APPENDIX F

SAMPLING/ANALYTICAL/FIELD METHOD

REGULATORY GUIDANCE

I. INVESTIGATION AND SAMPLING METHODS AND PROCEDURES

The purpose of this Appendix is to provide guidance on how to conduct field activities where environmental investigation, corrective action, sampling, or monitoring is being conducted or proposed. The site-specific RFI work plans should include the data quality objectives (DQOs) and the proposed methods to be used to conduct activities at each SWMU or AOC and, although not compulsory, generally should be prepared in accordance with the formats recommended in Appendix E of this Consent Order.

The methods used to conduct investigation, corrective action, and monitoring activities should be sufficient to achieve the DQOs presented in the work plan, fulfill the requirements of this Consent Order, and provide accurate data for the evaluation of site conditions, the nature and extent of contamination and Contaminant migration, and for corrective measures selection and implementation, where necessary. The methods presented in Section I.B of this Appendix (F) for environmental investigation and sampling are not intended to be an exhaustive inventory of the possible methods that may be necessary to fulfill the requirements of this Consent Order. The methods for conducting investigations, corrective actions, and monitoring must be determined based on the DQOs and conditions and Contaminants that exist at each SWMW or AOC.

DOE may propose alternative methods for data collection from those included in this Appendix (F). Such alternative methods should be discussed with NMED prior to implementation.

I.A. Standard Operating Procedures

DOE should provide a brief description of investigation, sampling or analytical methods and procedures in documents submitted to NMED. DOE may reference relevant Standard Operating Procedures as presented on the Los Alamos National Laboratory (LANL) website. The reference should include the appropriate Internet address.

I.B. Investigation, Sampling, and Analysis Methods

I.B.1. Introduction and Purpose

This Section (I.B) of this Appendix (F) provides recommendations for field investigations, sample collection, handling and screening procedures, field and laboratory sample analysis, and quality assurance procedures for samples of the medium being investigated or tested at the Facility.

The purpose of this Section (I.B) is to: 1) provide recommendations for drilling and sample collection in exploratory borings and other excavations; 2) provide recommendations for sampling of the target media; 3) provide recommendations for monitoring of groundwater and vadose zone conditions; and 4) identify screening, analytical, and quality assurance procedures that should be implemented during field sampling activities and laboratory analyses.

The quality assurance procedures referenced in the previous paragraph include: 1) the Facility investigation DQOs; 2) the methods for QA/QC recommended during field investigations and by the analytical laboratories; and 3) the methodology for the review and evaluation of the field and laboratory QA/QC results and documentation.

I.B.2. Field Exploration Activities

Exploratory borings should be advanced as approved by NMED in site-specific work plans. Any additional boring locations, if required, may be determined by DOE or NMED, consistent with the Consent Order. The depths and locations of all exploratory and monitoring well borings should be specified in the site-specific work plans submitted to NMED for approval prior to the start of the respective field activities.

I.B.3. Subsurface Features/Utility Geophysical Surveys

DOE should conduct surveys to locate underground utilities, pipelines, structures, drums, debris, and other buried features, including buried waste, in the shallow subsurface prior to the start of field exploration activities. The methods used to conduct the surveys, such as magnetometer, ground penetrating radar, resistivity, or other methods, should be selected based on the characteristics of the site and the possible or suspected underground structures. The results of the surveys should be included in the investigation reports submitted to NMED. DOE is responsible for locating and clearing all above- and below-ground utilities or other hazards at any site prior to conducting field work.

I.B.4. Drilling and Soil, Rock, and Sediment Sampling

I.B.4.a)Drilling

Exploratory and monitoring well borings should be drilled using the most effective, proven, and practicable method for recovery of undisturbed samples and potential Contaminants.

DOE should propose drilling methods in the site-specific work plans submitted for each subject area. Exploratory borings should be advanced to the unit- and location-specific depths specified in the work plan and approved by NMED. The borings should be advanced in accordance with the following guidance:

- In all borings, 25 ft below the deepest detected contamination based on field screening, laboratory analyses, and/or previous investigations at the site.
- Twenty ft below the base of disposal units if contamination is not detected.
- Five ft below the base of shallow structures such as piping or building sumps, foundations, footings, or other building structures.
- Five ft below the contact between canyon alluvium and bedrock.
- Five feet below the alluvial groundwater table.
- One hundred ft below the deepest known intermediate perched groundwater zone.
- One hundred ft below the top of the regional aquifer.
- Depths specified by NMED based on regional or unit specific data needs.

Precautions should be taken to prevent the migration of Contaminants between geologic, hydrologic, or other identifiable zones during drilling and well installation activities. Reasonable efforts should be made to isolate Contaminant zones from other zones encountered in the borings.

The drilling and sampling should be accomplished under the direction of a qualified engineer or geologist who should maintain a detailed log of the materials and conditions encountered in each boring. Both sample information and visual observations of the cuttings and core samples should be recorded on the boring log. Known site features and/or site survey grid markers should be used as references to locate each boring prior to surveying the location as described in Section I.B.2.f of this Appendix (F). The boring locations should be measured to the nearest foot, and locations should be recorded on a scaled site map upon completion of each boring.

Trenching and other exploratory excavation methods should follow the applicable general procedures outlined in this Appendix (F). The particular methods proposed for use by DOE for exploratory excavation and sampling at any specific unit should be included in the site-specific investigation work plan submitted to NMED.

I.B.4.b) Soil and Rock Sampling

Relatively undisturbed discrete soil and rock samples should be obtained, where possible, during the advancement of each boring for the purpose of logging, field screening, and analytical testing. The samples should be collected in accordance with the following guidance:

- At the depth immediately below the base of the disposal unit or facility structure and at the fill-native soil interface.
- At the maximum depth of each boring.
- At the depths of contacts or first encounter, observed during drilling, with geologic units of different lithology, structural or textural characteristics, or of relatively higher or lower permeability.
- Of soil or rock types relatively more likely to sorb or retain Contaminants than surrounding lithologies.
- At the depth of the first encounter, during drilling, with shallow or intermediate saturated zones.
- At intervals suspected of being source or contaminated zones.
- At the top of the regional aquifer.
- At other intervals approved or required by NMED.

The sampling interval for the borings may be modified, or samples may be obtained from a specific depth, based on field observations. A decontaminated split-barrel sampler lined with brass sleeves, a coring device, or other method approved by NMED should be used to obtain samples during the drilling of each boring.

A split barrel sampler lined with brass sleeves or a coring device is the preferred sampling method for borehole soil, rock, and sediment sampling. The following procedures should be followed if a split barrel sampler is used. Upon recovery of the sample, one or more brass sleeves should be removed from the split barrel sampler and the open ends of the sleeves covered with Teflon tape or foil and sealed with plastic caps fastened to the sleeves with tape for shipment to the analytical laboratory. If brass sleeves are not used, a portion of the sample should be directly placed in pre-cleaned, laboratory-prepared sample containers for laboratory chemical analysis. Encore™ samplers or equivalent sampling devices are preferred for collection of solid samples for VOC analysis, if brass sleeves are not used. The remaining portions of the sample should be used for logging and field screening, as described in Sections I.B.2.c and I.B.2.d of this Appendix (F), respectively.

Discrete samples should be collected for field screening and laboratory analyses. Homogenization of discrete samples collected for analyses other than for VOC and SVOC analyses should be performed by the analytical laboratory, if homogenization is necessary. DOE may submit site-specific, alternative methods for homogenization of samples in the field to NMED for review and written approval.

Samples to be submitted for laboratory analyses should be selected based on: 1) the results of the field screening or mobile laboratory analyses; 2) the position of the sample relative to groundwater, suspected releases, or site structures; 3) the sample location relative to former or altered site features or structures; 4) the stratigraphy encountered in the boring; and 5) the specific objectives and requirements of this Consent Order. The proposed number of samples and analytical parameters should be included as part of the site-specific work plan submitted to NMED for approval prior to the start of field investigation activities at each unit. In accordance with Section XIII.C, work plans should allow for flexibility in modifying the project-specific tasks based on information obtained during the course of the investigation.

1. Sediment Sampling

Sediment samples should be collected in the same manner as described in Section I.B.2.b.ii for soil and rock sampling where borings are drilled to explore alluvial subsurface conditions. The sampling device should be a decontaminated, hand-held stainless steel coring device, shelby tube, thin-wall sampler, or other device approved by NMED where sediment sampling is conducted without the use of the drilling methods described in Section I.B.2.b.i of this Appendix (F). The samples should be transferred to pre-cleaned laboratory prepared containers for submittal to the laboratory. Samples obtained for volatiles analysis should be collected using Encore™ or equivalent samplers, shelby tubes, thin-wall samplers, or other device approved by NMED. With the exception of Encore™ or equivalent samplers, the ends of the samplers should be lined with Teflon tape or aluminum foil and sealed with plastic caps fastened to the sleeves with tape for shipment to the analytical laboratory.

The physical characteristics of the sediment (such as mineralogy, ASTM soil classification, rock classification, moisture content, texture, color, presence of stains or odors, and/or field screening results), depth where each sample was obtained, method of sample collection, and other observations should be recorded in the field log.

