GROUNDWATER CONTAMINATION
in the
REGIONAL AQUIFER
Beneath the
LOS ALAMOS NATIONAL LABORATORY
PART TWO

(Version May 20, 2005 with revision to include DOE Order 450.1a on February 08, 2010)

Robert H. Gilkeson
Registered Geologist
P.O. Box 670
Los Alamos, NM 87544
(505) 412-1930
rhgilkeson@aol.com

Groundwater Contamination in the Regional Aquifer Beneath the Los Alamos National Laboratory: Part Two by Robert H. Gilkeson, version May 20, 2005

Executive Summary

The University of California (UC) staff and contractors who are responsible for activities of the Los Alamos National Laboratory (LANL) Hydrogeologic Workplan have recently published a report titled "*Response to Concerns About Selected Regional Aquifer Wells at Los Alamos National Laboratory"* (the Bitner Report) by Kelly Bitner, David Broxton, Patrick Longmire, Steve Pearson, and David Vaniman. The Bitner Report is a response to findings that are presented in the report titled "*Groundwater Contamination in the Regional Aquifer Beneath the Los Alamos National Laboratory*" by Robert H. Gilkeson (Gilkeson, 2004). The Bitner Report seeks to discredit the findings presented in Gilkeson (2004), but is without credible support. In fact, the information presented in the tables and figures in the Bitner Report support many of the conclusions in Gilkeson (2004).

Gilkeson (2004) concluded that many of the activities of the LANL Hydrogeologic Workplan are not in compliance with the Resource Conservation and Recovery Act (RCRA). In addition, many of the activities of the Hydrogeologic Workplan do not meet the regulatory requirements of the New Mexico Environment Department (NMED) or the United States Department of Energy (DOE).

Gilkeson (2004) noted the following problems with the characterization wells installed by the LANL Hydrogeologic Workplan:

1 Inappropriate drilling methods were used for the installation of many of the LANL characterization wells (e.g., conventional mud-rotary and fluid-assisted air rotary that caused invasion of the aquifer strata important for monitoring with organic drilling additives and bentonite clay drilling muds).

2 LANL well development procedures were inadequate to remove the drilling additives and restore the pre-drilling chemical and physical properties to the aquifer strata.

3 The drilling additives (e.g., biodegradable drilling fluids, biodegradable foam, and bentonite clay drilling muds) have caused irreparable damage to the aquifer strata for a). detection of contamination; and b). knowledge of aquifer properties.

4 Groundwater samples collected from many LANL wells impacted by drilling additives are not representative of aquifer chemistry; the majority of the contaminant analyses on the "not representative" water samples are <u>spurious</u>.

5 Trend analysis of the contaminant data from well R-7 confirms that strontium-90 contamination is present in groundwater at the top of the regional aquifer.

6 Trend analysis of the contaminant data from well R-22 confirms that technetium-99 contamination is present in groundwater at the top of the regional aquifer immediately downgradient of Area G.

7 Improper drilling methods have caused cross-contamination between perched zones of saturation and the regional aquifer, and cross-contamination across confining layers within the regional aquifer.

8 Screened intervals are not installed in the aquifer strata with high permeability; the strata that are most important for understanding the presence of contamination and the speed of travel of contaminated groundwater.
9 Long screened intervals in some LANL characterization wells cause dilution which prevents accurate knowledge of the groundwater contamination.
10 Aquifer tests performed in many of the LANL wells have generated spurious values for aquifer permeability because of a). plugging of the permeability of the aquifer strata by the residual drilling additives, b). failure to install screened intervals in the aquifer strata with high permeability; the strata that are of most importance for knowledge of groundwater travel, c). screened intervals are too long and straddle aquifer strata of high and low permeability; the aquifer tests underestimate the permeability of the discrete strata with high permeability, and d). the use of inappropriate methods for calculating aquifer properties.

The Gilkeson (2004) report shows how these issues in the installation of monitoring wells render the contaminant data and the aquifer property data inconclusive at best, and possibly misleading. The limited number of contaminants that the Bitner Report acknowledges to be present in the regional aquifer include nitrate, perchlorate, tritium, uranium, the high explosive compounds RDX and TNT, and degradation products associated with TNT. The omission in the Bitner Report of the contaminants technetium-99, strontium-90, semivolatile organic contaminants, and volatile organic contaminants is a serious issue as these contaminants have been detected in groundwater samples collected from characterization wells installed for the Hydrogeologic Workplan.

The information in Table 4 in the Bitner Report illustrates that groundwater samples from many of the wells installed for the Hydrogeologic Workplan are not representative of aquifer chemistry because of the presence of residual drilling additives in the strata that surround the screened intervals. Figures 6 and 7 in the Bitner Report acknowledge that the chemical environment created by the residual drilling additives will cause removal from groundwater of many contaminants including perchlorate and the isotopes of americium, plutonium, strontium, technetium, and uranium. Unfortunately, the text of the Bitner Report does not acknowledge the spurious contaminant data in the <u>not representative</u> groundwater samples.

The Bitner Report is mistaken to place reliance on the spurious contaminant data in the groundwater samples collected from well R-7 (located upgradient of Los Alamos County supply wells) and well R-22 (located immediately downgradient of Area G, the Laboratory's active landfill for disposal of low-level radioactive waste, and upgradient of a). the property of San Ildefonso Pueblo, and b). supply wells for the city of Santa Fe). For the two wells the Bitner Report is wrong to state - "Specifically, the regional aquifer water at wells R-7 and R-22 does not contain americium-241, cesium-137, iodine-129, plutonium-238, plutonium-239, plutonium-240, strontium-90, or technetium-99 in measurable quantities." The contaminant data in water samples collected from the two wells are <u>spurious</u> and do not meet the RCRA requirement for data to be of sufficient known quality to withstand scientific and legal challenges.

ES.3

The information from LANL characterization well R-22 (e.g., the groundwater contamination and the highly permeable aquifer strata) requires revision to the Performance Assessment and Composite Analysis (PA/CA) for Area G. The revision is a requirement of DOE Order 435.1 for continued operation of Area G for the landfill disposal of low-level radioactive wastes. The revision of the PA/CA requires additional information from the installation of monitoring wells to define the nature and extent of contamination in the regional aquifer from wastes disposed of at Area G.

The detection of radionuclide and chemical contamination in well R-22 requires the installation of monitoring wells on San Ildefonso Pueblo for a careful investigation of a). the presence of chemical and radioactive contaminants in the highly permeable aquifer strata that are the fast pathways for contaminated groundwater to travel away from Area G, and b). to monitor for contamination in the future. In addition, there is a need for a careful investigation of the presence of contamination in the regional aquifer beneath waste disposal sites at Area G where large quantities of the highly mobile technetium-99 and iodine-129 wastes were disposed of.

The Bitner Report does not recognize that the contaminant data for groundwater samples collected from well R-15 are unreliable because of a long well screen that causes dilution. Perchlorate, tritium and strontium-90 are detected in the diluted groundwater samples. The dilution prevents accurate knowledge of the level of contamination that is present, and complete knowledge of all contaminants that are present. Well R-15 is located within a center of large groundwater withdrawal by Los Alamos County supply wells. The Bitner Report claims that the long well screen is necessary to assure a 50-year life for the monitoring well. The installation of a monitoring well with optimal design for the detection of contamination takes precedence to a fifty year life.

The conclusion in the Bitner Report that - "The small amount of residual drilling fluid left after development has short term impact on the geochemical environment surrounding each well"- is not supported by the facts:

- Other LANL reports estimate that the residual drilling additives will have an impact on the geochemical environment surrounding the wells for a period of three to ten years. In reality, the impact for many wells is permanent for the scheduled 50-year life.
- Well development procedures were not performed in the screened intervals of some monitoring wells (e.g., wells R-7 and R-22).
- For many wells, the long delay before the performance of well development procedures to remove the biodegradable drilling additives resulted in irreparable damage to the geochemical and physical environment surrounding the well by the process known as "biofouling plugging".
- Well development procedures in boreholes drilled with the mud-rotary method used chemicals to disaggregate and spread the bentonite clay drilling mud outward into the aquifer strata beyond a distance for recovery.

- For boreholes drilled with the mud-rotary method, the thousands of pounds of bentonite clay that invaded the aquifer strata is direct evidence that well development procedures cannot recover more than a small amount of the clay.

LANL does not purge a volume of water from the multiple-screen wells before collecting samples for analyses. In addition, LANL does not use a flow-through cell at the multiple-screen wells for measuring sensitive groundwater parameters. The LANL groundwater sampling methods do not meet the requirements of RCRA, the NMED Consent Order, or DOE Orders.

The record shows that LANL has inappropriately placed reliance on borehole geophysics to determine the aquifer strata for screen placement (e.g., well R-22), screen length (e.g., well R-15), and aquifer permeability (e.g., wells R-7, R-19, R-22, and CdV-R-15-3). The failure of LANL to properly gather knowledge of the permeability of aquifer strata in the regional aquifer is a serious problem. The anomalously low values in the LANL reports cause an underestimation of the speed of groundwater travel and an underestimation of the valuable groundwater resource that is available to supply wells.

LANL has expended much effort on the development of a computer model for groundwater flow in the regional aquifer beneath and surrounding the Laboratory facility. However, LANL has failed to gather accurate knowledge of the physical properties of the regional aquifer that are required as input to the model. It is important to note that the regional groundwater flow model will not capture the required information on the transport of contamination in the “fast pathway” aquifer strata that are present in the local settings beneath the Laboratory facility. Examples of local settings are 1. the “fast pathway” aquifer strata present beneath Area G, and 2. the flow of groundwater to the public supply wells in the “fast pathway” aquifer strata that are present beneath Los Alamos and Mortandad Canyons. The “fast pathway” strata may contain contamination.

The information gathered by the LANL Hydrogeologic Workplan does not support the proposed DOE and LANL accelerated cleanup strategy that will leave the large volume of legacy chemical and radioactive wastes disposed of in trenches and shafts at many locations across the Laboratory facility “buried in place” with little additional study.

The misinformation presented in the Bitner Report confirms the recommendation in Gilkeson (2004) for the establishment of an expert panel to review all of the activities of the LANL Hydrogeologic Workplan. The review should include a study of each “characterization well” installed by the LANL Hydrogeologic Workplan to determine their future value as monitoring wells. An important activity in the study is the use of a low-flow pump and a flow-through monitoring cell to measure sensitive groundwater parameters and to determine when it is appropriate to collect groundwater samples for the analytical suite.

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Groundwater Contamination in the Regional Aquifer Beneath the Los Alamos National Laboratory: Part Two by Robert H. Gilkeson, version May 20, 2005.

Introduction

The University of California (UC) staff and contractors who are responsible for activities of the Los Alamos National Laboratory (LANL) Hydrogeologic Workplan have recently published a report titled "*Response to Concerns about Selected Regional Aquifer Wells at Los Alamos National Laboratory"* (the Bitner Report) by Kelly Bitner, David Broxton, Patrick Longmire, Steve Pearson, and David Vaniman. The Bitner Report claims to be a response to the issues raised in the report "*Groundwater Contamination in the Regional Aquifer Beneath the Los Alamos National Laboratory"* by Robert H. Gilkeson (Gilkeson, 2004). Unfortunately, the Bitner Report is not responsive to the issues raised in Gilkeson (2004). In fact, the Bitner Report confirms many of the conclusions in Gilkeson (2004).

Topic 1: The regulatory requirements for the installation of monitoring wells in the regional aquifer at the Los Alamos National Laboratory.

The position in the Bitner Report that the monitoring wells installed for the LANL Hydrogeologic Workplan[43] are "characterization wells" and therefore, they do not have to meet the requirements of RCRA monitoring wells is unconscionable because of the high cost of each well and the intrusion of boreholes into the regional aquifer should be held to a minimum. The requirements of the EPA RCRA Manual[54] include the following:

- early detection of contamination,
- collect representative groundwater samples from the discrete strata where contamination is most likely to be present,
- install screens in the highly permeable aquifer strata; the strata with fast travel of groundwater and the strata where the greatest contamination is expected,
- characterize aquifer properties,
- avoid using drilling methods that cause damage to the physical and chemical properties of the aquifer strata that are important for monitoring, and
- implement Quality Assurance (QA) programs and Quality Control (QC) procedures to ensure that all data be scientifically valid, defensible, and of known precision and accuracy. Data should be of sufficient known quality to withstand scientific and legal challenges relative to the use for which the data are obtained,

The RCRA requirements are not unique; they are minimum requirements to assure that characterization/monitoring wells provide the necessary knowledge of aquifer properties and the impact of the Laboratory facility on contamination of the regional aquifer.

The New Mexico Environment Department (NMED) Consent Order[47] requires that LANL monitoring wells are designed and constructed in compliance with the RCRA requirements of the United States Environment Protection Agency (EPA) that are presented in the EPA RCRA Manual[54] (NMED Consent Order, Page 189). The NMED Consent Order is summarized in Appendix B of this report.

The Los Alamos National Laboratory is a federal facility under management by The United States Department of Energy (DOE). The DOE has awarded the prime contract for operations at LANL to the University of California (UC). The DOE is the regulatory agency that has primary responsibility[6,47] for the protection of groundwater resources from contamination by radionuclides that are released from the Laboratory facility. From page 1 of the NMED Consent Order –

> "The requirements of this Order do not apply to radionuclides, including, but not limited to, source, special nuclear, or byproduct material as defined in the Atomic Energy Act of 1954, as amended, or the radioactive portion of mixed waste."

The regulatory requirements of DOE are presented in DOE Orders[6]. The DOE Orders that require monitoring of the release of radionuclide contaminants to the regional aquifer are summarized in Appendix B. For Area G, the active facility at LANL for landfill disposal of low-level radioactive waste, and where unretrievable TRU wastes and mixed low-level radioactive wastes were disposed of, DOE Order 435.1 requires an environmental monitoring program that is in compliance with RCRA and is capable of a). monitoring for the presence of radionuclide contamination in the regional aquifer, and b). detecting changing trends in radionuclide contamination.

I disagree with the statement –

> "The RCRA monitoring requirements do not yet apply to LANL because this investigation phase comes before, and provides the basis for, formal RCRA-monitoring" (Bitner Report page 8).

The requirements for formal RCRA-monitoring cannot be understood without the installation of characterization wells in the investigation phase that meet the RCRA monitoring requirements. Furthermore, for facilities at LANL such as Area G, the responsibility of UC and DOE to be in compliance with RCRA is a requirement of DOE Orders 435.1 and 450.1, and is independent of the negotiations with NMED for the "formal RCRA-monitoring".

This reply to the Bitner Report refers to the "characterization" wells installed by the LANL Hydrogeologic Workplan[43] as HW wells. Gilkeson (2004) provides irrefutable evidence that many LANL HW wells (some examples are wells R-7, R-9i, R-13, R-15, R-16, and R-22) do not meet characterization requirements and also do not meet the monitoring requirements of RCRA, the NMED Consent Order, or the DOE Orders. Nevertheless, the Bitner Report and many LANL reports show the intention to use these HW wells as RCRA-compliant monitoring wells. Many of the LANL HW well completion reports and HW well geochemistry reports contain a statement that the wells meet the requirements of RCRA monitoring wells. As an example, the LANL HW well R-22 geochemistry report[34] contains the following statement:

> "Although well R-22 is primarily a characterization well, its design and construction also meet the requirements of a Resource Conservation and Recovery Act (RCRA)-compliant monitoring well as described in the US Environmental Protection Agency (EPA) document, "RCRA Groundwater Monitoring: Draft Technical Guidance, November, 1992" also known as the EPA RCRA Manual[54].

In addition, the Bitner Report contains the following description of the LANL HW wells installed for the Hydrogeologic Workplan:

> "Many of the characterization wells are expected to be used as monitoring wells and may become part of different RCRA monitoring systems that will be established at LANL in the future. For example, one of these possible systems is RCRA monitoring around TA-54 (Areas G, H, and L), which is considered a RCRA regulated unit. Wells that are part of that system will meet all RCRA requirements for monitoring of an operating facility." (Bitner Report, page 8)

Area G is the Laboratory's active landfill for disposal of low-level radioactive waste. Disposal operations at Area G[46] began in 1957. In addition to radioactive wastes, large volumes of chemical wastes were disposed of in trenches at Area G[46]. Area L is a disposal facility that began operations in the 1950's for trench and shaft disposal of liquid and solid chemical wastes. The chemical wastes[46] disposed of at Areas G and L include large volumes of semivolatile organic compounds (SVOCs) and volatile organic compounds (VOCs). The VOC wastes are also known as solvents.

The LANL Hydrogeologic Workplan has installed six HW wells surrounding TA-54. <u>None</u> of the six wells meet the requirements of RCRA, the NMED Consent Order, or DOE Orders for monitoring of an operating treatment/storage/disposal (TSD) facility. Four of the HW wells (R-16, R-20, R-23, and R-32) were installed in boreholes drilled with the mud rotary method using bentonite clay drilling mud. For these wells, the aquifer strata that are important for monitoring for radionuclide contaminants are invaded with thousands of pounds of unrecoverable bentonite clay. Two of the HW wells (R-21 and R-22) were installed in aquifer strata that were invaded by organic polymer-based drilling fluid and organic foam. The information in Table 4 in the Bitner Report is proof that the contaminant data on groundwater samples from HW wells R-16 and R-22 are spurious because of the drilling additives.

The NMED Consent Order has the following requirement for the use of organic polymer-based drilling fluids in the boreholes for the LANL monitoring wells:

> "-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" (NMED Consent Order page 191).

LANL did not use a dispersant to chemically breakdown the organic polymer-based drilling additives that were used in the boreholes for the LANL HWwells. The organic drilling additives used in the borehole for LANL HW well R-22 include Baroid EZ Mud* and Baroid Quik FOAM*. The damage caused to well R-22 by the organic additives is described in Topics 3 and 8 of this report.

The consensus in the monitoring well industry and also of the EPA, the NMED, and the DOE is that the hydrogeologic setting beneath TA-54 and the contaminants of concern for monitoring at Areas G, H, and L require drilling methods that prevent the invasion of the aquifer strata that are important for monitoring with organic polymer-based drilling fluids, organic foams, and bentonite clay drilling mud. The importance to avoid drilling methods that invade the aquifer strata with the drilling additives is presented in the articles of Appendix A. The monitoring requirements of the EPA, the NMED, and the DOE are presented in Appendix B. The preferential properties of bentonite clay to remove radionuclide contaminants from groundwater are described in Appendix C. The changes to the aquifer strata that occur because of the organic drilling additives are described in Appendix D. The changes cause a decrease in permeability and enhanced chemical properties for removal of radionuclide contaminants from groundwater.

The HW wells that LANL has installed surrounding TA-54 to characterize the impact of Areas G, H, and L on the regional aquifer (e.g., wells R-16, R-20, R-21, R-22, R-23, and R-32)

- a). do not accurately assess the presence of contamination in the regional aquifer,
- b). do not provide the necessary knowledge of aquifer properties, and
- c). do not meet the regulatory requirements of EPA RCRA, the NMED Consent Order, and the DOE Orders for monitoring wells at an active TSD facility. LANL HW well R-22 is located immediately downgradient of Area G at an important location for knowledge of the presence of contamination from Area G in the regional aquifer. The failure of well R-22 to characterize the impact of Area G on the regional aquifer is presented in Topics 4 and 8 of this report.

Concerning Area G, DOE Order 435.1 requires the preparation of a Performance Assessment and Composite Analysis (PA/CA) to assure protection of the public and the environment. Maintenance of the PA/CA is an important DOE requirement for continued operation of Area G. The geologic and contaminant information from HW well R-22 confirm errors in the PA/CA[44] of Area G. The DOE requirement for a revision to the PA/CA of Area G is described in Appendix B.

The Bitner Report lists the following requirement from the New Mexico Environment Department (NMED) RCRA/HSWA Permit[49] for the installation of monitoring wells in the regional aquifer beneath the Laboratory facility:

- Section 4. “Protection of the Main Aquifer” specifies that borings that reach the regional aquifer shall ensure that the regional aquifer is hydraulically isolated from perched aquifers with conductor casing or bentonite seals.

The LANL RCRA/HSWA Permit is being replaced with the NMED Los Alamos National Laboratory Consent Order[47]. The NMED Consent Order contains the following requirement to avoid cross-contamination:

- Contamination and cross-contamination of groundwater and aquifer materials during drilling shall be avoided (NMED Consent Order, page 189).

The failure of LANL to comply with the NMED Consent Order and the HSWA Permit is shown by the drilling of many boreholes on the Laboratory facility that allowed

- cross-communication and cross-contamination of groundwater in perched zones of saturation with the regional aquifer, and

- cross-contamination of groundwater within the regional aquifer.

The cross-communication and cross-contamination between the perched zones of saturation and the regional aquifer often occurred over a long period of time during the installation and development of multiple-screened HW wells that contain individual well screens installed in the perched zone(s) and also in the regional aquifer. A few examples of multiple-screened wells with this construction are LANL HW wells R-4, R-6, R-7, R-12, R-19, R-25, R-26, R-31, CdV-R-15-3, and CdV-R-37-2. HW well R-25 is an example of where the cross-communication contaminated the regional aquifer over a period of several months with high explosive contamination present in the perched aquifer[26].

LANL HW wells R-15 and R-22 are two examples of cross-contamination within the regional aquifer caused by the inadvertent drainage of groundwater at the top of the regional aquifer across a confining layer into deeper aquifer strata. The improper construction of well R-15 with a 60-foot screen is described in Topic 5. The improper drilling methods used for the installation of well R-22 are described in Topic 8.

Topic 2: Drilling methods used for the LANL HW wells.

