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Los Alamos National Laboratory's Response to National Academy of Sciences Report "Plans and Practices for Groundwater Protection at the Los Alamos National Laboratory"

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Los Alamos National Laboratory's Response to National Academy of Sciences Report "Plans and Practices for Groundwater Protection at LANL"

November 2007

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Executive Summary

From 2006 to 2007, the National Academy of Sciences (NAS) conducted an 18-month review of plans and practices for groundwater protection at the Los Alamos National Laboratory (LANL or the Laboratory). The review was requested by the Los Alamos Site Office (LASO) of the U.S. Department of Energy (DOE) to ascertain the effectiveness of the Laboratory's groundwater monitoring program. The review committee was given a statement of task that included such topics as the control of sources of groundwater contamination, issues of groundwater data quality, and the effectiveness of the Laboratory's groundwater monitoring approach. The specific wording of the committee's charter can be found in its final report (NRC, 2007).

The Laboratory has received the committee's final report (NRC, 2007) and has discussed its 17 recommendations, contained within the report, with the committee. Although the committee has concluded its work and has disbanded, the Laboratory felt it worthwhile to respond formally to the recommendations. The responses will be used for internal planning and reporting purposes and for communication with stakeholders and the interested public. Of the responses to the 17 recommendations, 13 responses clarify work that has been completed or describe approaches to ongoing work. Four responses describe work that is planned and approved in the baseline and will be considered during the annual work plan prioritization process. A number of responses describe work that may be proposed for consideration if warranted by new information.

The italicized text below provides the verbatim wording of the 17 NAS recommendations as stated in chapter 6 of the committee's final report (NRC, 2007) (with bold emphasis added to highlight the main idea). Following each recommendation is the Laboratory's and DOE/LASO's coordinated response.

NAS Recommendation:

1. *LANL should* ***complete the characterization of major contaminant disposal sites and their inventories****, i.e., complete the investigation of historical information about these disposal sites with emphasis on radionuclides and chemicals likely to impact human health and the environment. Selected sites should be characterized by field analysis when historical information is insufficient to determine quantities of major contaminants disposed and to confirm the degree of transport that has occurred. LANL should devote greater effort to characterizing sources with significant inventories of contaminants (especially plutonium) that usually are strongly sorbing but still have the long-term potential to migrate in the presence of water.*

LANL Response:

1. The complete characterization of the major contaminant disposal sites is included in the program's life-cycle baseline and is in process in accordance with a schedule established between the Laboratory and the New Mexico Environment Department (NMED). The approach is to first characterize those sites with more substantial inventories and move to lesser-sites later in the program. Currently, the inventory at Material Disposal Areas (MDAs) H and AB are well known and are fairly well known at MDAs G and L. Limited records were kept for MDA C, so it is unlikely that the inventory at MDA C can be determined, but it may be possible to calculate volatile releases from this site without knowing the inventory explicitly.

   Inventory records for some of the solid waste management units (SWMUs) do not exist; for this reason, it can be difficult to determine the source term. However, with respect to the SWMUs, the Laboratory has a good estimate of the amount of strontium-90 released in Bayo Canyon and of radionuclides released in Los Alamos/Pueblo canyons. Additional information about soil contamination in Bayo Canyon was collected in the summer of 2007. In general, however, most of the SWMUs either will be cleaned up or require no action.

NAS recommendation:

2. *For the major disposal sites, LANL should* ***develop mass balance estimates*** *of the quantities of disposed chemicals and radionuclides remaining in the surface soil and/or residing in the shallow alluvium, the vadose zone, and the regional aquifer.*

   Sitewide, LANL should perform a mass balance for hazardous and radioactive substances by assessing the types, quantities, and volumes of individual hazardous materials that have entered the site over the years.

LANL Response:

2. The Laboratory employs mass-balance calculations as one of its tools to assess waste disposal sites and determine appropriate remedies and cleanup goals. The Laboratory will be unable to perform a sitewide mass balance of the hazardous materials that have entered the site over the years because a mass balance requires knowledge of inventories of materials disposed, and records were not kept of inventories during the Laboratory's early years. However, a sitewide mass balance is not as relevant as mass balance studies that have been conducted or are planned for certain areas. As a foundation for these and other studies, Birdsell et al. (2006) compiled an extensive amount of historical information on Laboratory sources and inventories that was presented to the NAS committee during its August workshop. This information will be valuable in assessments of contaminant transport for the individual areas within the site.