I.B.4.c) Investigation Derived Waste

Investigation derived waste (IDW) includes general refuse, drill cuttings, excess sample material, water (decontamination, development and purge), and disposable equipment generated during the course of investigation, corrective action, or monitoring activities. Drill cuttings, excess sample material and decontamination fluids, and all other IDW should be contained and characterized using methods based on the boring location, boring depth, drilling method, and type of Contaminants suspected or encountered. Proposed IDW management should be included with the unit-specific investigation work plan submitted to NMED for approval prior to the start of field investigations. Borings not completed as groundwater or vapor monitoring wells should be abandoned in accordance with the recommended methods listed in Section II.D of this Appendix (F). Borings completed as groundwater monitoring wells should be constructed in accordance with the recommendations described in Section II.C of this Appendix (F).

I.B.4.d) Logging of Soil/Rock and Sediment Samples

Samples obtained from all exploratory borings and excavations should be visually inspected and the soil or rock type classified in general accordance with ASTM D2487 (Unified Soil Classification System) and D2488, (Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)). Detailed logs of each boring should be completed in the field by a qualified engineer or geologist. Additional information, such as the presence of water-bearing zones and any unusual or noticeable conditions encountered during drilling should be recorded on the logs. Field boring logs, test pit logs, and field well construction diagrams should be converted to the format acceptable for use in final reports submitted to NMED. If requested, draft boring logs, test pit logs, and well construction diagrams should be submitted to NMED for review within thirty (30) days after the completion of each boring or monitoring well.

I.B.4.e) Soil, Rock, and Sediment Sample Field Screening

Samples obtained from borings should be screened in the field for evidence of the potential presence of Contaminants. Field screening results should be recorded on the exploratory boring and excavation logs. Field screening results are used as a general guideline to determine the nature and extent of possible contamination. In addition, screening results should be used to aid in the selection of soil, rock, sediment, and vapor-phase samples for laboratory analysis. NMED recognizes that field screening alone will not detect the possible presence or full nature and extent of all Contaminants that may be encountered at the site.

The primary screening methods to be used should include: 1) visual examination; 2) headspace vapor screening for VOCs; and 3) metals screening using X-ray fluorescence (XRF). Additional screening for site- or release-specific characteristics such as pH, high-explosives (HE), or for other specific compounds using field test kits should be conducted where appropriate.

Headspace vapor screening should target VOCs and should be conducted by placing a soil or rock sample in a plastic sample bag or a foil-sealed container allowing space for ambient air. The container should be sealed and then shaken gently to expose the soil or rock to the air trapped in the container. The sealed container should be allowed to rest for a minimum of five minutes while vapors equilibrate. Vapors present within the sample bag headspace should then be measured by inserting the probe of the instrument in a small opening in the bag or through the foil. The maximum value and the ambient air temperature should be recorded on the field boring or test pit log for each sample. The monitoring instruments should be calibrated each day to the manufacturer’s standard for instrument operation. A photo-ionization detector (PID) equipped with a 10.6 or higher electron volt (eV) lamp, combustible gas indicator, or other instrument approved by NMED may be used for VOC field screening. The limitations, precision, and calibration procedures of the instrument to be used for VOC field screening should be included in the site-specific investigation work plan prepared for each unit.

XRF may be used to screen soil, rock, or sediment samples for the presence of metals. XRF screening requires proper sample preparation and proper instrument calibration. Sample preparation and instrument calibration procedures should be documented in the field logs. The methods and procedures for sample preparation and instrument calibration should be determined prior to the start of field activities. Field XRF screening results for selected metals may be used in lieu of laboratory analyses; however, the results should, at a minimum, be confirmed by laboratory analyses at a frequency of 20 percent (one sample per every five analyzed by XRF analysis).

Field screening results are site- and boring-specific and the results vary with instrument type, media screened, weather conditions, moisture content, soil or rock type, and type of Contaminant. DOE should record on the field logs all conditions capable of influencing the results of field screening. DOE should submit to NMED conditions potentially influencing field screening results as part of the site-specific investigation, corrective action, or monitoring reports.

DOE should submit the samples with the greatest apparent degree of contamination, based on field observations and field screening, for laboratory analysis. DOE should also use the location of the sample relative to groundwater, stratigraphic units or contacts, and the proximity to significant site or subsurface features or structures as a guideline for sample selection. In addition, DOE should submit the samples with no or little apparent contamination, based on field screening, for laboratory analysis if the intention is to confirm that the base (or other depth interval) of a boring or other sample location is not contaminated.

I.B.4.f) Soil, Rock, and Sediment Sample Types

DOE should collect soil, rock, and sediment samples at the frequencies outlined in the site-specific investigation, corrective action, or monitoring work plans for each SWMU, AOC, or other site submitted by DOE for review and written approval by NMED. The samples collected should be representative of the media and site conditions being investigated or monitored. DOE should collect QA/QC samples to monitor the validity of the soil, rock, and sediment sample collection procedures. Field duplicates should be collected at a rate of ten percent. DOE should collect equipment blanks from all sampling apparatus at a frequency of ten percent for chemical analysis. Equipment blanks should be collected at a frequency of one per day if disposable sampling equipment is used. DOE should collect field blanks at a frequency of one per day for each medium (with the exception of air samples) at each SWMU or AOC. Reagent blanks should be used if chemical analytical procedures requiring reagents are employed in the field as part of the investigation or monitoring program. The resulting data will provide information on the variability associated with sample collection, handling, and laboratory analysis operations. The blanks and duplicates should be submitted for laboratory analyses associated with the project-specific Contaminants, data quality concerns, and media being sampled.

I.B.4.g) Sample Point and Structure Location Surveying

The horizontal and vertical coordinates of the top of each monitoring well casing and the ground surface at each monitoring well location should be determined by a registered New Mexico professional land surveyor in accordance with the State Plane Coordinate System (NMSA 1978 47-1-49 through 56 (Repl. Pamp. 1993)). The surveys should be conducted in accordance with Sections 500.1 through 500.12 of the Regulations and Rules of the Board of Registration for Professional Engineers and Surveyors Minimum Standards for Surveying in New Mexico. Alternative survey methods may be proposed by DOE in site-specific work plans. Any alternative survey method must be discussed with NMED prior to implementation. Horizontal positions should be measured to the nearest 0.1-ft, and vertical elevations should be measured to the nearest 0.01-ft. DOE should prepare site map(s), certified by a registered New Mexico professional land surveyor, presenting all surveyed locations and elevations including relevant site features and structures for submittal with all associated reports to NMED.

Site attributes (e.g., soil sample locations, sediment sample locations, springs, outfalls, pertinent structures, monitoring stations, as well as staked out sampling grids) should be located by using the global positioning system (GPS), the electronic total station with prism reflectors, or a combination of both surveying systems, or by using a registered New Mexico Registered Land Surveyor using the methods described in the paragraph above. Horizontal locations should be measured to the nearest 0.5 ft.

I.B.4.h) Subsurface Vapor-phase Monitoring and Sampling

Samples of subsurface vapors should be collected from vapor monitoring points from both discrete zones, selected based on investigation and field screening results, and as total well subsurface vapor samples.

DOE should, at a minimum, collect vapor samples for field measurement of the following:

- Percent oxygen;
- Organic vapors (using a photo-ionization detector with an 11.7 eV (electron volt) lamp, a combustible vapor indicator or other method;
- Percent carbon dioxide;
- Static subsurface pressure; and
- Other parameters (such as carbon monoxide and hydrogen sulfide) if required by NMED.

DOE also should collect vapor samples for laboratory analysis of the following as required:

- Percent moisture;
- VOCs; and
- Other analytes if requested.

Vapor samples analyzed by the laboratory for percent moisture and VOCs should be collected using SUMMA canisters or other equivalent sample collection method. The samples should be analyzed for VOC concentrations by EPA Method TO-15, as it may be updated, or equivalent VOC analytical method.

Field vapor measurements, the date and time of each measurement, and the instrument used should be recorded on a vapor monitoring data sheet. The instruments used for field measurements should be calibrated daily in accordance with the manufacturer’s specifications. The methods used to obtain vapor-phase field measurements and samples should be discussed with NMED prior to the start of air monitoring at each SWMU, AOC, or other site where vapor-phase monitoring is conducted.

I.B.5. Groundwater Monitoring

I.B.5.a)Groundwater Levels

Groundwater levels should be obtained, either through manual measurements or using a water-level pressure transducer, prior to purging in preparation for a sampling event. If the transducer is malfunctioning and manual water-level measurements cannot be obtained, historical water level data may be used to meet the water level measurement requirement, to calculate purge volume, and to allow sampling to proceed.

The depth to groundwater should be recorded relative to the surveyed well casing rim or other surveyed datum, and should be measured and recorded at levels of accuracy consistent with manufacturers specifications.

Where possible, monitoring wells that are routinely sampled should be equipped with pressure transducers to measure and record water levels on a regular basis. The pressure transducer recording frequency will vary depending on the monitoring objectives for the well, but should always be less than 24 hours, and more typically 1-2 hours.