The Bitner Report defends the use of drilling fluids in the boreholes for the LANL HWwells with the following statement:

> "LANL used drilling fluids as part of its drilling methods as is standard industry practice for drilling deep wells. Without use of these fluids and drilling methods, drilling of some wells may not have been possible." (Bitner Report, page 20)

The drilling methods used by LANL are <u>not</u> the standard industry practice for the installation of deep monitoring wells. The methods used by LANL caused the unacceptable invasion of the aquifer strata that are important for monitoring with drilling additives that were not removed from the strata by LANL's well development procedures. The drilling additives were primarily biodegradable (organic) polymer-based fluid (e.g., Baroid EZ-MUD*)**,** biodegradable foam (e.g., Baroid Quik-FOAM*), and bentonite clay mud (e.g., Baroid Quik-gel*). Table 4 in the Bitner Report confirms that many screened intervals in the LANL HWwells do not provide groundwater samples that are representative of aquifer chemistry because the unrecovered drilling additives caused irreparable changes to the chemistry of the groundwater and the aquifer strata. It is important to understand that most contaminant data in the nonrepresentative groundwater samples are spurious.

The standard industry practice for the construction of monitoring wells is to avoid the invasion of the aquifer strata that are important for monitoring with the above listed drilling additives. The technical literature for the construction of monitoring wells is summarized in Appendix A. The EPA and NMED guidance against the invasion of the aquifer strata with the drilling additives is presented in Appendix B.

One of the drilling methods used by LANL is conventional mud-rotary with bentonite clay muds to stabilize the open borehole. The general consensus in the monitoring well industry (see Appendix A) and also with EPA and NMED (see Appendix B) is that the mud -rotary drilling method should not be used for the construction of monitoring wells. For the geologic setting beneath LANL, the mud-rotary drilling method caused an unacceptable invasion of the aquifer strata that are important for monitoring with thousands of pounds of bentonite clay and also with materials that were used to stabilize the boreholes in aquifer strata where lost circulation of the bentonite clay drilling mud occurred.

The development of screened intervals in the wells installed in the mud-rotary boreholes required the use of chemical additives (see Table 5, Bitner Report) to disaggregate and disperse outward in the aquifer strata the bentonite clay that had formed an impermeable “mud cake” in the aquifer strata surrounding the screened interval. The EPA RCRA Manual[53] advises against the use of chemical additives to develop the screened intervals in monitoring wells (See Appendix B and Topic 7).

Article A-2 in Appendix A describes the features of the LANL HW wells that prevent well development procedures from recovering more than a small amount of the bentonite clay from the aquifer strata. Appendix C describes the preferential properties of bentonite clay to remove radionuclide contaminants from groundwater. Monitoring for radionuclide contaminants is an important requirement for the LANL HW wells that were installed in boreholes drilled with the conventional mud-rotary method using bentonite clay drilling mud. Appendix E describes the unsuccessful construction of LANL HW well R-14 with the mud-rotary method. The use of the mud-rotary drilling method for the construction of many LANL HW wells was unnecessary and a serious mistake.

A drilling method used by LANL for many LANL HW wells is a combination of air-rotary under-reamer casing advance and air-rotary open borehole drilling with the use of Baroid EZ-MUD* and Baroid Quik-FOAM* to stabilize the borehole. The biodegradable (organic) drilling additives were allowed to invade the aquifer strata where well screens were installed. The failure of LANL to quickly and thoroughly remove the biodegradable drilling fluids has caused irreparable damage to the permeability and chemistry of the screened intervals in many LANL HW wells (e.g., some examples are wells R-7, R-9i, R-12, R-19, R-22, and R-32).

The permanent damage to monitoring wells that is caused by the biodegradable drilling additives is well known in the monitoring well industry[3,19] and is called “biofouling plugging”. Appendix A contains articles that describe the damage to monitoring wells that is caused by biodegradable drilling additives. Appendix D describes the great change in the chemistry of the aquifer strata that is caused by the biodegradable drilling additives. It was a serious mistake for LANL to invade the aquifer strata that are important for monitoring with the organic drilling additives that were the fuel for a “bloom” of microbial activity.

The drilling method that is appropriate for the installation of monitoring wells beneath LANL in perched zones of saturation and in the regional aquifer is air-rotary under-reamer casing advance with a minimum of three sets of telescoped retractable drill casings and the use of an appropriate drilling fluid on the backside of the retractable drill casings for lubrication. For drilling in the unsaturated zone, dry air-rotary reverse circulation drilling can be performed in advance of the drill casing to explore for perched zones and to collect information on the in situ moisture content of the rock and sediments.

It is very important to avoid the invasion of biodegradable drilling fluids, biodegradable foams, and bentonite clay muds into perched zones and into the aquifer strata where screens are installed. It is not necessary to use the liquid or foam drilling additives for drilling with the air rotary under-reamer casing advance drilling method. The boreholes for LANL HW wells R-9 and R-12 are examples of where drilling through the entire thickness of the unsaturated zone into the top of the regional aquifer was successfully achieved using the air rotary under-reamer casing advance drilling method with the use of only air as a drilling fluid.

Drilling activities for the LANL Hydrogeologic Workplan have installed many HW wells in the regional aquifer with the air-rotary under-reamer casing advance drilling method. The following is an incomplete list that contains examples of wells, the total depth drilled (TD), and the depth drilled into the regional aquifer (RA), with the casing-advance method:

- well R-9, TD – 771 ft, RA – 82 ft; well R-12, TD – 886 ft, RA – 81 ft;
- well R-13, TD – 1133 ft, RA – 279 ft; well R-14, TD – 1327 ft, RA – 145 ft;
- well R-15, TD – 1107 ft, RA – 143 ft; well R-22, TD – 1489 ft, RA – 559 ft;
- well R-25, TD – 1942 ft, RA – 656 ft; and well R-31, TD – 1103 ft, RA – 569 ft.

The well installation record of the Hydrogeologic Workplan activities is proof that the air-rotary under-reamer casing advance drilling method has installed HW wells deep into the regional aquifer at locations distributed across the Laboratory facility. Unfortunately, for all of the wells in this list, drilling in the aquifer strata where well screens were installed used biodegradable drilling additives, and bentonite clay muds were used at wells R-14, R-25 and R-31.

Topic 3: Effects of drilling additives on groundwater samples

The Bitner Report makes the following claims:

> "All of the changes that result from the introduction of drilling fluids are ultimately reversible, although kinetics of chemical reactions and hydrologic properties of aquifer materials are factors that control how fast reversal occurs" (Bitner Report, page 23). "The small amount of residual drilling fluid left after development has short-term impact on the geochemical environment surrounding each well" (Bitner Report, page 36).

The Bitner Report does not predict when the "short-term" impacted screened intervals in many LANL HW wells will provide representative groundwater samples. However, a LANL Report[23] acknowledges that the time required for the collection of representative groundwater samples will range from three years to as great as ten years. This is not a "short-term impact". This is an unacceptable amount of time.

In reality, the Bitner Report and the LANL Report fail to understand that for many screened intervals, the drilling additives have caused chemical and physical changes to the aquifer strata that will prevent the collection of representative groundwater samples for a period of time much greater than ten years. The damage to most of the LANL HW wells is permanent in terms of the planned 50-year life for the wells.

It is important to note that the Bitner Report does not acknowledge that there were no well development procedures performed in the screened intervals of some LANL HW wells. It is also important to note

- a). the thousands of pounds of bentonite clay and borehole stabilization materials that invaded the aquifer strata in boreholes drilled with the mud-rotary method and
- b). the use of chemicals to spread the bentonite clay outward into the aquifer strata, are direct evidence that very large amounts of bentonite clay remain in the strata surrounding the well screens.

- **Effect of biodegradable drilling additives on groundwater chemistry:**

Figure 6 in the Bitner Report is an illustration of the effects of the biodegradable drilling fluids on groundwater chemistry. However, much important information is missing from the illustration.

The figure acknowledges that the biodegradable drilling fluids cause a bloom of microbes (bacteria) which results in a change in groundwater from an oxidizing to a reducing (anaerobic) chemistry. The figure does not acknowledge the long period of time between the invasion of the aquifer strata with the biodegradable drilling additives and the performance of well development procedures to remove the fluids; for many screened intervals this time period caused considerable "biofouling plugging" damage to the screened intervals to occur before any well development procedures were performed.

It is important to note that Figure 6 shows groundwater to have an anaerobic chemistry after the termination of the LANL well development procedures. The anaerobic chemistry is proof that the well development procedures did not successfully remove the residual biodegradable drilling additives from the aquifer strata that surround the screened intervals.

Figure 6 does not acknowledge that the anaerobic chemistry with high concentrations of dissolved iron and manganese is direct evidence of the presence of the chemical process known as "biofouling plugging"; a chemical process that causes deposits of iron and manganese compounds to form on the surfaces of the aquifer strata and even on the well screen and filter pack sediments. The deposits greatly lower the permeability of the screened intervals and have enhanced chemical properties for removal of many chemical and radionuclide contaminants from groundwater. The "biofouling plugging" process is described in articles A.11 to A.14 in Appendix A. The chemical properties of the iron and manganese compounds are described in Appendix D.

Figure 6 does not acknowledge that no well development was performed in some screened intervals (e.g., screen #1 in well R-7[37] and screen #1 in well R-22[33]) or that the minimum well development procedures performed in some HW wells did not meet EPA requirements (e.g., screen #3 in well R-7[37] and screen # 3 in well R-31[40]). The failure of LANL well development procedures to properly remove the biodegradable additives from screened intervals in LANL HW wells is proven by wells R-7, R-9i, and R-22 in Table 4 in the Bitner Report. The table acknowledges that the groundwater samples collected from the three wells are not representative of pre-drilling chemistry.

Figure 6 does acknowledge the presence of an anaerobic chemistry in the groundwater after the performance of well development procedures as the cause of increased concentrations of dissolved iron, manganese, alkaline earth metals, and hydrogen sulfide gas. It is important to note that Figure 6 acknowledges the anaerobic chemistry will cause the removal of contaminants from groundwater including perchlorate and isotopes of americium, plutonium, technetium, and uranium.

The information presented on Figure 6 is an admission that the contaminant data from LANL HW wells R-7, R-9i, and R-22 are spurious. The LANL HW well geochemistry reports[34,38] and the Bitner Report are wrong to use the spurious data to claim that contamination is not present in the regional aquifer beneath Los Alamos Canyon and beneath Area G.

Figure 6 is mistaken to show that the aquifer strata and groundwater return to their original properties when an oxidizing chemistry returns to the groundwater. The new deposits of iron and manganese compounds[19] are stable in the oxidizing groundwater and the damage to the permeability and the chemical properties of the screened intervals are permanent for the fifty year life of the impacted HW wells.

- **Effect of bentonite clay drilling mud on groundwater chemistry:**

Figure 7 in the Bitner Report is an illustration of the effects of the bentonite clay drilling mud on groundwater chemistry. However, much important information is missing from the illustration.

Figure 7 does acknowledge that the invasion of the aquifer strata with bentonite clay causes removal from groundwater of trace metals and radionuclides including isotopes of americium, plutonium, and strontium. However, the figure does not acknowledge that the thousands of pounds of bentonite clay that have invaded the regional aquifer strata in LANL HW wells are direct evidence that it is impossible for well development procedures to remove more than a small amount of the bentonite clay (e.g., >28,000 pounds in well R-14 and > 31,000 pounds of bentonite clay in well R-16[27]).

Figure 7 is mistaken to describe the bentonite clay that is present in the aquifer strata as “bentonite colloids”. In reality, most of the clay colloids in the drilling fluid flocculate[3,7] out of solution as a “sticky paste” on the surface of the aquifer strata to form a “mud cake” of low permeability[3,52] that surrounds the borehole. The figure does not inform the reader that chemicals were used to disaggregate and disperse the large quantities of the bentonite clay outward in the aquifer strata beyond a distance for removal by well development procedures (see Table 5 in Bitner Report). The caution of EPA against the use of chemicals to develop the screened intervals in monitoring wells is described in Topic 7 and Appendix B.

Figure 7 does not acknowledge that the very high permeability of the aquifer strata in the LANL boreholes required the use of the drilling additives Pac-L*, N-Seal* and Magma Fiber* (see Table 1 in Bitner Report) to reduce the permeability of the strata and stop the flow of the bentonite clay drilling muds into the regional aquifer. The highly permeable aquifer strata are the very strata that are important for monitoring. The invasion of large volumes of bentonite clay into the strata with the required use of drilling additives to stop the invasion is proof of permanent damage to the aquifer strata. The damage that occurred to the highly permeable aquifer strata in LANL HW well R-14 during the unsuccessful drilling of the borehole with the mud-rotary method is described in Appendix E.

Figure 7 does not acknowledge that the great depth and restrictive design of the LANL HW wells are obstacles for well development procedures to thoroughly remove the bentonite clay from the aquifer strata. The great difficulty for well development procedures to recover the bentonite clay from LANL HW wells is described in Article A.2 in Appendix A. The claim in Figure 7 of "Removal of bentonite colloids through hydrologic processes such as pumping and purging" is a mistake because a). "pumping and purging" is not performed in the multiple-screened HW wells, and b). the restrictive design of the single-screened HW wells prevents pumping from recovering the very large quantity of bentonite clay that is pasted onto the strata surrounding the screened intervals.

Well development methods can only recover a small amount of the bentonite clay drilling muds from the screened intervals in <u>any</u> of the LANL HW wells. The fact that LANL well development procedures did not remove the large quantity of bentonite clay that surrounds screened intervals in LANL HW wells is proven by well R-16 in Table 4 in the Bitner Report. For HW well R-16, Table 4 makes the following statement:

> "Screens 2, 3, 4 are not yet representative of pre-drilling chemistry, they are affected by bentonite mud."

The chemical properties of bentonite clay for the preferential removal of radionuclide contaminants from groundwater are described in Appendix C. These chemical properties will not become exhausted over the scheduled 50-year life of the HW wells.

Topic 4: The failure of LANL to install monitoring wells in the appropriate permeable strata in the regional aquifer.

The Bitner Report recognizes the importance for the installation of monitoring wells in the regional aquifer in the discrete aquifer strata that have high permeability with the following statement:

> "Our approach has been to place screens within zones where the aggregate hydrologic properties indicate rocks with greater permeability, thus maximizing chances for intersecting a preferred contaminant pathway" (Bitner Report, Page 9).

However, an important conclusion in Gilkeson (2004) is that LANL has failed to install monitoring wells in the aquifer strata with high permeability at the locations of LANL HW wells R-7, R-15, and R-22.

The Bitner Report defends this failure with the following statement –

> "It is also important to note that the wells referenced in the Gilkeson (2004) report are primarily for hydrogeologic characterization. Some screens are installed to provide hydrogeologic data from units about which little is known" (Bitner Report, page 10).

It is also important to note that the LANL HW wells referenced in the Gilkeson (2004) report are at locations where there is an immediate need for knowledge of the presence of radionuclide and chemical contamination at the top of the regional aquifer and in the highly permeable aquifer strata that are present to a depth of several hundred feet within the regional aquifer. The primary, very important requirement of the LANL monitoring wells is to gain knowledge **now** of the possible presence of radionuclide and chemical contamination in the regional aquifer beneath the Laboratory facility in the aquifer strata that are important for monitoring, and to provide a network of monitoring wells to provide **reliable** **detection** of the presence of contamination in the important aquifer strata in the **future.**

The permeable aquifer strata are the strata where the contamination is most likely to be present, and present at the highest concentrations[13]. In addition, the permeable strata are the fast pathways for travel of the contamination, and the permeable strata are the important groundwater resource to the Los Alamos County drinking water wells.

Gilkeson (2004) focused on LANL HW wells R-7, R-15, and R-22 because the wells are installed at locations with a long history of waste disposal and the improper construction of the three wells will mask the presence of radionuclide and chemical contaminants at the top of the regional aquifer. In addition, the screened intervals in the three wells are not installed in the aquifer strata with high permeability that are important contaminant pathways:

- Well R-7 in Los Alamos Canyon at a location of release of liquid wastes for decades by LANL waste management practices, and at a location that is upgradient of Los Alamos County supply wells.

- Well R-15 in Mortandad Canyon at a location of release of liquid wastes for decades by LANL waste management practices, and at a location of large production of groundwater to Los Alamos County supply wells.

- Well R-22 at a location immediately downgradient of Area G, the Laboratory's active landfill for disposal of low-level radioactive waste where disposal of chemical and radioactive wastes began in 1957, at a location immediately upgradient of San Ildefonso Pueblo, and at a location that is upgradient of the Buckman well field, a major water supply to the city of Santa Fe.

The three LANL HW wells do not resolve four "fundamental hydrogeologic issues/questions that remain unresolved at LANL" (NMED letter dated August 17, 1995, from Bitner Report, page 8):

- 1). Individual zones of saturation beneath LANL have not been adequately delineated and the "hydraulic interconnection" between these is not understood.
- 2). The recharge area(s) for the regional and intermediate aquifers have not been identified.
- 3). The groundwater flow direction(s) of the regional and intermediate aquifers, as influenced by pumping of production wells are unknown.
- 4). Aquifer characteristics cannot be determined without additional monitoring wells installed within specific intervals of the various aquifers beneath the facility.

LANL HW well R-7: At the location of HW well R-7 the water table of the regional aquifer is at a depth of ~ 903 feet below ground surface (bgs). Screen #3 is the only screen installed in the regional aquifer. The 42 ft long screen is installed across the water table in the depth interval of 895.5 to 937.4 ft bgs. The geologic log in the well R-7 completion report describes the aquifer strata at the depth of the well screen as follows:

> "sandy gravel with fine to very coarse sand matrix."

The aquifer strata with this description should provide an adequate flow of groundwater to screen #3 but the flow was not sufficient for use of pumping methods for well development. The pertinent excerpt from page 10 in the well R-7 completion report is pasted below:

> "Development of screens #1 and #2 was not possible because of insufficient water production from these zones. Screen #3 was wire-brushed and bailed. However, it soon became apparent that productivity was also low in screen #3. It was not possible to develop screen #3 by pumping. Water rarely reached the surface, and the pump tripped off repeatedly because the pumping rate exceeded the production rate."

> "As a result, R-7 was developed as much as possible by bailing. Field parameters were checked at the outset of bailing and checked periodically thereafter. The ranges of values are presented in Table 5.0-1 and are shown graphically in Figure 5.0-1. The initial turbidity value was 237 nephelometric turbidity units (NTU). The withdrawal of 3000 gal. of water over a 1.5-day period reduced this figure to 21 NTU. Since turbidity hovered around 21 NTU during approximately 10 hr of bailing and did not seem to be improving, development was halted."

The well R-7 completion report is proof that screen #3 in HW well R-7 was not properly developed to remove the organic drilling additives. In addition, the poor production of water from the screen during use of a submersible pump indicates "biofouling plugging" of the screen was in progress.

The borehole log in the LANL HW well R-7 completion report describes the Puye sediments in the depth interval of 962 to 982 feet below ground surface as “very coarse sand (SP)”. The well-sorted very coarse sands are the first sediments of high permeability below the top of the regional aquifer for the location of well R-7. The sand may have a hydraulic conductivity greater than 100 feet/day[14].

The 20-foot thick interval of very coarse sand is underlain by a 30-foot thick interval of sediments with a very low permeability that are described as “clayey gravel”. The clayey gravel sediments form a confining layer that are a barrier to downward flow of contaminated groundwater. The contaminated groundwater will flow laterally in the layer of very coarse sand that overlie the clayey sediments. There is an important need for the installation of a monitoring well in the highly permeable sand strata that are at a depth of 60-feet below the water table of the regional aquifer at the location of well R-7.

The borehole log in the LANL HW well R-7 completion report shows Totavi Lentil river gravel sediments are present in the depth interval of 1087 to 1097 ft bgs, the total depth of the borehole. These sediments are known to have a very high permeability, possibly greater than 250 feet/day[14]. For well R-7, the top of the regional aquifer is at a depth of 903 feet below ground surface and the top of the Totavi Lentil sediments is at a depth of 184 feet in the regional aquifer. The LANL HW well R-7 completion report predicts that the Totavi Lentil sediments at the location of well R-7 have a total thickness of 67 feet. Table 3 in the Bitner Report gives the following reason for why a monitoring well was not installed in the highly permeable river gravel strata:

> “A screen could not be placed within the highly productive river gravels below 1087 ft because of [the] unstable borehole.”

The borehole of HW well R-7 was drilled in the regional aquifer with reverse-circulation fluid-assisted air-rotary drilling in an open borehole[36]. It is no surprise that this drilling method failed to provide a stable borehole in the highly permeable river gravels. The correct drilling method to use for drilling through the river gravel strata is air-rotary under-reamer casing advance using only air and small amounts of water as drilling additives.

There is an immediate need to replace LANL HW well R-7 with three properly constructed single-screen monitoring wells that will provide knowledge of the level of chemical and radionuclide contamination in the aquifer strata 1). at the top of the regional aquifer, 2). in the very permeable coarse sands that are present at a depth of 60 feet below the top of the regional aquifer, and 3). in the very permeable river gravel strata that are present at a depth of 184 ft below the top of the regional aquifer with a predicted thickness of 67 ft.

LANL HW well R-15: A concern for the location of LANL HW well R-15 is that the borehole log in the LANL HW well R-15 completion report shows that highly permeable Totavi Lentil sediments are present in the depth interval of 1100 to 1107 feet, the total depth of the borehole. For well R-15, the water table of the regional aquifer is at a depth of 964 feet and the top of the Totavi Lentil sediments is at a depth of 136 feet below the water table. The LANL HW well R-15 completion report predicts that the Totavi Lentil sediments at the location of well R-15 have a total thickness of 65 feet. It is unfortunate that the R-15 borehole did not drill through the total thickness of the Totavi Lentil sediments and install a monitoring well in this interval of important aquifer strata.

Well HW R-15 is at an important location for knowledge of groundwater contamination in the regional aquifer from the many decades of release of LANL liquid wastes to Mortandad Canyon[32].

Table 3 in the Bitner Report describes the river gravel strata in the well R-15 borehole as follows:

> "The only zone of higher transmissivity (e.g., high permeability and great production of groundwater) was within the Totavi Lentil river gravels below 1100 ft depth that could not be penetrated safely."

