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NMED Hazardous Waste Bureau

Mr. James Bearzi,
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New Mexico Environment Department
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Dear Mr. Bearzi:

On behalf of the Department of Energy (DOE) and Sandia Corporation, DOE is submitting the Burn Site Groundwater Corrective Measures Evaluation (CME) Work Plan. This submittal is required under the Compliance Order on Consent (Consent Order) for Sandia National Laboratories, New Mexico, EPA ID No. 5890110518.

The CME Work Plan has been developed under the direction of Section IV of the Consent Order, which identifies the Burn Site as an area of groundwater contamination requiring completion of a CME. The Burn Site Groundwater CME Work Plan complies with requirements set forth in the Consent Order and with the guidance of the Resource Conservation and Recovery Act Corrective Action Plan.

If you have any questions regarding this work plan, please contact me at (505) 845-6036, or Dan Pellegrino of my staff, at (505) 845-5398.

Sincerely,

Patty Wagner

Patty Wagner
Manager

Enclosure

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Document title: **Burn Site Groundwater Corrective Measures Evaluation Work Plan**

Document authors: **Mike Skelly, Department 06765**

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision according to a system designed to ensure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine or imprisonment for knowing violations.

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Sandia National Laboratories/New Mexico

Corrective Measures Evaluation Work Plan
Burn Site Groundwater

March 2008

United States Department of Energy
Albuquerque Operations Office

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SNL 1180

Corrective Measures Evaluation Work Plan
Burn Site Groundwater

Sandia National Laboratories
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Abstract

This document was prepared as directed by a Compliance Order on Consent (the Order) issued by the New Mexico Environment Department and identifies and outlines a process for evaluating remedial alternatives and identifying a corrective measure for the Sandia National Laboratories/New Mexico Burn Site Groundwater Area of Concern. The Order provides guidance for implementing a Corrective Measures Evaluation (CME) for the Burn Site Groundwater. This Work Plan documents initial screening of remedial technologies and presents a list of possible remedial alternatives for those technologies that passed the screening. The Work Plan outlines the methods for evaluating these remedial alternatives and describes possible site-specific evaluation activities necessary to estimate remedy effectiveness and cost. These methods will be reported in the CME Report. The Work Plan also outlines the CME Report, including key components and a description of the corrective measures process.

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Acronyms and Abbreviations

bgs	below ground surface
BSG	Burn Site Groundwater
CME	Corrective Measures Evaluation
CMI	Corrective Measures Implementation
COC	contaminant of concern
CYN	canyons (used in well designations)
DOE	U.S. Department of Energy
DRO	diesel range organic
EPA	Environmental Protection Agency
ER	Environmental Restoration
ft	foot or feet
FY	fiscal year
GRO	gasoline range organic
GWRTAC	Ground-Water Remediation Technologies Analysis Center
HE	high explosives
HI	Hazard Index
HQ	Hazard Quotient
IMWP	Interim Measures Work Plan
ISB	in situ bioremediation
KAFB	Kirtland Air Force Base
L	liter
LTS	long-term stewardship
MCL	maximum contaminant level
MDL	method detection limit
mg	milligrams
MNA	monitored natural attenuation
MW	monitoring well (used in well designations)
N_2	molecular nitrogen
NMED	New Mexico Environment Department
NNSA	National Nuclear Security Administration
NPN	nitrate plus nitrite
Order	Compliance Order on Consent
PMP	Project Management Plan
POTW	publicly owned treatment works
PRB	permeable reactive barrier
RCRA	Resource Conservation and Recovery Act
SNL/NM	Sandia National Laboratories/New Mexico
SVOC	semivolatile organic compound
SWMU	Solid Waste Management Unit
μg	micrograms
VOC	volatile organic compound
WQCC	Water Quality Control Commission

1.0 INTRODUCTION

Sandia National Laboratories/New Mexico (SNL/NM) is located on Kirtland Air Force Base (KAFB), south of Albuquerque, New Mexico (Figure 1-1). SNL/NM manages the Coyote Canyon Test Area, which consists of three large canyons in the Manzanita Mountains (Madera Canyon from the north, Sol se Mete Canyon from the south, and Lurance Canyon from the east). These canyons are the headwaters of the Arroyo del Coyote. The Lurance Canyon Burn Facility, located within Lurance Canyon, is a test site in the Coyote Canyon Test Area (Figure 1-1) that has operated since 1967.