I.B.5.b) Surface Water Measurements

Stream flow rates within each watershed should be measured in conjunction with sampling events.

I.B.5.c) Groundwater Sampling

Groundwater samples should initially be obtained from newly installed alluvial monitoring wells between ten (10) and thirty (30) days after completion of well development. Groundwater samples should initially be obtained from newly installed intermediate zone and regional aquifer monitoring wells between ten (10) and sixty (60) days after completion of well development. Groundwater monitoring and sampling should be conducted at an interval agreed to by NMED and DOE after the initial sampling event. All monitoring wells within a watershed or area-specific monitoring group should be sampled within twenty one (21) days of the start of the groundwater sampling event. Sampling should be conducted in accordance with an NMED-approved groundwater monitoring work plan, if applicable.

Groundwater samples should be collected from all saturated zones, where possible, within exploratory borings not intended to be completed as monitoring wells prior to abandonment of the borings.

I.B.5.d) Well Purging

Monitoring wells should be purged prior to sampling to remove stagnant water and to ensure that samples collected are representative. The U.S. Environmental Protection Agency (EPA) outlines two purging methods to remove stagnant water from a well casing before sampling: the “low-flow approach” and the “well-volume approach.” Either approach is valid, and can provide representative samples, depending on the well construction and aquifer characteristics.

To ensure groundwater samples are as representative as possible, field parameter stability criteria for purging should be based on guidance or recommendations by the EPA, the USGS or other current perspectives for groundwater sampling. In some cases, purge-volume and/or field-parameter stability requirements cannot be met or special sampling requirements may need to be implemented. In these cases, well-specific sampling protocols may be applied.

Groundwater quality field parameters measured during purging include pH, specific conductance, dissolved oxygen concentrations, turbidity, redox potential, and temperature. Where possible, the groundwater quality parameters should be measured using a flow-through cell and a multiparameter meter. The volume of groundwater purged, the instruments used, and the readings obtained at each interval should be recorded on the field monitoring log, or in an electronic equivalent log on a computer or mobile device.

Groundwater samples should be obtained from each well after field parameters have stabilized, and sufficient volume has been purged to ensure that the sample is representative of formation water. The groundwater samples should be collected in appropriate, clean, laboratory-prepared containers provided by the analytical laboratory. Recommended sample handling and chain-of-custody procedures are described in Sections I.B.6. and I.B.9.of this Appendix (F). Decontamination procedures should be established for reusable water sampling equipment as described in Section I.B.3 of this Appendix (F).

All purged groundwater should be characterized based on the results of the analysis of water samples from the well from which the purge water originated or by direct sampling and analysis of the purge water. Purge water should be land applied if it meets the criteria in the NMED-approved Notice of Intent (NOI) for land application of groundwater. If the purge water is RCRA hazardous, it should be managed in accordance with appropriate hazardous waste management requirements.

I.B.5.e) Surface Water Sample Collection

Surface water samples should be collected using methods agreed to by the Parties. Samples should be collected in clean laboratory-prepared sampling containers. The methods and instruments used to measure field parameters should be agreed to by the Parties prior to conducting surface water sampling. The sampling and monitoring techniques used and the measurements obtained should be recorded in the field monitoring reports.

I.B.5.f) Groundwater and Surface Water Sample Types

Groundwater samples should be collected from monitoring wells identified in the monitoring plan, and surface water samples should be collected at predetermined locations identified in the plan. Field duplicates, field blanks, equipment rinsate blanks, reagent blanks, if necessary, and trip blanks should be obtained for quality assurance during water sampling activities. The samples should be handled as described in Sections I.B.6. and I.B.9. of this Appendix (F).

Quality assurance/quality control sample collection including field duplicates, field blanks, equipment rinsate blanks, performance evaluation blanks (PEBs), and trip blanks should be described and collected in accordance with an approach presented in each annual Interim Facility-Wide Groundwater Monitoring Plan.

I.B.6. Sample Handling

The following recommended procedures should be used when collecting samples during investigation, corrective action, and monitoring activities:

I.B.6.a) Neoprene, nitrile, or other protective gloves should be worn when collecting samples. All samples collected of each medium for chemical analysis should be transferred into clean sample containers supplied by the project analytical laboratory with the exception of soil, rock, and sediment samples obtained in brass sleeves or in Encore™ or equivalent samplers. Upon recovery of the sample collected using split barrel samplers with brass sleeves, the brass sleeves should be removed from the split barrel sampler and the open ends of the sleeves should be lined with Teflon tape or foil and sealed with plastic caps. The caps should be fastened to the sleeve with tape for storage and shipment to the analytical laboratory. The sample depth and the top of the sample should be clearly marked. Sample container volumes and preservation methods should be in accordance with the most recent EPA SW-846 and established industry practices for use by accredited analytical laboratories. Sufficient sample volume should be obtained for the laboratory to complete the method-specific QC analyses on a laboratory-batch basis.

I.B.6.b) Sample labels and documentation should be completed for each sample following procedures included in the site-specific work plans approved by NMED. Immediately after the samples are collected, they should be stored in a cooler with ice or other appropriate storage method until they are delivered to the analytical laboratory. Standard chain-of-custody procedures, as described in Section I.B.6.b of this Appendix (F), should be followed for all samples collected. All samples should be submitted to the laboratory soon enough to allow the laboratory to conduct the analyses within the method holding times. Where possible, samples should be submitted to the laboratory within 48 hours after their collection.

Shipment procedures should include the following:

- Individual sample containers should be packed to prevent breakage and transported in a sealed cooler with ice or other suitable coolant or other EPA or industry-wide accepted method. The drainage hole at the bottom of the cooler should be sealed and secured in case of sample container leakage. Temperature blanks should be included with each shipping container.
- Each cooler or other container should be delivered directly to the analytical laboratory.
- Glass bottles should be separated in the shipping container by cushioning material to prevent breakage.
- Plastic containers should be protected from possible puncture during shipping using cushioning material.
- The chain-of-custody form and sample request form should be shipped inside the sealed storage container to be delivered to the laboratory.
- Chain-of-custody seals should be used to seal the sample-shipping container in conformance with EPA protocol.
- Signed and dated chain-of-custody seals should be applied to each cooler prior to transport of samples from the site.

I.B.6.c) In-situ Testing

In-situ permeability tests, corrective measures system pilot tests, stream flow tests, and other tests conducted to evaluate site and subsurface conditions should be designed to accommodate specific site conditions and to achieve the test objectives. The tests should be conducted in order to appropriately represent site conditions and in accordance with USGS, ASTM or other methods generally accepted by the industry. Detailed logs of all relevant site conditions and measurements should be maintained during the testing events. A summary of the general test results, including unexpected or unusual test results and equipment failures or testing limitations should be reported to NMED. The summary should be presented in a format acceptable to NMED and in general accordance with the report formats recommended in Appendix E.

I.B.6.d) Decontamination Procedures

The objective of the decontamination procedures is to minimize the potential for cross-contamination. A designated decontamination area should be established for decontamination of drilling equipment, reusable sampling equipment and well materials. The drilling rig should be decontaminated prior to entering the site or unit. Drilling equipment or other exploration equipment that may come in contact with the borehole should be decontaminated by steam cleaning, by hot-water pressure washing, or by other method prior to drilling each new boring.

Sampling or measurement equipment, including but not limited to, stainless steel sampling tools, split-barrel or core samplers, well developing or purging equipment, groundwater quality measurement instruments, and water level measurement instruments, should be decontaminated in accordance with the following procedures or other methods before each sampling attempt or measurement:

- Brush equipment with a wire or other suitable brush, if necessary or practicable, to remove large particulate matter.
- Rinse with potable tap water.
- Wash with nonphosphate detergent or other detergent (examples include Fantastik™, Liqui-Nox®) followed by a tap water rinse.
- Rinse with 0.1 M nitric acid (to remove trace metals, if necessary) followed by a tap water rinse.
- Rinse with methanol (to remove organic compounds, if necessary) followed by a tap water rinse.
- Rinse with potable tap water.
- Double rinse with deionized water.

All decontamination solutions should be collected and stored temporarily as described in Section I.B.5 of this Appendix (F). Decontamination procedures and the cleaning agents used should be documented in the daily field log.

I.B.7. Field Equipment Calibration Procedures

Field equipment requiring calibration should be calibrated to known standards, in accordance with the manufacturers' recommended schedules and procedures. At a minimum, calibration checks should be conducted daily, or at other intervals consistent with the manufacturer’s specifications, and the instruments should be recalibrated, if necessary. Calibration measurements should be recorded in the daily field logs. If field equipment becomes inoperable, its use should be discontinued until the necessary repairs are made. In the interim, a properly calibrated replacement instrument should be used.

I.B.8. Collection and Management of Investigation Derived Waste

All IDW should be properly characterized and disposed of in accordance with all Federal, State, and local rules and regulations for storage, labeling, handling, transport, and disposal of waste. DOE should include a description of anticipated management of IDW as part of the applicable work plan submitted to NMED for review prior to disposal of any IDW produced during investigation, corrective action, or monitoring activities. All water generated during sampling and decontamination activities should be temporarily stored at satellite accumulation areas or transfer stations in labeled 55-gallon drums or other containers until proper characterization and disposal can be arranged. The IDW may be characterized for disposal based on the known or suspected Contaminants potentially present in the waste.