I disagree with the perspective in the Bitner Report that it is not necessary to install a monitoring well in the very permeable river gravel strata that underlie Mortandad Canyon because "they could not be penetrated safely". In fact, the important strata could have been penetrated safely for the installation of a monitoring well with the drilling equipment that was used to drill the R-15 borehole.

The casing advance drilling method drilled into the top of the river gravel strata with the 11-inch retractable drill casing[31]. The proper procedure to drill through the entire section of river gravel strata was to stabilize the 11-inch drill casing above the 1100 foot depth, and telescope down to the 9.75-inch drill casing for drilling through the river gravel strata. The air rotary under-reamer casing advance drilling method can drill through the permeable aquifer strata that are important for installation of monitoring wells without invading the aquifer strata with biodegradable drilling fluids, biodegradable foam, or bentonite clay drilling muds.

There is an immediate need to replace LANL HW well R-15 with two properly constructed single-screen monitoring wells that will provide accurate knowledge of the chemical and radionuclide contamination in the aquifer strata 1). at the water table of the regional aquifer and 2). in the very permeable river gravel strata that are present at a depth of 136 feet below the top of the regional aquifer.

LANL HW well R-22: A correct conclusion in Gilkeson (2004) is that screened intervals were not installed in the fast groundwater travel pathways that are present in the regional aquifer beneath Area G. Unfortunately, the LANL HW well R-22 completion report and the Bitner Report fail to realize that screened intervals in well R-22 are not installed in

1). the discrete interval of highly permeable strata that is present in the Cerros Del Rio Basalt at the top of the regional aquifer,
2). the two discrete intervals of highly permeable strata that are present at depth in the regional aquifer within the Cerros Del Rio Basalt, or in
3). the highly permeable river gravel strata that underlie the basalt.

It is important to note that the three highly permeable intervals of aquifer strata in the basalt are identified in the geophysical logs for well R-22 that are presented in Figure 5 in the Bitner Report. Unfortunately, the thick interval of highly permeable river gravel strata was not identified by the borehole geophysics. The proof of the presence of the river gravel strata is the primary information that is presented in the LANL HW well R-22 completion report[33].

The Bitner Report cites the Schlumberger geophysical logs as evidence that permeable river gravel strata were not present in the borehole for HW well R-22. However, the drilling record[33] for this borehole shows that highly permeable river gravel strata are present in the regional aquifer over a distance of 50 feet in the depth interval of 305 to 355 feet below the water table of the regional aquifer.

The reliability of the Schlumberger geophysical logs is further questioned as they were used to locate screen no. 3 in well R-22 in alluvial sediments beneath the river gravel strata "where the estimated permeability is the highest" (the Bitner Report, p.16).

However, the geologic log in the LANL HW well R-22 completion report shows that screen no. 3 is installed in strata described as "very fine silty sand to pebble gravel". Introductory text books in hydrogeology[13,14] teach that poorly sorted sediments with this description have a low permeability. The measured permeability of the strata that surround screen #3 is 0.2 feet/day[24] compared to estimated permeability values of greater than one hundred feet/day[14] for the highly permeable river gravel strata beneath Area G that are located above screen #3 and are not being monitored.

There is an immediate need to install a minimum of three single-screen monitoring wells immediately downgradient of Area G; one in the highly permeable basalt strata at the top of the regional aquifer, a second within the highly permeable basalt strata at a greater depth within the regional aquifer, and a third within the highly permeable river gravel strata that underlie the basalt.

Topic 5: The poor understanding of contamination in the regional aquifer because of the installation of LANL monitoring wells with well screens that are too long for reliable monitoring.

LANL has installed long well screens at the top of the regional aquifer in many HW wells because of a concern for the decline in the static water level that may occur over the 50-year life of the well[20]. However, the permissible length of the screened interval in a monitoring well is determined by the hydrogeologic setting at each well location, the sources of the contamination, and the nature of the contamination for monitoring.

- **LANL HW well R-22 located immediately downgradient of Area G**:

It is essential for a monitoring well located immediately downgradient of Area G to have an optimal design for the detection of contamination at the top of the regional aquifer. LANL HW well R-22 is a failure for this concern because of a 42-foot screened interval invaded with biodegradable drilling additives that straddles the water table of the regional aquifer[33]. There is an immediate need to replace well R-22 with a single-screen monitoring well with a screen length of 10 feet that is installed in the highly permeable basalt strata located at a depth of 893 feet to 903 feet; 10 feet below the static water level of 883 feet below ground surface. The highly permeable basalt strata are in the borehole log of the LANL HW well R-22 completion report and in the borehole geophysics displayed in Figure 5 of the Bitner Report. The serious issues that result from the improper construction of LANL HW well R-22 are discussed in Topic 8 of this report.

- **LANL HW well R-13 located in Mortandad Canyon near the Laboratory boundary with San Ildefonso Pueblo:**

The purpose of LANL HW well R-13 is to investigate contamination in the regional aquifer from Laboratory releases that include treatment plant effluents[29] from the active radioactive waste treatment plant at TA-50 and a former radioactive waste treatment plant located at TA-35. The waste effluents from TA-35 and TA-50 are responsible for the presence of contamination in alluvial sediments and perched zones of saturation beneath Mortandad Canyon[31,32]. LANL HW well R-13 is located approximately 250 feet from the boundary of the Laboratory facility with San Ildefonso Pueblo[29].

The borehole for LANL HW well R-13 determined the strata at the top of the regional aquifer to have high permeability. The water table is at a depth of 834 feet below ground surface and the aquifer strata in the depth interval of 832 feet to 854 feet are described as "gravel with sand (GW)" with special note of "coarse gravel" in the depth interval of 837 feet to 847 feet below ground surface[29]. A screen was not installed in the permeable strata that are present at the top of the regional aquifer. The borehole log[29] describes the strata in the depth interval of 854 feet to 918 feet as "clayey sand with gravel (SC)", "gravel with clay and sand (GW)", and "clayey gravel with sand (GC)". The poorly sorted clayey strata have properties of a confining bed. The 60-foot long well screen in HW well R-13 was installed in strata beneath the confining bed in the depth interval of 958.3 feet to 1018.7 feet below ground surface.

The screen in well R-13 is installed across strata with markedly different properties that range from "clayey gravel with sand (GC)" to "medium to very coarse sand (SP)". Another problem is that a mistake in well construction invaded the screened interval in well R-13 with bentonite clay grout.

Below the depth interval where the well screen is installed in HW well R-13, the borehole log and the performance of drilling activities[29] identify the presence of highly permeable intervals of aquifer strata described as "medium to coarse sand with gravel (SP)", and "gravel with sand (GW)". The borehole was terminated at a depth of 1133 feet below ground surface in highly permeable sediments that posed difficulty to continued drilling[29].

LANL HW well R-13 does not meet the requirements for monitoring water quality in the regional aquifer beneath Mortandad Canyon at the Laboratory boundary with San Ildefonso Pueblo. There is a need for installation of a monitoring well in the permeable strata at the top of the regional aquifer, and installation of a monitoring well in the highly permeable strata that are present beneath the strata where HW well R-13 is installed.

- **LANL HW well R-15 located in Mortandad Canyon within a pumping center of Los Alamos County supply wells**:

It is essential for monitoring wells located within the pumping center for water supply wells to be of the best design for the identification of contamination in the discrete aquifer strata where the presence of contamination has the greatest potential. For LANL HW well R-15, there is a need for knowledge of contamination

1). in the highly permeable aquifer strata at the top of the regional aquifer, and
2). to a depth of several hundred feet in the regional aquifer in the discrete aquifer strata that has high permeability.

The requirement for accurate knowledge of contamination in groundwater at the top of the regional aquifer takes precedence to the installation of a long well screen to ensure a 50- year life for the LANL HW well.

Another concern in Gilkeson (2004) is the 60-foot screen length in LANL HW well R-15 that is improperly installed across a confining layer that separates hydraulic communication between the overlying and underlying aquifer strata (e.g., discrete hydrogeologic units). The Bitner Report is mistaken to describe the aquifer strata present in the screened interval of well R-15 as follows:

> "Within screened intervals there is fine-scale stratigraphic variability in most aquifer units, which Gilkeson (2004) defined as "multiple hydrogeologic units" (Bitner Report page 11).

The confining layer that is straddled by the long screen in well R-15 is **not** "fine-scale stratigraphic variability". The confining layer is shown on Figure 4 of the Bitner Report as a "pumice bed". The confining layer is identified in the borehole log in the LANL HW well R-15 completion report as a "monolithologic layer of clay-coated pumice". The described sediments represent a regionally extensive air-fall blanket deposit of a bed of volcanic ash. The importance of clayey ash beds as confining layers is described in the text book *Applied Hydrogeology*[13].

Gilkeson (2004) described the aquifer strata above and below the confining layer in well R-15 as multiple hydrogeologic units that are important to keep separate in the construction of monitoring wells. It is important to note that the installation of well screens across confining layers is a violation of EPA RCRA and the NMED Consent Order. From the EPA RCRA Manual:

> "The lengths of well screens used in groundwater monitoring wells can significantly affect their ability to intercept releases of contaminants. - Well screens and filter pack materials should not interconnect, or promote the interconnecting of zones that are separated by a confining layer. - Generally, screen lengths should not exceed 10 feet." (EPA RCRA Manual[54], page 5-7)

The installation of a 60-foot well screen at the top of the regional aquifer in LANL HW well R-15 was a serious mistake because the screen is causing dilution that prevents accurate knowledge of the chemical and radionuclide contaminants that are present in the highly permeable aquifer strata at the water table of the regional aquifer.

Perchlorate, tritium and strontium-90 contamination[32] is present in the diluted groundwater samples collected from the well. Well R-15 is located within a region of Mortandad Canyon that has received liquid wastes over periods of decades[31,32], and within a region of large groundwater withdrawal by Los Alamos County supply wells.

The large groundwater withdrawal in the region of well R-15 is illustrated on Figure 2 in the Bitner Report. At the location of LANL HW well R-15 the very important need for accurate knowledge of contamination at the top of the regional aquifer takes precedence to a long well screen to assure a 50-year life for the monitoring well.

The LANL EAG[11] advised LANL that the installation of long well screens was inappropriate as follows:

> "The problems with long well screens have become fairly well known in recent years. In effect, such screens
>
> - Tend to average contaminant concentrations by mixing waters from truly high concentration zones and low concentration zones
> - Yield little, if any, information about the zone of contaminant transport or the location and thickness of a plume
> - Serve as a conduit for contaminants to move from contaminated to uncontaminated regions of the aquifer
> - Confound hydrogeologic understanding due to variable stratigraphy and flow across the screened interval ("short-circuiting")."

The Bitner Report is mistaken to dismiss the finding in Gilkeson (2004) that the 60-foot screen in HW well R-15 was improperly installed to straddle a confining layer. The well construction is causing groundwater at the top of the regional aquifer to flow downward across the confining layer to mix with deeper groundwater. An additional feature in the construction of well R-15 that assures dilution of groundwater at the top of the regional aquifer is that the pump intake is located below the confining layer near the bottom of the well screen[31]. The Bitner Report defends the 60-foot screen in LANL HW well R-15 with the following statement:

> "To ensure a 50-year design, longer screens are installed at the water table in wells near pumping centers" - (Bitner Report page 11).

The position is Gilkeson (2004) is that the need for accurate knowledge of the chemical and radioactive contamination in groundwater at the top of the regional aquifer takes precedence to a 50-year life for the well.

My point is this: from the data currently derived from the regional aquifer at LANL HW well R-15, a person cannot conclude whether or not many contaminants of concern are present in groundwater. However, the available information supports the finding that strontium-90, tritium and perchlorate contamination is present in the groundwater samples and the level of the contamination is not accurately known because of dilution.

The purpose for LANL HW well R-15 is accurate knowledge of the presence of contamination in the regional aquifer beneath Mortandad Canyon at a location of historical Laboratory releases of liquid wastes and within a pumping center of Los Alamos County supply wells, and a continued monitoring over time for contamination. It is on that basis that I assert the installation of HW well R-15 is inadequate and LANL's interpretation of the spurious contaminant data from the well is misleading.

Topic 6: The number of screened intervals in LANL HW wells with spurious groundwater samples

A primary purpose of the LANL monitoring wells is the investigation of the presence of radionuclide and chemical contamination in the regional aquifer. To accomplish this purpose, it is very important for the screened intervals to be installed in the discrete aquifer strata where the contamination is most likely to be present. Screened intervals installed to investigate contamination at the top of the regional aquifer shall not have an excessive length that results in dilution (e.g., the groundwater samples collected from LANL HW well R-15 are spurious because of dilution – see Topic 5).

In addition, it is very important to install screened intervals in the highly permeable strata (see Topic 4) as these strata are most likely to reveal the earliest presence of contamination and also contain the highest levels of contamination[13] (e.g., the groundwater samples collected from LANL HW well R-22 are spurious because the screened intervals are not installed in the discrete aquifer strata with high permeability and also are spurious because of the irreparable damage caused to groundwater chemistry by the improper drilling procedures and by the biodegradable drilling fluids – see Topic 8).

The statement on page 20 of the Bitner Report that - "The majority of wells and screens are not impacted by residual drilling fluid -" is an admission that a large number (up to 49%) of screened intervals in the LANL HWwells may be impacted by residual drilling fluid. It is important to understand that an accurate assessment of the number of impacted screened intervals is not possible because of the improper methods that are used for the collection of groundwater samples from all of the LANL HW wells. The methods used by LANL for the collection of groundwater samples are described in Appendix F. For comparison, the appendix also describes the groundwater sampling methods required by the NMED Consent Order and the industry standard practice for the collection of groundwater samples from monitoring wells.

Nevertheless, the available information proves that a large number of the LANL HW wells do not provide representative groundwater samples. The large impact of the residual drilling fluids is proven because Table 4 in the Bitner Report identifies water samples collected from nine screened intervals in the LANL HW wells R-7, R-9i, R-16, and R- 22 as not representative of aquifer chemistry.

Table 4 in the Bitner Report mistakenly identifies water samples collected from screen #1 in well R-7 as representative of aquifer chemistry. The data in the LANL HW well R-7 reports[37,38] show that a dissolved uranium concentration of 0.0014 mg/L was measured in a groundwater sample collected from the perched zone in the well R-7 borehole and an order of magnitude lower dissolved uranium concentrations of 0.000167 and 0.000252 mg/L were measured in the first two quarterly groundwater samples collected from screen #1 installed in the perched zone of saturation. Uranium was "not detected" in the groundwater samples collected in the third and fourth quarter from screen #1.

The uranium data are important evidence that groundwater samples collected from screen #1 in LANL HW well R-7 are spurious for the detection of contamination in groundwater in the perched aquifer, even though an oxidizing chemistry is present in the groundwater samples. The anomalously low uranium concentrations that is present in the oxidizing groundwater samples are because of the irreparable damage to the aquifer strata and even the filter pack sediments by the new mineralogy caused by the biodegradable drilling fluids.

The chemical data from screen # 1 in well R-7 are proof that the return of an oxidizing chemistry is not a guarantee that the groundwater samples are representative for uranium and many other contaminants of concern. The Bitner Report and other LANL reports[22] are mistaken to assign the presence of an oxidizing chemistry as evidence that the groundwater samples are not affected by the residual drilling additives. Another important issue is that groundwater samples are collected from well R-7 with a Westbay no-purge sampling system.

The claim in Table 4 of the Bitner Report that the water samples collected from screen #2 in LANL HW well R-22 are representative of aquifer chemistry is inapplicable because of the striking low permeability of the aquifer strata at screen #2 of 0.04 feet/day[24]. For the LANL monitoring wells, there is an essential need for knowledge of the contaminant chemistry of groundwater in aquifer strata that have high permeability. LANL has failed to install well screens in the highly permeable strata that are present in the regional aquifer at the location of well R-22. The highly permeable strata are estimated to have a permeability of greater than one hundred feet/day (see Topic 4).

Topic 5 in this report presents evidence that the groundwater samples collected from the 60-foot screen in LANL HW well R-15 are not reliable to detect contamination from LANL sources because of dilution. In final analysis, the groundwater samples collected from <u>twelve</u> of the thirteen screened intervals listed in Table 4 in the Bitner Report are not reliable for the necessary characterization of groundwater contamination in perched zones of saturation (wells R-7 and R-9i) and in the regional aquifer (wells R-7, R-15, R-16, and R-22).

The fact that Table 4 in the Bitner Report lists water samples collected from LANL HW well R-16 as not representative of aquifer chemistry is important as this well was drilled with the mud-rotary method with the result that the aquifer strata that are important for monitoring are irreparably damaged by invasion with thousands of pounds of bentonite clay drilling mud. The design features of the LANL HW wells that prevent recovery of much of the bentonite clay from the aquifer strata are described in Article A-2 in Appendix A. Table 1 in the Bitner Report lists eight LANL HW wells with seventeen screened intervals installed in boreholes drilled with the conventional mud-rotary method.

It is reasonable to conclude that the groundwater samples collected from the <u>seventeen</u> screened intervals are not reliable for many radionuclide contaminants. The properties of bentonite clay to remove radionuclide contaminants from groundwater are described in Appendix D.

Other LANL reports[23,30] acknowledge that the water samples collected from screened intervals in LANL HW wells R-7, R-9i, R-12, R-19, R-22, and R-32 are not representative of aquifer chemistry because of residual biodegradable drilling fluids and biodegradable foam. The set of LANL reports including the Bitner Report prove that the total number of screened intervals that do not provide representative groundwater samples is a <u>minimum</u> <u>of</u> <u>forty</u> (<u>40</u>). The actual number of screened intervals that are irreparably damaged for groundwater samples representative of aquifer chemistry will not be known until proper methods are used to collect groundwater samples. The concerns for the methods used by LANL for the collection of groundwater samples from the LANL HW wells are described in Appendix F.

Topic 7: The methods used for the development of screened intervals in LANL HW wells.

The Bitner Report describes the LANL well development procedures as follows:

> "The well development procedures at LANL are consistent with industry standards. LANL has gone above and beyond industry by ensuring that no additives were used without complete analytical characterization and by making the concentration of TOC (total organic carbon) a performance criteria for satisfactory well development" (Bitner Report, page 30).

The well development procedures at LANL are **not** consistent with industry standards. No well development procedures were performed in some screened intervals in LANL HWwells (e.g., screen #1 in LANL well R-7 and screen #1 in well R-22). In addition, the well development procedures performed in some wells do not meet the requirements of RCRA (some examples are screen #3 in well R-7, screen #3 in well R-31, screen # 4, 5, 6, and 7 in well R-19).

An inaccurate statement in the Bitner Report is the following:

> "Table 5 summarizes the development techniques used in the wells cited in the report by Gilkeson (2004)" (Bitner Report, page 30).

However, it is important to note that Table 5 does not present any information on the well development activities in LANL HW wells R-7, R-22, and R-31. The inconsistent practice of LANL development procedures is illustrated by Table 3 in the LANL Hydrologic Tests Report[24].

The industry standard practice is to avoid the use of the conventional mud-rotary drilling method for the installation of monitoring wells and as a general practice it is important to avoid the invasion of aquifer strata that are important for monitoring with biodegradable polymer-based drilling fluids, biodegradable foams, and bentonite clay drilling muds. It is very important to avoid the invasion of aquifer strata with these drilling additives when trace radionuclides and metals are contaminants of concern. Appendix A presents the guidance in the technical literature to avoid the invasion of aquifer strata with the drilling additives used at LANL.

Furthermore, when these drilling additives are used, it is essential for the well development procedures to be performed as soon as possible and carefully to completely remove the drilling additives[3,19,and 51]. For many of the LANL HW wells there was a long delay between the invasion of the drilling additives into the aquifer strata and the performance of the well development procedures.

In addition, it is important to note that the great depth of the LANL HW wells and the as-built design of the wells are features that prevent the recovery of much of the drilling additives from the aquifer strata. The difficulty for removal of the drilling additives from the screened intervals in the LANL HW wells is described in Article A-2 in Appendix A.

Another reason well development could not recover the drilling additives is that LANL used chemicals (see Table 5 in Bitner Report) to disaggregate and disperse the bentonite clay drilling muds outward in the impacted strata even though the EPA RCRA Manual[54] cautions that the chemicals should not be used:

> "Additives to modulate the viscosity and density of the bentonite muds may also introduce contaminants in the groundwater or force large, unrecoverable quantities of mud into the formation." (EPA RCRA Manual, page 6-12)

The industry standard practice[1,2] is that the well development procedures are performed until the screened intervals produce representative groundwater samples. Table 4 in the Bitner Report is proof that LANL terminated the performance of well development procedures before the biodegradable drilling fluids, biodegradable foams, and bentonite clay muds were removed from the impacted aquifer strata.

The statement in the Bitner Report that no additives were used without complete analytical characterization is meaningless because the properties of the biodegradable polymer-based drilling fluids, biodegradable foams, and the bentonite clay drilling muds are well understood in the monitoring well industry as additives that are inappropriate in general for monitoring wells and specifically when trace radionuclides and metals are contaminants of concern. The technical literature against the use of the drilling additives is summarized in Appendix A. The guidance of EPA and NMED against the invasion of aquifer strata with the drilling additives are described in Appendix B. The chemical properties of bentonite clay to remove trace radionuclides from groundwater are described in Appendix C. The chemical properties of the biodegradable polymer-based drilling additives that cause preferential removal of many contaminants of concern including radionuclides from groundwater are described in Appendix D.

A LANL report[42] that was published in 2000 describes the sorption properties of the BAROID EZ-MUD* biodegradable polymer-based drilling fluid that was used in the boreholes for many LANL HWwells as follows:

> "The EZ-MUD* drilling fluid has a negative charge density of 30% which may enhance the polymers ability to adsorb the cations Sr^{2+}, PuO_2^{1+}, UO_2^{2+}, and $AmCO_3^{1+}$."
>
> "EZ-MUD* is strongly hydrophobic (high molecular weight polymer), which probably has the ability to adsorb organic compounds such as RDX, HMX, and TNT."

