2. <u>An Important Finding of the NAS Committee is that LANL/DOE have Failed to Install a Reliable Network of Monitoring Wells in the Regional Aquifer</u>.

The overall failure of the LANL scientists and DOE managers to install a reliable network of monitoring wells across the laboratory facility for early detection of the release of the LANL contaminants to the regional aquifer is a general finding in many sections of the prepublication copy of the NAS report.

The failure of LANL/DOE to comply with the DOE Orders is a serious infraction because of the detection of plutonium-238 in a recent sample of the groundwater produced from a drinking water well for the City of Santa Fe. In addition, LANL reports dated 1999 and 2006 have listed many radionuclide contaminants from nuclear weapons research as present in several of the drinking water wells for both Los Alamos County and the City of Santa Fe. This is an emerging environmental emergency that the NAS Final Report must accurately describe.

The new network of LANL R-wells that were installed in the regional aquifer during the past ten years as an activity of the LANL Hydrogeologic Workplan Project is displayed on Figure 2-1. Below are excerpts from the prepublication copy concerning the NAS committee's general findings on monitoring and data quality:

> Many if not all of the wells drilled into the regional aquifer under the Hydrogeologic Workplan appear to be compromised in their ability to produce water samples that are representative of ambient groundwater for the purpose of monitoring." p. 79.

In the above excerpt, the NAS committee is referring to the fact that all of the LANL R-wells, with greater than 80 discrete screened intervals, were drilled with methods that invaded the screened intervals with various drilling fluids and additives that have well known properties to mask the detection of many LANL contaminants, and especially the radionuclide contaminants produced from nuclear weapons research and manufacture, including isotopes of plutonium, americium, neptunium, cesium, and strontium.

In the excerpt below, the NAS committee is presenting their finding that the LANL scientists have not applied a valid geochemical process to the assessment that the screened intervals have recovered from the damage caused by the drilling additives.

> Any monitoring activity faces a conundrum: If little or no contamination is found, does it mean that there is in fact little or no contamination, or that the monitoring itself is flawed? During this study the committee was presented a good deal of information indicating that most or all wells into the regional aquifer at LANL (R-wells) are flawed for the purpose of monitoring. The committee did not disagree, but rather found a lack of basic scientific knowledge that could help ensure future success. Evidence about the conditions prevalent around the screens in the compromised wells is indirect—relying on plausible but unproven[3] chemical interactions, general literature data, analyses of surrogates, and apparent trends in sampling data that may not be statistically valid. p. 97.

[3] Not directly observed and measured under LANL site conditions.

In the last sentence in the above excerpt, the NAS committee is referring to the technically invalid scheme that is used in the LANL *Well Screen Analysis Report-Revision-2* (WSAR-2) for the assessment that the impacted well screens have "cleaned up" and are producing reliable and representative water samples. The geochemical criteria used in the WSAR-2 are not scientifically correct for the assessment that the screens have "cleaned up." In addition, the WSAR-2 fails to consider all of the factors that control the ability of each screened interval to be useful for the detection of the LANL groundwater contamination now and in the long-term.

The assessment in the WSAR-2 is only based on a study of water chemistry data from the impacted well screens and the NAS committee pointed out that the study only of water chemistry could not prove that a discrete screened interval had "cleaned up" to produce reliable and representative water quality data. The NAS committee described the need to perform field and laboratory studies of the properties of the drilling additives and of the new mineralogy formed by the additives.

Two earlier reports by the Environmental Protection Agency (EPA) (Ford, R., S.D. Acree, and R.R. Ross. 2006) (Ford, R., and S.D. Acree. 2006) also concluded that the study alone of water chemistry data could not be the sole criteria that a discrete screen produced reliable and representative water quality data. The EPA scientists concluded the:

1). LANL WSAR reports did not make the best use of the water quality data because the trends were not examined; instead the WSAR was only a "snapshot" study of the most recent water samples collected from a discrete screen,
2). Poor knowledge of the background water quality at the location of a given well limits the application of the use of water quality data and
3). Failure of the WSAR reports to study all of the factors that control if a discrete screened interval is useful for detection of the LANL contaminants. The factors include:
    a. overly long well screens that cause dilution,
    b. well screens installed too deep below the water table,
    c. well screens installed in geologic formations with low saturated hydraulic conductivity (Ksat) instead of in the nearby aquifer strata with high Ksat,
    d. reduction of the Ksat of the screened interval by the:
        i. invasion with the drilling additives,
        ii. new mineralogy formed by the drilling additives, or
        iii. mistakes in well construction that damaged the performance of the well screen. For example,
            a. plugging the screen with the bentonite clay/cement grout backfill materials,

b. plugging the well screen with slough sediments washed down the borehole wall during well construction, and

c. plugging by the collapse of the well screen, etc.).