   It is most relevant to conduct a mass balance where there are known releases so the mass retained can be compared with the initial mass to estimate the mass released. This calculation has been done in the performance assessment for Area G (LANL, 2005) and is being considered for Area AB. The Laboratory expects to perform a release scenario for every corrective-action area through investigation reports. A mass balance performed for perchlorate provided important information for the Mortandad Canyon assessment (LANL, 2007a).

NAS Recommendation:

3. *LANL needs to* ***quantify the inventories of contaminants released in the canyons*** *in order to understand their potential threat to groundwater. The sitewide mass balance of inventories of hazardous and radioactive substances should include the surface water transport pathway.*

   LANL should continue to develop surface water and sediment monitoring programs. LANL should continue, and improve, its control of contaminants moving down the canyons to prevent further surface transport and redistribution offsite of both mobile and sorbing contaminants. Measures to control surface transport down canyons, including further reduction of aqueous discharges, removal of contaminated media, and appropriate use of barriers, etc., are needed.

LANL Response:

3. Where possible, the Laboratory has quantified or will quantify as part of its work scope the inventory of contaminants released into canyons. This calculation has been done for Mortandad Canyon (LANL, 2007a); it is currently being done for Sandia Canyon, and an attempt is currently underway for the south canyons (Water, Ancho, and Cañon de Valle) related to Technical Area (TA) 16. The inventory cannot be determined for Los Alamos/Pueblo Canyon because of limited records kept during early years of the Laboratory. These are the main canyon areas that have contamination. See the response to comment #2 regarding determination of a sitewide mass balance.

   With regard to surface water and sediment monitoring programs, the Laboratory is moving from the Federal Facility Compliance Act to an individual stormwater permit. As the next phase of improved stormwater monitoring program, the Total Daily Maximum Load (TDML) is being developed as part of the permit to further address sediment and contamination flux.

   Measures to control surface transport down canyons are part of the stormwater program. A weir was constructed to contain sediments with contaminants released from upper parts of the Los Alamos Watershed after the Cerro Grande fire. Other barriers are being considered as part of remediation required by the Consent Order. For example, permeable reactive barriers have been proposed as part of the remedy for control of high explosives in the TA-16 area. Corrective actions will be implemented as approved by NMED.

NAS Recommendation:

4. *LANL needs to* ***better integrate geochemistry into its conceptual modeling.*** *Laboratory experiments and field tests, in addition to literature data, are necessary to substantiate LANL's general observations and assumptions about the geochemical behavior of contaminants.*

LANL Response:

4. Geochemistry is an important aspect of conceptual modeling. Several efforts have been ongoing since the 2005 completion of the Hydrogeologic Workplan (HWP) (LANL, 1998) to improve the integration of geochemistry into both conceptual and numerical models of flow and transport.

   Flow and transport modelers and geochemists at the Laboratory have specifically discussed integration, including (1) geochemical evidence that would distinguish conceptual models of contaminant transport along the top of the water table versus transport of contaminants at greater depths within the regional aquifer, (2) geochemical evidence for the Pajarito Fault Zone as a barrier to mountain block recharge, and (3) geochemical evidence relevant to understanding sources of recharge (both spatially and temporally).

As work is prioritized in fiscal year (FY) 09 and beyond, the Laboratory will consider enhancements to conceptual and numerical models using geochemistry data. For example, geochemistry data that the Laboratory has collected, including carbon-14 dates, helium-tritium isotope data, oxygen and deuterium isotopes, and contaminant concentration trends, could be incorporated into the Laboratory's Regional Aquifer Flow and Transport Model to improve identification of aquifer structure, parameters to use, and boundary conditions. In addition, modeling efforts include upscaling of reactive transport parameters determined from column experiments (preexisting data and results from activities described in response to recommendation #10) to define the reactive transport parameters. These parameters include dispersivity, matrix diffusion coefficients, sorption constants, and forward (and inverse) kinetic rate constants of the sorbed chemical species.

NAS Recommendation:

5. *LANL should continue to review all operations and reduce discharges and releases to the greatest extent practical. This includes efforts to minimize the disposal of solid wastes on mesa tops because waste disposal in those areas can pose a long-term threat to the regional groundwater.*

LANL Response:

5. The Laboratory continues to review all operations to reduce liquid discharges and to minimize generation of low-level waste. The Laboratory must reduce discharges from its wastewater treatment facilities in order to ensure compliance with the Laboratory's National Pollutant Discharge Elimination System Permit, to reduce potable water demand, and to provide for long-term sustainable operations. Since 1993, the Laboratory has reduced the total number of outfalls discharging to the environment from 141 to 15. Over the same period, total liquid discharges have been reduced from 1,300 to approximately 200 million gallons per year.