I.B.9. Documentation of Field Activities

I.B.9.a) General

Daily field activities, including observations and field procedures, should be recorded on appropriate forms. The original field forms should be maintained at the Facility. Copies of the completed forms should be maintained in a bound and sequentially numbered field file for reference during field activities. Indelible ink should be used to record all field activities. Alternatively, electronic field forms may be maintained on a routinely backed up server. Photographic documentation of field activities should be performed, as appropriate. The daily record of field activities should include the following:

- Site or unit designation;
- Date;
- Time of arrival and departure;
- Field investigation team members including subcontractors and visitors;
- Weather conditions;
- Daily activities and times conducted;
- Observations;
- Record of samples collected with sample designations and locations specified;
- Photographic log;
- Field monitoring data, including health and safety monitoring if conditions arise that require modification of required work;
- Equipment used and calibration records, if appropriate;
- List of additional data sheets and maps completed;
- An inventory of the waste generated and the method of storage or disposal; and
- Signature of personnel completing the field record.

I.B.9.b) Sample Custody

All samples collected for analysis should be recorded in the field report or data sheets. Chain-of-custody forms should be completed at the end of each sampling day, prior to the transfer of samples off site, and should accompany the samples during shipment to the laboratory. A signed and dated custody seal should be affixed to the lid of the shipping container. Upon receipt of the samples at the laboratory, the custody seals will be broken, the chain-of-custody form should be signed as received by the laboratory, and the conditions of the samples should be recorded on the form. The original chain-of-custody form should remain with the laboratory and copies should be returned to the relinquishing party. DOE should maintain copies of all chain-of-custody forms generated as part of sampling activities. Copies of the chain-of-custody records (either paper copies or electronically scanned in PDF format) should be included with all draft and final laboratory reports submitted to NMED.

I.C. Chemical Analyses

DOE should submit all samples for laboratory analysis to accredited contract laboratories. The laboratories should use the most recent EPA and/or industry-accepted extraction and analytical methods for chemical analyses for target analytes as the testing methods for each medium sampled.

DOE should submit a list of analytes and analytical methods to NMED for review and written approval as part of each site-specific investigation, corrective action, or monitoring work plan. The detection and reporting limits for each method should be less than applicable background, screening, or regulatory cleanup levels. The preferred method reporting (practical quantitation) limits are a maximum of 20 percent of the cleanup, screening, or background levels. Analyses conducted with detection limits that are greater than applicable background, screening, and regulatory cleanup levels should be considered data quality exceptions and the reasons for the elevated detection limits should be reported to NMED. These data should not be used for statistical analyses. All analytical data (non-detects, estimated values, and detects) should be included in the electronic copy of the investigation report in Microsoft™ Excel format with qualifiers as attached from the analytical laboratory. The summary tables should include only detects of the data based on the corresponding qualifiers. DOE should not censor the data based on detection limits, quantitation limits, or measurement uncertainty.

I.C.1. Laboratory QA/QC Requirements

The following recommendations for laboratory QA/QC procedures should be considered the minimum QA/QC standards for the laboratories employed by DOE that provide analytical services for environmental investigation, corrective action, and monitoring activities conducted at the Facility.

- Quality Assurance Procedures

Contract analytical laboratories should maintain internal quality assurance programs in accordance with EPA and industry-wide accepted practices and procedures. At a minimum, the laboratories should use a combination of standards, blanks, surrogates, duplicates, matrix spike/matrix spike duplicates (MS/MSD), blank spike/blank spike duplicates (BS/BSD), and laboratory control samples to demonstrate analytical QA/QC. The laboratories should establish control limits for individual chemicals or groups of chemicals based on the long-term performance of the test methods. In addition, the laboratories should establish internal QA/QC that meets EPA's laboratory certification requirements. The specific procedures that should be completed are identified in the following sections.

I.C.1.a)Equipment Calibration Procedures and Frequency

The laboratories' equipment calibration procedures, calibration frequency, performance criteria, and calibration standards should be in accordance with the EPA test methodology requirements and documented in the laboratories' quality assurance and SOP manuals. All instruments and equipment used by the laboratory should be operated, calibrated, and maintained according to manufacturers' guidelines and recommendations as well as governing analytical methods. Operation, calibration, and maintenance should be performed by personnel who have been properly trained in these procedures. A routine schedule and record of instrument calibration and maintenance should be kept on file at the laboratory.

I.C.1.b) Laboratory QA/QC Samples

Analytical procedures should be evaluated by analyzing reagent or method blanks, surrogates, MS/MSDs, BS/BSDs, and laboratory duplicates, as appropriate for each method. The laboratory QA/QC samples and frequency of analysis to be completed should be documented in the cited EPA or other accepted test methodologies. At a minimum, the laboratory should analyze laboratory blanks, MS/MSDs, BS/BSDs, and laboratory duplicates at a frequency of one in twenty for all batch runs requiring EPA test methods and at a frequency of one in ten for non-EPA test methods or as required by the governing methodology. Laboratory batch QA/QC samples should be specific to the project.

I.C.1.c) Laboratory Deliverables

The laboratory analytical data package should be prepared in accordance with EPA-established Level III or IV analytical support protocol. The following should be provided in the analytical laboratory reports either electronically or in hard (paper) copy for this project:

- Transmittal letter, including information about the receipt of samples, the testing methodology performed, any deviations from the required procedures, any problems encountered in the analysis of the samples, any data quality exceptions, and any corrective actions taken by the laboratory relative to the quality of the data contained in the report.
- Sample analytical results, including sampling date; date of sample extraction or preparation; date of sample analysis; dilution factors and test method identification; soil, rock, or sediment sample results in consistent units (mg/kg) or micrograms per kilogram in dry-weight basis; water sample results in consistent units (milligrams per liter or micrograms per liter (µg/L)); vapor sample results in consistent units (ppmv or $\mu g/m^3$); and detection limits for undetected analytes. Results should be reported for all field samples, including field duplicates and blanks, submitted for analysis.
- Method blank results, including detection limits for undetected analytes.
- Surrogate recovery results and corresponding control limits for samples and method blanks (organic analyses only).

- MS/MSD and/or BS/BSD spike concentrations, percent recoveries, relative percent differences (RPDs), and corresponding control limits.
- Laboratory duplicate results for inorganic analyses, including relative percent differences and corresponding control limits.
- Sample chain-of-custody documentation.
- Holding times and conditions.
- Conformance with required analytical protocol(s).
- Instrument calibration.
- Blanks.
- Detection/quantitation limits.
- Recoveries of surrogates.
- Variability for duplicate analyses.
- Completeness.
- Data report formats.
- The following data deliverables for organic compounds should be required from the laboratory:
    - A cover letter referencing the procedure used and discussing any analytical problems, deviations, and modifications, including signature from authority representative certifying to the quality and authenticity of data as reported;
    - Report of sample collection, extraction, and analysis dates, including sample holding conditions;
    - Tabulated results for samples in units as specified, including data qualification in conformance with EPA protocol, and definition of data descriptor codes;
    - Reconstructed ion chromatograms for gas chromatograph/mass spectrometry (GC/MS) analyses for each sample and standard calibration;
    - Selected ion chromatograms and mass spectra of detected target analytes (GC/MS) for each sample and calibration with associated library/reference spectra;
    - Gas chromatograph/electron capture device (GC/ECD) and/or gas chromatograph/flame ionization detector (GC/FID) chromatograms for each sample and standard calibration;
    - Raw data quantification reports for each sample and calibrations, including areas and retention times for analytes, surrogates, and internal standards;
    - A calibration data summary reporting calibration range used and a measure of linearity [include decafluorotriphenylphosphine (DFTPP) and p-bromofluorobenzene (BFB) spectra and compliance with tuning criteria for GC/MS];
    - Final extract volumes (and dilutions required), sample size, wet-to-dry weight ratios, and instrument practical detection/quantitation limit for each analyte;
    - Analyte concentrations with reporting units identified, including data qualification in conformance with the CLP Statement of Work (SOW) (include definition of data descriptor codes);
    - Quantification of analytes in all blank analyses, as well as identification of method blank associated with each sample;
    - Recovery assessments and a replicate sample summary, including all surrogate spike recovery data with spike levels/concentrations for each sample and all MS/MSD results (recoveries and spike amounts) when analyzed; and

    - Report of tentatively identified compounds with comparison of mass spectra to library/reference spectra.
- The following data deliverables for inorganic compounds should be required from the laboratory:
    - A cover letter referencing the procedure used and discussing any analytical problems, deviations, and modifications; including signature from authority representative certifying to the quality and authenticity of data as reported;
    - Report of sample collection, digestion, and analysis dates, with sample holding conditions;
    - Tabulated results for samples in units as specified, including data qualification in conformance with the CLP SOW (including definition of data descriptor codes);
    - Results of all method QA/QC checks, including inductively coupled plasma (ICP) Interference Check Sample and ICP serial dilution results;
    - Tabulation of instrument and method practical detection/quantitation limits;
    - Raw data quantification report for each sample;
    - A calibration data summary reporting calibration range used and a measure of linearity, where appropriate;
    - Final digestate volumes (and dilutions required), sample size, and wet-to-dry weight ratios;
    - Quantification of analytes in all blank analyses, as well as identification of method blank associated with each sample; and
    - Recovery assessments and a replicate sample summary, including post-digestate spike analysis; all MS data (including spike concentrations) for each sample, if accomplished; all MS results (recoveries and spike amounts); and laboratory control sample analytical results).