Section IV.C of the Compliance Order on Consent (The Order) between the New Mexico Environment Department (NMED), Department of Energy (DOE) for SNL/NM, and Sandia Corporation (Sandia) for SNL/NM (NMED April 2004) identified the Burn site as an area with groundwater contamination as follows:

> *In 1996, sampling results from the Burn Site Well, a non-potable water supply well, showed elevated nitrate levels at 26 mg/L (maximum contaminant level (MCL) is 10 mg/L [as nitrogen]). The Department required monitoring wells at the Burn Site; these wells have yielded groundwater samples with levels of nitrate greater than 10 mg/L. Fuel constituents below state and Environmental Protection Agency (EPA) standards have also been detected in some wells. The contamination is found in canyon alluvium and fractured bedrock aquifers that may connect to the regional aquifer in the Albuquerque Basin to the west.*

Although the Order states that sampling results from the Burn Site well showed elevated nitrate levels at 26 milligrams per liter (mg/L), historical data records report the nitrate concentration from the Burn Site Well in 1996 as 25 mg/L. However, the highest reported nitrate concentration in the Burn Site Groundwater (BSG) wells is 32.6 mg/L reported at CYN-MW6 in June 2006 (SNL/NM March 2008). The Order identifies the Burn Site as an area of groundwater contamination requiring completion of a Corrective Measures Evaluation (CME) (see Section VI, "Facility Investigation" of the Order).

In response to the Order, DOE and Sandia submitted a "Current Conceptual Model of Groundwater Flow and Contaminant Transport at Sandia National Laboratories Burn Site" and the "Corrective Measures Evaluation Work Plan Burn Site Groundwater" to the NMED (SNL/NM June 2004a and June 2004b). On March 1, 2005, the DOE and Sandia received a letter from NMED (NMED February 2005) in response to these documents with the following information:

- DOE/Sandia must prepare and submit an Interim Measures Work Plan (IMWP) within 90 days from the receipt of the letter (by May 30, 2005).
- Additional characterization of the nitrate-contaminated groundwater near the Burn Site must be conducted. Specifically, the downgradient extent of groundwater with nitrate concentrations >10 mg/L shall be determined.
- NMED does not accept the CME Work Plan because they are not satisfied with the existing characterization of nitrate-contaminated groundwater near the Burn Site.