   In 2007, the Laboratory established an institutional objective to "Achieve Zero Liquid Discharge by 2012." This objective was determined to meet new permit conditions, to provide for water conservation, and to limit the flow of water available to remobilize contaminants in canyons and below the surface. A feasibility study has been initiated by the Laboratory to meet this objective. The study is evaluating options to reduce sources of wastewater, to reuse treated effluent, and to eliminate each of the remaining 15 outfalls. This feasibility study is a cooperative effort by the Laboratory's Environment, Safety, Health, & Quality Directorate and Environmental Programs Directorate in coordination with all outfall owners. It is scheduled to be completed by December 2007. In addition, the Laboratory has developed the Zero Liquid Discharge (ZLD) Project to eliminate the discharge of treated effluent from the TA-50 Radioactive Liquid Waste Treatment Facility into Mortandad Canyon. The ZLD Project is scheduled to be designed and constructed in 2008.

   The Laboratory has reduced the volume of low-level waste generated annually, and will close the current low-level waste disposal site known as MDA G by the end of 2015. A new solid waste disposal area known as Zone 4 of Area G has been proposed to accommodate anticipated future work at the Laboratory. The proposed Zone 4 disposal area incorporates improvements that minimize the chance of transport to the regional aquifer. Approval of this site is under consideration by DOE.

NAS Recommendation:

6. *LANL should* ***add a sitewide perspective to its future groundwater monitoring plans****. This perspective would include the following:*

   - *Design additional characterization, modeling, and geochemical investigations to better understand potential fast pathways between watersheds.*
   - *Increase the area of the regional aquifer that is monitored by sampling inter-canyon areas from mesas or using directional wells from canyon bottoms.*
   - *Provide additional monitoring locations in the southern area of the site and on Pueblo de San Ildefonso lands.*
   - *Develop more applications of geophysical techniques to supplement information provided by well drilling and sampling, especially for understanding vadose zone pathways.*
   - *As LANL's site characterization and monitoring programs mature, well locations should be derived from a quantitative spatial analysis of monitoring well locations to identify areas with the greatest uncertainty in plume concentrations, using geostatistics or other methods, possibly coupled with flow and transport modeling.*

LANL Response:

- The Laboratory will consider additional characterization, geochemistry, and modeling where warranted by monitoring network evaluations or other assessments that indicate gaps where understanding is lacking. Fast pathways between watersheds are currently being examined in the chromium investigation, for example.
- The NAS committee has made the recommendation to increase the area of the regional aquifer that is monitored by sampling intercanyon areas from mesas or using directional wells from canyon bottoms. The Laboratory is reluctant to follow this recommendation for two reasons. First, the mesa intercanyon areas are much narrower than the canyon areas themselves and the infiltration areas that they contribute to the regional aquifer are small. At regional aquifer depths of hundreds to thousands of feet, the relative contribution of contaminants derived from mesa tops compared to intercanyon areas cannot easily be distinguished. Second, available information indicates that existing mesa monitoring locations are sufficient for monitoring contaminants in those areas.
- The NAS committee has recommended additional monitoring locations in the southern area of the site and on Pueblo de San Ildefonso lands. With respect to the southern areas, the Laboratory has scheduled in its baseline the installation of two additional regional aquifer wells and two intermediate-depth groundwater wells in the south canyons areas in Water and Ancho Canyons. The Laboratory's water supply wells and the site boundary are considered primary points of groundwater protection; if evaluations of monitoring network efficiency identify gaps in monitoring with respect to off-site migration, the Laboratory will include recommendations for wells in those locations, such as on San Ildefonso lands.
- The NAS committee has recommended that more applications of geophysical techniques be developed to supplement information provided by well drilling and sampling, especially for understanding vadose zone pathways. The Laboratory's environmental programs have conducted numerous geophysical investigations to assist in characterization, both sitewide and at the watershed scale, of which the committee may not be aware. These investigations are as

follows, along with possibilities for extending them in the future to aid in understanding flow and transport.

(1) Geophysical borehole field logs are available for every monitoring and characterization well. These logs were used in correlating geologic units and aided in construction of the geologic framework model for the Pajarito Plateau. The processed logs can be used to ascertain hydrologic properties of different stratigraphic units in the sitewide flow model.

(2) A time-domain airborne electromagnetic (AEM) survey of a large part of the Pajarito Plateau was conducted to determine the depths and lateral extent of perched aquifers in the vadose zone and the depths and pathways of infiltration to the regional aquifer (Baldridge et al., 2007). Further mining of this data set could yield additional insights.

(3) Aeromagnetic survey data collected by the Laboratory for the western Española Basin area was provided to the U.S. Geological Survey for its use in compiling a regional map showing buried geologic structures and contacts.