It is important to note that the EZ-MUD* additive was used for the drilling of the boreholes for many LANL HW wells ***after*** LANL released the information on the adsorption properties of the drilling fluid for contaminants of concern. It was inappropriate for LANL to use drilling fluids that have adsorption properties for many contaminants of concern in groundwater beneath the Laboratory facility.

The claim in the Bitner Report that LANL used the concentration of total organic carbon (TOC) as a performance criterion for satisfactory well development is without merit. TOC measurements are not diagnostic of the removal of the bentonite clay drilling mud from the impacted aquifer strata. In addition, the elevated concentrations of TOC and iron, and the anaerobic chemistry in the quarterly groundwater samples collected from many LANL HWwells[34,35,36,38] after the termination of the well development procedures are proof that the organic drilling additives were not removed from the aquifer strata by the LANL well development procedures. The organic additives were a fuel for irreparable damage to the screened intervals in the monitoring wells by the chemical process that is known as “biofouling plugging” The “biofouling plugging” process is described in Articles A.11 to A.14 in Appendix A.

Additional evidence of the biofouling plugging of the screened intervals are the very high concentrations of dissolved iron and manganese in the quarterly samples from many LANL HWwells[34,35,36,38]. The high concentrations are direct evidence[7,19] of the formation of deposits on the aquifer strata and even the filter pack sediments of precipitates of iron and manganese that have strong properties to remove trace radionuclide contaminants from groundwater and also dramatically lower the permeability[3,19] of the aquifer strata and the filter pack sediments. For the impacted HW wells, samples are collected from the “stagnant zone” of groundwater that surrounds the screened intervals.

The importance of open hydraulic connection of screened intervals to the aquifer strata being monitored is described in Article A-3 in Appendix A. The chemical processes that accompany the biofouling plugging of screened intervals are described in Appendix D.

Topic 8: LANL’s failure to accurately characterize contamination in the regional aquifer beneath Los Alamos Canyon and beneath Area G.

The arguments in the Bitner Report against the trend analyses of strontium-90 and technetium-99 in Gilkeson (2004) are a distraction from the irrefutable fact that the contaminant data in the quarterly samples collected from LANL HWwells R-7 and R-22 are spurious. The often repeated claim in the Bitner Report and other LANL reports[34,38] that radionuclide contamination is “not detected” in the regional aquifer at wells R-7 and R-22 is disingenuous as Table 4 in the Bitner Report acknowledges that the groundwater samples collected from the two wells are not representative of the aquifer chemistry.

Furthermore, Figure six in the Bitner Report acknowledges that the anaerobic chemistry surrounding the well screens will remove the radionuclide contaminants from groundwater. The LANL HW well geochemistry reports and the Bitner Report describe the spurious contaminant data as “not detected” values because the discrete analyses do not meet the LANL arbitrary method detection limits (MDL).

The text book *Applications of Environmental Chemistry*[56] has the following discussion of the “not detected” values reported by analytical laboratories:

> “When a laboratory reports that a target contaminant was “not detected”, it does not mean that the contaminant was not present. It always means that the contaminant was not present in a concentration above a certain lowest reporting limit (method detection limit). There always is the possibility that the contaminant was present at a concentration below the reporting limit.”

The Bitner Report acknowledges that the trend analyses in Gilkeson (2004) are based on method detection limit data. The trend analyses were an appropriate technique to confirm the presence of the strontium-90 and technetium-99 contamination in the regional aquifer. The misrepresentation in the Bitner Report of the method detection limit (MDL) data from HWwells R-7 and R-22 as "minimum detection limits" is a serious mistake as shown by the following statement:

> "The instrument detection limit (i.e., method detection limit) decreases during that period (of quarterly sampling) because matrix interferences decreased as the well equilibrates with groundwater. After the first sampling round, technetium-99 was not detected, despite the improved ability to detect it" (Bitner Report, page 35).

The decline in the "not detected" values of technetium-99 (and also of strontium-90) is not because of an improvement in detection. One example of where the decline in the radionuclide contaminant data is not accompanied by a decline in matrix interference (i.e., "background noise") is the quarterly samples from screen no. 1 in HW well R-22.

The specific conductance (SC) values for the groundwater samples are a measure of matrix interference. For the quarterly samples[34] from screen no. 1, the SC values trend to higher values from 458 to 549 uS/cm[2] as compared to a trend to lower values in the "not detected" MDL data for technetium-99. The trend to lower values for the technetium-99 contamination is because of precipitation of technetium-99 from groundwater by the unnatural anaerobic chemistry[34] surrounding screen no. 1. The confusion in the Bitner Report concerning "method detection limits" and "minimum detection limits" is a serious problem that requires investigation.

LANL HW wells R-7 and R-22 are multiple-screen wells that are equipped with Westbay* sampling systems. For the analytical suite, the Westbay* sampler collects the stagnant groundwater within the well, in the filterpack, and in the strata with a new mineralogy immediately surrounding the well that are affected by the biofouling plugging process (see Topic 7 and the discussion of LANL sampling methods in Appendix F).

LANL HW well R-7: LANL does not have the necessary knowledge of the presence of contamination in the regional aquifer below landscapes in Los Alamos Canyon where there is a long history of discharge of liquid wastes that contained high concentrations of chemicals and radionuclides including strontium-90. The strontium-90 data in the trend analysis in Gilkeson (2004) are from the LANL geochemistry report for HW well R-7[38]. The data in the LANL report are not minimum detection limits. The LANL report describes the data as values recorded by the analytical instrument at levels that do not meet the three standard deviations requirement.

However, NMED[48] disagrees with the three standard deviations requirement by LANL for radionuclide analyses with the following statement:

> "With respect to the interpretation of analytical results of radionuclide monitoring under the Safe Drinking Water Act, EPA has stated that "the analytical result is the number that the laboratory reports, not including (i.e. not adding or subtracting) the standard deviation." 65 Fed. Reg. 76,727 Dec. 7, 2000). LANL routinely applies standard deviations to its analytical results of groundwater monitoring. In its ground-water monitoring reports, LANL defines detections as "values exceeding

> both the analytical method detection limit (where available) and three times the individual measurement uncertainty." – the Environment Department disagrees with this restrictive definition of "detection", -" (NMED, November 26, 2002).

Furthermore, the NMED LANL Consent Order[47] regulates against LANL's data validation requirements as follows:

> "The respondents (LANL) shall not censor the data based on detection limits, quantitation limits, or measurement uncertainty." (NMED Consent Order, page 183)

The trend analysis of the strontium-90 data in Gilkeson (2004) show a consistent pattern, indicating that strontium-90 is detected, even if not with the accuracy required by LANL. Furthermore, the trend is consistent with the observed alteration of the geochemistry that was caused by the use of drilling fluids in the borehole. The decline in dissolved concentrations of the alkaline earth elements calcium, magnesium, strontium, and strontium-90 in the quarterly samples[38] is because of precipitation from groundwater due to changes in the carbonate chemistry[53] of groundwater at HW well R-7 because of the organic drilling additives that invaded the screened interval.

It is very important to gain knowledge of where strontium-90 recharge to the regional aquifer is occurring because of the detection of strontium-90 in groundwater samples collected from the public supply well Otowi-1. For groundwater samples collected in June and August of 2000, the measured activities with 3-standard deviation validation were 0.19 pCi/L and 0.23 pCi/L, respectively[48]. This supply well is located downgradient of LANL HW well R-7. The NMED[48] has expressed the following concern for strontium-90 contamination in the regional aquifer:

> "The extent of strontium-90 contamination at the LANL facility has not been fully investigated. Moreover, the levels of strontium-90 detected in the drinking water supply wells are likely to have been substantially diluted. The rate of groundwater withdrawal in municipal water supply wells often exceeds one thousand gallons per minute, and the screened interval is typically hundreds of vertical feet across multiple producing zones, resulting in a high degree of dilution. The Environment Department believes that this evidence is sufficient to support its finding that there may be an imminent and substantial endangerment to health and the environment from strontium-90 contamination at the LANL facility" (NMED, November 26 2002).

The altered aquifer chemistry that surrounds HW well R-7 prevents accurate knowledge of the presence of strontium-90 and many other contaminants (including perchlorate) that may be present in the regional aquifer. The altered chemistry is responsible for the anomalously low concentrations of dissolved uranium that are present in samples collected from the regional aquifer. Uranium is also a contaminant of concern in groundwater beneath LANL. The LANL HW well R-7 reports show that a uranium concentration of 0.0021 mg/L was measured in a groundwater sample collected at the top of the regional aquifer from the borehole for well R-7 and significantly lower dissolved uranium concentrations of 0.000084 and 0.000051 mg/L were measured in the first two quarterly samples collected from screen #3 the top of the regional aquifer in well R-7. Uranium was "not detected" in the groundwater samples collected in the third and fourth quarter from screen #3 in well R-7. LANL does not have accurate knowledge of the levels of dissolved uranium and many other contaminants in the regional aquifer beneath Los Alamos Canyon at the location of LANL HW well R-7.

The Bitner Report (page 23) acknowledges that the biodegradable drilling fluids have caused a reducing chemistry at screen #3 in well R-7 and that this reducing chemistry will lower the concentrations of perchlorate in groundwater (i.e., LANL does not have knowledge of the presence or absence of perchlorate in the regional aquifer at well R-7).

Nevertheless, the LANL HW well R-7 Geochemistry Report states that "Concentrations of perchlorate were less than detection." The report does not acknowledge that the contaminant data for perchlorate (and many other contaminants) are spurious.

The Bitner Report (page 33) cites the low concentrations of tritium in groundwater samples collected from screen #3 in HW well R-7 as evidence that the regional aquifer is not impacted by Laboratory derived contamination. However, it is important to be aware that even the tritium data for the regional aquifer are unreliable because of the methods that LANL uses for collection of water samples from the "stagnant zone" of groundwater that surrounds wells such as R-7 (See Appendix F).

The Bitner Report does not acknowledge the semivolatile organic compounds (SVOCs) and volatile organic compounds (VOCs) that were detected in the groundwater samples collected from screen #3[38]. The organic contaminants include acetone, isopropyl benzene, nitrosodiphenylamine[N-] and DDT[4,4'].

The presence of these contaminants is proof that the regional aquifer is impacted by Laboratory derived contamination and the nature and extent of the contamination is not known because of the improper construction of LANL HW well R-7. The validated detection of VOC and SVOC contaminants in the groundwater samples collected from screen no. 3 is an indication of the presence of serious contamination in the regional aquifer. In addition, the anaerobic chemistry that is present in the aquifer strata surrounding screen no. 3 prevents accurate knowledge of the type and concentrations of VOC and SVOC contaminants that are present at the top of the regional aquifer. The transformation and degradation of the VOC and SVOC contaminants in the anaerobic groundwater that is present in the aquifer strata at screen no 3 is well documented in the technical literature[50].

My point is this: from the data currently derived from the regional aquifer at LANL HW well R-7, a person cannot conclude whether or not many contaminants of concern are present in groundwater. However, the available information supports the finding that strontium-90, VOC, and SVOC contamination is present in the groundwater samples and the level of the contamination is not accurately known. The purpose for LANL HW well R-7 is accurate knowledge of the presence of contamination in the regional aquifer beneath Los Alamos Canyon at a location that is upgradient of Los Alamos County supply wells and a continued monitoring over time for contamination. It is on that basis that I assert the installation of HW well R-7 is inadequate and LANL's interpretation of the spurious contaminant data from the well is misleading.

LANL HW well R-22: This reply to the Bitner Report describes the serious mistakes in the construction of LANL HW well R-22 at a location where there is an immediate need to have accurate knowledge of the impact of the Laboratory's active landfill for the disposal of low-level radioactive waste (Area G) on the regional aquifer. The important fact for LANL well R-22 is that the accurate detection of the presence of contamination in the regional aquifer beneath Area G is not possible because of

1). the improper use of biodegradable polymer-based drilling fluids and biodegradable drilling foam in the borehole,
2). the failure to perform thorough well development procedures to remove the biodegradable drilling additives – no well development activities were performed in screen #1 located at the top of the regional aquifer; for the location of well R-22, there is a very important need for accurate characterization of contamination at the top of the regional aquifer,
3). the improper drilling activities[33] penetrated a confining layer in the regional aquifer with the result that the in situ groundwater at the top of the regional aquifer that contained 109.2 pCi/L tritium[33] drained down the open borehole. The "flushing" action caused cross-contamination in deeper aquifer strata and a large fifty-fold dilution of dissolved contaminants that was present at the top of the regional aquifer (e.g. tritium was diluted[34] from greater than 109.2 pCi/L to 2.01 pCi/L),
4). semivolatile organic compounds (SVOCs) and volatile organic compounds (VOCs) are detected[34] in the diluted, anaerobic groundwater samples collected from screen #1,
5). technetium-99 contamination was detected at validated levels[34] in the first quarterly samples collected from screen #3 and screen #4, and
6). the misplacement of screened intervals in the multiple-screen monitoring well. Screened intervals were not installed in the fast groundwater pathways that are present in either the basalt strata or the river gravels present in the ancestral channel of the Rio Grande River; it is essential to have accurate monitoring for the presence of contamination in the aquifer strata that are the "fast pathways" for travel of contaminated groundwater.

The detection of technetium-99 at validated levels (levels greater than the LANL arbitrary MDL's) in the first quarterly samples collected from screen #3 and #4 in well R-22[34] is important information because the technetium-99 contamination may be from the cross-contamination that occurred when the groundwater at the top of the regional aquifer was flushed down the open borehole. A large volume of technetium-99 wastes were disposed of in trenches at Area G[46]. The improper construction of well R-22 prevents accurate detection of the presence of this highly mobile contaminant in the regional aquifer beneath Area G. The trend analyses in Gilkeson (2004) were an appropriate technique to establish the presence of technetium-99 in the anaerobic, diluted groundwater samples collected from screen #1 at the top of the regional aquifer. In addition, the anaerobic chemistry will cause precipitation of technetium-99[19].

The cross-contamination that occurred in the R-22 borehole is a violation of RCRA[54] and also of the following requirement in the NMED Consent Order:

- Contamination and cross-contamination of groundwater and aquifer materials during drilling shall be avoided (NMED Consent Order, page 189).

The detection of SVOC and VOC contamination[34] in the groundwater samples collected from well R- 22 at concentrations higher than the safe drinking water standards (MCL's) of the EPA is a serious issue because of the large volume of these chemical wastes that were disposed of in trenches at MDA G[46].

The collection of no-purge water samples from the five screened intervals in well R-22 also prevents knowledge of the nature and extent of radionuclide and chemical contamination in groundwater in the regional aquifer beneath Area G.

The validated detection of VOC and SVOC contaminants in the groundwater samples collected from well R-22 is an indication of the presence of serious contamination in the regional aquifer from the wastes buried in Area G. In addition, the anaerobic chemistry that is present in the aquifer strata surrounding screen no. 1 also prevents accurate characterization of the types and concentrations of VOC and SVOC contaminants that are present at the top of the regional aquifer. The transformation and degradation of VOC and SVOC contaminants in the anaerobic groundwater that is present in the aquifer strata at screen no 1 is well documented in the technical literature[50].

Unfortunately, the Bitner Report and the LANL HW well R-22 geochemistry report do not identify the serious groundwater contamination that is indicated because of the presence of elevated tritium, technetium-99, VOC, and SVOC contaminants in groundwater in the regional aquifer beneath Area G. A very large volume of these wastes were disposed of in trenches at Area G[46]. There is a need to install three properly constructed single-screen monitoring wells near the location of well R-22 to define the nature and extent of radionuclide and chemical contamination 1. at the top of the regional aquifer, 2. in the fast groundwater pathways in the basalt strata, and 3. in the river gravel strata present in the ancestral channel of the Rio Grande River.

The detection of radionuclide and chemical contamination in well R-22 requires the installation of monitoring wells on San Ildefonso Pueblo for a careful investigation of a). the presence of chemical and radioactive contaminants in the highly permeable aquifer strata that are the fast pathways for contaminated groundwater to travel away from Area G, and b). to monitor for contamination in the future. In addition, there is a need for a careful investigation of the presence of contamination in the regional aquifer beneath waste disposal pits and shafts at Area G where large quantities of the highly mobile technetium-99, carbon-14, and iodine-129 wastes were disposed of.

The disposal records should be reviewed to identify disposal pits and shafts where high volumes of these highly mobile wastes were disposed of. For example, the Area G records report that Iodine-129 wastes were disposed of in large volumes at a specific location[44] in the southern part of Area G. The necessary investigation requires the location of monitoring wells in the regional aquifer below Area G immediately downgradient of the disposal sites for the technetium-99, carbon-14, and iodine-129 wastes.

My point is this: from the data currently derived from the regional aquifer at LANL HW well R-22, a person cannot conclude whether or not many contaminants of concern are present in groundwater beneath Area G. A person also cannot conclude the direction or speed of groundwater in the "fast pathways" that are present in the regional aquifer. However, the available information supports the finding that tritium, technetium-99, VOC, and SVOC contamination is present in the groundwater samples and the level of the contamination is not accurately known.

The purpose for LANL monitoring well R-22 is accurate knowledge now of the presence of contamination in the regional aquifer beneath the Laboratory's active landfill for disposal of low-level radioactive waste and a continued monitoring over time for contamination. It is on that basis that I assert the installation of monitoring well R-22 is inadequate and LANL's interpretation of the unreliable data has lead to misleading conclusions.

Topic 9: LANL's poor understanding of groundwater travel in the regional aquifer

The Bitner Report avoids discussion of the conclusions in Gilkeson (2004) that LANL has failed to accurately characterize the physical properties of the regional groundwater flow system. This failure by LANL

- prevents knowledge of the speed and direction with which contaminants travel in the groundwater flow system,
- prevents the identification of "fast pathways" for travel of contaminated groundwater, and also
- prevents an understanding of the valuable groundwater resource that is available across the Laboratory facility to supply wells.

There reasons why LANL has failed to acquire accurate knowledge of aquifer properties include the following:

- 1). The failure to install screened intervals in the aquifer strata with high permeability (e.g., HW well R-7 located upgradient of a region of large groundwater withdrawal by Los Alamos County supply wells, HW well R-15 located within a region of large groundwater withdrawal by Los Alamos County supply wells, and HW well R-22 located downgradient of Area G and upgradient of a). San Ildefonso Pueblo, and b). an important, very large groundwater supply to the city of Santa Fe.
- 2). The failure to properly develop the screened intervals to restore the *in situ* properties to the aquifer strata. Many of the injection tests and pumping tests were performed in screened intervals where the well development procedures were not adequate to remove the drilling additives and restore the *in situ* permeability to the aquifer strata. Many of the hydraulic conductivity values in LANL reports[24,25] are spurious because of the damage to the aquifer strata that was caused by the drilling additives. (See Topics 3 and 7, and the articles in Appendix A.)
- 3). The failure to recognize that screened intervals are surrounded by an envelope of slough sediments; the injection tests measured the permeability of the slough sediments (e.g., screen #3 in well R-22[33] and screens #4 and #5 in well R-31[40]). This issue is discussed below.

- 4). The failure to recognize that the screened interval is surrounded by the bentonite clay backfill annular sealant that was misplaced during the construction of the well (e.g., screen no. 5 in HW well CdV-R-15-3). The injection test data is spurious for the permeability of the aquifer strata. This issue is discussed below.
- 5). The installation of long screened intervals across aquifer strata with great differences in permeability. Injection and pumping tests in the long screened intervals determined an average hydraulic conductivity value that greatly underestimates the hydraulic conductivity in the “fast pathway” strata. Examples are the 60-foot screens in LANL HWwells R-13 and R-15.

  For the Los Alamos County supply wells, examples of screen length[45] (SL) and “average” aquifer permeability[25] (HC) are Otowi-1 (SL - 1,460 feet, HC - 0.63 feet/day), Otowi-4 (SL – 1,480 feet, HC – 4.02 feet/day), PM-1 (SL – 1,534 feet, HC – 4.15 feet/day), PM-3 (SL – 1,576 feet, HC - 23.99 feet/day), PM-4 (SL – 1,594 feet, HC – 3.22 feet/day), and PM-5 (SL – 1,632 feet, HC – 0.71 feet/day).

  It is essential to understand that the “average” hydraulic conductivity values for the supply wells do not represent the much greater (by orders of magnitude) hydraulic conductivity of the highly permeable strata that is present within the screened interval; the strata that are a). the fast pathways for travel of contaminants, and b). the important groundwater resource.
- 6). The group of external consultants (the EAG) that advised LANL on activities of the Hydrogeologic Workplan reviewed the data gathered in the injection tests performed in the LANL HW wells[8]. The EAG advised LANL that it was inappropriate to use slug-test analytical methods to calculate the hydraulic conductivity for the injection test data from many screened intervals. Nevertheless, LANL rejected the expert advice and LANL reports[24,25] publish the markedly low hydraulic conductivity values that were calculated from the slug-test methods. This issue is discussed below.
- 7). The EAG advised LANL of inaccurate data for injection and pumping tests[8.]. However, LANL failed to correct all of the data inaccuracies in the LANL reports[24,25].
- 8). The failure to critically review the aquifer property values listed in historical LANL reports for pumping tests and the failure to critically review the aquifer property values gathered from outside sources. (See Table 4.3-2, “Hydraulic Conductivity Estimates” in the LANL Groundwater Annual Status Report for Fiscal Year 2002, LA-UR-03-0244.) The data presented in Table 4.3-2 are much too low (by orders of magnitude) for many of the aquifer lithologies that are present in the regional aquifer beneath the Laboratory facility. An additional problem with the data in Table 4.3-2 is that all of the values are described by formal stratigraphic names (e.g., Puye sediments, Cerros Del Rio Basalt, etc.), or by unimportant lithofacies (e.g., fanglomerate sediments and pumiceous sediments), and <u>not</u> by the physical properties that control permeability (e.g., coarse gravel, clayey gravel, coarse sand, silty sand, clayey sand, unfractured basalt, highly fractured basalt, coarse scoria gravels, etc.).
- 9). LANL has placed undue reliance on borehole geophysics to determine screen length and screen placement in monitoring wells, and for calculation of the permeability of discrete aquifer strata. This issue is discussed below.