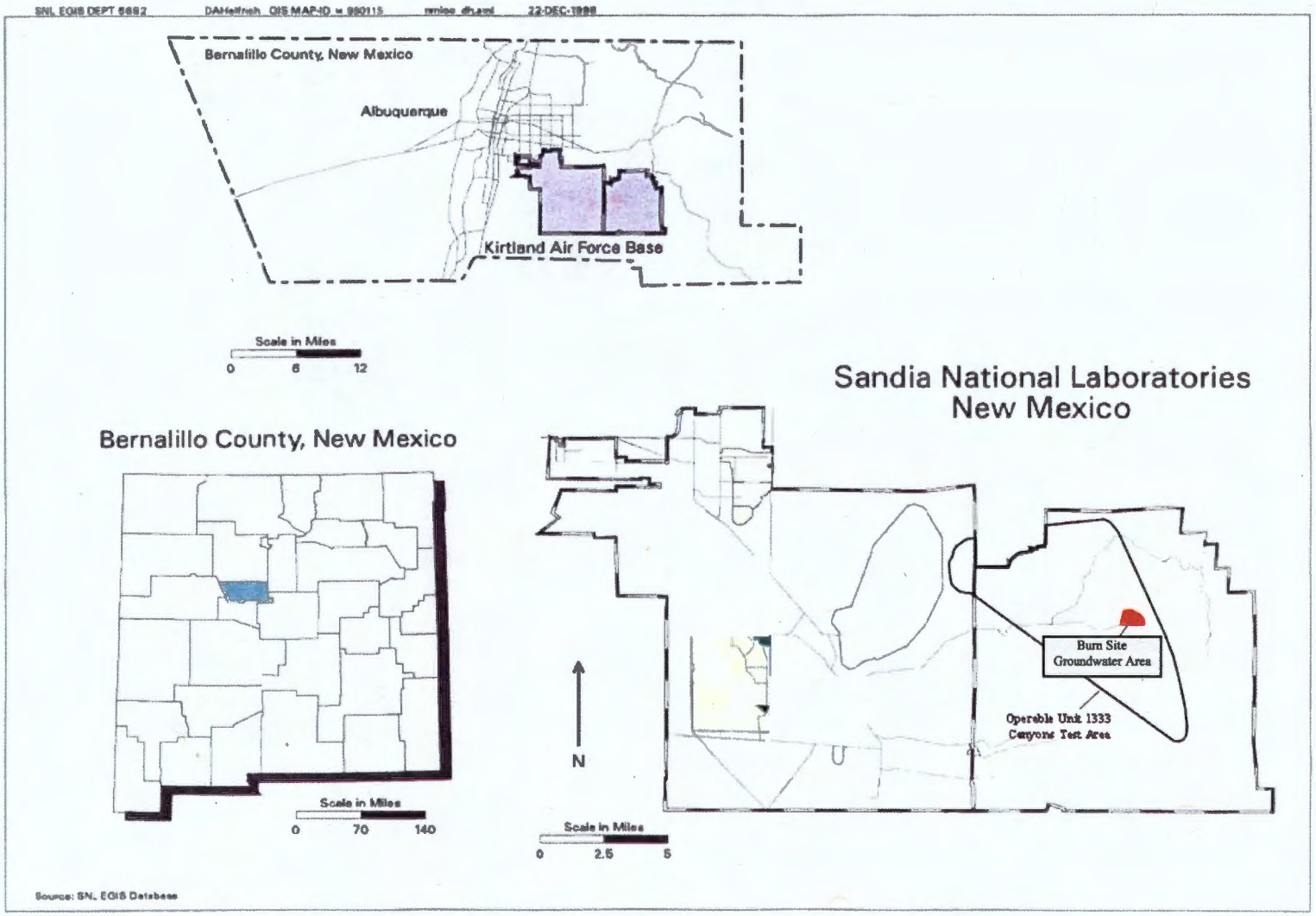

Figure 1-1. Location map of SNL/NM and the Burn Site.

- One additional monitoring well "adjacent to Solid Waste Management Unit (SWMU) 94F must be installed in order to establish groundwater conditions in this petroleum-contamination source area."

In response, DOE and Sandia submitted the BSG IMWP (SNL/NM September 2005) on May 30, 2005. This plan included additional characterization of the groundwater near the Burn Site and implementation of institutional controls. Three new monitoring wells (CYN-MW6, CYN-MW7, and CYN-MW8) were installed from December 2005 to January 2006 as planned in the IMWP (locations shown on Figure 1-2). CYN-MW6 was installed adjacent to SWMU 94F; CYN-MW7 and CYN-MW8 were installed downgradient of CYN-MW1D. Quarterly sampling for eight quarters was conducted from March 2006 through December 2007 for the three new monitoring wells. Nitrate samples were collected from the newly installed wells downgradient of CYN-MW1D, including CYN-MW7 and CYN-MW8. Gasoline range organics (GROs), diesel range organics (DROs), nitrate, and other parameters were collected from CYN-MW6 near SWMU 94F. The groundwater monitoring program is continuing as outlined in the IMWP (SNL/NM September 2005).

This CME Work Plan has been developed to address the concerns of the March 1, 2005 letter from NMED and to comply with requirements of the Order. This work plan includes information and data gathered during interim measures, and performance and compliance goals and objectives for the remediation of the BSG. An unpublished draft of the plan "*Corrective Measures Evaluation Work Plan, Burn Site Groundwater*" was prepared by North Wind, Inc. in November, 2006 (Hall, Dettmers, and Witt November 2006). That draft CME Work Plan formed the basis for this plan. The main contribution of this edition of the CME Work Plan is the inclusion of recent groundwater monitoring data through the December 2007 sampling event.

1.1 Purpose and Organization

The purpose of this Work Plan is to identify and outline a process for evaluating remedial alternatives for BSG at SNL/NM. The CME will be conducted to identify a remedy that most effectively meets the project goals and objectives for cleanup within the regulatory framework; this remedy will be the preferred remedy or recommended corrective measure. This process will evaluate remedial alternatives considering the known physical characteristics of the contaminant plume and the corrective measure cleanup goals and objectives outlined in this document.

This document is organized according to guidance presented in the Resource Conservation and Recovery Act (RCRA) Corrective Action Plan [U.S. Environmental Protection Agency (EPA) May 1994]. Table 1-1 shows a crosswalk of the sections specified by the guidance and the sections of this document. An important aspect of meeting the requirements of the Order, and an objective of the CME, is evaluating existing groundwater and subsurface data and compiling that information into a Current Conceptual Model that accurately reflects the nature and extent of the groundwater plume. The "Current Conceptual Model of Groundwater Flow and Contaminant Transport at Sandia National Laboratories/New Mexico Burn Site Groundwater" (SNL/NM March 2008), referred to in this document as the Burn Site Groundwater Current Conceptual Model, is summarized in Section 1.2. Section 2 presents the cleanup goals and objectives for the BSG remediation. Section 3 identifies, describes, and presents the results of an initial screening of

technologies considered for potential implementation as a BSG corrective measure. Section 4 presents remedial alternatives to be evaluated and outlines the evaluation approach, while Section 5 details the evaluation plan for remedial alternatives. Section 6 outlines the content of the CME Report, and Section 7 presents the project management plan for the BSG CME.

Table 1-1. CME Work Plan crosswalk table.