(4) Biehler et al. (1991) constructed a geophysical model of the Española Basin that estimated thickness of the Santa Fe Group sediments. Ferguson et al. (1995) conducted a regional gravity study that detected a prominent, northeast-trending gravity low beneath the Pajarito Plateau. Based on these data, the gravity low detected by Ferguson et al. (1995) was interpreted as a sediment-filled graben within the western part of the Española Basin. This interpretation has been incorporated into the Laboratory's geologic framework model. Further use could be made of Ferguson's work to determine the penetration of faults at depth, and this information could then be used in flow models.

(5) A two-dimensional geophysical survey was conducted across Mortandad Canyon as part of investigations in that watershed. The Laboratory may propose to extend this to a three-dimensional survey across Mortandad to Sandia Canyon to investigate infiltration between the two canyons. The previously mentioned AEM survey results could guide the location of such a future study.

(6) GEOPHEX conducted high-resolution direct current resistivity surveys in portions of Mortandad, Delta Prime, Pueblo, Los Alamos, Sandia, Two Mile, and Pajarito Canyons that were presented in the Hydrogeologic Site Atlas (LANL, 2006).

Future work could include a broad geophysical survey to detect the extent of perched water at TA-54 after the planned wells are drilled. This survey would be especially useful if perched water is encountered during drilling. In addition, an electrical resistivity method in the Sandia wetlands could determine whether the fault detected in that area is a conduit for flow and transport. The geologic framework model would be able to incorporate the fault at a 50-ft grid scale and the resulting geology could then be imported into the sitewide flow and transport model.

- The NAS committee has recommended that new well locations should be derived from a quantitative spatial analysis of monitoring well locations to identify areas with the greatest uncertainty in plume concentrations, using geostatistics or other methods, possibly coupled with flow and transport modeling. In fact, the Laboratory is using a comprehensive, integrated, decision-centered approach to recommend monitoring sites for current and future groundwater monitoring plans, as presented at the NAS briefing in Santa Fe in August 2006 (Echohawk, 2006). This approach is being implemented through monitoring network evaluations that are ongoing.

- The monitoring network design process is now directly tied to the remedy selection process, using a probabilistic approach to conceptual model development and subsequent modeling. This probabilistic approach translates uncertainties in the conceptual model, including concerns about fast paths, via geostatistics into the numerical flow and transport modeling and ultimately into the remedy selection process. If there is insufficient understanding of the system to support remedy selection, the additional characterization that would be necessary (i.e., the gap) is identified by this approach. The characterization can then be performed and the conceptual and numeric modeling repeated.
- The overall programmatic approach is to assess the existing Laboratory groundwater network, and then add to or modify this network as remediation sites emerge from the corrective measures evaluation (CME) phase that requires monitoring to support selected remedies. Ultimately, the result will be a long-term stewardship groundwater monitoring network incorporating both overall monitoring and remedy performance monitoring requirements. This network will monitor for off-site migration of contaminants and impacts to regional drinking water wells.

NAS Recommendation:

7. *LANL should increase its efforts to develop and use quantitative methods to describe contaminant pathways through the vadose zone and into the regional aquifer, as follows:*

   - *Mathematical models that incorporate the uncertainties from alternative conceptual models should underpin plans for design and operation of the sitewide monitoring system. Characterization of the vadose zone begun under the Hydrogeologic Workplan should continue with emphasis on new results from characterization and monitoring being used to test and improve the mathematical models.*
   - *To support an evaluation of the effectiveness of the monitoring system to provide early warning of potential impacts on the regional aquifer, LANL should quantify, to the extent possible, the inventory and current location of the contaminants disposed of in the major waste sites.*

LANL Response:

7. Having a quantitative understanding of contaminant pathways between the vadose zone and the regional aquifer is important. One of the recently initiated activities at Area G involves utilizing tritium data collected from two intermediate (vadose zone) wells to construct a three-dimensional numerical representation of the existing vapor-phase plume. The next step will be to project the model to the aqueous phase and extend it to well R-22 to predict transport from the vadose zone to the regional aquifer at this downgradient well.

   The mathematical models employed in the area assessments incorporate uncertainties from alternative conceptual models. As area assessments are conducted, the Laboratory will continue to evolve its conceptual models of wet versus dry settings with the idea that wet canyons and wet mesas should have similar infiltration characteristics and that these would differ from dry canyons and dry mesas. Similar to the work initiated at Area G, the other area assessments will evaluate the transport of vapor-phase constituents and both mobile and sorbing constituents in the aqueous phase. A starting point for the area assessments necessitates knowing the inventory and current location of the contaminants disposed of in the major waste sites. The results of modeling through the various area assessments can then be joined conceptually at a larger scale for the design of an overall monitoring system. Outcomes of the area assessment may require new characterization and/or monitoring wells. Data collected from the new locations can then be incorporated into updated models. The integration of knowledge from the different area assessments will provide greater

confidence in the overall monitoring network. (Currently, a sitewide three-dimensional model that captures the vadose zone and the regional aquifer is restricted by grid size and the time needed for computation.)