LANL injection tests in HW well R-31: The significance of the failure of LANL to acquire accurate knowledge of aquifer properties is shown by the LANL injection tests in three screened intervals in LANL HW well R-31. An interesting feature in the LANL hydrologic tests report[24] is the performance of injection tests before and after all development procedures were performed in screen # 3 in HW well R-31. The higher hydraulic conductivity of 1.95 feet/day measured in the first injection test compared to the significantly lower value of 0.41 feet/day for the second test after "full development" of the screened interval is evidence that the well development procedures increased the "plugging" of the filter pack sediments and the aquifer strata in the impacted zone that surrounds the screened interval.

For the development of screened intervals in LANL HW well R-31 (and many other HW wells), LANL operated the surge block on a wire line[40]. The surge block caused flow of water into the well but did not have a back-flushing action. The EPA RCRA Manual[54] advises against the operation of a surge block on a wire line as follows:

> **"**Inducing movement of groundwater into the well (i.e., in one direction) generally results in bridging the particles. A means of inducing flow reversal is necessary to break down bridges and produce a stable filter."

In addition, the hydraulic conductivity value of 0.41 feet/day published in the LANL hydrologic tests report[24] is unreasonably low for the aquifer strata based on the description in the LANL HW well R-31 completion report[39] of the drilling activities in the basalt strata where screen #3 is installed. The report describes the aquifer strata as clay-free, columnar jointed basalt that yielded enhanced groundwater flow during the drilling. The low permeability measured for screen #3 is evidence of improper well development procedures and also because of "biofouling plugging" by the organic drilling additives that were used in the borehole for well R-31. The aquifer strata where screen #3 is installed may have a hydraulic conductivity greater than 100 feet/day[14]. Nevertheless, the LANL reports[24,25] publish the much lower value of 0.41 feet/day.

The EAG advised LANL that incorrect methods were used to calculate the hydraulic conductivity for screen #4 and #5 in well R-31[8]. The EAG used the correct analytical methods to calculate significantly higher hydraulic conductivity values for screen #4 and #5 of 36.2 feet/day and 16.7 feet/day, respectively[8] . Nevertheless, LANL reports[24,25] published the unreasonably low hydraulic conductivity values of 1.23 feet/day and 0.75 feet/day for the two screened intervals.

It is important to be aware that the HW well R-31 completion report shows that screen #4 and #5 are surrounded by slough sediments that flowed into the borehole as the drill casing was retracted during the construction of the monitoring well. The injection tests measured the hydraulic conductivity of the slough sediments. The description in the well R-31 completion report of the drilling activities in the thick interval of coarse sediments where screen #4 and #5 are installed and the very large production of groundwater while drilling through the greater than 393-ft thick interval are evidence that supports a hydraulic conductivity for the aquifer strata at screen #4 and #5 of greater than 250 feet/day[14]. The drilling record for well R-31 is evidence that a large groundwater resource is present in the region of LANL HW well R-31 and this valuable resource is not recognized by the spurious hydraulic conductivity values that are published in LANL reports[24,25]. The injection test results are summarized as follows:

- LANL HW well R-31; screen #3 — Hydraulic Conductivity
  - LANL injection test (before development) - - - - - - - - - - - - 1.95 feet/day
  - LANL injection test (after development)- - - - - - - - - - - - - - 0.41 feet/day
  - Estimated permeability[14] - 50 to >100 feet/day

- LANL HW well R-31; screen #4 — Hydraulic Conductivity
  - LANL injection test - 1.23 feet/day
  - EAG correction of LANL test
    lower-bound value from Specific Capacity method - - - - - - - - 18.10 feet/day
    value from Theis Recovery method - - - - - - - - - - - - - - - - - - 36.20 feet/day
  - Estimated permeability[14] - 100 to >250 feet/day

- LANL HW well R-31; screen #5 — Hydraulic Conductivity
  - LANL injection test - 0.75 feet/day
  - EAG correction of LANL test
    lower-bound value from Specific Capacity method - - - - - - - - - - 15.10 feet/day
    value from Theis Recovery method - 16.70 feet/day
  - Estimated permeability[14] - 100 to >250 feet/day

<u>Injection tests and borehole geophysics in HW well R-19</u>: Another example of the spurious values for aquifer permeability that are published in LANL reports[24,25] are the results for injection tests and borehole geophysics for LANL HW well R-19. It is informative to compare the hydraulic conductivity values listed in the LANL reports[24,25] for well R-19 to the markedly higher values that were calculated in the EAG review[8] of the LANL injection tests:

- LANL HW well R-19; screen #6 — Hydraulic Conductivity
  - Schlumberger* geophysics - 1.40 feet/day
  - LANL injection test - 1.10 feet/day
  - EAG correction of LANL test
    lower-bound value from Specific Capacity method - - - - - - - 27.60 feet/day
    value from Theis Recovery method - - - - - - - - - - - - - - - - - 55.90 feet/day
  - Estimated permeability[14] - 75 to >150 feet/day

- LANL HW well R-19; screen #7 — Hydraulic Conductivity
  - Schlumberger* geophysics - 0.60 feet/day
  - LANL injection test - 0.73 feet/day
  - EAG correction of LANL test
    lower-bound value from Specific Capacity method - - - - - - - - - - 31.40 feet/day
    value from Theis Recovery method - 43.90 feet/day
  - Estimated permeability[14] - 75 to >150 feet/day

The EAG analysis of the LANL injection tests for screens 6 and 7 determined that LANL had incorrectly used slug test methods for calculation of the hydraulic conductivity. Using correct analytical methods, the EAG determined a 50-fold higher hydraulic conductivity for the two screened intervals than either the LANL calculated values or the values determined from the Schlumberger* geophysics.

It is important to be aware that biodegradable drilling fluids and biodegradable foam were used in the borehole for HW well R-19[35]. The chemical data in the LANL HW well R-19 geochemistry report are evidence that the chemical processes that cause “biofouling plugging” of the aquifer strata were present in the groundwater samples collected from screen #6 and #7. Therefore, the hydraulic conductivity of the aquifer strata that are outside of the zone impacted by the biodegradable drilling additives are expected to be much greater than the values calculated by the EAG. The loss of permeability in screened intervals because of “biofouling plugging is described in Articles A.11 to A.14 in Appendix A.

Injection tests and borehole geophysics in HW well CdV R-15-3: Another example of a well where it was inappropriate for LANL to perform injection tests is screen no. 5 in HW well CdV-R-15-3. Table 4.3-2[25] lists hydraulic conductivity values for injection tests (0.25 feet/day) and geophysics (0.20 feet/day) performed in screen no. 5 of well CdV-R-15-3. The data are spurious because the LANL Well CdV-R-15-3 Completion Report[39] describes all of the 6.9-foot long well screen (except the upper 0.6 feet) to be surrounded by bentonite clay backfill because of a mistake in well construction. It was a mistake for LANL to perform an injection test in the severely plugged screened interval.

The borehole log in the HW well CdV-R-15-3 completion report describes the aquifer strata where screen no. 5 is installed as a 50-foot thick interval of gravel and coarse sand with “washouts” identified by borehole video. The description indicates strata with a permeability greater than 100 feet/day[14]. The Schlumberger geophysics was performed in the open borehole before installation of the well. The close comparison of the Schlumberger geophysics value for aquifer permeability (0.20 feet/day) to the spurious value determined by the injection test (0.25 feet/day) requires investigation.

Table 4.3.-2[25] lists three hydraulic conductivity estimates described as “all Puye” for HW wells CdV-R-15-3 (0.60 feet/day) and R-19 (0.30 feet/day), and as “pumiceous Puye” for HW well R-7 (0.10 feet/day). The estimates were determined from borehole geophysics and are presented as average values for the entire section of the Puye strata at the location of the well. The estimates are not described by lithologic properties that are diagnostic of aquifer properties or by depth interval in the borehole (to allow comparison to the borehole log). The data are meaningless for any application, and also spurious as shown by the spurious data from the borehole geophysics for screens 6 & 7 in well R-19 and screen no. 5 in well CdV-R-15-3 that are discussed above. In addition, the geophysics values are anomalously low and spurious because the borehole logs in the HW well R-7, R-19, and CdV-R-15-3 completion reports are evidence that the regional aquifer in the environs of the three wells contain aquifer strata with high permeability.

The record shows that LANL has inappropriately placed reliance on borehole geophysics to determine the aquifer strata for screen placement (e.g., HW well R-22), screen length (e.g., HW well R-15), and aquifer permeability (e.g., HW wells R-7, R-19, R-22, and CdV-R-15-3). The undue reliance assigned by LANL to borehole geophysics is illustrated by the following statement in the Bitner Report:

> “Because there are no *a priori* methods for selecting which of these many depositional layers represent preferred contaminant pathways, geophysical logs are used to identify representative sections of high permeability” (Bitner Report, page 11).

In reality, the direct evidence from the performance of the drill rig (e.g., water production, lost circulation intervals, unstable borehole, speed, and jerky or smooth drilling, etc.) and the geologic description of aquifer strata from core and cuttings are valuable "real time" information that identify the highly permeable aquifer strata that are important for monitoring. The record shows that the values determined from pumping tests, injection tests, and borehole geophysics were not compared to the important information in the drilling record and the geologic description of core and cuttings.

Injection tests and pumping tests in monitoring wells constructed in boreholes drilled with the mud-rotary method: Injection tests and pumping tests have been performed in many LANL HW wells that are installed in boreholes drilled with the mud-rotary method (some examples are HW wells R-2, R-4, R-6, R-14, R-16, R-26, and R-32). Appendix E describes the great damage to the aquifer strata that was caused by the mud-rotary method in the borehole for HW well R-14. The drilling record shows great invasion of bentonite clay drilling mud and borehole stabilization materials into the aquifer strata with high permeability, the very strata that are important for knowledge of aquifer properties. The large volume of drilling additives that have invaded the aquifer strata will cause a large reduction in the aquifer permeability. The permeability determined by the injection tests and pumping tests are spurious and anomalously low for the *in situ* permeability of the aquifer strata.

The failure of LANL to properly gather knowledge of the hydraulic conductivity of aquifer strata in the regional aquifer is a serious problem. The anomalously low values in LANL reports[24,25] from aquifer tests and borehole geophysics cause a misunderstanding of a). the speed of groundwater travel, and b). the valuable, very large groundwater resource that is available to supply wells. The decision by LANL to publish aquifer property data after the EAG[8] had identified the data as spurious is a serious problem that requires investigation. In addition, the close comparison of the aquifer property data from borehole geophysics to the spurious, unreasonably low values determined by the LANL injection tests is a serious problem that must be investigated.

- **LANL's Regional Groundwater Flow Model**

LANL has expended much effort on the development of a computer model for groundwater flow in the regional aquifer beneath and surrounding the Laboratory facility[41]. However, LANL has failed to gather accurate knowledge of the physical properties of the regional aquifer that are required as input to the model. Examples of this failure are the poor knowledge of hydraulic conductivity, effective porosity, thickness, and hydraulic head for the discrete aquifer strata that control groundwater flow.

It is important to understand that a regional groundwater flow model will not provide the required information on the transport of contamination in the "fast pathway" aquifer strata that are present in the discrete environs beneath the Laboratory facility[1]. Two examples of discrete environs are 1. the regional model will not resolve the flow of groundwater in the "fast pathway" aquifer strata present beneath Area G, and 2. the regional model will not capture the required knowledge of the flow of groundwater to the public supply wells in the "fast pathway" aquifer strata that are present beneath Los Alamos, Mortandad, and Pueblo Canyons. The "fast pathway" strata may contain contamination. The necessary information on the dynamics of groundwater flow for these local environs requires the installation of monitoring wells in the fast pathway strata and the performance of appropriate pumping tests, flow tests, tracer tests, dilution tests, etc.

The regional groundwater flow model calculates the direction and speed of groundwater flow from knowledge of the elevation of the surface of the water table on the top of the regional aquifer. The direction and speed of groundwater flow in the fast pathway aquifer strata beneath LANL may be very different from the predicted direction and speed as determined by the water level contours on the top of the regional aquifer[1,13].

Post Script to Topic 9.
I was informed on March 3, 2005 that LANL has revised the aquifer properties report by Stone and McLin[24] as a report titled – "*Hydrologic Tests at Characterization Wells R-9i, R-13, R-19, R-22, and R-31, Revision 1",* LANL Report LA-14121-MS, June 2004. The revised values for wells R-19 and R-31 are listed here with comparison to the values published in the original report[24], the recommended corrections by the LANL EAG[8], and to estimated values based on the physical information in the drilling record, borehole video, and description of cuttings. The revised values are anomalously low when compared to the physical information. The LANL injection tests in wells R-19 and R-31 were performed in screened intervals where the permeability of the filter pack sediments and the aquifer strata were lowered because of the presence of residual drilling additives, the presence of slough sediments, and the failure of the well development procedures to restore the in situ permeability.

- LANL HW well R-31; screen #3

	Hydraulic Conductivity (feet/day)
- LANL injection test (before development)	1.95
- LANL injection test (after development)	0.41
- LANL Revision 1 (after development)	0.48
- Estimated permeability	50 to >100

- LANL HW well R-31; screen #4

	Hydraulic Conductivity (feet/day)
- LANL injection test	1.23
- EAG correction of LANL test	
lower-bound value from Specific Capacity method	18.10
value from Theis Recovery method	36.20
- LANL Revision 1 (Specific Capacity method)	11.1
- LANL Revision 1 (Theis Recovery method)	4.8 to 57.6
- Estimated permeability	100 to >250

- LANL HW well R-31; screen #5

- LANL injection test	0.75
- EAG correction of LANL test	
lower-bound value from Specific Capacity method	15.10
value from Theis Recovery method	16.70
- LANL Revision 1 (Specific Capacity method)	8.3
- LANL Revision 1 (Theis-Recovery method)	1.0 to 16
- Estimated permeability	100 to >250

- LANL HW well R-19; screen #6
  - Schlumberger* geophysics - 1.40
  - LANL injection test - 1.10
  - EAG correction of LANL test
    lower-bound value from Specific Capacity method - - - - - - - 27.60
    value from Theis Recovery method - - - - - - - - - - - - - - - - - - 55.90
  - LANL Revision 1 (Specific Capacity method) - - - - - - - - - - - - 18.6
  - LANL Revision 1 (Theis-Recovery method) - - - - - - - - - - - - - 4.8 to 250.1
  - Estimated permeability - 75 to >150

- LANL HW well R-19; screen #7
  - Schlumberger* geophysics - 0.60
  - LANL injection test - 0.73
  - EAG correction of LANL test
    lower-bound value from Specific Capacity method - - - - - - - - - 31.40
    value from Theis Recovery method - 43.90
  - LANL Revision 1 (Specific Capacity method) - - - - - - - - - - - - - 22.0
  - LANL Revision 1 (Theis-Recovery method) - - - - - - - - - - - - - 2.5 to 131.3
  - Estimated permeability - 75 to >150

The borehole video and “enhanced water production” from the strata in the interval of screen no. 3 in well R-31 are strong evidence that the low value of hydraulic conductivity in the Revision 1 report (0.48 feet / day) does not represent the aquifer properties. In addition, the production of a very large quantity of groundwater while drilling through the thick interval of strata where screens no. 4 and no. 5 are installed in well R-31, and the description of cuttings are strong evidence that the low values published in the Revision 1 report do not represent the aquifer properties of the important groundwater resource located in the region surrounding well R-31.

The turbidity and total organic carbon (TOC) data for the quarterly groundwater samples collected from screens no. 6 and no. 7 in well R-19[35] are evidence that the screened intervals are partially plugged by the biodegradable, polymer-based drilling fluid and biodegradable foam that were used for drilling the open borehole. For screen no. 7, there is additional plugging of the permeability by the misplacement of bentonite clay grout during the construction of the well[35]. The geochemical data in the quarterly samples are evidence that the plugging of the two screened intervals is ongoing by the chemical process know as “biofouling plugging”. The borehole video record and the description of cuttings are evidence that support estimated permeability values for the strata at the two screened intervals to range from 75 feet/day to greater than 150 feet/day.

An important issue that requires resolution is that many of the permeability and transmissivity values published in the LANL reports including the Revision 1 report does not provide accurate knowledge of the in situ physical properties of the aquifer strata. As an example, note the large range from low to high hydraulic conductivity values that are published in the Revision 1 report for each of the screened intervals in well R-19.

The Revision 1 report acknowledges a poor understanding of aquifer properties as the abstract of the report describes all of the data published in the report as “suggested values”. In fact, the physical information described in this Post Script and in Topic 9 is evidence that most of the aquifer property data published in the Revision 1 report are ***still spurious.***

Nevertheless, the "suggested" lower-bound permeability values from the Revision 1 report are published on a LANL map titled "*Hydraulic conductivity estimates in the regional aquifer.*" This LANL map was presented as part of a written document at the Feb 2, 2005 Groundwater Protection Quarterly Meeting and in a LANL presentation titled "*Synthesis of Hydrologic Information for the Pajarito Plateau*" by Bruce Robinson. The presentation was to the 4th Annual Espanola Basin Workshop – Geology and Hydrology of the Espanola Basin that convened on March 1-2, 2005 in Santa Fe, New Mexico.

The LANL map in the Robinson presentation illustrates the poor knowledge of aquifer properties for the regional aquifer beneath the LANL facility. LANL's retraction of the original aquifer properties report by Stone and McLin[24] from publication was an appropriate action. Unfortunately, retraction of the Revision 1 report and the map titled "*Hydraulic conductivity estimates in the regional aquifer*" is also a necessary action. LANL's failure to use all available information to establish estimated values for aquifer properties is a serious problem.

Topic 10: How does Los Alamos National Laboratory provide the public with groundwater information?

The Bitner Report defends the LANL presentation of information to the regulators and the public by listing the large number of public meetings and written reports since 1997. It is important to note that the quantity of communication has no measure of the quality of the communication. In addition, a catalog of meetings and documents has no basis to disprove the conclusions in the Gilkeson report (2004). I disagree with the claim made by the Bitner Report that is pasted below:

> "This report [the Bitner Report] demonstrates that the issues in the Gilkeson report (2004) and their resolutions have been extensively published, presented, and discussed by LANL over eight years" (Bitner Report, page 37).

In fact, a review of the LANL quarterly meeting reports shows that many of the issues were **not** resolved, and the Bitner Report is another example of the failure of the activities of the LANL Hydrogeologic Workplan to develop the necessary knowledge of the impact of LANL waste management practices on contamination of the regional aquifer. The Gilkeson report (2004) and this reply to the Bitner Report document that failure.

- Gilkeson (2004) was first to report that many of the characterization wells installed for the LANL Hydrogeologic Workplan do not meet either characterization requirements or the EPA RCRA requirements for monitoring wells.
- Gilkeson (2004) was first to report the spurious uranium concentrations in the groundwater samples collected from LANL HW wells R-7 and R-22 because the screened intervals are impacted by the organic drilling additives.
- Gilkeson (2004) was first to report that screened intervals in many LANL HW wells have very low permeability because of the "biofouling plugging" process that was the result of the organic drilling additives and that groundwater samples are collected from a "stagnant zone" that surrounds the screened intervals (some examples are HW wells R-7, R-9i, R-12, R-19, R-22, and R-32).

- Gilkeson (2004) brought attention to the spurious contaminant data from many LANL HW wells because of the altered chemistry caused by the residual organic and bentonite clay drilling additives that surround the screened intervals. The EAG[10] previously advised LANL about this problem but LANL did not heed their advice.
- Gilkeson (2004) was first to recognize the spurious contaminant data in LANL well R-15 that result from dilution in the 60-foot long well screen installed straddling a confining bed. The EAG[11] previously advised LANL to not install long well screens.
- Gilkeson (2004) was first to identify the failure of LANL to install screened intervals in the aquifer strata with high permeability; the very strata that are most sensitive for the presence of contamination, and the fast pathways for travel of contamination (e.g., HWwells R-7, R-15, and R-22).
- Gilkeson (2004) brought attention to the failure of LANL to correctly characterize the physical properties of the aquifer strata (e.g., permeability – also known as hydraulic conductivity). The EAG[8,9] previously brought attention to this issue. However, LANL did not heed the expert advice.
- Gilkeson (2004) brought attention to the fact that the mud rotary drilling method should not be used for the installation of LANL monitoring wells. Gilkeson[17] in 1997 and the EAG[11] in 1999 brought attention to this issue. However, LANL did not heed the expert advice.
- Gilkeson (2004) was first to recognize that information gathered by the LANL Hydrogeologic Workplan does not support the proposed DOE and LANL accelerated cleanup strategy[21] that will leave the large volume of legacy wastes disposed of in trenches and shafts at many locations across the Laboratory facility "buried in place" with little additional investigation.
- Gilkeson (2004) was first to recognize that information from LANL HW well R-22 (e.g., the groundwater contamination and the highly permeable aquifer strata) requires revision to the Performance Assessment and Composite Analysis for Area G. The
  revision is a requirement of DOE Order 435.1 for the continued operation of Area G for the landfill disposal of low-level radioactive wastes.

The information presented in Table 4 and Figures 6 & 7 of the Bitner Report prove that the contaminant data for the groundwater samples collected from LANL HW wells R-7 and R-22 is spurious. Therefore, it is misleading for the Bitner Report to contain the following statements:

> "However, groundwater samples collected and analyzed from the regional aquifer at wells R-7 and R-22 do not contain americium-241, cesium-137, iodine-129, plutonium-238, plutonium-239, plutonium-240, strontium-90, or technetium-99 in measurable quantities" (Bitner Report, page 33). "The contaminants (Tc-99, Sr-90) cited by Gilkeson (2004) to be present in the regional aquifer at R-7 and R-22, respectively, have not been detected over five sampling rounds (a duration of one and a half years), despite successively increased ability to detect them with lower detection limits" (Bitner Report, page 38).