RCRA CMS Guidance Section (EPA May 1994)	CME Work Plan for BSG (Section)
1.0 Purpose	1.0 Introduction
2.0 Cleanup Goals, Objectives and Requirements	2.0 Cleanup Goals, Objectives and Requirements
3.0 Technology Identification and Development	3.0 Technology Identification and Screening
4.0 Technology Evaluation Approach	4.0 Remedial Alternative Evaluation Approach
5.0 Technology Evaluation Plan	5.0 Remedial Alternative Evaluation Plan
6.0 CME Report	6.0 CME Report
7.0 Project Management Plan	7.0 Project Management Plan

BSG = Burn Site Groundwater.
CME = Corrective Measures Evaluation.
CMS = Corrective Measures Study.
EPA = U.S. Environmental Protection Agency.
RCRA = Resource Conservation and Recovery Act.

1.2 Site Description

The SNL/NM Burn Site is located in Lurance Canyon, within the Manzanita Mountains, east of the Albuquerque Basin of the Rio Grande Rift, in north-central New Mexico. The terrain is characterized by large topographic relief [exceeding 500 feet (ft)]. Lurance Canyon is deeply incised into Paleozoic and Precambrian rocks and provides local westward drainage of surface flows to Arroyo del Coyote.

Nitrate has been identified as the contaminant of concern (COC) in groundwater at concentrations above the maximum contaminant level (MCL) of 10 mg/L in a deep, heterogeneous aquifer with relatively low groundwater flux. Primary downgradient receptors are Coyote Springs and Cattail Springs at the base of the Manzanita Mountains approximately three miles west of the Burn Site. These springs discharge groundwater moving through the fractured rocks and provide water for local wildlife. Due to the remote location of and limited access to the springs, risk to human health is minimal. Table 1-2 identifies the maximum concentration, most recent concentration, and MCL for nitrate.

Figure 1-2. Location of wells, piezometers, and springs at and near the Burn Site.

Historically, groundwater monitoring activities performed at the Burn Site have included collecting samples from all, or a subset of, the following wells: CYN-MW1D, CYN-MW3, CYN-MW4, CYN-MW5, and the Burn Site Well. Analyses performed have included organic analyses (volatile organic compounds [VOCs], semivolatile organic compounds [SVOCs], DROs, GROs, and high explosives [HE]); inorganic analyses (total metals, general chemical analysis [including nitrogen species], major ions, and alkalinity); and radiological analyses (gamma spectroscopy, radium, gross alpha/beta, and tritium). Given the identification of nitrate as the COC based on past data collection, future groundwater monitoring will focus on monitoring for nitrate at the frequency required by the Order (NMED April 2004; Table XI-1) and may include monitoring for additional analytes (i.e., DROs).

Table 1-2. Maximum and most recent concentrations of nitrate in groundwater from Burn Site wells.

Contaminant	Historical Maximum Concentration	Recent Maximum Concentration	Regulatory Limit (MCL)
Nitrate[a]	32.6 mg/L[b]	29.3 mg/L[c]	10 mg/L[d]

mg/L = milligrams per liter
a. Nitrate or nitrate plus nitrite (NPN) both expressed as nitrogen.
b. Detected in a sample from well CYN-MW6 collected in June 2006. Duplicate result was 29.5 mg/L.
c. Detected in a sample from well CYN-MW6 collected in December 2007. Duplicate result was 27.7 mg/L.
d. 40 CFR 141.62, "Maximum Contaminant Levels for Inorganic Contaminants (2003)."

Nitrate in groundwater near the Burn Site is attributed to non-point sources derived either from nitrate disseminated from open detonation of HE from 1967 until the early 1980s at sites within Solid Waste Management Unit (SWMU) 65 or from concentration of nitrate present in rainwater via evaporation or transpiration of water from alluvial deposits in Lurance Canyon. Evaluation of nitrate in sediments from nearby pristine alluvial deposits and springs that discharge from fractured metamorphic rocks will be useful in determining the source of nitrate in groundwater at the Burn Site and evaluating whether that source has been depleted. The trends of nitrate concentrations over time indicate that a pulse of nitrate has moved downgradient across the Burn Site since 1995.

Organic constituents present in BSG are not considered to be COCs because concentrations have been less than EPA and state standards; however, these constituents provide information about groundwater flow and contaminant migration. These organic compounds may have moved with wastewater or jet fuel and entered bedrock at buried exposures of the brecciated fault zones that cross the canyon at the Burn Site. Trace concentrations of HE constituents in groundwater are attributed to the open detonation of HE. These constituents may have been mobilized and concentrated in infiltrating precipitation and runoff, and migrated to fault zones and to the water table.

Section IV.B of the Order stipulates that a select group of groundwater monitoring wells be sampled for perchlorate at SNL/NM (NMED April 2004). The wells in the perchlorate screening groundwater monitoring well network were either specifically listed in the Order (for example, CYN-MW1D and CYN-MW5), or are in the category of "new" wells, meaning any well installed after the Order was finalized (for example, CYN-MW6, CYN-MW7, and CYN-MW8). Since June 2004 (the start of sampling required by the Order), perchlorate has only been detected

above the screening level/method detection limit (MDL) in one of the Burn Site wells in the perchlorate-screening monitoring-well network (CYN-MW6).