As the area assessments are conducted, the assumptions, conceptualizations, input parameters, data used (including inventories and location of disposed contaminants), modeling processes, and other information will be formally documented through a modeling procedure (in draft). In addition, the Laboratory expects to publish results of the modeling in peer-reviewed literature.

NAS Recommendation:

8. *LANL should confirm the integrity (lack of surface disturbances or conditions leading to increased infiltration) of the major disposal sites in the dry canyons and mesas.*

   LANL should schedule regular subsurface surveillance beneath disposed wastes on dry mesas and in dry canyons.

LANL Response:

8. The Laboratory conducts monthly surveillances at all nuclear environmental sites (NESs) to confirm their integrity. MDAs have regularly scheduled surveillances as well. If the integrity of any site is in jeopardy of being compromised such that its disturbance could create fast transport pathways, steps are taken to restore its integrity. Some examples might be repairs to drainage, restoration of damage done by prairie dogs, and removal of storm-driven debris.

   The subsurface disposal sites are in trenches that are excavated in volcanic tuff and not in unconsolidated materials. Surveillance is therefore of a different nature than in the surface disposal sites. Subsurface surveillance beneath disposed wastes has been, and continues to be, through pore-gas sampling and long-term vadose zone monitoring.

NAS Recommendation:

9. *LANL should* ***continue efforts begun under the Hydrogeologic Workplan to characterize the regional aquifer****. More large-scale pumping tests and improved analyses of the drawdown data are needed to establish a scientifically defensible conceptual model of the aquifer, i.e., leaky-confined, unconfined, or layered.*

LANL Response:

9. The Laboratory plans to continue efforts to characterize the regional aquifer. Typically, hydraulic properties of the regional aquifer are estimated using specially designed field (pumping) tests. A series of single-hole and cross-hole pumping tests have been conducted at water-supply and monitoring wells near the Laboratory that provided important information about the properties of the regional aquifer (Mclin, 2005; McLin, 2006). However, instead of conducting additional tests, it has been proposed to use the long-term data collected during naturally occurring variability in the water-supply pumping and the respective responses at the various observation points. The analyses of these data will produce a cost-effective and time-efficient estimation of the regional aquifer properties and will encompass responses over a wider area. An additional advantage of this approach compared to pumping tests is that the longer temporal record in water-level data reduces uncertainty and potential ambiguity in the observed drawdown at the monitoring wells from pumping. In addition, the heavier stresses placed on the aquifer during regular water-supply pumping produce cones of depression that are larger than those produced during pumping tests. The pumping regime can also

be adjusted through communication with Los Alamos County authorities managing the water-supply wells to increase the information content of the collected data; for example, different wells can be selected to be the major water producers during different stress periods. The objective is to perform a simultaneous interpretation using an inverse numerical model of the long-term record of the water-supply pumping and water-level data to obtain a large hydraulic tomography of the regional aquifer properties. A similar type of analysis has been successfully performed and published by Vesselinov et al. (2002). Currently, most of the boreholes and wells near the Laboratory are equipped with pressure transducers that yield data that can be used for this purpose. Preliminary analyses demonstrate the high-information content of the collected data; water-supply pumping responses are observed at most of the monitoring wells. The results of this study will yield a refined and more complete set of regional aquifer properties. This work will be considered in work plan prioritization for FY09.

NAS Recommendation:

10. *LANL should* ***increase its attention to geochemistry within the context of its site characterization*** *work. LANL scientists should conduct more field and laboratory studies to measure basic geochemical parameters such as sorption coefficients with the goal of testing and verifying their conceptualizations of subsurface hydrogeochemical processes.*

LANL Response:

10. Geochemistry is an important aspect of site characterization, which is linked closely to conceptual models of flow and transport (see response to comment #4). Geochemistry has been an integral aspect of all well reports (see many reports by Longmire et al., for example, the *Characterization Well R-25 Geochemistry Report* (Longmire, 2005). Geochemistry has also been integral in the interpretation of results of the aquifer test at R-28. In addition, isotope geochemistry has provided important insights into flow pathways and the ages of groundwaters (Longmire et al., 2007).

