaning of the new mineralogy produced by the drilling additives from the filter pack that surrounds the well screen and from the zone surrounding the borehole was not feasible.

- The LANL wells installed in the regional aquifer for monitoring TA-54 that were constructed with the pipe-based screens include R-16, R-20, R-22, R-23 and R-32.