Perchlorate concentrations in water samples collected from CYN-MW6 since March 2006 ranged from 5.94 to 8.93 micrograms per liter (μg/L) with an average concentration of 7.04 μg/L (SNL/NM March 2008). Per the Order (NMED April 2004) a human health risk screening was conducted to determine whether perchlorate in groundwater in CYN-MW6 might pose a potential unacceptable risk to human receptors at the Burn Site. The maximum groundwater perchlorate concentration was used as the exposure point concentration in the screening risk evaluation. The current and future land use at the Burn Site is industrial (DOE et al. October 1995). However, under an industrial scenario there is no current viable exposure pathway for contact with groundwater. Therefore, residential land use was evaluated as the primary decision scenario for the human health screening risk assessment and the primary pathway for residential exposure to groundwater is ingestion (SNL/NM March 2008).

EPA has not established an MCL for perchlorate, but has published risk information that allows the associated risk to be calculated. Based on the maximum concentration for perchlorate, the Hazard Quotient (HQ) is 0.35, which is less than the NMED target level of a Hazard Index (HI) of 1.0 (NMED June 2006). [The HI is the sum of the HQs.] The perchlorate concentrations in groundwater from CYN-MW6 do not pose an unacceptable risk to human health under a residential scenario (SNL/NM March 2008). Therefore, perchlorate present in BSG is not considered to be a COC because concentrations do not pose an unacceptable risk to human health.

Groundwater in metamorphic rocks underlying the SNL/NM Burn Site in Lurance Canyon moves as semiconfined fracture flow, and eventually discharges into unconsolidated basin-fill deposits in the Albuquerque Basin to the west. Some discharge takes place at springs at the base of the Manzanita Mountains. Local recharge to this low-permeability system occurs through a series of north-trending brecciated fault zones that cross the Burn Site and the Lurance Canyon drainage. These fault zones provide a permeable conduit between the land surface and the fractured water-bearing metamorphic rocks at depth.

Based on the limited streamflow information and Burn Site piezometer data, streamflows at the Burn Site sufficient to saturate channel sediments and to provide a source of recharge to brecciated fault zones are sporadic and infrequent. Infiltrating water from these streamflows temporarily saturates alluvial sediments adjacent to the arroyo. Much of the water retained as bank and channel bottom storage most likely returns to the atmosphere through evapotranspiration. If infiltrating water from a flow event or sequence of events is adequate to exceed evapotranspiration losses, then water moves downward through the canyon alluvium and is available to enter brecciated fault zones in underlying bedrock. Observations indicate that groundwater is only rarely present in the canyon alluvial fill.

2.0 CLEANUP GOALS, OBJECTIVES, AND REQUIREMENTS

This CME Work Plan provides a framework for identifying the most effective corrective measure for implementation at the Burn Site. An effective corrective measure must ensure that cleanup goals and objectives are met and must be cost effective. Cleanup goals and objectives can be divided into two types (performance and compliance) based on when the goal or objective is to be achieved. Goals are established as the milestones to be met upon completion of remediation. Objectives are tasks to be completed in order to meet the goals.

Performance goals and objectives are defined to support performance evaluation during implementation of the remedy prior to final closure of the site; whereas compliance goals and objectives are defined to provide the framework to determine that the remedy has restored groundwater to beneficial use within the restoration timeframe, and they also support decision making at the end of the remedy. It is important to distinguish between performance and compliance goals because the type of data needed to evaluate attainment of them may be quite different. The goals and objectives stated in this document will be finalized in the CME Report. The following sections outline the goals and objectives for remediation of the BSG.

2.1 Performance Goals and Objectives

Performance goals and objectives are criteria and actions used to measure meaningful progress toward achieving cleanup goals and show that the remedy remains protective to human health and the environment until cleanup goals have been achieved. Analysis of performance monitoring data leads to periodic decisions on whether or not the remedy is performing as expected and whether or not the remedy will ultimately achieve the compliance remediation goal. The performance goals and objectives for the BSG include:

Performance Goals:

- Monitor COC concentrations and distribution to verify that the remedy is performing as anticipated, and
- Collect groundwater monitoring data using consistent sampling and analytical methods in order to support operational decisions.

Performance Objectives:

- Implement the selected remedy,
- Compile and analyze groundwater monitoring data to monitor the progress of the remedy, and
- Collect sufficient data to support operational decisions.