    As mentioned in the response to recommendation #5, planned modeling efforts will include upscaling of reactive transport parameters determined from column experiments (preexisting data and results from activities described below) to define the reactive transport parameters, including dispersivity, the matrix diffusion coefficient, sorption constant and forward (and inverse) kinetic rate constant of the sorbed chemical species.

    Batch sorption experiments were conducted for americium, neptunium, plutonium, technetium, and uranium transport through the Bandelier Tuff at Los Alamos (Longmire et al., 1997) to generate input to the performance assessment for Area G. Traditionally, however, the Laboratory has used sorption coefficients from analog sites (e.g., Yucca Mountain tuffs) in most of its modeling efforts. In addition to expanding the analog literature base from other DOE sites, a limited suite of sorption experiments for key contaminants and aquifer materials is planned to verify the applicability of these analog sites. The need for additional geochemistry studies will also be evaluated. For example, if monitoring data suggest that actinides have been transported farther than expected based on modeling studies, the Laboratory will consider experiments designed to examine colloid-facilitated transport of actinides. These experiments would supplement the limited number of experimental and modeling studies conducted to date related to colloid transport of contaminants at the site.

    The program has plans to continue a proof-of-concept activity to determine the applicability of isotopic measurements of contaminants to distinguish among background and anthropogenic sources of contaminants (including non-Laboratory anthropogenic sources) and to identify signatures of monitored natural attenuation processes. This information can be used to validate the Laboratory's

assumptions about contaminant sources and behavior. Preliminary isotopic studies of perchlorate and chromium contamination have already begun.

The findings from integrated modeling studies and from laboratory studies will be examined to assess the need for field-scale geochemistry tests.

NAS Recommendation:

11. *LANL should* ***demonstrate better use of its current understanding of contaminant transport pathways in the design of its groundwater monitoring program****. Tables in the monitoring plan that give the rationale for locating monitoring wells should at least provide a general linkage between the proposed locations and the site's hydrology, or a section discussing the relation between well locations and pathway conceptualizations should be added.*

    LANL should take a sitewide approach to monitoring the intermediate and regional aquifers. Furthermore, the interim plan should summarize (e.g., in Section 1.6) the ways in which the information from related studies will be used for updating the plan. The current description of the conceptual models (in Appendix A of the plan) is useful, but it should be improved. First and foremost would be a description of potential pathways, both surface and subsurface, that connect the sources (listed in Appendix A) with the groundwater that is being monitored.

    LANL should examine the potential for approaches that both optimize the monitoring network and incorporate uncertainty into its design (Minsker 2000; EPA, 2006).

LANL Response:

11. The Laboratory will apply its understanding of contaminant transport pathways in designing its monitoring network. Ongoing canyons reports and network evaluations being done under NMED's direction will optimize monitoring locations; these reports will discuss a site's hydrology and the link between proposed monitoring locations and pathway conceptualizations. The canyons reports and network evaluations will then be referenced in the 2008 Interim Facility-wide Groundwater Monitoring Plan (IFGMP). Data from the 2007 periodic monitoring reports (PMRs) will also help to update the analytical suites and frequencies at each collected at each monitoring location.

    The Laboratory takes a sitewide approach to monitoring. The Compliance Order on Consent (Consent Order) drives monitoring on a watershed basis but for deeper zones in the intermediate and regional aquifers the sitewide approach is used because the regional aquifer underlies the entire site and intermediate zones are not restricted to a single watershed. The sitewide perspective is included in monitoring network evaluations by including objectives to protect drinking water supplies and detect off-site transport.

    The conceptual model in the IFGMP (Appendix A of that plan) will be updated using information from the 2007 PMRs. As additional monitoring events are conducted and data provide insights into surface and subsurface pathways that connect contaminant sources to monitoring locations, this information will be captured in the PMRs and then used to update the IFGMP.

    The Laboratory has examined the potential for approaches that optimize the monitoring network (see response to comment #6); the ensuing network evaluations or area assessments incorporate uncertainty through a probabilistic modeling approach to ensure that the monitoring network achieves its protection objectives at a 95% confidence level.