The EPA scientists and the NAS committee both recommended for LANL/DOE to use drilling methods that prevented the invasion of screened intervals with any drilling fluids or additives. The recommendations on page 15 and 16 in the EPA report by Ford, R., S.D. Acree, and R.R. Ross. 2006 are below:

> 1. Strive to drill boreholes using no bentonite or organic additives within screened intervals. Additives may be used in intervals above the target monitoring zone if telescoping casing constructions are used and the hole is adequately cleaned before drilling the final footage within the interval to be screened. Targeting of monitoring intervals prior to drilling should be possible at locations where data from the existing characterization wells are available.
>
> 2. Use screen types and well designs that maximize the open area of the screen and allow for the most uniform and effective well development. Use aggressive development methods that result in water movement into and out of the well screen.
>
> 3. Minimize the time between drilling and well development, particularly if additives have been used within the screened zone. As indicated in Table 1, many of the hydrogeologic characterization wells were not developed in a timely fashion following well completion. It should be noted that the time between the drilling of any given interval in a multi-completion well and the development of that interval is often longer than the time lag calculated in this table. This time lag will often exacerbate the difficulties in removing residual drilling fluids.
>
> 4. At locations determined to be critical to the detection monitoring program, consider replacement of wells that were drilled using bentonite or that exhibit impacts due to organic additives with wells installed without additives in the screened zones, if needed to meet the DQOs for that monitoring location.
>
> 5. The path for resolution of issues concerning the impacts of drilling additives on the quality of ground-water samples should include identification of all well screens impacted by drilling additives, specification of the corrective actions to be taken, and field studies performed to verify these evaluations. Based on the uncertainty in characterizing the condition of aquifer materials adjacent to the well screens and the potentially long time frames that some impacts may last, installation of replacement wells at critical locations should also be considered."

The recommendations of the NAS committee for LANL/DOE to use drilling methods that prevent the invasion of the screened intervals with any drilling additives are below:

> ***Recommendation:*** *LANL should design and install new monitoring wells with the following attributes:*

• *A borehole drilled through the monitoring zone without the introduction of drilling muds or additives (i.e., use air or water),*
• *One screened interval that targets a single saturated zone, and*
• *A carefully planned design (length and depth) of the well screen, which is confirmed with information collected in the drilling process.* p. 98.

Further, the NAS recommends:

> For monitoring wells, given the uncertainties about effects of drilling muds and additives and the importance of minimizing alterations in the groundwater environment around screened intervals, the portion of the borehole to be sampled should be drilled to the extent possible with air or water as the circulating fluid. Advancing an outer casing to keep the borehole open can reduce or prevent the need for more complex drilling fluids. p. 89.

The recent successful use of the dry air-rotary reverse circulation casing advance drilling method for the installation of two deep monitoring wells in the regional aquifer, the R-35 a and b wells, is proof that drilling methods are available that prevent the invasion of any organic drilling agents, bentonite clay muds, or any other additives into the screened intervals of monitoring wells installed across the laboratory facility. The only drilling fluid used for drilling in the regional aquifer was air. The installation of the R-35 wells is discussed in Section 3.

The inappropriate use of no-purge sampling methods to collect water samples from most of the R-wells. The figure below presents the assessment of the well screens in the most recent version; revision-2 of the LANL *Well Screen Analysis Report*.