DOE should present summary tables of these data and Level II QA/QC results to NMED in the formats described in Appendix E of this Consent Order. The raw analytical data, including calibration curves, instrument calibration data, data calculation work sheets, and other laboratory support data for samples from this project, should be compiled and kept on file at the Facility for reference.

I.C.2. Review of Field and Laboratory QA/QC Data

DOE should evaluate the sample data, field, and laboratory QA/QC results for acceptability with respect to the DQOs. Each group of samples should be compared with the DQOs and evaluated using data validation guidelines contained in EPA guidance documents, the most recent version of SW-846, and industry-accepted QA/QC methods and procedures. DOE should contact NMED of laboratory notification of data quality exceptions that may affect the ability to meet the objectives of the investigation or compliance activity in order to discuss the implications and determine whether the data will still be considered acceptable or if sample re-analysis or resampling is necessary. DOE should summarize the results of the discussion with NMED regarding the data quality exceptions via email.

I.C.2.a)Blanks, Field Duplicates, Reporting Limits and Holding Times

The analytical results of field blanks and field rinsate blanks should be reviewed to evaluate the adequacy of the equipment decontamination procedures and the possibility of cross-contamination caused by decontamination of sampling equipment. The analytical results of trip blanks should be reviewed to evaluate the possibility for contamination resulting from the laboratory-prepared sample containers or the sample transport containers. The analytical results of laboratory blanks should be reviewed to evaluate the possibility of contamination caused by the analytical procedures. If Contaminants are detected in field or laboratory blanks, the sample data should be qualified, as appropriate.

I.C.2.b) Field Duplicates

Field duplicates should consist of two samples either split from the same sample device or collected sequentially. Field duplicate samples should be collected at a minimum frequency of ten percent of the total number of samples submitted for analysis. RPDs for field duplicates should be calculated. A precision of no more than 20 percent for duplicates should be considered acceptable for soil, rock, and sediment sampling conducted at the Facility. The analytical DQO for precision should be used for water duplicates.

I.C.2.c)Method Reporting Limits

Method reporting limits for sample analyses for each medium should be established at the lowest level practicable for the method and analyte concentrations and should not exceed soil, groundwater, surface water, or vapor emissions background levels, cleanup standards, or screening levels. The preferred method detection limits are a maximum of 20 percent of the background, screening, or cleanup levels. Detection limits that exceed established soil, groundwater, surface water, or air emissions cleanup standards, screening levels, or background levels and are reported as “not detected” should be considered data quality exceptions and an explanation for the exceedance and its acceptability for use should be provided.

I.C.2.d) Holding Times

DOE should review the sampling, extraction, and analysis dates to confirm that extraction and analyses were completed within the recommended holding times, as specified by EPA protocol. Appropriate data qualifiers should be noted if holding times were exceeded.

I.C.3. Representativeness and Comparability

I.C.3.a) Representativeness

Representativeness is a qualitative parameter related to the degree to which the sample data represent the relevant specific characteristics of the media sampled. DOE should implement procedures to assure representative samples are collected and analyzed, such as repeated measurements of the same parameter at the same location over several distinct sampling events. DOE should note any procedures or variations that may affect the collection or analysis of representative samples and should qualify the data.

I.C.3.b) Comparability

Comparability is a qualitative parameter related to whether similar sample data can be compared. To assure comparability, DOE should report analytical results in appropriate units for comparison with other data (past studies, comparable sites, screening levels, or cleanup standards), and should implement standard collection and analytical procedures. Any procedure or variation that may affect comparability should be noted and the data should be qualified.

I.C.4. Laboratory Reporting, Documentation, Data Reduction, and Corrective Action

Upon receipt of each laboratory data package, data should be evaluated against the criteria outlined in the previous sections. Any deviation from the established criteria should be noted and the data will be qualified. A full review and discussion of analytical data QA/QC and all data qualifiers should be submitted as appendices or attachments to investigation and monitoring reports prepared in accordance with Appendix E of this Consent Order. Data validation procedures for all samples should include checking the following, when appropriate:

- Holding times;
- Detection limits;
- Field equipment rinsate blanks;
- Field blanks;
- Field duplicates;
- Trip blanks;
- Reagent blanks;
- Laboratory duplicates;
- Laboratory blanks;
- Laboratory matrix spikes;
- Laboratory matrix spike duplicates;
- Laboratory blank spikes;
- Laboratory blank spike duplicates; and
- Surrogate recoveries.

If significant quality assurance problems are encountered, appropriate corrective action should be implemented. All corrective action should be defensible and the corrected data should be qualified.

II. MONITORING WELL CONSTRUCTION REQUIREMENTS

II.A. Types of Monitoring Wells

Three types of groundwater monitoring wells have been installed at the Facility: alluvial, intermediate, and regional wells. In addition, vadose zone monitoring wells may be required for subsurface vapor monitoring. Alluvial wells are shallow wells which monitor groundwater or the vadose zone in the alluvium located in the canyon bottoms. Intermediate wells monitor perched groundwater or the vadose zone beneath the Facility and generally extend from depths of approximately 100 to 700 ft below ground surface. Regional wells monitor the deep regional aquifer beneath the Facility and generally are deeper than 700 ft below ground surface.

The well construction, installation, and completion procedures for these wells differ because each well monitors a different stratigraphic horizon and at different depths. General drilling procedures are presented in Section II.B and monitoring well construction recommendations are presented in Section II.C of this Appendix (F).

II.B. Drilling Methods

Groundwater and vadose zone monitoring wells and piezometers should be designed, constructed and developed in a manner which will most likely yield high quality samples, best enable the well to last the duration of the project, and best ensure that the well will not serve as a conduit for Contaminants to migrate between different stratigraphic units or aquifers. The design, construction, and development of monitoring wells should 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;
- 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.

A variety of methods are available for drilling, constructing, and developing monitoring wells. While the selection of the drilling, construction, and development procedures is usually based on the site-specific geologic conditions, the following issues should also be considered:

- Drilling should be performed in a manner that minimizes impacts to the natural properties of the subsurface materials.
- Contamination and cross-contamination of groundwater and aquifer materials during drilling and construction should be avoided.
- The drilling method should allow for the collection of representative samples of rock, unconsolidated materials, and soil.
- The drilling method should allow DOE to determine when the appropriate location for the screened interval(s) has been encountered.
- The drilling method should allow for the proper placement of the filter pack and annular sealants. The borehole diameter should 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 drilling method should allow for the collection of representative vapor and groundwater samples. Drilling fluids (which includes air) should be used only when necessary and in a manner that minimizes impact to the surrounding formation and groundwater.

A brief description of the different drilling methods that may be appropriate for the construction of monitoring wells at the Facility follows. Many of these methods may be used alone, or in combination, to install monitoring wells at the Facility. While the selection of the specific drilling, construction and development procedures will usually depend on the site-specific geologic conditions, justification for the method selected should be provided through Drilling Work Plans to NMED for approval prior to commencing drilling.

II.B.1. Hollow-Stem Auger

The hollow-stem continuous flight auger consists of a hollow, steel shaft with a continuous, spiraled steel flight welded onto the exterior site of the stem. The stem is connected to an auger bit and, when rotated, transports cuttings to the surface. The hollow stem of the auger allows drill rods, split-spoon core barrels, Shelby tubes, and other samplers to be inserted through the center of the auger so that samples may be retrieved during the drilling operations. The hollow stem also acts to temporarily case the borehole, so that the well screen and casing (riser) may be inserted down through the center of the augers once the desired depth is reached, minimizing the risk of possible collapse of the borehole. A bottom plug or pilot bit can be fastened onto the bottom of the augers to keep out most of the soils and/or water that have a tendency to clog the bottom of the augers during drilling. Drilling without a center plug is acceptable provided that the soil plug, formed in the bottom of the auger, is removed before sampling or installing well casings. The soil plug can be removed by washing out the plug using a side discharge rotary bit, or augering out the plug with a solid-stem auger bit sized to fit inside the hollow-stem auger. In situations where heaving sands are a problem, potable water may be poured into the augers to equalize the pressure so that the inflow of formation materials and water should be held to a minimum when the bottom plug is removed. The hollow-stem auger method is best suited for drilling shallow overburden wells.