2.2 Compliance Goals and Objectives

Compliance goals and objectives are criteria and actions that are required to show compliance with agreements between the NMED and DOE/Sandia during and upon completion of the remedy. Compliance goals and objectives serve to show that the remedy is being implemented in a fashion that is consistent with the Order (NMED April 2004), and that the remedy has accomplished the cleanup goals at the end of the corrective measure. Groundwater cleanup levels for BSG are defined in Section VI.K.1.a of the Order as the more restrictive of EPA MCLs or Water Quality Control Commission (WQCC) standards. As presented in Section 1.2 and Table 1-2, the cleanup level for the COC in BSG is defined by the MCL, as this is the more restrictive of the two standards. The anticipated remedial timeframe for BSG will be defined in the Corrective Measures Implementation (CMI) Plan. The compliance goals and objectives for the BSG include:

Compliance Goals:

- Operate all remediation systems or strategies in compliance with applicable requirements,
- Reduce COC concentrations throughout the plume to below the cleanup goal (MCL), and
- Implement institutional controls to protect human health and the environment during the remediation timeframe.

Compliance Objectives:

- Monitor all remediation systems or strategies for compliance with applicable requirements,
- Collect groundwater samples at Burn Site wells for COCs,
- Compare COC concentrations to cleanup standards, and
- Recommend site closure or continuation of operations based on groundwater monitoring data.

3.0 TECHNOLOGY IDENTIFICATION AND SCREENING

The technology identification and screening process is an initial evaluation to identify feasible technologies to be considered for implementation for BSG. The primary objective of this section is to identify potential remediation technologies and subject those technologies to a screening process. The "Survey of Subsurface Treatment Technologies for Environment Restoration Sites at Sandia National Laboratories, New Mexico" (SNL/NM August 2003) and other scientific and engineering literature were used to facilitate selection of the technologies. This section includes a description of the threshold criteria used in the initial screening process, identification and description of remediation technologies, the initial screening process, and results of the initial technology screening.

3.1. Threshold Criteria

The Order (NMED April 2004) identified threshold criteria for evaluating each remedial alternative. These threshold criteria are reflective of cleanup standards identified in the RCRA Corrective Action Plan for evaluation of a final corrective measure alternative (EPA May 1994). Technologies potentially used as part of a remedy and other remedy components must be evaluated against these threshold criteria. The four threshold criteria listed in the Order and their relevance to the Burn Site are described below.

1. **Protective of human health and the environment.** Any proposed remedy must be protective of human health and the environment. As stated in the RCRA Corrective Action Plan, "Remedies may include those measures that are needed to be protective, but are not directly related to media cleanup, source control, or management of wastes" (EPA May 1994). Components of remedies considered for BSG include:
    - Evaluating protection of human health and the environment for potential formation of hazardous degradation products,
    - Considering hazards associated with operations and maintenance of the remedy,
    - Completing remediation within an appropriate timeframe.
2. **Attain media cleanup standard or alternative, approved risk-based cleanup goals.** Any proposed remedy must attain groundwater cleanup standards or goals. As stated in the RCRA Corrective Action Plan, "Remedies will be required to attain media cleanup standards set by the implementing agency, which may be derived from existing state or federal regulations (e.g., groundwater standards) or other standards. The media cleanup standards for a remedy will often play a large role in determining the extent of, and technical approaches to, the remedy" (EPA May 1994). The potential effectiveness of attaining media cleanup standards for a remedy depends on a number of site-specific factors. Site-specific factors for the Burn Site include:

    a. Depth to groundwater at the Burn Site ranges from approximately 110 to 320 ft below ground surface (bgs). Groundwater is located in bedrock faults and fractures.

    b. Fracture flow in the Burn Site is characterized by a minimum apparent groundwater velocity of approximately 160 ft/year. The groundwater flow direction is generally to the west; however, a wide range in localized aquifer properties suggests that

c. The Burn Site is underlain by a structurally complex sequence of Precambrian metamorphic and Paleozoic sedimentary rocks cut by a system of north-trending faults.

d. A typical range of effective porosity in fractured metamorphic and igneous rocks is 10^{-2} to 10^{-5} (Freeze and Cherry 1979). The effective porosity may affect technologies that involve injection or extraction of water.

e. Since October 1997 the peak historic nitrate concentration is 32.6 mg/L occurring in CYN-MW6 in June 2006.

3. **Control the source or sources of releases so as to reduce or eliminate, to the extent practicable, further releases of contaminants that may pose a threat to human health and the environment.** Any proposed remedy must control the original source of the contamination in order to prevent any further releases. As stated in the RCRA Corrective Action Plan, "Unless source control measures are taken, efforts to clean up releases may be ineffective or, at best, will essentially involve a perpetual cleanup" (EPA May 1994). Section 1.2 identifies a non-point source of nitrate release to the BSG; therefore, any technologies designed to aggressively remediate or control a specific point source will not be effective as a corrective measure for the BSG.