Figure of assessment of residual drilling effects in the LANL characterization wells

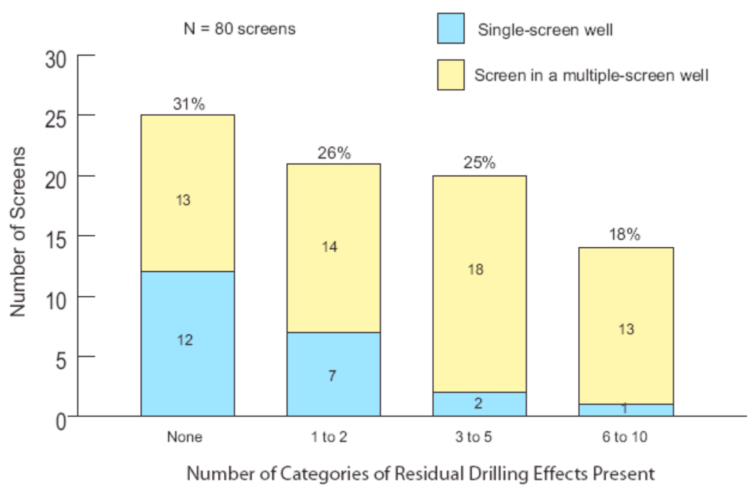

Figure ES-1. Number of categories of residual drilling effects present in the most recent sample from each screen (as of December 31, 2006)

Source: LANL *Well Screen Analysis Report-Revision 2.* LA-UR-07-2852, May 2007.

The above figure shows that 58 of the 80-screened intervals are in multiple-screen wells. The figure shows that an inherent problem with the assessment results in the WSAR-2 is that water samples are produced from 56 – *i.e.*, 70% of the screened intervals with no-purge sampling methods. Both the NAS committee and the staff of the New Mexico Environment Department describe the poor reliability of water samples collected with no-purge methods. Below is an excerpt from the NAS prepublication copy about the poor quality of the no-purge water samples:

> Given that drilling and well construction inevitably causes disturbance of the subsurface formation, industry experience is that typically the native geochemical and hydrological conditions tend to re-establish as groundwater flows around and through the well screen. To help ensure this re-equilibration, application of proper purging techniques in both well development and groundwater sampling is necessary for collection of representative groundwater samples, especially in the regional aquifer. The most trustworthy sampling technique includes purging three or more well volumes from the monitoring well before sample collection (ASTM D 4448, 1992). While this method requires containment and potential treatment of much more water that the minimum-purge techniques, it better ensures that samples from the developed wells represent the conditions in the nearby aquifer. Purging is much easier to control and complete with single-screened monitoring wells, as noted earlier. p. 90.

On September 18, 2006, the NMED issued a Notice of Disapproval (NOD) concerning the LANL *Well Screen Analysis Report-Revision 1*. Below are excerpts from the NOD on the requirement to purge water from the LANL monitoring wells:

> Despite the fact that the quality of water samples collected from a screen is closely associated with a sampling method, the Report [the LANL Well Screen Analysis Report] does not provide further analysis of the potential influence of sampling methods on the quality of water samples.
>
> The sampling method, specifically whether purging is conducted before collection of samples, may play a crucial role in determining the quality of water samples. This is especially critical if residual drilling fluids and bentonite are present around screened intervals in the affected wells. According to *Ground-Water Sampling Guidelines for Superfund and RCRA Project Managers* (EPA 542-S-02-001, 2002), monitoring wells must be purged so that water samples representative of formation water can be obtained. [Emphasis Added.]
>
> Purging is a safeguard against collecting a sample biased by stagnant water. Purging is also an efficient way to reduce the contact time of formation water with a screen and any surrounding areas impacted by drilling fluids or other anthropogenic influences on water quality, which helps to minimize the potential influence of such factors on water sample quality.

There needs to be caution with the NMED position in the third paragraph of the excerpt that purging is an efficient way to remedy the effects of the new mineralogy created by the drilling additives on water sample quality. In fact, for many of the LANL characterization wells, including also the single-screen wells, even purging very large amounts of groundwater may not ensure that representative water samples are collected for many of the LANL chemical and radionuclide contaminants. As the Northern New Mexico Citizens' Advisory Board, EPA and NAS have recommended, there is a need to perform field studies of the ability of purging large amounts of water to improve the ability of the LANL single-screen and multiple-screen characterization wells to produce reliable and representative water samples.

An additional reason the purging studies are necessary is because all of the LANL characterization wells are constructed with stainless steel screens and it is well known in the technical literature (US EPA, 1992) (Hewitt, 1994) (LANL, 2007) that corrosion of stainless steel screens results in the formation of coatings on the screens that have strong properties for the sorption of many radionuclide contaminants produced from nuclear weapons research and manufacture.