II.B.2. Air Rotary/Air Down-The-Hole Hammer/ODEX

The air rotary method consists of a drill pipe or drill stem coupled to a drill bit that rotates and cuts through soils and rock. The cuttings produced from the rotation of the drilling bit are transported to the surface by compressed air, which is forced down the borehole through the drill pipe and returns to the surface through the annular space (between the drill pipe and the borehole wall). The circulation of the compressed air not only removes the cuttings from the borehole but also helps to cool the drill bit. The use of air rotary drilling is best suited for hard-rock formations. In soft unconsolidated formations, casing is driven to keep the formation from caving. When using air rotary, the air compressor should have an in-line filter system to filter the air coming from the compressor. The filter system should be inspected regularly to insure that the system is functioning properly. In addition, a cyclone velocity dissipator or similar air containment/dust-suppression system should be used to funnel the cuttings to one location instead of allowing the cuttings to discharge uncontrolled from the borehole. Air rotary that employs the dual-tube (reverse circulation) drilling system is acceptable because the cuttings are contained within the drill stem and are discharged through a cyclone velocity dissipator to the ground surface.

The injection of air into the borehole during air rotary drilling has the potential to alter the natural properties of the subsurface. This can occur through air-stripping of the VOCs in both soil and groundwater in the vicinity of the borehole, altering the groundwater geochemical parameters (e.g., pH and redox potential), and potentially increasing biodegradation of organic compounds in the aquifer near the borehole. These factors may prevent the well from yielding vapor or groundwater samples that are representative of in-situ conditions.

In hard, abrasive, consolidated rock, a down-the-hole hammer may be the more appropriate air rotary method. In this method, compressed air is used to actuate and operate a pneumatic hammer as well as lift the cuttings to the surface and cool the hammer bit. One drawback of the down-the-hole hammer is that oil is required in the air stream to lubricate the hammer-actuating device, and this oil could potentially contaminate the soil in the vicinity of the borehole and the aquifer.

The ODEX method is a variation of the air rotary method in which a casing-driving technique is used in combination with air rotary drilling. With the ODEX system, the drill bit extends outward and reams a pilot hole large enough for a casing assembly to slide down behind the drill bit assembly. As a result, casing is advanced simultaneously while drilling the hole.

II.B.3. Water Rotary and Mud Rotary

The water and mud rotary drilling methods consist of rotary drilling techniques where water or drilling mud is used as the circulating fluid. In both methods, the circulating fluid is pumped down through the drill pipe and is returned back up the borehole through the annular space. The circulating fluid stabilizes the borehole, cools the drill bit, and carries the drill cuttings up to the surface. While the water and mud rotary drilling techniques are rapid and effective drilling methods, the recognition of water-bearing zones is hampered by the addition of water into the system.

Mud rotary drilling is similar to water rotary drilling with the exception that mud additives are added to the water to change the properties (e.g., density, viscosity, yield point, gel strength, fluid-loss-control effectiveness, and lubricity) of the circulating fluid. Drilling muds provide greater borehole stabilization than water alone. There are several types of mud presently available, including bentonite, barium sulfate, organic polymers, cellulose polymers, and polyacrylamides. While drilling muds enhance the stability of the borehole and allow for drilling in formations not appropriate to other methods, they can adversely affect the hydrologic properties and geochemistry of the aquifer. For example, drilling fluid invasion and the buildup of borehole filter cake may reduce the effective porosity of the aquifer in the vicinity of the borehole. In addition, bentonite drilling muds may affect the pH of groundwater and organic polymer drilling muds have been observed to facilitate bacterial growth, which reduces the reliability of sampling results. If polymer emulsions are to be used in the drilling program at the Facility, polymer dispersion agents should 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) should be used to disperse and chemically breakdown the polymer prior to developing and sampling the well.

II.B.4. Dual-Wall Reverse Circulation

The dual-wall reverse circulation drilling method utilizes a double-wall drill pipe and has the reverse circulation of other conventional rotary drilling methods. The circulating fluid (water or air) is pumped down the borehole between the outer and inner drill pipe, and returns up the inner drill pipe. Cuttings are lifted to the surface through the inner drill pipe. The inner drill pipe rotates the bit, and the outer drill pipe acts as a casing and stabilizes the borehole. Typically, a tri-cone bit is used when drilling through unconsolidated formations and a down-the-hole hammer is used in hard rock.

The dual-wall reverse circulation rotary method is one of the better methods available for obtaining representative and continuous formation samples while drilling. If a roller cone bit is used, the formation that is being drilled is located only a few inches ahead of the double-wall pipe. As a result, the cuttings observed at the surface represent no more than one foot of the formation at any point in time.

When drilling with air, an in-line filter should be used to remove oil or other impurities from the airstream. However, if a down-the-hole hammer is used, it should be used with caution since it requires oil in the airstream to lubricate the hammer. This could possibly introduce Contaminants to the borehole and aquifer.

II.B.5. Resonant Sonic

Resonant sonic drilling is a method that uses a sonic drill head to produce high-frequency, high-force vibrations in a steel drill pipe. The vibrations in the pipe create a cutting action at the bit face, which allows a continuous core of the formation to move into a core barrel. The method requires no drilling fluid, drills very fast (up to one ft/sec in certain formations), drills at any angle through most formations (rock, clay, sand, boulders, permafrost, glacial till), and yields virtually no cuttings in the drilling process. This drilling method has been tested by DOE and used at various DOE facilities.

II.B.6. Cryogenic

Cryogenic drilling is a technique that uses standard air rotary drilling methods, but employs cold nitrogen gas as the circulating fluid instead of compressed air. The use of nitrogen gas as the circulation fluid freezes the borehole wall while drilling, which stabilizes unconsolidated sediments and prevents potential cross-contamination of different water-bearing zones. In addition, the method produces fewer cuttings than liquid based drilling methods, requires minimal equipment modifications to existing drill rigs, and does not add Contaminants to the borehole during the drilling process due to the benign nature of nitrogen gas. The method is especially applicable for drilling through alternating hard (competent) and soft (unconsolidated) formations. This drilling method has been tested by DOE and proposed for future use at various DOE facilities.

II.C. Well Construction/Completion Methods

II.C.1. Well Construction Materials

Well construction materials should be selected based on the goals and objectives of the proposed monitoring program and the geologic conditions at the site. When selecting well construction materials, the primary concern should be selecting materials that will not contribute foreign constituents or remove Contaminants from the vadose zone or groundwater. Other factors to be considered include the tensile strength, compressive strength, and collapse strength of the materials; length of time the monitoring well will be in service; and the material's resistance to chemical and microbiological corrosion. Generally, if the monitoring program requires the analysis of organic Contaminants, stainless steel or fluoropolymer materials should be used. However, if the monitoring program requires only inorganic Contaminant analyses, polyvinyl chloride (PVC) materials may be used. PVC is less desirable for monitoring wells where organic Contaminants will be analyzed due to its potential for sorption and leaching of Contaminants. If stainless steel is used for monitoring wells where low levels of metals may be present, the steel must be passivated to minimize sorption and leaching of metals.

Well screen and casing materials acceptable for the construction of RCRA monitoring wells include stainless steel (304 or 316), rigid PVC (meeting American National Standards Institute/National Sanitation Foundation Standard 14), and fluoropolymer materials (polytetrafluoroethylene, fluorinated ethylene propylene, and polyvinylidene). In addition, there are other materials available for the construction of monitoring wells including acrylonitrile butadiene styrene (ABS), fiberglass-reinforced plastic (FRP), black iron, carbon steel, and galvanized steel, but these materials are not recommended for use in long term monitoring wells due to their low resistance to chemical attack and potential contribution of contamination to the groundwater. However, these materials may be used in the construction of monitoring wells where they will not be in contact with the groundwater that will be sampled (e.g., carbon steel pipe used as surface casing).

II.C.2. Well Construction Techniques

II.C.2.a) Single-Cased Wells

The borehole should be bored, drilled, or augered as close to vertical as possible, and checked with a plumb bob, level, or appropriate downhole logging tool. Slanted boreholes should not be acceptable unless specified in the design. The borehole should be of sufficient diameter so that well construction can proceed without major difficulties. To assure an adequate size, a minimum two-inch annular space is recommended between the casing and the borehole wall (or the hollow-stem auger wall). The two-inch annular space around the casing will allow the filter pack, bentonite seal, and annular grout to be placed at an acceptable thickness. Also, the two-inch annular space will allow up to a 1.5-inch outer diameter tremie pipe to be used for placing the filter pack, bentonite seal, and grout at the specified intervals.

It may be necessary to overdrill the borehole so that any soils that have not been removed (or that have fallen into the borehole during augering or drill stem retrieval) will fall to the bottom of the borehole below the depth where the filter pack and well screen are to be placed. Normally, three to five ft is sufficient for overdrilling shallow wells. Deep wells may require deeper overdrilling.

The borehole can also be overdrilled to allow for an extra space for a well sump to be installed. If the borehole is overdrilled deeper than desired, it can be backfilled to the designated depth with bentonite pellets or the filter pack.