The statements show the confusion in the Bitner Report for "method detection limits" and "minimum detection limits" (See Topic 8). The spurious contaminant data do not prove that the radionuclide contaminants are not present in the regional aquifer for the environs of wells R-7 and R-22. In fact, Tc-99 was detected at validated levels[33] in the first samples collected from the regional aquifer in HW well R-22. The nonrepresentative water samples collected from many LANL HW wells do not comply with the requirement of RCRA[54] that all data and especially contaminant data be scientifically valid, legally defensible, and of known precision and accuracy.

The misinformation presented in the Bitner Report confirms the recommendation in Gilkeson (2004) for the establishment of an expert panel to review all of the activities of the LANL Hydrogeologic Workplan. The review should include a study of each of the wells installed by the Hydrogeologic Workplan to determine their future value. An important activity in the study is the use of a low-flow pump and a flow-through monitoring cell to measure sensitive groundwater parameters and to determine when it is appropriate to collect groundwater samples for the analytical suite.

The review should be conducted by a panel of experts in the following disciplines:

- Drilling methods for installation of monitoring wells.
- Hydrogeology with expertise in measurement of aquifer properties and contaminant hydrology.
- Geochemistry with expertise in sampling methods to acquire reliable information on contaminant chemistry.
- Geophysics with expertise in groundwater borehole geophysics.
- Groundwater modeling of groundwater flow in aquifer strata that are anisotropic and heterogeneous.
- Regulatory requirements of EPA, NMED, and DOE for groundwater monitoring at the LANL facility.
- Risk assessment with expertise to evaluate the impact of past and present LANL waste management practices on the groundwater resource.

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APPENDICES

Appendix A. Technical literature with reasons for not installing monitoring wells in boreholes drilled with the mud rotary method and the special requirement to not invade aquifer strata that are important for monitoring with biodegradable drilling additives or bentonite clay drilling muds

Article A-1: The article by Ericson et al (1985) describes the impact of drilling fluids on the installation of monitoring wells in boreholes that were drilled with conventional rotary methods. The wells were installed on uranium mill tailings sites to investigate radionuclide and metals contamination in groundwater. Bentonite clay muds were not used in any of the boreholes because of the sorption properties of bentonite clay for the contaminants. The authors do not claim that the drilling environment uniquely required the mud rotary drilling method. They also used temporary casing to stabilize the boreholes at some well sites. The maximum depth for boreholes was not greater than 200 feet.

The Ericson et al article has the following recommendation:

> "Bentonite clay drilling muds, anionic polymer emulsion products (i.e., Baroid EZ-MUD), and synthetic, biodegradable surfactant drilling media (i.e., Baroid Quik FOAM) should not be used in or near the aquifer strata to be screened or sampled for radionuclide and metal contaminants".

<u>The LANL monitoring wells have screened intervals installed in aquifer strata that are invaded by bentonite clay drilling muds, Baroid EZ-MUD, and Baroid Quik FOAM.</u>

I am familiar with the conclusions of the Ericson et al. article as I was the Corporate Technical Director for the Earth Sciences at WESTON*, an environmental consulting company that was part of the "team" of companies doing investigations on the uranium mill tailings sites. I would not have used the conventional fluid rotary drilling method for the installation of any of the monitoring wells for the geologic conditions described in the Ericson et al article. The wells could have been installed in boreholes drilled to depths of a few hundred feet without the use of any fluids other than air by using either the air rotary top-head casing driver method (Driscoll, 1986) or the Becker* reverse air percussion method to drive temporary casing to stabilize the boreholes. Drilling to greater depths without the use of fluids other than air may be accomplished with the air rotary under-reamer casing advance drilling method.

Article A-2: The article by Gibb and Jennings (1987) describes how drilling fluids and grouting materials affect the integrity of groundwater samples from monitoring wells. The article has no discussion of the mud rotary drilling method as uniquely suited for drilling in deep, unstable geologic formations. The article has the following discussion concerning the drilling of boreholes for monitoring wells with the mud rotary method using drilling fluids and/or bentonite clay muds:

> "In geologic environments where drilling fluids are a necessity, inorganic clay muds are preferred over those containing organic materials. The introduction of substrates for microbial activity can seriously impact the integrity of water samples."

A.2

"Rotary drilling methods using bentonite or organic based drilling fluids present serious problems in the construction of monitoring wells. Wells constructed with these drilling methods are seldom capable of providing accurate hydrologic or chemical data for a wide variety of inorganic and organic constituents. - - The amount of drilling fluids lost into formations or deposits (aquifer strata) is directly proportional to their hydraulic conductivity."

"In addition to the migration of drilling fluids into the subsurface materials, monitoring wells normally are constructed in the borehole while it is still filled with the drilling fluid. The casing, screen, and gravel pack materials are placed directly into the drilling fluid. The gravel pack materials often become suspended in the drilling fluid making it extremely difficult to determine where the gravel pack materials terminate and the overlying well seal begins. It is almost impossible to document the "as built condition" of monitoring wells constructed using rotary drilling methods and drilling fluids."

"Breaking down the mud cake and removal of all drilling fluids introduced during the drilling and construction process is extremely difficult. Groundwater velocities required to remove drilling fluids, and the colloidal size particles associated with them from the aquifer materials usually cannot be created during development of small diameter monitoring wells."

"Experience has shown that drilling muds not effectively removed from the well bore opposite the screen and gravel pack will interfere with the chemical and biological quality of samples from those wells."

"The potential consequences of using drilling fluids (fluids and muds) should be obvious. The use of drilling fluids and muds should be curtailed whenever possible. Migration of bentonite or even "clean water" into the aquifer materials disturbs the subsurface environment and creates chemical and biological conditions that have the potential for altering water quality in the immediate vicinity of the well and the area impregnated. Due to the limited area of influence experienced during the development of monitoring wells, drilling fluids seldom are removed to the extent that they will not cause "well trauma". ("well trauma" means the monitoring well provides groundwater samples with a chemistry that is not representative of the aquifer. Water samples from many LANL monitoring wells exhibit "well trauma".)

"Similarly, the improper placement of well sealing materials often results in these materials being in the flow path to the well or in such close proximity that they also chemically interfere with the quality of water collected from the well". (See the above discussion on the difficulty of installing monitoring wells in boreholes that are filled with drilling fluids. The well sealing materials for the LANL monitoring wells are bentonite clay that has properties to remove radionuclide contaminants from groundwater.) The inability to measure in situ groundwater quality conditions prevents field documentation or measurement of these types of chemical interferences. The sparsity of field documentation or evidence should not be used as an excuse to overshadow common sense and laboratory evidence that clearly indicates the potential for chemical interference from drilling fluids and grout materials."

A.3

The features of LANL monitoring wells that prevent the recovery of most of the drilling fluids that have invaded the aquifer strata where screens are installed include 1. the great depth of the monitoring wells limits the pumping energy for development, 2. the small inside diameter for well casing of 4.5 inches limits the size (power) of submersible pumps, 3. the short length of the well screens, the small spacing of 0.01 inch for the slots on the well screens, and the medium-grained sand in the filter pack that surrounds the well screens restricts the energy for recovering the drilling fluids, 4. the long delay before the performance of well development allowed much damage to the aquifer strata by the chemical processes that result from the use of biodegradable drilling fluids, and 5. the mud rotary drilling method caused the invasion of thousands of pounds of bentonite clay into the aquifer strata that are important for monitoring. For well development, LANL used chemical dispersing agents that spread the bentonite clay further outward in the aquifer strata beyond a distance where recovery is feasible.

Article A-3: The article by Puls and Barcelona (1989) is titled “Ground Water Sampling for Metals Analyses”. The article has the following recommendations for the construction and development of monitoring wells:

> “The disturbance of the subsurface environment as a result of well construction and sampling procedures presents serious obstacles to the interpretation of ground-water quality results. The impact of improper well construction and sampling techniques can permanently bias the usefulness and integrity of wells as sampling points.”

> “If no alternative to the use of drilling muds or fluids exists, these materials must be removed from the well bore and adjacent formations by careful well development.”

The Puls and Barcelona article and the ASTM Standard (Article 4) do not describe the mud rotary drilling method as uniquely suited to drilling in unstable aquifer strata or for drilling deep boreholes. One drilling environment that may be appropriate for the mud rotary drilling method is the presence of very high levels of contamination because the mud rotary method provides safe containment of the contaminated drill cuttings that are produced from the borehole.

> “It should be recognized, however, that the well must first provide a representative hydraulic connection to the geologic formation of interest. Without the assurance of this hydraulic integrity, the water chemistry information cannot be interpreted in relation to the dynamics of the flow system or the transport of chemical constituents.”

Many of the screened intervals in the LANL monitoring wells are not developed sufficiently to provide an open hydraulic connection to the aquifer strata.

> “Maintenance of the hydraulic performance of monitoring wells and the connection of wells to the zones of greatest hydraulic conductivity, where contaminant transport is most probable, should take equal importance to the collection of representative water quality data.”

A.4

An example of a LANL monitoring well that does not meet this requirement is well R-22. This well is installed at a location for monitoring the impact of the Laboratory's active radioactive waste landfill on the regional aquifer. In addition, for many of the LANL monitoring wells, the mud rotary drilling method has caused invasion of thousands of pounds of bentonite clay into the highly permeable strata that are important for monitoring for the presence of contamination. Well development procedures can not restore the irreparably damaged aquifer strata to its' original hydraulic performance.

Article A-4: The ASTM (1990) article is ASTM Standard D 5092 – Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers. The ASTM article does not identify any unique aquifer environments that require the use of the mud rotary drilling method for the successful installation of monitoring wells. The ASTM article presents the following guidance for drilling methods and well development:

> "Whenever feasible, drilling procedures should be utilized that do not require the introduction of water or liquid fluid into the borehole. When the use of drilling fluids is unavoidable, the selected fluid should have as little impact as possible on the water samples for the constituents of interest. In addition, care should be taken to remove as much drilling fluid as possible from the well and the aquifer during the well development process."

> "Well development should be continued until representative water, free of the drilling fluids, cuttings, or other materials introduced during well construction is obtained. Representative water is **assumed** to have been obtained when pH, temperature, and specific conductivity readings stabilize and the water is visually clear of suspended solids."

The above guidance for successful well development does not guarantee that all or even most of the drilling fluids are removed from the aquifer strata that are in contact with groundwater samples that are collected from the monitoring wells for contaminant analyses. The small diameter of the LANL monitoring wells, the great depth of the wells, the short screen length, the small slot size of the screen openings, and the small size of the filter pack sediments that surround the well screen are factors that prevent removal of most of the bentonite clay muds and drilling fluids that are entrained into the aquifer strata. The well development may eventually produce groundwater samples that meet the ASTM guidance. Nevertheless, groundwater samples collected from the monitoring wells are not representative of groundwater in the aquifer outside of the strata that is invaded by the bentonite clay muds or drilling fluids. Also, see the discussion in article A-2 by Gibb and Jennings (1987) concerning the difficulty of construction and development of monitoring wells installed in boreholes drilled with the mud rotary method.

Article A-5: The article by Claassen (1982) presents guidelines and techniques for obtaining water samples that accurately represent the water chemistry of an aquifer. The article has no discussion of the mud rotary drilling method as uniquely suited to drilling in unstable geologic formations or for drilling deep boreholes. The article describes mud rotary drilling as follows:

> "Drilling with cable tool produces some fine rock chips that fill some native pore spaces; rotary drilling produces a similar effect, but also contributes additional plugging material in the form of additives to the circulating fluid. The most

> common of these is “mud”, a mixture of water, bentonite clay and other additives. Mechanical requirements for efficiently producing a hole to be used for collecting hydrologic data are counterproductive to obtaining the data. – If a significant part of the drilled hole is plugged by drilling fluids, well development will be difficult or inadequate. This may result in a water sample that does not represent the entire thickness of aquifer, and also results in incorrect hydrologic data being obtained from the aquifer. It may be argued that permeable intervals will be under sufficient hydraulic head to remove mud caked on the borehole wall when the hole is jetted, but this is not a foregone conclusion.”

> “There is some evidence both from onsite experience and laboratory experimentation that significant changes in water quality are effected by the presence of drilling mud in a well. Most of the changes can only be qualitatively inferred from estimates of mud composition; however, very significant affects on both major- and minor-constituent concentrations are caused by mud contamination.”

Article A-6: The article by Walker (1983) reviews the installation and chemical analysis data from 20 background water quality monitoring wells at six locations in northern New England. Eighteen of the wells are not installed at a depth greater than 70 ft. The deepest well is installed at a depth of 135 ft. The article has no discussion of the mud-rotary drilling method as uniquely suited for drilling in unstable geologic formations or for drilling deep boreholes. Concerning drilling methods the article has the following recommendations:

> “Minimize or eliminate the introduction of water in installing the well: do not use bentonite or other drilling fluids unless absolutely needed.”

> “Replace wells that display extreme or slowly dissipating trauma.”

The term “trauma” describes monitoring wells where groundwater samples have a non-representative water chemistry. The screened intervals in many LANL monitoring wells such as R-7, R-9i, and R-22 display “extreme trauma” and “slowly dissipating trauma”

Article A-7: The article by Brobst and Buszka (1986) describes their research of the effect of three drilling fluids on groundwater sample chemistry. One of the drilling fluids was bentonite clay mud. The groundwater analytes that were studied include only chemical oxygen demand, chloride, and sulfate. The effect of bentonite clay muds on the trace constituents including radionuclides and heavy metals was not studied. The article has the following discussion of the mud rotary drilling method:

> “In many environments similar to those in the study area, mud rotary drilling represents the most practical method of borehole construction. However, the parties responsible for well installation, groundwater sampling and interpretation of analytical results must be aware of the changes that mud rotary drilling imposes on the subsurface environment.”

A.6

> "The principal disadvantages of conventional mud rotary drilling are the damage the method causes to formation permeability and the changes the method effects to hydrochemistry".
>
> "The invasion of mud filtrate may alter the geochemical equilibrium between groundwater and formation solids. Therefore, a successfully installed well is one in which both wall cake and mud filtrate is fully removed from the formation during well development. Even in well development procedures employing either borehole flushing prior to well installation, surging with a pump or surge block or bailing, substantial quantities of drilling fluid residue may still remain in the borehole and the formation."
>
> "Because of the thixotropic behavior of bentonite drilling fluids, vigorous well development and purging efforts may be the only means of reducing the amount of drilling mud left downhole. The addition of dispersing agents such as barium phosphate or organic polymers may possibly reduce mud viscosity and enhance mud recovery. However, the geochemical changes imparted to groundwater and the geologic matrix by the dispersing agents may render the well unfit for water quality monitoring."

<u>Dispersing agents were routinely used for the development of the LANL monitoring wells that were installed in mud rotary boreholes drilled with bentonite clay muds.</u>

I disagree with the authors' analysis that the mud-rotary drilling method represents the most practical method of borehole construction for the geologic formations in the study area. The study installed three monitoring wells in glacial deposits to a maximum depth of 105 ft. I gained much experience in the installation of monitoring wells in glacial tills and outwash sediments during my 17 years of employment as a Research Scientist in the Hydrogeology and Geophysics Sections of the Illinois Geological Survey. Three drilling methods that are suitable for the glacial deposits described in this article are the air-rotary casing-advance with a surface operated air hammer (Driscoll, 1986), the Becker* reverse air percussion to drive casing, and the Rotasonic* (Australian Drilling Committee, 1997). These methods do not use water, drilling fluids, or bentonite clay muds.

Article A-8: The article by Hix (1993) describes the use of the conventional mud rotary drilling method with bentonite clay muds for drilling boreholes for monitoring wells and remediation wells. Mr. Hix describes the use of the mud-rotary drilling method for drilling deep boreholes in difficult formations as follows:

> "There are those who maintain it [i.e. the mud-rotary drilling method] is the best way to drill monitoring wells, especially deeper wells in difficult formations. Some regulators, however, are concerned that the drilling fluid can invade some formations, making it difficult to remove through well screens and gravel packs. Manufacturers and suppliers of these products claim their products are environmentally safe and easy to remove, noting that they are NSF- and EPA-approved."

The approvals by NSF and EPA are for the use of the bentonite clay products for the construction of groundwater supply wells. The approvals do not address the issues concerning the use of these products for the construction of monitoring wells. It is possible to develop water supply wells and remediation wells adequately for production of the required groundwater supply. Most supply wells and remediation wells are constructed with long screens, large screen openings and a gravel pack surrounding the screen. This construction is very different from the restrictive design of most monitoring wells. The difficulty in developing monitoring wells to remove biodegradable drilling fluids and bentonite clay drilling muds is described in article A-2.

Article A-9: The article by Jennings (1989) is titled “The Effect of Grouts, Sealants, and Drilling Fluids on the Quality of Ground-Water Samples”. The conclusion of the Jennings article includes the following statement:

> “Drilling fluids and additives may introduce contamination to the well which may persist even after repeated cleanings (repeated well development activities). The inability to properly clean the formation and borehole may necessitate the construction of a new well. Where possible, hollow stem auger, cable tool, or air rotary should be used to install (monitoring) wells.”

Article A-10: LANL established a team of experts as the External Advisory Group (EAG) to review activities conducted by the Hydrogeologic Workplan. The EAG Semi-Annual Report (EAG, Dec. 23, 1999) lists 17 disadvantages for installing monitoring wells in boreholes that were drilled with the mud rotary method. The EAG report contains the following summary statements concerning use of the mud rotary drilling method:

> “The use of mud-rotary drilling techniques is largely inappropriate for the goal of the LANL Hydrogeologic Workplan. Drilling with mud carries the risk of adsorbing contaminants onto the bentonite that permeates into the pore space around the well screen and is not removed by well development. Should this occur, it could result in reduced concentrations or non-detects on contaminants that are actually present in the vicinity of the well.”

> “The artificial entrainment of bentonite clay drilling muds in the pore space around a monitoring well is clearly not desirable. This is because these materials can remove from solution the very constituents that need to be monitored by the well.

> <u>This is a significant concern for LANL since radionuclides are known to be adsorbed by these clays</u>. That the drilling mud, i.e., bentonite, penetrates into the aquifer strata is not disputed. It is reasonable to assume that fairly extensive intrusion of the bentonite into the aquifer strata can be expected. It is argued that well development, via high-flow pumping, using surge blocks, etc. is sufficient to remove blockage and create adequate flow through the well screen when a well has been drilled with mud. This is generally true. However, sufficient water flow is not the only consideration here. It is extremely unlikely that such well development techniques can remove the extruded bentonite sufficiently to assure that residual clay materials are not present in the pore space around the wells and serving as an adsorptive barrier to contaminant detection and quantification. <u>Unfortunately, if</u>

no contamination is detected then there is simply no way (without drilling another well by a different technique) to determine whether the contaminant is truly absent at this point or whether it is being adsorbed by residual drilling fluids."

"The EAG would therefore caution LANL about using mud drilling techniques for the installation of the deep regional monitoring wells. If bentonite clay drilling mud is to be used, it should be used sparingly (e.g., as a lubricant only) and it would be best to avoid it altogether when drilling zones where the well screens will be located."

Article A-11: "*DRILLING – The Manual of Methods, Applications and Management*" by The Australian Drilling Industry Training Committee Limited (1996).

From page 480 of the Drilling Manual:

"Drilling fluids, if used, must be carefully chosen to avoid contamination or alteration of final water (chemistry of groundwater produced from monitoring wells) or soil chemistry (chemistry of aquifer strata),"

"When metals or radionuclides are the target compounds, bentonite muds must be avoided. They have cation-exchange properties, and bind up these constituents. In this case, synthetic polymers may be a better choice. Biodegradable muds may also be used; but they must be completely removed to the trace level; otherwise they promote bio-fouling, which also alters groundwater quality."

From page 472 of the Drilling Manual:

"Causes of biofouling plugging of well screens: Microbial oxidation and precipitation of Fe, Mn, and S, with associated growth and slime production. Usually associated with simultaneous chemical encrustation and corrosion. Associated problem: water quality degradation. Includes, but not always, "iron bacteria". Biofouling plugging causes reduced specific capacity and efficiency, reduced yield, and even complete well production loss."

The geochemical data in many of the LANL monitoring well geochemistry reports is direct evidence that serious "biofouling plugging" has occurred in screened intervals (e.g., screen #3 in well R-7, screen #1 in well R-22).

Article A-12: "*Handbook of Ground Water Development*" by Roscoe Moss Company (1990).

From page 211 of the Handbook:

"Because iron and sulfur bacteria are ubiquitous, - care should be taken in drilling and casing and screen installation so as not to introduce gross organic contamination into the aquifer."

The biodegradable drilling additives used in the boreholes of many LANL monitoring wells are a form of gross organic contamination.

A.9

From page 371 of the Handbook:

> "Excessive growth of filamentous iron bacteria results in gelatinous slimes that may seriously reduce water yield from wells. This problem is more likely to occur in a well that is inactive or intermittently operated."

The LANL multiple-screen monitoring wells are essentially "inactive" as no volume of water is purged from the screened intervals before water samples are collected for the analytical suite. The LANL single-screen monitoring wells are inactive for long periods of time between sampling events.

Article A-13: "*Groundwater and Wells, Second Edition*" by Fletcher Driscoll (1986), published by Johnson Screens, St. Paul, Minnesota.

From page 455:

> "If the iron content of the groundwater exceeds 0.5 mg/l. precipitation of iron is likely, although some precipitation may begin at concentrations as low as 0.25 mg/l."

From page 456:

> "The most common bacteria affecting the condition of a well are iron bacteria. Iron bacteria are nuisance organisms that cause plugging of pores in water-bearing formations and openings in well screens. Iron bacteria produce accumulations of slimy material of gel-like consistency, and oxidize and precipitate dissolved iron and manganese. The combined effect of growing organisms and the precipitating minerals can plug a well almost completely within a short time. Cases have been reported where a 75-percent reduction in well yield has occurred in three months to a year."