NAS Recommendation:

12. *LANL should plan and carry out* ***geochemical research to ascertain the interactive behavior of contaminants, materials introduced in drilling and well completion, and the geologic media.*** *As a part of LANL's future plans for sitewide monitoring, this work would include:*

    - *Determining the nature of interactions among materials proposed for use in constructing monitoring wells and the types of geological media that LANL intends to monitor,*
    - *Quantitative measurement of sorption of contaminants onto the natural, added, and possibly altered constituents that constitute the sampling environment of a monitoring well, and*
    - *Publication of results in peer-reviewed literature.*

LANL Response:

12. The Laboratory has planned bench-scale experiments that will examine the nature of interactions among materials that have been used in the past for drilling and constructing monitoring wells, contaminants, and the geologic media. The experiments will utilize core and cuttings from previously constructed wells and will also use knowledge gained from sorption measurements on tuff materials (see response to recommendation #10). The Laboratory is also exploring the possibility of conducting a nondestructive field experiment at a well screen that is impacted by drilling fluids. Rock samples would be collected from various distances, extending laterally away from the well bore into nonimpacted aquifer material. The samples would be analyzed to identify secondary minerals, the extent and degree of drilling fluid impacts, and the sorption of materials onto both primary and secondary minerals.

    The results of the planned experiments will enhance the Laboratory's understanding of drilling fluid impacts, as described in the *Well Screen Analysis Report, Revision 2* (LANL, 2007b). The natural site groundwater chemistry, aquifer-groundwater interactions, and interactions with drilling fluids will be synthesized in a report that will be submitted to a peer-reviewed journal.

NAS Recommendation:

13. *LANL should plan and* ***conduct future characterization drilling and monitoring well drilling as separate tasks.*** *For monitoring locations where characterization data are unavailable, LANL should consider drilling simple test holes to obtain this data before attempting to drill the monitoring well(s).*

LANL Response:

13. It should first be noted that the Laboratory's overall site characterization program, the HWP (LANL, 1998), has been completed and documented in a hydrogeologic synthesis report (Collins et al., 2005). Objectives for wells drilled during the HWP included their use for both characterization and monitoring purposes. Since completion of the HWP, the Laboratory has assessed the existing Laboratory groundwater monitoring network by area and has added to or modified this network as remediation sites with monitoring requirements are identified from the CME phase of an investigation. During the CME phase, additional specific characterization may be required. In this case, the Laboratory will first drill test holes to obtain data before drilling a monitoring well. The precedent for this step-wise approach was established during phase one of the chromium investigation, in which several test boreholes were drilled before the locations of monitoring wells R-35a and R-35b were selected.

NAS Recommendation:

14. LANL should ***design and install new monitoring wells with the following attributes:***

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

LANL Response:

14. The Laboratory implemented this recommendation with the installation of well R-35 (LANL, 2007c).

Because of ongoing concerns raised both internally and by stakeholders regarding the use of additives during drilling, the Laboratory will continue to attempt to advance boreholes through target monitoring intervals with water and air only. The first wells (R-35a and R-35b) attempted with this method were advanced with a combination of casing advance and open-hole drilling using foam/air-rotary to approximately 100 ft above the regional aquifer (the target monitoring interval). From 100 ft above the regional aquifer to total depths up to 350 ft into the regional aquifer, the use of drilling additives (foam) was suspended and drill casing was advanced with air-rotary using minimal amounts of municipal water to cool the drill bit as needed.

As indicated above, well R-35 consisted of a pair of boreholes (R-35a and R-35b) targeting different intervals within the regional aquifer. To reduce the potential for cross-communication between the zones of interest at each well and to ease the well development (well-screen and filter-pack cleaning), the Laboratory chose to drill two separate boreholes rather than to complete a single well with two isolated screen intervals. The added effort and expense that this undertaking entailed appear to have been worthwhile. The wells are providing distinguishably different chemical signatures, they respond to nearby municipal well pumping differently, and both provide low turbidity and stable field parameters.

Decisions on both screen length and placement within the aquifer were based on careful review of data collected during drilling, including observations of groundwater production rate, open borehole groundwater chemistry, drill cuttings, and borehole geophysics. It should be noted that the usefulness of the geophysical logging suite was reduced through the presence of drill casing in the borehole. Specifically, a combinable magnetic resonance (CMR) log, which provides valuable information on aquifer pore size and amount of "movable water," cannot be run through steel casing. The processes used in the successful design and installation of R-35a and R-35b will serve as a template for the installation of future wells.

NAS Recommendation:

15. LANL should ensure that there is consistency and clarity of all related sampling and analytical procedures with documented follow-through and appropriate action. This especially relates to:

- *Having clear data quality objectives;*
- *Documenting how samples are to be collected;*
- *Documenting how data are handled, statistically compiled, and reported;*
- *Clear documentation of the quality of the data; and*
- *Identification of all suspect data.*

LANL Response:

15. The Laboratory strives for continuous improvement in providing consistency and clarity in the quality assurance (QA) associated with the groundwater monitoring program. The Quality Assurance Project Plan (QAPP) for the Groundwater and Persistent Surface Water Monitoring Project follows a flow-down of requirements in the Consent Order for defining data quality objectives. The QAPP requires data quality objectives to be clearly stated in work plans approved by NMED. Similarly, the QAPP requires that documentation of sample collection methods is contained in sampling procedures and described in work plans.