The well casings (riser assembly) should be secured to the well screen by flush-jointed threads or other appropriate connections and placed into the borehole and plumbed by the use of centralizers, a plumb bob, or a level. No petroleum-based lubricating oils or grease should be used on casing threads. Teflon tape can be used to wrap the threads to insure a tight fit and minimize leakage. No glue of any type should be used to secure casing joints. Teflon "O" rings can also be used to ensure a tight fit and minimize leakage. "O" rings made of materials other than Teflon should not be used if the well will be sampled for organic compound analyses. Before the well screen and casings are placed at the bottom of the borehole, at least six inches of filter material should be placed at the bottom to serve as a firm footing. The string of well screen and casing should then be placed into the borehole and plumbed. If centralizers are used, they should be placed below the well screens and above the upper transition sand so that the placement of the filter pack, overlying bentonite seal, and annular grout will not be hindered. Centralizers placed in the wrong locations can cause bridging during material placement. If installing the well screen and casings through hollow-stem augers, the augers should be slowly extracted as the filter pack, bentonite seal, and grout are tremied or poured into place. The gradual extraction of the augers will allow the materials being placed in the augers to flow out of the bottom of the augers into the borehole. If the augers are not gradually extracted, the materials will accumulate at the bottom of the augers causing potential bridging problems. After the string of well screen and casing is plumb, the filter material should be placed around the well screen (preferably by the tremie pipe method) up to the designated depth. After the filter pack has been installed, the bentonite seal should be placed directly on top of the filter pack up to the designated depth or a minimum of two ft above the filter pack, whichever is greater. After the bentonite seal has hydrated for the specified time, the annular sealant should be pumped by the tremie method into the annular space around the casings (riser assembly) up to within two ft of the ground surface or below the frost line, whichever is greater. The grout should be allowed to cure for a minimum of 24 hours before the surface pad and protective casing are installed. After the surface pad and protective casing are installed, bumper guards (guideposts) should be installed (if necessary).

II.C.2.b) Double-Cased Wells

Double-cased wells should be constructed when there is reason to believe that interconnection of two aquifers by well construction may cause cross contamination, or when flowing sands make it impossible to install a monitoring well using conventional methods. A pilot borehole should be advanced through the overburden and the contaminated zone into a clay, confining layer, or bedrock. An outer casing (surface or pilot casing) should be placed into the borehole and sealed with grout. The borehole and outer casing should extend into tight clay a minimum of two ft or into competent bedrock a minimum of one foot. The total depth into the clay or bedrock will vary depending upon the plasticity of the clay and the extent of weathering and fracturing of the bedrock. The size of the outer casing should be of sufficient inside diameter to contain the inner casing and the two-inch annular space. In addition, the borehole should be of sufficient size to contain the outer casing and the two-inch minimum outer annular space, if applicable.

The outer casing should be grouted by the tremie method from the bottom of the borehole to within two ft of the ground surface. The grout should be pumped into the annular space between the outer casing and the borehole wall. This can be accomplished by either placing the tremie pipe in the annular space and pumping the grout from the bottom of the borehole to the surface, or placing a grout shoe or plug inside the casing at the bottom of the borehole and pumping the grout through the bottom grout plug and up the annular space on the outside of the casing. The grout should consist of a Type I Portland cement and bentonite or other approved grout to provide a rigid seal. A minimum of 24 hours should be allowed for the grout plug (seal) to cure before attempting to drill through it. When drilling through the seal, care should be taken to avoid cracking, shattering, and washing out of the seal. If caving conditions exist so that the outer casing cannot be sufficiently sealed by grouting, the outer casing should be driven into place and a grout seal placed in the bottom of the casing.

II.C.2.c) Bedrock Wells

The installation of monitoring wells into bedrock can be accomplished in two ways. The first method is to drill or bore a pilot borehole through the soil overburden into the bedrock. An outer casing is installed into the borehole by setting it into the bedrock, and grouting it into place. After the grout has set, the borehole can be advanced through the grout seal into the bedrock. The preferred method of advancing the borehole into the bedrock is rock coring. Rock coring makes a smooth, round hole through the seal and into the bedrock without cracking or shattering the seal. Roller cone bits are used in soft bedrock, but extreme caution should be taken when using a roller cone bit to advance through the grout seal in the bottom of the borehole because excessive water and bit pressure can cause cracking, eroding (washing), and/or shattering of the seal. Low volume air hammers may be used to advance the borehole, but they have a tendency to shatter the seal because of the hammering action. If the structural integrity of the grout seal is in question, a pressure test can be utilized to check for leaks. If the seal leaks, the seal is not acceptable. When the drilling is complete, the finished well will consist of an open borehole from the ground surface to the bottom of the well. The major limitation of open borehole bedrock wells is that the entire bedrock interval serves as the monitoring zone.

The second method is to install the outer surface casing and drill the borehole into bedrock, and then install an inner casing and well screen with the filter pack, bentonite seal, and annular grout. The well is completed with a surface protective casing and concrete pad. This well installation method gives the flexibility of isolating the monitoring zone(s) and minimizing inter-aquifer flow. In addition, it gives structural integrity to the well, especially in unstable areas (e.g., steeply dipping shales) where the bedrock has a tendency to shift or move when disturbed.

II.C.3. Well Screen and Filter Pack Design

Well screens and filter packs should be designed to accurately sample the vadose zone interval or aquifer zone that the well is intended to target, minimize the passage of formation materials (turbidity) into the well, and ensure sufficient structural integrity to prevent the collapse of the intake structure. The selection of the well screen length depends upon the objective of the well. Piezometers and wells where only a discrete flow path is monitored are generally completed with short screens (two ft or less). While monitoring wells are usually constructed with longer screens (usually five to twenty ft), they should be kept to the minimum length appropriate for intercepting a Contaminant plume. The screen slot size should be selected to retain from 90 to

100 percent of the filter pack material in artificially filter packed wells, and from 50 to 100 percent of the formation material in naturally packed wells. All well screens should be factory wire-wrapped or machine slotted.

A filter pack should be used when: 1) the natural formation is poorly sorted; 2) a long screen interval is required or the screen spans highly stratified geologic materials of widely varying grain sizes; 3) the natural formation is uniform fine sand, silt, or clay, 4) the natural formation is thin-bedded; 5) the natural formation is poorly cemented sandstone; 6) the natural formation is highly fractured or characterized by relatively large solution channels; 7) the natural formation is shale or coal that will act as a constant source of turbidity to groundwater samples; or 8) the diameter of the borehole is significantly greater than the diameter of the screen. The use of natural formation material as a filter pack is only recommended when the natural formation materials are relatively coarse-grained, permeable, and uniform in grain size.

Filter pack materials should consist of clean, rounded to well-rounded, hard, insoluble particles of siliceous composition (industrial grade quartz sand or glass beads). The required grain-size distribution or particle sizes of the filter pack materials should be selected based upon a sieve analysis of the aquifer materials or the formation to be monitored, or the characteristics of the aquifer materials using information acquired during previous investigations.

Where sieve analyses are used to select the appropriate filter pack particle size, the results of a sieve analysis of the formation materials are plotted on a grain-size distribution graph, and a grain-size distribution curve is generated. The 70 percent retained grain size value should be multiplied by a factor between four and six (four for fine, uniform formations and six for coarse, non-uniform formations). A second grain-size distribution curve is then drawn on the graph for this new value, ensuring that the uniformity coefficient does not exceed 2.5. The filter pack that should be used will fall within the area defined by these two curves.

Once the filter pack size is determined, the screen slot size should be selected to retain at least 90 percent of the filter pack material. DOE may propose the use of a pre-determined well screen slot size and filter pack for monitoring wells in the site-specific work plans submitted to NMED.

The filter pack should be installed in a manner that prevents bridging and particle-size segregation. Filter packs placed below the water table should be installed by the tremie pipe method. Filter pack materials should not be poured into the annular space unless the well is shallow (e.g., less than 30 ft deep) and the filter pack material can be poured continuously into the well without stopping. At least two inches of filter pack material should be installed between the well screen and the borehole wall, and two ft of material should extend above the top of the well screen. A minimum of six-inches of filter pack material should also be placed under the bottom of the well screen to provide a firm footing and an unrestricted flow under the screened area. In deep wells (e.g., greater than 200 ft deep), the filter pack may not compress when initially installed. As a result, filter packs may need to be installed as high as five ft above the screened interval in these situations. The precise volume of filter pack material required should be calculated and recorded before placement, and the actual volume used should be determined and recorded during well construction. Any significant discrepancy between the calculated and actual volume should be explained. Prior to installing the filter pack annular seal, a one to two-ft layer of chemically inert fine sand should be placed over the filter pack to prevent the intrusion of annular sealants into the filter pack.

II.C.4. Annular Sealant

The annular space between the well casing and the borehole should be properly sealed to prevent cross-contamination of samples and the groundwater. The materials used for annular sealants should be chemically inert with respect to the highest anticipated concentration of Contaminants expected in the groundwater or vadose zone at the Facility. In general, the permeability of the sealing material should be one to two orders of magnitude lower than the least permeable parts of the formation in contact with the well. The precise volume of annular sealants required should be calculated and recorded before placement, and the actual volume should be determined and recorded during well construction. Any significant discrepancy between the calculated volume and the actual volume should be explained.