4. **Comply with standards for management of wastes.** Any proposed remedy must comply with all applicable state or federal regulations. As stated in the RCRA Corrective Action Plan, "Waste management activities will be conducted in compliance with all applicable state or federal regulations (e.g., closure requirements, land disposal restrictions)" (EPA May 1994). For remedies considered for the BSG, waste could be generated during the life cycle of the remedy in the form of contaminated groundwater brought to the surface and laboratory and field sampling wastes, and at the completion of the remedy during final decommissioning of the remedy system.

3.2 Technology Identification and Description

A number of treatment technologies are considered for remediation of BSG. This section identifies technologies selected for initial screening (Table 3-1) and provides a description of the technologies. Table 3-1 lists the technologies alphabetically and identifies the corresponding section number. A literature review of the technologies was performed to compile information for technology descriptions. A description of each technology includes information about applicability, system design, and operation. Also included in this section are the advantages, disadvantages, and references for each technology.

Table 3-1. Technologies evaluated for remediation of nitrate during the initial screening process.

Technologies	CME Work Plan for BSG Section
Groundwater Monitoring	3.2.1
In Situ Bioremediation	3.2.2
Monitored Natural Attenuation	3.2.3
Monolithic Confinement	3.2.4
Permeable Reactive Barriers	3.2.5
Phytoremediation	3.2.6
Pump and Treat	3.2.7

BSG = Burn Site Groundwater.
CME = Corrective Measures Evaluation.

3.2.1 Groundwater Monitoring

Groundwater monitoring consists of collecting samples from a network of monitoring wells with the objective of monitoring contaminant concentrations and transport in groundwater over time. Groundwater monitoring is applicable for relatively low concentration groundwater plumes with long remedial timeframes and minimal risk of harm to human health and the environment. A monitoring plan will be established to identify monitoring locations, frequency and duration of sample collection, and analysis parameters. Knowledge of site-specific geohydrologic conditions and contaminant distribution and transport, which is presented in the Burn Site Current Conceptual Model (SNL/NM March 2008), is required to establish an appropriate monitoring plan.

Groundwater monitoring is not considered to be a no-action approach because active monitoring will take place and a contingency plan will be established. A no-action approach would not require monitoring or a contingency plan, and is not being evaluated for this study.
A contingency plan will include reevaluation of criteria in the event that groundwater monitoring is no longer effectively protecting human health and the environment (e.g., dramatic increases in contaminant concentrations and contaminant distribution and transport beyond control location). Unlike monitored natural attenuation (MNA), the groundwater monitoring approach makes no attempt to verify pathways of natural attenuation or to predict contaminant transport and degradation.

Advantages:

- Potentially less expensive than other technologies, although required project duration is unknown,
- Minimal risk to workers compared to aggressive technologies,

- Minimal site disturbance,
- Implementation flexibility, and
- In situ technology that requires no removal, treatment, or storage of groundwater, except for minor amounts generated during well purging and sampling.

Disadvantages:

- Timeframe for remediation can be long,
- Monitoring can proceed for an indefinite period, resulting in increased life-cycle cost,
- End point may be undefined, and
- Potential for transport of contaminants toward receptors.

3.2.2 In Situ Bioremediation

Bioremediation is the application of biological treatment for remediation of contaminants. In situ bioremediation (ISB) is the application of bioremediation in the subsurface and can be used for remediation of a wide variety of organic and inorganic contaminants, under both aerobic and anaerobic conditions. It combines an understanding of biology, geochemistry, hydrogeology, and engineering into a cohesive strategy for the destruction of groundwater contaminants using microbes. Thorough data evaluation is necessary to determine ISB effectiveness. The data that must be evaluated include the type of microorganisms, the type of contaminant, and the geochemical and hydrogeologic conditions at the site.

Anaerobic bioremediation techniques can include injection of an electron donor to increase activity of indigenous microorganisms that remove contaminants via anaerobic biodegradation processes. In the absence of oxygen and in the presence of an electron donor, nitrate can be used as an electron acceptor in microbial respiration, and thereby be converted into nitrite and ultimately to molecular nitrogen (N_2).

Advantages:

- Contaminant degradation occurs in situ, minimizing worker exposure to hazardous contaminants,
- Effective on a wide range of contaminants and concentration levels,
- Commercially available equipment,
- Effective for both dissolved and sorbed phases of contamination, and
- In situ technology requiring no removal, treatment, or storage of groundwater.

Disadvantages:

- Biological growth may affect injection wells and flowpaths (biofouling),
- Operations and monitoring may be continuous,
- Difficult to implement in low-permeability aquifers,
- Remediation may occur only within the higher permeability portions of the aquifer, and
- The potential exists for activation (transformation of the contaminant into a more hazardous substance).