The failure of the LANL scientists to use valid geochemical concepts and to conduct the necessary geochemistry studies. The above discussion describes the failure of the LANL scientists and DOE managers to use appropriate geochemical criteria and even a valid sampling methodology to assess that the discrete screened intervals produce reliable and representative water samples.

The NAS committee also found that the LANL scientists and DOE managers have not performed the necessary geochemical investigations to understand the natural controls on how contaminants actually move, or don't move, along with groundwater. The NAS committee views on geochemistry and contaminant migration are summarized in the prepublication copy:

> As discussed in this section, geochemical interactions are important for contaminant migration. Like the hydrogeology, the geochemistry of the LANL site is quite complex. However, the committee received little evidence that LANL has sought to understand the geochemistry of contaminant migration at a level of detail comparable to the site investigations conducted under the Hydrogeologic Workplan. For example, the Synthesis Report (LANL, 2005a) that summarizes site characterization under the workplan is some 300 pages long but contains only a 50-page description of groundwater chemistry with no discussion of how this chemistry could affect contaminant migration. During the course of this study, few data were presented to the committee from laboratory experiments or field tests that would begin to quantify the general knowledge about geochemical effects on contaminant migration described in Sidebar 3.2 ["Chemical Factors that Affect the Migration of Contaminants in the Environment"] or to substantiate LANL's general observations and assumptions about the geochemical behavior of sorbing contaminants that have been described in this section. p. 45.

The geochemical effects described in Sidebar 3.2 include the

1). **solubility** of the contaminants in the natural *in situ* groundwater chemistry, 2). natural properties of the rock/water system that remove contaminants from groundwater by **sorption** processes including adsorption, ion exchange, and co-precipitation,

3). *in-situ* oxidation-reduction potential of the groundwater in the natural rock/water setting. The invasion of drilling fluids into the screened intervals caused a great upset to the natural **oxidation state,** and accordingly, a great change in the solubility of many of the radionuclide and hazardous contaminants,

4). mobility of contaminants because of the natural properties of the rock/water chemistry that form strong aqueous complexes with certain contaminants. Knowledge of the natural complexes is important to understand the mobility of the transuranic contaminants. The invasion of the screened intervals with the drilling fluids prevents characterization of the natural **complexation** chemistry, and

5). The role of **colloids** to increase the mobility of certain contaminants.

Gaining knowledge of the geochemical controls on the mobility of the LANL contaminants requires the installation of monitoring wells in pristine environments in the important aquifer strata. The LANL scientists and DOE managers have failed to do this because of the use of drilling methods that invaded the screened intervals with drilling fluids with properties to cause great changes to the natural chemistry. Gaining knowledge of how contaminants interact with the *in situ* rock/water chemistry requires the installation of monitoring wells in the future with the air rotary reverse circulation casing advance drilling methods that were used for the recent installation of the pair of R-35 wells.

<u>Special concern for increased mobility due to colloid transport</u>. The NAS committee was especially concerned about the failure of the LANL scientists to study the mobility of the radionuclide contaminants, such as plutonium, americium, neptunium and strontium, by colloids. Studies at other sites in the United States and Russia have determined that colloids are important for the transport of plutonium in both surface water and groundwater. The critical importance of colloidal transport is because of the ultra tiny amount of radionuclides that are a danger to public health.

For example, the EPA drinking water standard for strontium-90 is 8 picoCuries per liter (pCi/L) in terms of disintegration units. However, 8 pCi/L of strontium-90 represents a very tiny mass of strontium-90 in water of only 60 parts per quintillion. A part per quintillion progresses from a part per million, to billion, to trillion, to quadrillion, and then quintillion in steps of three order of magnitude, or 10^{-18}. The levels of plutonium, americium, and neptunium that are a danger to public health are also very tiny amounts with concern for transport as colloids. In addition, the concern to health is cumulative for the three transuranics with new studies that show the EPA drinking water standard for the combination of the three radionuclides should be reduced to 0.15 pCi/L. With the exception of the new R-35 wells, LANL does not have <u>any</u> monitoring wells in the regional aquifer or in perched zones of saturation that produce reliable water samples for the detection of the radionuclide contaminants discussed in this paragraph. Installation of a network of monitoring wells in pristine aquifer environments is a fundamental requirement for the design of field studies to characterize colloidal transport.