During well construction, an annular seal should be placed on top of the filter pack and any transition sand. This seal should consist of a high solids (10-30 percent) bentonite material in the form of bentonite pellets, granular bentonite, or bentonite chips. The bentonite seal should be placed in the annulus through a tremie pipe if the well is deep (greater than 30 ft), or by pouring directly down the annulus in shallow wells (less than 30 ft). If the bentonite materials are poured directly down the annulus (which is an acceptable method only in wells less than 30 feet deep), a tamping device should be used to ensure that the seal is emplaced at the proper depth and the bentonite has not bridged higher in the well casing. The bentonite seal should be placed above the filter pack a minimum of two ft vertical thickness. The bentonite seal should be allowed to completely hydrate in conformance with the manufacturer's specifications prior to installing the overlying annular grout seal. The time required for the bentonite seal to completely hydrate will differ with the materials used and the specific conditions encountered, but is generally a minimum of four to 24 hours.

A grout seal should be installed on top of the filter pack annular seal. The grout seal may consist of a high solids (30 percent) bentonite grout, a neat cement grout, or a cement/bentonite grout. The grout should be pumped under pressure (not gravity fed) into the annular space by the tremie pipe method, from the top of the filter pack annular seal to within a few ft of the ground surface. The tremie pipe should be equipped with a side discharge port (or bottom discharge for grouting at depths greater than 100 feet) to minimize damage to the filter pack or filter pack annular bentonite seal during grout placement. The grout seal should be allowed to cure for a minimum of 24 hours before the concrete surface pad is installed. All grouts should be prepared in accordance with the manufacturer's specifications. High solids (30 percent) bentonite grouts should have a minimum density of ten pounds per gallon (as measured by a mud balance) to ensure proper setup. Cement grouts should be mixed using six and one-half to seven gallons of water per 94-pound bag of Type I Portland cement. Bentonite (five to ten percent) may be added to delay the setting time and reduce the shrinkage of the grout.

II.C.5. Well Development

All groundwater monitoring wells should be developed to create an effective filter pack around the well screen, correct damage to the formation caused by drilling, remove fine particles from the formation near the borehole, and assist in restoring the natural water quality of the aquifer in the vicinity of the well. Development stresses the formation around the screen, as well as the filter pack, so that mobile fines, silts, and clays are pulled into the well and removed. Development is also used to remove any foreign materials (e.g., water, drilling mud) that may have been introduced into the borehole during the drilling and well installation activities, and to aid in the equilibration that will occur between the filter pack, well casing, and the formation water. The development of a well is extremely important to ensuring the collection of representative groundwater samples.

Newly installed groundwater monitoring wells should not be developed for at least 48 hours after the surface pad and outer protective casing are installed. This will allow sufficient time for the well materials to cure before the development procedures are initiated. A new monitoring well should be developed until the column of water in the well is free of visible sediment, and the pH, temperature, turbidity, and specific conductivity have stabilized. In most cases, the above requirements can be satisfied. However, in some cases, the pH, temperature, and specific conductivity may stabilize but the water remains turbid. In this case, the well may still contain well construction materials, such as drilling mud in the form of a mud cake or formation soils that have not been washed out of the borehole. Thick drilling mud cannot be flushed out of a borehole with one or two well volumes of flushing. Instead, continuous flushing over a period of several days may be necessary to complete the well development. If the well is pumped dry, the water level should be allowed to sufficiently recover before the next development period is initiated. The common methods used for developing wells include:

- Pumping and overpumping;
- Backwashing;
- Surging (with a surge block);
- Bailing;
- Jetting; and
- Airlift pumping.

These development procedures can be used, either individually or in combination, to achieve the most effective well development. However, the most favorable well development methods include pumping, overpumping, bailing, surging, or a combination of these methods. Well development methods and equipment that alter the chemical composition of the groundwater should not be used. Development methods that involve adding water or other fluids to the well or borehole, or that use air to accomplish well development should be avoided, if possible. If water is introduced to a borehole during well drilling and completion, then the same or greater volume of water should be removed from the well during development. In addition, the volume of water withdrawn from a well during development should be recorded.

II.C.6. Surface Completion

Monitoring wells may be completed either as flush-mounted wells, or as above-ground completions. A surface seal should be installed over the grout seal and extended vertically up the well annulus to the land surface. The lower end of the surface seal should extend a minimum of one foot below the frost line to prevent damage from frost heaving. The composition of the surface seal should be neat cement or concrete. In above-ground completions, a three-feet wide, four-inch thick concrete surface pad should be installed around the well at the same time the protective casing is installed. The surface pad should be sloped so that drainage will flow away from the protective casing and off the pad. In addition, a minimum of one inch of the finished pad should be below grade or ground elevation to prevent washing and undermining by soil erosion.

A locking protective casing should be installed around the well casing (riser) to prevent damage or unauthorized entry. The protective casing should be anchored in the concrete surface pad below the frost line and extend several inches above the well riser stickup. A weep hole should be drilled into the protective casing just above the top of the concrete surface pad to prevent water from accumulating and freezing inside the protective casing around the well riser. A cap should be placed on the well riser to prevent tampering or the entry of foreign materials, and a lock should be installed on the protective casing to provide security. If the wells are located in an area that receives traffic, a minimum of three bumper guards consisting of steel pipes three to four inches in diameter and a minimum of five-feet length should be installed. The bumper guards should be installed to a minimum depth of two feet below the ground surface in a concrete footing and extend a minimum of three feet above ground surface. The pipes should be filled with concrete to provide additional strength. The pipes should be painted a bright color to reduce the possibility of vehicular damage.

If flush-mounted completions are required (e.g., in active roadway areas), a protective structure such as a utility vault or meter box should be installed around the well casing. In addition, measures should be taken to prevent the accumulation of surface water in the protective structure and around the well intake. These measures should include outfitting the protective structure with a steel lid or manhole cover that has a rubber seal or gasket, and ensuring that the bond between the cement surface seal and the protective structure is watertight.

II.D. Well Abandonment

Wells may be abandoned when they are eliminated from the Facility monitoring network or when they are damaged beyond repair. Well plugging and abandonment methods and certification should be conducted in accordance with the *Rules and Regulations Governing Well Driller Licensing: Construction, Repair and Plugging of Wells* [19.27.4 NMAC]. DOE should notify NMED and submit a well abandonment plan to NMED prior to the date the wells are to be removed from the monitoring network.

The goal of well abandonment is to seal the borehole in such a manner that the well cannot act as a conduit for migration of Contaminants from the ground surface to the aquifer or between aquifers. To properly abandon a well, the preferred method is to completely remove the well casing and screen from the borehole, clean out the borehole, and backfill with a cement or bentonite grout, neat cement, or concrete.

For wells with small diameter casing, abandonment should be accomplished by overdrilling the well with a large diameter hollow-stem auger. After the well has been overdrilled, the well casing and grout can be lifted out of the ground with a drill rig, and the remaining filter pack can be drilled out. The open borehole can then be pressure grouted (via the tremie pipe method) from the bottom of the borehole to the ground surface. After the grout has cured, the top two-feet of the borehole should be filled with concrete to insure a secure surface seal.

Several other well abandonment procedures are available for wells with larger diameter screens and casings. One method is to force a drill stem with a tapered wedge assembly or a solid-stem auger into the well casing and pull the casing out of the ground. However, if the casing breaks or the well cannot be pulled from the ground, the well will have to be grouted in place. To abandon a well in place, a tremie pipe should be placed at the lowest point in the well (at the bottom of the screen or in the well sump). The entire well is then pressure grouted from the bottom of the well upward. The pressurized grout will be forced out through the well screen into the filter pack and up the inside of the well casing sealing off all breaks and holes in the casing. Once the well is grouted, the casing is cut off even with the ground surface and covered with concrete.

If a PVC well cannot be abandoned due to internal casing damage (e.g., the tremie pipe cannot be extended to the bottom of the screen), it may be necessary to drill out the casing with a roller cone or drag bit using the wet rotary drilling method, or grind out the casing using a solid-stem auger equipped with a carbide tooth bit. Once the casing is removed, the open borehole can be cleaned out and pressure grouted from the bottom of the borehole upward.

II.E. Documentation

All information on the design, construction, and development of each monitoring well should be recorded and presented on a boring log, a well construction log, and well construction diagram. The well construction log and well construction diagram should include the following information:

- Well name/number;
- Date/time of well construction;
- Borehole diameter and well casing diameter;
- Well depth;
- Casing length;
- Casing materials;
- Casing and screen joint type;
- Screened interval(s);
- Screen materials;
- Screen slot size and design;
- Filter pack material and size;
- Filter pack volume (calculated and actual);
- Filter pack placement method;
- Filter pack interval(s);
- Annular sealant composition;
- Annular sealant placement method;
- Annular sealant volume (calculated and actual);
- Annular sealant interval(s);
- Surface (grout) sealant composition;
- Surface (grout) seal placement method;
- Surface (grout) sealant volume (calculated and actual);
- Surface (grout) sealant interval;
- Surface completion and well apron design and construction;
- Well development procedure and turbidity measurements;
- Well development purge volume(s) and stabilization parameter measurements;

- Type and design and construction of protective casing;
- Well cap and lock;
- Ground surface elevation;
- Survey reference point elevation on well casing;
- Top of monitoring well casing elevation; and
- Top of protective steel casing elevation.