Article A.14: *"Aqueous Environmental Geochemistry",* by Donald Langmuir, 1997 by Prentice-Hall, Inc., Upper Saddle River, New Jersey.

From page 436:

> "Crystallization of hydrous ferric oxide (HFO) takes years in waters low in iron, but may occur in a few hours or days, in the presence of several mg/kg (mg/L) of dissolved iron."

From page 462:

> "They (iron precipitates) are especially a problem in fouling of iron pipes in water supply systems and well screens. They can cause a loss of up to 90 % in the productivity of a well."

From Page 538:

> "Among common minerals, the strongest sorbents for most actinide cations (e.g., cations of uranium, plutonium, americium) are the ferric oxyhydroxides and especially hydrous ferric oxide."

A.10

The concentration of dissolved iron in LANL monitoring wells that are impacted by bio-degradable drilling fluids are commonly greater than several mg/L, and even greater than 10 mg/L (e.g., screen #3 in monitoring well R-7 and screen #1 in monitoring well R-22). The high iron concentrations are direct evidence of the biofouling plugging process to cause a great reduction in permeability for the screened interval due to the precipitation of ferric oxyhydroxides and hydrous ferric oxides as deposits on the aquifer strata and even on the filter pack sediments.

Appendix B: The regulatory requirements of USEPA RCRA, NMED Consent Order, and DOE Orders for the installation of monitoring wells

❖ **Regulatory requirements of RCRA**

Many of the LANL monitoring well reports include a statement that the design and construction of the monitoring wells meet the requirements of a RCRA – compliant monitoring well as described in the US Environmental Protection Agency (EPA) document "RCRA Groundwater Monitoring: Draft Technical Guidance," November, 1992, EPA/530-R-93-001. The NMED requires that LANL monitoring wells shall comply with the guidance in this EPA document.

This EPA RCRA document (known as the EPA RCRA Manual, 1992) has the following concerns for installation of monitoring wells in boreholes drilled with the mud rotary method and the invasion of aquifer strata with drilling additives:

Concern 1:

> "While there are hydrogeologic conditions where mud rotary drilling is the best option (e.g., where it is extremely difficult to maintain a stable borehole), mud rotary creates a high potential for affecting aquifer characteristics and ground-water quality. If the mud rotary method is used, the drilling mud(s) should not affect the chemistry of ground-water samples." (page 6-12)

The biodegradable, polymer-based drilling fluids, biodegradable foams, and bentonite clay drilling muds that were used in the boreholes for the LANL monitoring wells have a large affect on the chemistry of groundwater samples for many radionuclide and chemical contaminants of concern for monitoring at LANL.

Concern 2:

> "The ability of a well development method to remove clays from the sides of the borehole should be considered, because clays retained in the borehole may alter the chemical composition of groundwater in the well." (page 6-50)

The great depth and physical design of the LANL monitoring wells are obstacles to the removal of the large volume of bentonite clay that has invaded the aquifer strata.

A.11

Concern 3:

> "Additives to modulate the viscosity and density of the bentonite muds may also introduce contaminants in the groundwater or force large, unrecoverable quantities of mud into the formation." (page 6-12)

LANL has used additives to develop the screened intervals in monitoring wells installed in boreholes drilled with the mud rotary method using bentonite clay mud

Concern 4:

> "Some organic polymers and compounds provide an environment for bacterial growth, which reduces the reliability of sampling results." (page 6-12)

Many of the LANL monitoring wells are installed in boreholes that were drilled with fluids and foams that are organic polymers and compounds. The result was bacterial growth that caused irreparable damage to the aquifer strata that surround the screened intervals. The groundwater samples collected from many of the impacted wells are not representative of groundwater quality in the regional aquifer.

Concern 5:

> "Drilling should be performed in a manner that preserves the natural properties of the subsurface materials." (page 6-2)

For many LANL monitoring wells, the invasion of the aquifer strata with biodegradable drilling fluids, biodegradable foam, and bentonite clay drilling mud has caused a great change to the natural properties of the aquifer strata; a lowering of the permeability and an increase of the chemical properties for removing contaminants from groundwater.

Concern 6:

> "Drilling fluids, drilling fluid additives, or lubricants that impact the analysis of hazardous constituents in groundwater samples should not be used." (page 6-2)

LANL has used drilling methods that have entrained the aquifer strata with drilling fluids that impact the analysis of hazardous and radioactive constituents in groundwater samples collected from the wells. The drilling fluids include biodegradable polymer-based EZ-MUD*, biodegradable Quick-FOAM* surfactant, and bentonite clay drilling muds.

A.12

- **Regulatory requirements of the NMED LANL Consent Order**

The requirements of NMED for monitoring wells at LANL are presented in the NMED Los Alamos National Laboratory Order dated March 1, 2005.

From pages 189 to 190 of the NMED LANL Consent Order:
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. The design and construction of groundwater monitoring wells shall comply with the guidelines established in various EPA RCRA guidance, including, but not limited to:

- U.S. EPA, *RCRA Groundwater Monitoring: Draft Technical Guidance*, EPA/530-R-93-001, November, 1992; (the EPA RCRA Manual)

- U.S. EPA, *RCRA Groundwater Monitoring Technical Enforcement Guidance Document*, OSWER-9950.1, September, 1986; and

- Aller, L., Bennett, T.W., Hackett, G., Petty, R.J., Lehr, J.H., Sedoris, H., Nielsen, D.M., and Denne, J.E., *Handbook of Suggested Practices for the Design and Installation of Groundwater Monitoring Wells*, EPA 600/4-89/034, 1989.

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A variety of methods are available for drilling monitoring wells. While the selection of the drilling procedure is usually based on the site-specific geologic conditions, the following issues shall also be considered:

- Drilling shall be performed in a manner that preserves the natural properties of the subsurface materials.

The drilling methods used at LANL have caused great damage to the natural properties of the subsurface materials because of the invasion of the aquifer strata that are important for monitoring with biodegradable drilling additives and bentonite clay drilling mud.

- Contamination and cross-contamination of groundwater and aquifer materials during drilling shall be avoided.

The drilling methods used at LANL have resulted in contamination and cross-contamination of groundwater and aquifer materials.

- The drilling method shall allow for the collection of representative samples of rock, unconsolidated materials, and soil.

The mud rotary drilling method used at LANL has not allowed for the collection of representative samples of rock, unconsolidated materials, and soil.

A.13

- The drilling method shall allow the Respondents to determine when the appropriate location for the screened interval(s) has been encountered.

The record shows that LANL has failed to install screened intervals in the appropriate locations in many monitoring wells. The responsible factors include drilling methods and interpretation of borehole geophysics.

- The drilling method shall allow for the proper placement of the filter pack and annular sealants. The borehole diameter shall be at least four inches larger in diameter than the nominal diameter of the well casing and screen to allow adequate space for placement of the filter pack and annular sealants.

The mud rotary drilling method used at LANL poses difficulty to the proper placement of the filter pack and annular sealants. See Article A.2 in Appendix A.

- The drilling method shall allow for the collection of representative groundwater samples. Drilling fluids (including air) shall be used only when minimal impact to the surrounding formation and groundwater can be ensured.

The LANL Reports (including the Bitner Report, 2004) prove that the drilling fluids (e.g., biodegradable polymer-based fluid, biodegradable foam, and bentonite clay mud) have a large impact to the aquifer strata and groundwater surrounding many monitoring wells with the result that groundwater samples collected from the impacted screened intervals are not representative of aquifer chemistry.)

From page 191 of the NMED LANL Consent Order:

"-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."

LANL did not use a dispersant to chemically breakdown the organic polymer drilling additives that were used in the boreholes for LANL monitoring wells. The drilling additives used in the boreholes for many LANL monitoring wells R-22 include Baroid EZ Mud and Baroid Quik FOAM*.*

From page 181 of the NMED LANL Consent Order:

IX.B.2.i.i Well Purging

"All zones in each monitoring well shall be purged by removing groundwater prior to sampling in order to ensure that formation water is being sampled. Purge volumes shall be determined by monitoring, at a minimum, groundwater pH, specific conductance, dissolved oxygen concentrations, turbidity, redox potential, and temperature during purging of volumes and at measurement intervals approved by the Department. The groundwater quality parameters shall be measured using a flow-through cell and instruments approved by the Department. The volume of groundwater purged, the instruments used, and the readings obtained at each interval shall be recorded on the field monitoring log. Water samples may be obtained from the well after the measured parameters of the purge water have stabilized to within ten percent for three consecutive measurements."

LANL does not purge any volume of groundwater from the multiple-screen monitoring wells before groundwater samples are collected for analyses. In addition, LANL does not use a flow-through cell to monitor groundwater parameters to determine that in situ formation water is being sampled from the large number of multiple-screen wells that are sampled with the Westbay no-purge sampling systems

❖ Regulatory Requirements of the United States Department of Energy

The U.S. Department of Energy (DOE) is a regulatory agency and the activities of the LANL Hydrogeologic Workplan are required to be in compliance with DOE ORDERS 450.1, 435.1 and 5400.5. <u>It is important to note that the DOE ORDERS also require the activities of the Hydrogeologic Workplan to be conducted in compliance with the technical requirements of RCRA.</u>

- DOE ORDER 450.1 — Approved: 1-15-03
  Review Date: 1-15-05
  Chg 1: 1-24-05

SUBJECT: ENVIRONMENTAL PROTECTION PROGRAM

1. OBJECTIVES. To implement sound stewardship practices that are protective of the air, water, land, and other natural and cultural resources impacted by Department of Energy (DOE) operations and by which DOE cost effectively meets or exceeds compliance with applicable environmental; public health; and resource protection laws, regulations, and DOE requirements. This objective must be accomplished by implementing Environmental Management Systems (EMSs) at DOE sites. An EMS is a continuing cycle of planning, implementing, evaluating, and improving processes and actions undertaken to achieve environmental goals. These EMSs must be part of Integrated Safety Management Systems (ISMSs) established pursuant to DOE P 450.4, Safety Management System Policy, dated 10-15-96.

4. REQUIREMENTS.

a. General Requirements. All DOE elements must ensure that site ISMSs include an EMS that does the following.

(1) Provides for the systematic planning, integrated execution, and evaluation of programs for—
(a) public health and environmental protection,
(b) pollution prevention (P2), and
(c) compliance with applicable environmental protection requirements.

(2) Includes policies, procedures, and training to identify activities with significant environmental impacts, to manage, control, and mitigate the impacts of these activities, and to assess performance and implement corrective actions where needed.

(3) Includes measurable environmental goals, objectives, and targets that are reviewed annually and updated when appropriate.

b. Integration of an EMS into ISMS. As part of integrating EMSs into site ISMSs, DOE elements must do the following.

(1) Consider the following for inclusion as applicable:

(a) conformity of DOE proposed actions with State Implementation Plans to attain and maintain national ambient air quality standards,

(b) implementation of a watershed approach for surface water protection,

(c) implementation of a site-wide approach for groundwater protection,

(d) protection of other natural resources including biota,

(e) protection of site resources from wild land and operational fires, and

(f) protection of cultural resources.

(2) Promote the long-term stewardship of a site's natural and cultural resources throughout its operational, closure, and post-closure life cycle.

(3) Reduce or eliminate the generation of waste, the release of pollutants to the environment, and the use of Class I ozone-depleting substances (ODS) through source reduction, re-use, segregation, and recycling and by procuring recycled-content materials and environmentally preferable products and services.

(4) <u>Ensure the early identification of, and appropriate response to, potential adverse environmental impacts associated with DOE operations, including, as appropriate, preoperational characterization and assessment, and effluent and surveillance monitoring.</u>

5. RESPONSIBILITIES. All DOE elements, as specified in paragraph 3a of this Order,are responsible for implementing the requirements specified in paragraph 4. Corporate responsibilities for management of environment, safety and health assigned to DOE elements are delineated in Section 9 of DOE M 411.1-1C, Safety Management Functions, Responsibilities, and Authorities Manual, dated 5-22-01. Specific responsibilities for implementing this Order are set forth below.

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(14) Conduct environmental monitoring, as appropriate, to support the site's ISMS, to detect, characterize, and respond to releases from DOE activities; assess impacts; estimate dispersal patterns in the environment; characterize the pathways of exposure to members of the public; characterize the exposures and doses to individuals, to the population; and to evaluate the potential impacts to the biota in the vicinity of the DOE activity.

(15) Ensure the analytical work supporting environmental monitoring is implemented using—

(a) a consistent system for collecting, assessing, and documenting environmental data of known and documented quality;

(b) a validated and consistent approach for sampling and analysis of radionuclide samples to ensure laboratory data meets program-specific needs and requirements within the framework of a performance-based approach for analytical laboratory work; and

(c) an integrated sampling approach to avoid duplicative data collection.

- **DOE ORDER 450.1A SUBJECT:** ENVIRONMENTAL PROTECTION PROGRAM

- Approval Date: June 04, 2008

- CANCELLATION. DOE O 450.1, *Environmental Protection Program*, dated 1-15-03. Cancellation of a directive does not, by itself, modify or otherwise affect any contractual obligation to comply with the Order. Contractor requirement documents (CRDs) that have been incorporated into or attached to a contract remain in effect until the contract is modified to either eliminate requirements that are no longer applicable or substitute a new set of requirements.

1. PURPOSE. To implement sound stewardship practices that are protective of the air, water, land, and other natural and cultural resources impacted by Department of Energy (DOE) operations, and by which DOE cost effectively meets or exceeds compliance with applicable environmental, public health, and resource protection requirements.

4. REQUIREMENTS.
a. Implementation of Environmental Management System. Each DOE site must develop and implement an environmental management system.

b. Elements of Environmental Management System. Each environmental management system must—

(4) Contain the elements of an Environmental Compliance Management Plan pursuant to the Council on Environmental Quality's *Instructions for Implementing E.O. 13423,* page 9, section B, including—

(c) An environmental compliance audit and review program that identifies compliance deficiencies and root causes of non-compliance.

(d) Integration of compliance management information and resource allocation procedures to ensure that audit findings and root causes of non-compliance are tracked and addressed, including allocation of funding.

c. Scope of the Environmental Management System. The environmental management system must address the following—

(2) Protection of public health and the environment including, but not limited to—

(c) <u>Implementation of a site-wide approach for groundwater protection</u> [emphasis added].

(5) The conduct of environmental and effluent monitoring, as appropriate, to characterize pre-operational conditions and to detect, characterize, and respond to releases from site operations and activities; assess impacts; estimate dispersal patterns in the environment; characterize the pathways of exposure to members of the public; characterize the exposures and doses to individuals and the population; and evaluate the potential impacts to the biota in the vicinity of the release. Where appropriate, use an integrated monitoring system and sampling approach to avoid duplicative data collection.

(6) Assurance that analytical work for environmental and effluent monitoring supports data quality objectives, using a documented approach for collecting, assessing, and reporting environmental data.

(7) The conduct of appropriate operational assessments, such as pollution prevention opportunity assessments, of site operations and activities to identify opportunities to implement sustainable practices as part of achieving DOE's Sustainable Environmental Stewardship goals found in Attachment 2 of DOE O 450.1A.

d. Validation of the Environmental Management System.

(1) An environmental management system shall be considered fully implemented when—

(a) The environmental management system has been the subject of a formal audit by a qualified party outside the control or scope of the environmental management system.

(b) The appropriate contractor senior management and DOE field office management have recognized and addressed the findings of the audit.

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(c) The appropriate senior manager accountable for implementation of the environmental management system and the cognizant Field Office Manager have declared conformance of the environmental management system to the requirements of paragraph 4b of this Order.

(2) Environmental management systems, including those already declared under the previous requirements of canceled DOE O 450.1 *Environmental Protection Program*, dated 1-15-03, must meet the new requirements for being "fully implemented" by June 30, 2009.

(3) To remain fully implemented, at least every three years: (a) the environmental management system must be audited by a qualified party outside the control or scope of the environmental management system, and

(b) the conformance declaration 4d(1)(c) is renewed, as appropriate.

e. DOE ISM Systems. As part of integrating environmental management systems into DOE ISM systems pursuant to DOE M 450.4-1, Program Secretarial Officers, Administrators, and Field Office Managers shall incorporate appropriate performance objectives, measures and commitments to support the following at site(s) under their purview—

(1) <u>Compliance with applicable environmental protection requirements</u> [emphasis added].

d. Field Office Managers, in coordination with their reporting sites and Program Secretarial Officers and Administrators, must do the following—

(1) Implement the requirements identified in paragraph 4e and the responsibilities of paragraph 5d(5) by June 30, 2009.

(5) Ensure that sites under their purview revise their environmental management system to encompass the requirements of paragraphs 4b, 4c, and 4d of this Order by June 30, 2009.

NOTE: Los Alamos National Laboratory (LANL) is not in compliance with the requirements of DOE Order 450.1a.
1).The site-wide approach to groundwater protection does not exist.
2). LANL is not in compliance with applicable state or federal environmental protection requirements.
3). Compliance with 1). and 2). was required by June 30, 2009.

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- **DOE ORDER 435.1**

The objectives of DOE Order 435.1 are to ensure that all DOE radioactive waste is managed in a manner that is protective of worker and public health and safety, and the environment:

- Mixed Transuranic Radioactive Waste. Mixed transuranic waste that is disposed of at LANL shall be managed in accordance with the requirements of RCRA and DOE Order 435.1.
- Mixed Low-Level Radioactive Waste. Mixed low-level waste that is disposed of at LANL shall be managed in accordance with the requirements of RCRA and DOE Order 435.1.
- Low-Level Radioactive Waste . At LANL, each operational or non-operational low-level radioactive waste treatment, storage, and disposal facility shall be monitored by an environmental monitoring program that conforms with DOE 5484.1 and, at a minimum, meet the requirements of paragraph 3K(2) through 3K(4) in DOE Order 435.1:

- 3K(2) The environmental monitoring program shall be designed to include measuring and evaluating releases, migration of radionuclides, disposal unit subsidence, and changes in disposal facility and disposal site parameters which may affect long-term performance.
- 3K(3) Based on the characteristics of the facility being monitored, the environmental program may include, but not necessarily be limited to, monitoring surface soil, air, surface water, and, in the subsurface, soil and water, both in the saturated and the unsaturated zones. The site-specific "performance assessment and composite analysis shall be used to determine the media, locations, radionuclides, and other substances to be monitored.
- 3K(4) The monitoring program shall be capable of detecting changing trends in performance sufficiently in advance to allow application of any necessary corrective actions prior to exceeding performance objectives.

Concerning AREA G, the active LANL low-level radioactive waste disposal facility, DOE Order 435.1 requires that the disposal facility be operated to "assure that external exposure to the waste and concentrations of radioactive materials which may be released into surface water, groundwater, soil, plants, and animals results in an effective dose equivalent that does not exceed 25 mrem/yr to any member of the public.

Concerning Area G, DOE Order 435.1 requires the preparation of a Performance Assessment and Composite Analysis (PA/CA) to assure protection of the public and the environment. Maintenance of the PA/CA is a critical requirement for continued operation of Area G. Doe Order 435.1 describes the required maintenance as follows:

(a) Performance assessments and composite analyses shall be reviewed and revised when - - - the improved understanding of the performance of the waste disposal facility in combination with the features of the site on which it is located alter the conclusions or the conceptual model(s) of the existing performance assessment or composite analyses.

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- The Objectives of DOE ORDER 5400.5 are Radiation Protection of the Public and the Environment.
  - Protecting the Public. It is DOE's objective to operate its facilities and conduct its' activities so that radiation exposures to members of the public are maintained within the limits established in this Order and to control radioactive contamination through the management of real and personal property. It is also a DOE operative that potential exposures to members of the public be as far below the limits as is reasonably achievable (ALARA) and that DOE facilities have the capabilities, consistent with the types of operations conducted, consistent with the types of operations conducted, to monitoring routine and non-routine releases and to assess doses to members of the public.
  - Protecting the Environment. In addition to providing protection to members of the public, it is DOE's objective to protect the environment from radioactive contamination to the extent practical.

  From DOE Order 5400.5 Concerning Monitoring and Surveillance

  - It is the intent of DOE that the monitoring and surveillance programs for the DOE activities, facilities, and locations be of <u>high quality</u>.

  - Drinking Water Pathway Only. All DOE Sources of Radionuclides. It is the policy of DOE to provide a level of protection for persons consuming water from a public drinking water supply operated by the DOE, either directly of through a DOE contractor, that is equivalent to that provided to the public by the public community drinking water standards of 40 CFR Part 141. These systems shall not cause persons consuming the water to receive an effective dose equivalent greater than 4 mrem (0.04 mSv) in a year.

Appendix C: Removal of trace radionuclide and metal contaminants from groundwater by bentonite clay

Many of the LANL monitoring wells are installed in boreholes that were drilled with the mud rotary drilling method using bentonite clay drilling muds. The aquifer strata that surround the screened intervals in these monitoring wells are invaded with a very large volume of bentonite clay. The properties of bentonite clay for preferential removal from groundwater of many of the LANL radionuclide contaminants of concern are well known. It was improper for LANL to use the mud rotary method for the installation of monitoring wells. Many of the wells require replacement.

It is important to understand the properties of bentonite clay for removal of the trace metal and radionuclide contaminants from groundwater. The term "trace contaminants" refers to contaminants that are present in groundwater at very low or extremely low levels compared to the major constituents like calcium, magnesium, and bicarbonate that are dissolved in the groundwater. For the groundwater beneath LANL, it is necessary for monitoring wells to provide groundwater samples that are valid for knowledge of extremely low levels of radionuclide contaminant**s.** Examples of trace radionuclide contaminants that are preferentially removed from groundwater by bentonite clay include americium-241, cesium-137, plutonium-238, plutonium-239,-240, and strontium-90.