    Several procedures address analytical laboratory measurements, handling of electronic and paper analytical records and field measurement records, secondary validation of analytical data, and management of electronic data. Compilation of data occurs partly in the reporting and data assessment processes; the latter is covered in QAPP and the Consent Order. Reporting of data is covered in the QAPP, DOE Orders 231.1, 450.1, and 5400.5, the Consent Order, and work plans.

    Data quality is documented through analytical laboratory contracts which specify standards and certifications that these laboratories must meet and procedures the laboratories must follow. Verification that the procedures are being followed is accomplished through audits and performance assessments of the analytical laboratories and through documentation and validation of the analytical results.

    Some data are determined on the basis of analytical laboratory or independent secondary validation evaluation as suspect. This identification occurs and is documented along with data results according to contracts and procedures. Other data are identified by the data user as suspect based on comparison with other analytical results or review of records. Where this comparison identifies analytical issues, they are documented in the water quality database along with data results according to analytical laboratory contracts and procedures and through secondary validation. Where suspect data are identified through the user but the potential problem cannot be documented as resulting from field collection or analytical errors, the data issues are documented in written reports.

    One special category of suspect data involves data that are unreliable because of drilling fluid impacts. These data have been evaluated by the methodology described in the *Well Screen Analysis Report, Revision 2* (LANL, 2007b) and the affected analytes will be documented in the water-quality-database.

NAS Recommendation:

16. *LANL should* ***ensure that measurements at or near background levels or near analytical detection limits (i.e., MDLs and PQLs levels) are scientifically and statistically sound and are reported appropriately****. The LANL site office of DOE should take steps to ensure that LANL and site regulators agree on how all such data are to be handled, compiled, and reported. LANL should make more effort to ensure that data uncertainties are made clear to public stakeholders.*

Response:

16. The Laboratory, DOE, and NMED are in mutual agreement on how groundwater data are handled and reported. The Laboratory's analytical measurements are acquired by scientifically and statistically sound methods, and the data are reported appropriately. Analytical laboratory measurements are obtained according to the National Nuclear Security Administration Service Center's Analytical Management Program's Model Statement of Work and QA requirements specified in DOE Orders. Analytical results are reported by the Laboratory according to requirements specified in DOE Orders. Analyses are conducted using analytical methods approved in work plans by NMED.

    Environmental monitoring data are handled, compiled, and reported according to requirements in DOE Orders, the Consent Order, and NMED-approved work plans. Where available (that is, for data acquired since 2000), analytical laboratory qualifiers and qualifiers resulting from secondary validation are provided with the analytical data.

NAS Recommendation:

17. LANL should continue to track regional groundwater monitoring wells and water supply wells routinely to improve the statistical basis for reporting any increases above background.

    LANL's Quality Assurance Program Plan should enforce the documentation of any and all instances where it is believed that chemicals or radionuclides detected in groundwater are not the result of LANL operations, e.g., naturally occurring or anthropogenic contaminants or the result of sampling artifacts.

LANL Response:

17. The Laboratory presently monitors the quality of regional groundwater in seven watersheds either quarterly or semiannually in accordance with the NMED-approved 2007 IFGMP (LANL 2007d) and the Consent Order. Monitoring includes sample collection at surface base flow stations, regional wells, natural springs, Los Alamos County, and City of Santa Fe water supply wells. The incoming data are reviewed weekly and are reported in scheduled periodic monitoring reports. It is in part because of monitoring data collected in 2006 that the number of background locations and the statistical basis for reporting background exceedances, known as the upper tolerance limit, were enhanced in the *2007 Groundwater Background Investigation Report, Revision 3* (LANL 2007e). The Laboratory plans to screen all analytical monitoring data to accepted background values.

    The Laboratory's groundwater data assessment team routinely compares analytical data results to QA/quality control (QA/QC) samples such as field blanks, trip blanks, duplicate samples, laboratory blanks, and other QC samples. Analytical results from primary monitoring samples are typically scrutinized alongside analytical laboratory QA/QC sample results to determine if false positives may be present because of improper handling of samples in the field, contamination during sample transport, or laboratory cross-contamination.

Documentation of occurrence of chemicals or radionuclides in groundwater that are not the result of Laboratory operations (naturally occurring or anthropogenic contaminants or the result of sampling artifacts) takes place in the annual report Environmental Surveillance at Los Alamos, in Resource Conservation and Recovery Act facility investigation reports, and other corrective actions reports.

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