<u>Sparse monitoring between LANL sources of contamination, the Pueblo de San Ildefonso and the Buckman well field</u>. The NAS committee brought attention to the need to install additional monitoring wells on the property of the Pueblo de San Ildefonso. The Pueblo lands are between many sources of LANL contamination, the springs that discharge to the Rio Grande, and the Buckman well field, which supplies Santa Fe with 40% of its drinking water:

> Another area that appears to be undersampled is the Pueblo de San Ildefonso to the east of LANL, which is generally downgradient from the site. Plans to install monitoring wells on Pueblo lands under the Memorandum of Understanding[8] described in Section 3 of LANL (2006a) are a step in the right direction. Additional monitoring to ensure early detection of contaminant plumes beneath these Pueblo lands will likely be required. p. 73.

Figure 2-1 displays the Pueblo de San Ildefonso property between LANL and the Rio Grande, and the location of the Buckman well field east of the Rio Grande. The figure shows that the only LANL R-wells on the Pueblo property are the pair of R-10 wells and well R-34. Appendix A – Well R-34 presents a case history report of the mistakes in the installation of well R-34 that require the replacement of the well.

Figure 2-2 displays the results of computer modeling that show a fast pathway across the Pueblo de San Ildefonso between the hexavalent chromium plume known to be present below Mortandad Canyon and the Buckman well field. Well R-34 is along the fast pathway, but is not reliable for knowledge of groundwater contamination with hexavalent chromium or the other LANL contaminants.

In July 2004, CCNS released a report by George Rice, groundwater hydrologist, entitled, *New Mexico's Right to Know: The Potential for Groundwater Contaminants from LANL to Reach the Rio Grande.* Rice used LANL and NMED data to determine the travel time for a particle discharged from the Radioactive Liquid Waste Treatment Facility at TA-50 into Mortandad Canyon to springs discharging at the Rio Grande. For a distance of eight miles through various fast pathway strata, the travel time was estimated to be 26 years or less.

As noted in Figure 2-1, the distance from R-28, the site of the hexavalent chromium plume in Mortandad Canyon, to the Buckman well field is five miles. Using the Rice calculations, the travel time to the Buckman well field may be 16 year or less. We request that the Rice report be referenced in the revision to the prepublication copy of the NAS report.

Sentry Wells for the Buckman well field. Figure 2-1 shows the location of the pair of LANL characterization wells R-16 and R-16r. The two wells were installed as sentry wells for groundwater contamination traveling to the Buckman well field from the LANL legacy waste disposal sites Material Disposal Area (MDA) G and MDA L. The locations of the two MDAs are displayed on Figure 2-3. Appendix A presents a case history report of the mistakes in the installation of well R-16 that require the replacement of the well. Replacement of well R-16r may also be necessary because of the new mineralogy formed in the screened interval by the organic drilling additives. A field study with continuous pumping and time-series sampling is necessary to investigate the ability of well R-16r to produce valid water quality data.

A journal article by LANL scientists, Keating et al., described the need for the installation of more monitoring wells across the property of the Pueblo de San Ildefonso between LANL wells R-22 east of MDA G and well R-16. Below are excerpts from Keating, Elizabeth, B.A. Robinson, and V.V. Vesselinov, 2005, *Development and Application of Numerical Models to Estimate Fluxes through the Regional Aquifer beneath the Pajarito Plateau,* "Vadose Zone Journal," Volume 4, August 2005:

> The current understanding of hydrostratigraphy, as implemented in the numerical models, is sufficient to explain general trends in heads (spatial and temporal) but is lacking in a few key areas such as in the vicinity of R-9, R-12, R-22, and R-16. Detailed transport calculations in the vicinity of these wells would benefit from a refinement of the hydrostratigraphic framework model.
>
> The implication of this work for contaminant transport issues is that because of parameter ***uncertainty,*** predicted fluxes and velocities are quite ***uncertain. Uncertainties*** in permeability and porosity values lead to additional model ***uncertainty.*** These ***uncertainties*** can be reduced meaningfully with more data collection, including multi-well pumping and tracer tests. [Emphasis Added.]
>
> Travel times through the regional aquifer are poorly understood because of the lack of tracer tests and *in situ* measurements of effective porosity.
>
> Data concerning the spatial distribution of anthropogenic [LANL] contaminants in the regional aquifer has been inconclusive because of the exceptionally thick and complex vadose zone which makes it impossible to define the location and timing of contaminant entry to the regional aquifer.