A.21

The text book *Environmental Chemistry* by Langmuir (1997) describes the preferential adsorption of trace contaminants as follows:

> "Adsorption (onto bentonite clay) of a dissolved ionic species is always part of an (ion) exchange reaction that involves a competing ionic species. The desorbing species creates the vacant site to be occupied by the adsorbing one. As the trace metal (or radioactive contaminant) level drops relative to that of a competing major ion, adsorption of the trace species is increasingly favored relative to competing major species."

The text book *Aquatic Chemistry* by Stumm and Morgan (1996) describes the preferential adsorption of trace contaminants by bentonite clay as follows:

> "The sorption of alkaline and earth-alkaline cations (e.g., strontium-90) on expandable three-layer clays (e.g., bentonite clays) can usually be interpreted as stoichiometric exchange of interlayer ions (ion exchange). To understand binding of trace heavy metals (e.g., also the trace radioactive contaminants such as plutonium and americium) on clays, one needs to consider – in addition to ion exchange – the surface complex formation on end–standing functional OH groups. Three layer silicates (e.g., bentonite clays) contain on the crystal edges (broken bonds) end-standing OH groups which can interact with (remove from groundwater) metal ions (and many radionuclide contaminants)."

The radioactive contaminants of concern in groundwater beneath LANL that are removed by adsorption on clay minerals are present at extremely low levels compared to the major ions in groundwater. The radioactive contaminants are preferentially removed from groundwater by adsorption on bentonite clay and are retained by the essentially infinite number of sorption sites in the large quantity of bentonite clay that is entrained into the aquifer strata surrounding the monitoring wells that are installed in mud rotary boreholes. If an individual radionuclide ion is desorbed from a sorption site, it will be immediately recaptured by another site.

The large volume of bentonite clay that is entrained into the aquifer strata surrounding the screened intervals in the LANL monitoring wells is there permanently. The clay will not be removed by natural groundwater flow. The preferential sorption capacity of the bentonite clay for trace radionuclide and metal contaminants will not become exhausted. There is a very high probability that the large quantity of bentonite clay that has invaded the aquifer strata will prevent groundwater samples collected from the impacted monitoring wells from being reliable for knowledge of many radionuclide contaminants in the regional aquifer for a period of time that is longer than the scheduled 50 year life for the LANL monitoring wells.

Appendix D: The chemistry of the biodegradable, polymer-based drilling fluids and biodegradable foams that are used for LANL monitoring wells

A LANL document (LANL, OCT. 2000) describes the sorption properties of the BAROID EZ-MUD* biodegradable polymer-based drilling fluid that was used in the boreholes for many LANL monitoring wells as follows:

> "The EZ-MUD* drilling fluid has a negative charge density of 30% which may enhance the polymers ability to adsorb the cations Sr^{2+}, PuO_2^{1+}, UO_2^{2+}, and $AmCO_3^{1+}$."
>
> "EZ-MUD* is strongly hydrophobic (high molecular weight polymer), which probably has the ability to adsorb organic compounds such as RDX, HMX, and TNT."

It is important to note that the drilling of the boreholes for many LANL monitoring wells with the use of EZ-MUD* was ***after*** LANL released the information on the adsorption properties of the drilling fluid for contaminants of concern. It was inappropriate for LANL to use drilling fluids that have sorption properties for many contaminants of concern in groundwater beneath the Laboratory facility.

An important ingredient in the biodegradable EZ-MUD* and Quik-FOAM* drilling additives that were used in the boreholes for many LANL monitoring wells is the organic carbon that resulted in a "bloom" of bacteria in the impacted aquifer strata. The enhanced respiration of the bacteria greatly increased the level of carbonic acid in groundwater with a corresponding dissolution of the alkaline earth metals from the aquifer strata. The alkaline earth metals include strontium, calcium, magnesium, and barium.

The enhanced bacterial respiration also created an anaerobic environment that resulted in high levels of dissolved iron and manganese in groundwater while causing the precipitation of dissolved uranium and some other radionuclide contaminants (if present in the groundwater). The natural level of dissolved iron in the regional aquifer is less than 0.05 mg/L. The high and increasing concentrations of dissolved iron listed in the LANL Well R-22 Geochemistry Report for the four quarterly samples from screen #1 of 5.0, 9.1, 9.46, and 14.9 mg/L, respectively, show that the anaerobic bacterial respiration is active, and causing dissolution of iron from the aquifer strata.

For comparison, the declining levels of dissolved iron in the LANL Well R-7 Geochemistry Report for the four quarterly samples from screen #3 of 17.0, 14.0, 12.4, and 8.75 mg/L, respectively, are an indication that the bacterial respiration is declining and the groundwater is changing back to an oxidizing chemistry. The high dissolved iron levels at wells R-7 and R-22 are direct evidence of the formation of iron precipitates as hydrous ferric oxides (HFO) and ferric oxyhydroxides on the aquifer strata that surrounds the screened intervals. (Langmuir, 1997, Roscoe Moss Company, 1990, and Driscoll, 1986).

The precipitation of HFO and ferric oxyhydroxides is important as these ”fresh coatings” on the aquifer strata and even on the well screen and the filter pack sediments have strong sorption properties for many radionuclide contaminants including the actinides and uranium (Langmuir, 1997). The sorption properties of the ferric oxyhydroxide precipitates is illustrated by comparing their cation exchange capacity (CEC) of 100 to 740 meq/100 gm to the CEC of 80 to 150 meq/100 gm for bentonite clay (Langmuir, 1997). The HFO and the ferric oxyhydroxide precipitates, and also the bentonite clays have strong sorption properties for many radionuclide and metal contaminants of concern for monitoring in groundwater beneath the Laboratory facility (Langmuir, 1997, Stumm and Morgan, 1996).

The high concentrations of dissolved iron that are present in the altered chemistry at many LANL monitoring wells because of the biodegradable drilling fluids will also cause the presence of high concentrations of suspended ferrihydrite as colloids in groundwater. The suspended ferrihydrites have strong sorption properties for many dissolved metal and radionuclide contaminants, including uranium (Langmuir, 1997).

The anomalously low concentrations of dissolved uranium in groundwater samples from many LANL monitoring wells that are impacted by the use of biodegradable drilling fluids and biodegradable foams is important evidence that chemical processes are removing constituents from groundwater. Uranium is a natural constituent in groundwater. However, uranium is also a contaminant of concern in groundwater because of its extensive use in LANL activities. There is a need for valid knowledge of the level of dissolved uranium in the regional aquifer for groundwater samples collected from the LANL monitoring wells.

The LANL well R-7 reports show that a uranium concentration of 0.0021 mg/L was measured in a groundwater sample collected at the top of the regional aquifer from the borehole for well R-7 and significantly lower dissolved uranium concentrations of 0.000084 and 0.000051 mg/L were measured in the first two quarterly samples collected from the top of the regional aquifer in well R-7. Uranium was “not detected” in the groundwater samples collected in the third and fourth quarter from well R-7. LANL does not have accurate knowledge of the levels of dissolved uranium in the regional aquifer beneath Los Alamos Canyon at the location of LANL monitoring well R-7 at the present time, and for an unknown period of time into the future.

The LANL well R-22 reports show that a dissolved uranium-238 level of 1.41 pCi/L was measured in a groundwater sample collected at the top of the regional aquifer from the borehole for well R-22, and significantly lower dissolved uranium-238 levels of 0.046, 0.062, 0.0156, and 0.0099 pCi/L, respectively, were recorded in the four quarterly samples collected from screen #1 installed in aquifer strata at the top of the regional aquifer immediately downgradient of MDA G.

For screen #1 in well R-22, the removal of dissolved uranium from groundwater samples by the anaerobic chemistry is evidence that the analytical data for many other radionuclides including technetium-99 are not reliable (Langmuir, 1997). Figure 6 in the LANL report by Bitner et al. (2004) acknowledges that the anaerobic chemistry at screen #1 in well R-22 will remove the radionuclide isotopes of americium, plutonium, technetium, and uranium from the groundwater.

It is essential to understand that the pervasive presence of the HFO and the ferric oxyhydroxide precipitates as fresh deposits on the well screen, the filter pack sediments and the aquifer strata for an unknown distance away from the monitoring well are a permanent change as the iron coatings are stable in the natural oxidizing groundwater chemistry that will eventually be restored to the groundwater within the impacted strata.

A location where the precipitation of HFO is increased by iron bacteria is where the anaerobic groundwater in the impacted strata transitions to the normal aerobic groundwater in the aquifer (Langmuir, 1997). The microbially mediated precipitation of the HFO as fresh deposits on the aquifer strata will result in the impacted screened intervals being surrounded by aquifer strata with enhanced properties for removal of trace metals and radionuclides from groundwater. There is a very high probability that the biodegradable, polymer-based drilling fluids and the biodegradable drilling foams that have invaded the aquifer strata may cause groundwater samples collected from the impacted monitoring wells to be invalid for knowledge of many radionuclide contaminants in the regional aquifer for a period of time that is longer than the scheduled 50 year life for the LANL monitoring wells.

Appendix E: LANL monitoring well R-14, an example of the failure of the mud rotary drilling method

The LANL Well Completion Report for Monitoring Well R-14 (LANL, 2003) shows that the mud rotary drilling method was unsuccessful for the installation of monitoring well R-14. The LANL report describes the mud rotary drilling of the R-14 borehole in the regional aquifer as follows:

> "The borehole then was drilled open-hole with a 12.25 in. tricone bit into the top of the regional aquifer, stopping at 1225 ft bgs (below ground surface) on June 26, 2002, to obtain a static water level, which was measured at 1180.9 ft bgs. On June 27, 2002, Dynatech (the drilling contractor) switched to the conventional mud-rotary system and continued open-hole drilling with the 12.25-in. bit from 1225 ft bgs to 1285 ft bgs. From June 29 to June 30, 2002, recurring problems with lost fluid circulation around 1285 ft bgs stalled progress. WGII (the field services contractor) and the Laboratory made the decision to install an 11.75-in. casing, to seal the zones where fluid loss was occurring [emphasis added]. On July 2, 2002, Dynatech completed casing installation and reamed through 14 ft of slough back down to 1285 ft bgs. Air-rotary drilling resumed using casing-advance [emphasis added] with a 12.75-in. under-reaming down-the-hole (UR-DTH) hammer bit and the 11.75-in drill casing to 1327 ft." (the total depth of the borehole)

After the failure of the mud-rotary drilling method, LANL monitoring well R-14 was installed in a borehole drilled to total depth with the air rotary under-reamer casing advance drilling method. The drilling history at LANL monitoring well R-14 attests to the fact that the mud-rotary drilling method was inappropriate, unsuccessful, and unnecessary for the installation of monitoring wells at LANL.

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The LANL Report for Well R-14 lists the following drilling additives for the borehole depth interval of 848 to 1315 ft: 28,250 lb of bentonite clay, 175 gal of Quick-Foam*, 22 gal of Liqui-Trol*, 700 lb of Pac-L*, 1830 lb of N-Seal* and 2160 lb of Magma Fiber*. The majority of materials on this list were used during drilling in the regional aquifer with the mud-rotary method. The drilling additives Pac-L*, N-Seal* and Magma Fiber* were used to stabilize the mud-rotary borehole in aquifer strata within the regional aquifer where lost circulation of the bentonite clay drilling mud was occurring. The intervals of lost circulation are direct evidence of aquifer strata with very high permeability: the very strata that are important for monitoring. Unfortunately, the invasion of large quantities of unrecoverable bentonite clay, Pac-L*, N-Seal*, and Magma Fiber* into the permeable aquifer strata has caused irreparable damage to the strata that are important for monitoring for contamination and for measurement of permeability.

LANL monitoring well R-14 has two screened intervals installed in the regional aquifer below the static water level of 1182 ft bgs. Screen #1 is 33 ft long and is installed in the depth interval of 1200.6 – 1233.2 ft bgs. Screen #2 is 6.6 ft long and is installed in the depth interval of 1286.5 – 1293.1 ft bgs. The screens have an internal dimension of 4.5 in. and are a perforated pipe-based design with a wrap of stainless steel wire over the perforations. The wire wraps have a very close spacing of 0.010 in. The filter pack sediments have a texture of medium-grained 20/40 sand. Given the restrictive design of the monitoring well, it is not possible for the well development procedures in well R-14 to have removed more than a small amount of the bentonite clay drilling mud that invaded the aquifer strata. The requirement to thoroughly remove bentonite clay mud from screened intervals in monitoring wells is well understood:

> “If no alternative to the use of drilling muds or fluids exists, these materials must be removed from the well bore and adjacent formations (aquifer strata) by careful well development.” (From Puls and Barcelona, 1989)

The fact that the physical design of the LANL monitoring wells prevents the removal of a large volume of bentonite clay mud from the aquifer strata is described in article A-2 in Appendix A. The LANL well completion report for Well R-14 shows that well development activities included the use of chemical additives to disaggregate the bentonite clay mud cake and further disperse the bentonite clay outward in the aquifer strata. The EPA RCRA Manual (1992) contains the following caution for the use of chemical additives as an aid in the development of monitoring wells:

> “Additives to modulate the viscosity and density of the bentonite muds may also introduce contaminants in the groundwater or force large, unrecoverable quantities of mud into the formation.”

The LANL Monitoring Well R-14 Completion Report describes the objective of the monitoring well as follows:

> “The potential sources of groundwater contamination of most concern at R-14 are the present-day radioactive liquid-waste treatment plant at TA-50 and the former radioactive liquid waste treatment plant at TA-35. R-14 primarily is designed to determine the potential impacts of TA-50 effluent discharges on groundwater quality in the regional zone of saturation just south of Mortandad Canyon. The R-

14 site in Ten Site Canyon also provides information about potential contaminants in the regional zone of saturation that could be drawn towards water supply well PM-5, located approximately one mile east-southeast."

LANL Monitoring Well R-14 is surrounded by aquifer strata that are invaded with a large volume of bentonite clay. The groundwater samples collected from the two screened intervals in this well were in contact with bentonite clay for a long period of time. The improper no-purge methods that are used for the collection of groundwater samples from the LANL multiple-screen monitoring wells are described in Appendix F. Groundwater samples collected from LANL monitoring well R-14 are not valid for the detection of the radionuclide and chemical contaminants that are a concern for the location of the well.

The monitoring objectives require replacement of this well with a properly constructed monitoring well in a borehole that is drilled without invading the aquifer strata with bentonite clay muds, biodegradable polymer-based drilling fluids, or biodegradable drilling foam. The required drilling method is air-rotary reverse circulation underreamer casing advance using only air and small amounts of water for drilling into the regional aquifer.

Appendix F: Concerns for the methods that are used to collect groundwater samples from the LANL characterization wells

- **Single-screen characterization wells:**

Many of the LANL single-screen characterization wells are installed with a long well screen that straddles the water table. A high-flow submersible pump is installed in the single-screen wells with the pump intake located near the bottom of the screened interval. For most of the single-screen wells, there is a concern for knowledge of the presence of contamination at the top of the regional aquifer. The long well screen with pump intake located at the bottom of the screen will cause dilution of contamination that is present in the strata at the top of the screen.

The LANL External Advisory Group (EAG) wrote a report to recommend changes in the design of the single-screen wells and in the methods that are used for the collection of groundwater samples from the existing wells (LANL EAG Semi-Annual Report, 9-12 April, 2002):

> "The EAG is somewhat concerned with the GIT (LANL Groundwater Integration Team) response to recommendation 12-01-19. The GIT merely disagrees with the need to carry out low-flow rate purging and sampling of the single completion wells without offering any rationale other than that the pumps that are currently installed are inappropriate for such sampling, a condition that might be correctable. The GIT then states that the procedures appear to be adequate because the samples are "consistent and representative of the aquifer." That sample consistency can be obtained in some wells by high flow rate sampling techniques is not surprising, but this is a matter of precision, not accuracy. The statement that the samples are "representative of the aquifer" does pertain to accuracy, but we would argue that it is impossible to know whether the samples obtained are truly representative of the aquifer in the absence of some sort of comparison to other sampling techniques, notably low-flow purging and sampling techniques."

- **Multiple-screen monitoring wells:**

LANL does not use a low-flow pump system or a flow-through cell to collect groundwater samples from the multiple-screen monitoring wells. Instead, an evacuated container (the Westbay* MOSDAX tool) is deployed to collect water samples from the discrete sampling ports in the Westbay* sampling systems. Many trips with the container may be necessary to collect the volume of groundwater required for the analytical suite. At LANL, no volume of groundwater is purged from the screened intervals prior to the measurement of groundwater parameters and the collection of groundwater samples. In addition, the field-measured parameters including temperature, specific conductance, dissolved oxygen, and turbidity were measured when the groundwater was in contact with the atmosphere (LANL Well R-7 Geochemistry Report, 2002).

The fact that a pumping system is not used to purge a volume of groundwater from the multiple-screen wells is a special concern because of the invasion of drilling additives into the strata that surround the screened intervals. The drilling additives have caused damage to the chemistry of the aquifer strata and have lowered the permeability of the aquifer strata. The groundwater samples collected from these wells have been in contact for a long period of time with aquifer strata that have an altered chemistry. For many of the impacted screened intervals, groundwater samples are collected from a "stagnant zone" that is cut off from active circulation with groundwater in the aquifer. The inappropriate methods used at LANL for measurement of important sensitive parameters and collection of analytical samples compromise data quality and prevent accurate knowledge of aquifer chemistry.

The failure of LANL to a). use a flow-through cell for the measurement of sensitive parameters, and to b). purge an appropriate volume of water before the collection of water samples for the analytical suite does not meet the following requirements from page 181 in the NMED LANL Consent Order:

> IX.B.2.i.i Well Purging
>
> "All zones in each monitoring well shall be purged by removing groundwater prior to sampling in order to ensure that formation water is being sampled. Purge volumes shall be determined by monitoring, at a minimum, groundwater pH, specific conductance, dissolved oxygen concentrations, turbidity, redox potential, and temperature during purging of volumes and at measurement intervals approved by the Department. The groundwater quality parameters shall be measured using a flow-through cell and instruments approved by the Department. The volume of groundwater purged, the instruments used, and the readings obtained at each interval shall be recorded on the field monitoring log. Water samples may be obtained from the well after the measured parameters of the purge water have stabilized to within ten percent for three consecutive measurements." (NMED LANL Consent Order, March 1, 2005)

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The LANL EAG (2001) recognized the need to use a low-flow pumping system for the collection of groundwater samples from the LANL multiple-screen monitoring wells as follows***:***

> "The presence of residual drilling additives is disappointing, but not surprising; it is both difficult (perhaps impossible) and expensive to develop wells at this depth sufficiently to completely remove such materials. The Westbay* tool (MOSDAX) currently being used for sampling provides no capability for avoiding sample contamination with the residual drilling additives; in fact, it probably maximizes it. This is because the tool almost passively collets the groundwater from the immediately adjacent zone of the sand pack/borehole wall/formation. In the absence of drilling additive contamination, this would be a desirable outcome, but not when it is present. Since the additives are impacting the samples and their subsequent evaluation, the EAG has one recommendation for altering the manner in which samples are being collected until the additives are no longer an issue.
>
> **RECOMMENDATION:**
> **Temporarily discontinue use of the measurement port and MOSDAX probe in the Westbay* wells. Instead, collect samples with the pump and the Westbay* pumping port via low-flow sampling techniques with equilibration of indicator parameters using a flow-through cell.**
>
> This sampling approach would increase the likelihood that groundwater from outside the borehole zone contaminated with drilling additives could be acquired. Observation of the stabilization of purging indicator parameters, such as dissolved oxygen, Eh, and conductivity, during the low-flow purging process can be used to detect this continuity with the aquifer water. Although the acquired water would still have to travel through the additive contaminated zones (the zones of altered chemistry that are contaminated with residual drilling fluids), the amount of contamination imparted to the samples during this brief contact should be minimal relative to the MOSDAX samples that have set in this zone for some time."

LANL has not followed the advice of the EAG for using a low-flow pumping system for collection of groundwater samples from any of the LANL monitoring wells. In addition LANL continues to collect no-purge water samples from a large number of multiple-screen wells. An EPA Superfund Forum Guidance document by Puls and Barcelona (1989) describes the proper methods for the collection of groundwater samples from monitoring wells:

- Use a positive displacement pump to pump groundwater from the screened interval.
- Groundwater samples should be collected in such manner to eliminate O_2 and CO_2 exchange with the atmosphere.
- Use a flow-through type cell to monitor the pumped groundwater. Monitoring for dissolved oxygen, temperature, conductivity and pH (also monitoring Eh and turbidity) aids in the interpretation that representative groundwater samples are collected for contaminant analyses.

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- Before collection of groundwater samples for the analytical suite, continue low-flow pumping and monitoring of groundwater parameters for a sufficient period of time to ascertain that the groundwater parameters have stabilized. The time of pumping necessary to collect representative water from the aquifer strata is around two times the time required to get plateau values for the above parameters.
- For analysis of metals (and radionuclides), routinely collect both filtered and unfiltered samples. Filtration should be performed in the field with no air contact. In-line pressure filtration is best with as small a filter pore size as practically possible (e.g., 0.05, 0.10 micron).

Groundwater contamination is perceived by the public as a major health issue and may present high risks at specific sites. From: Waste Management Series, 2004. Related termsÂ In many situations, particularly in the case of organic compounds, microbiological degradation effects are not well know, but it does appear, however, that a great deal of degradation can occur if the system is not overloaded and appropriate nutrients are available. Dispersion of a leachate in an aquifer causes the concentration of the contaminants to decrease with increasing length of flow. contaminating water flowed northward in the unsaturated zone along the geological structure until. reaching the water table of the regional carbonate aquifer, where mixing occurred. The industrial complex produced waste water at annual volumes and composition which are not fully. known.Â carbonate aquifer of the Judea Group. The contamination of the groundwater can be traced to its source. through major elementsî€' No noticeable change in the trace elements concentration was detected in the. contaminated water (except for boron) due to adsorption of these contaminants, most probably onto Fe