There is a critical need for the installation of many additional monitoring wells to investigate the travel of LANL contaminants onto and across the property of the Pueblo de San Ildefonso. The hexavalent chromium plume is located immediately north of the Pueblo de San Ildefonso below Mortandad Canyon. The nature and extent of the chromium plume is not known at the present time. High levels of chromium contamination may be present in the groundwater on the Pueblo de San Ildefonso.

Figure 2-3 shows that the large legacy waste MDAs G and L are located immediately south of the property of the Pueblo de San Ildefonso. A large number of radionuclide and chemical contaminants were detected in the water samples produced from LANL characterization well R-22 during the first two years of water sampling. Mistakes in the installation of well R-22 prevent the well from producing valid water quality data. There is an immediate need to replace well R-22 with a cluster of new monitoring wells located immediately south of MDA G to investigate the groundwater contamination from MDA G.

Similarly, mistakes in the installation of LANL well R-21 prevent the well from producing valid water samples for knowledge of groundwater contamination from the large quantity of chemical wastes disposed of at MDA L. There is an immediate need to replace well R-21 with a new monitoring well located near well R-21 and with other wells located immediately at MDA L.

The NAS committee brought attention to the need for monitoring wells at the locations of the legacy waste disposal sites. The NAS committee brought attention to the need for installation of monitoring wells into the regional aquifer at the immediate location of the legacy waste disposal sites that are located in dry canyons and atop dry mesas such as MDA G and MDA L. Presently, LANL has no monitoring wells installed to meet this concern. From the prepublication copy:

> **Large waste disposal sites in the dry canyons and on dry mesas have not received as much attention as wet canyons and wet mesas because they presumably lack an aqueous driver to move contamination. The presumed dry locations have received minimal characterization with regards to the presence, strength and potential impact of aqueous drivers. In some of these, surface disturbances have led to unexpected increased infiltration rates. LANL provided few data to justify assumptions about the relative immobility of wastes at these sites.**
>
> > ***Recommendation:*** *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.* p. 108.

Sparse monitoring in the southern region of the LANL site. The NAS committee identified the need for the installation of more monitoring wells in the southern region of the laboratory. From the prepublication copy:

> In looking at the regional monitoring network, the committee found that the southern portion of LANL is one area of the regional aquifer that is currently very sparsely monitored (see Color Plate 10 – *i.e.,* see Figure 1). The committee assumes that this is

> mostly due to the general southward progression of the canyon investigation plans, and that the area will receive additional deep monitoring wells when the canyon investigation process advances to the southern canyons (Ancho, Chaquehui, and Frijoles Canyons). pp. 73 and 74.

Figure 2-1 shows the sparse monitoring in the southern region of the laboratory includes LANL characterization wells R-27 and R-31 and the old LANL test wells DT-5A, DT-9, and DT-10. The water quality data in the LANL website show that the screened intervals in wells R-27 and R-31 are impacted by drilling additives. In addition, well R-31 is a multiple-screen well where no-purge water samples are collected with the Westbay^{R} sampling system.

The old DT test wells have never produced valid water quality data because of the use of the mud-rotary drilling method, the overly long well screens, and the corrosion of the well screens. Well DT-5A is located in the setting of the legacy waste disposal site MDA AB where a very large quantity of plutonium is buried in shafts that were used for the hydro nuclear experiments in the early 1960s. The prepublication copy presents the concerns of the NAS committee for the contamination of groundwater from the legacy wastes buried in MDA AB:

> Solid wastes, e.g., the 25 material disposal areas (MDAs), and certain contaminants deemed by LANL to be essentially immobile (e.g., Pu) have the potential for impacting groundwater in the future. MDA AB in Technical Area-49 (TA-49), which contains some 2300 Ci of Pu-239, is an example. The committee received little information that would provide assurance that these sources are well understood or well controlled.
>
> ***Recommendation:*** *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.* p. 104.

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