References:

- Interstate Technology and Regulatory Council, August 2002, "A Systematic Approach to In Situ Bioremediation in Groundwater including Decision Trees on In Situ Bioremediation for Nitrates, Carbon Tetrachloride, and Perchlorate." Technical/Regulatory Guidelines, 129 pp.

3.2.3 Monitored Natural Attenuation

MNA typically operates on the principle of indigenous microorganisms using a supply of nutrients and electron acceptors (or donors) already present in the environment to completely metabolize or cometabolize pollutants. In certain applications, non-destructive attenuation mechanisms (i.e., dispersion or dilution) may be sufficient to meet site-specific cleanup goals. Careful characterization and thorough monitoring are essential to ensure that sufficient attenuation will take place to comply with all regulatory requirements. This characterization is the difference between MNA and groundwater monitoring because groundwater monitoring makes no attempt to verify pathways of natural attenuation or to predict contaminant transport and degradation. MNA has wide applicability, relative low cost, and requires minimal infrastructure. The primary costs associated with this remedy are monitoring costs. Nitrate can be transformed through redox processes (e.g., denitrification) that are operative in the subsurface. Technologies designed to actively remediate nitrate (i.e., ISB) may affect natural attenuation processes of nitrate in the groundwater.

Advantages:

- Less construction and maintenance is required than other treatment options, making the technology less costly,
- Contaminants are ultimately transformed into innocuous degradation products,
- The non-intrusive nature of MNA allows continued use of infrastructure during remediation,
- Requires no removal, treatment, or storage of groundwater. There is less risk than engineered remedies that may transfer contaminants to the air during remediation,

- Not subjected to equipment limitations such as malfunction or other downtime, and
- Can be used in conjunction with or following other remedial measures conducted under similar conditions (e.g., anaerobic).

Disadvantages:

- Timeframe for remediation can be long,
- Subject to natural and induced changes in local hydrogeology,
- Aquifer heterogeneity can make characterization difficult,
- Potential for contaminant migration, and
- Remediation timeframes may be longer than some active remediation technologies.

References:

- DOE, May 1999, "Decision-Making Framework Guide for the Evaluation and Selection of Monitored Natural Attenuation Remedies at Department of Energy Sites," Office of Environmental Restoration, May 1999.
- EPA, April 1999, "Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites," OSWER Directive 9200.4-17P, http://www.epa.gov/swerust1/directiv/d9200417.pdf, April 1999.
- Interstate Technology and Regulatory Council, August 2002, "A Systematic Approach to In Situ Bioremediation in Groundwater including Decision Trees on In Situ Bioremediation for Nitrates, Carbon Tetrachloride, and Perchlorate." Technical/Regulatory Guidelines, 129 pp., August 2002.

3.2.4 Monolithic Confinement

Monolithic confinement consists of constructing barriers (e.g., cement or grout) to confine groundwater contamination. Barriers can be constructed by digging a trench and backfilling it or by injecting grouting fluids (i.e., cement, clay, or a solution to react in the subsurface to form a low permeability material) into a series of boreholes in order to reduce the permeability of the geologic materials. Surrounding a contaminant source with a barrier can reduce the flux of contaminants from the source, thereby limiting production of additional contaminated groundwater. If the barrier is not set in impermeable geologic materials, then the system will be open and contamination will not be contained.

Advantages:

- Passive technology that uses no above-ground infrastructure,
- In situ technology requiring no removal, treatment, or storage of groundwater,
- If installed properly, no contaminant migration occurs,

- Can be used for any type or state of contamination, and
- If installed properly, can be effective under a variety of geohydrologic characteristics.

Disadvantages:

- Expensive and difficult to implement for deep aquifer contamination,
- Emplacement can be disruptive to the site and is permanent,
- Used as a containment remedy; source area may remain indefinitely,
- Monitoring can proceed for an indefinite period resulting in increased cost,
- End point may be undefined, and
- Regulatory approval can be difficult because this technology does not involve active removal or destruction of contaminants.

References:

- National Research Council, 1999, "Groundwater and Soil Cleanup: Improving Management of Persistent Contaminants," National Academy Press: Washington D.C., 285 pp.

3.2.5 Permeable Reactive Barriers

A permeable reactive barrier (PRB) is a physical barrier that is installed in the aquifer downgradient along the flow path of the contaminant. As the contaminated groundwater passes through the barrier, the contaminants react with the barrier to either transform the contaminant into a less harmful byproduct or the contaminants are irreversibly absorbed into the permeable material. A PRB can contain such agents as zero-valent metals, chelators, sorbents, microbes, or other agents. A funnel and gate approach can be utilized to contain the contaminant plume with low hydraulic conductivity barriers in the crossgradient direction and direct the flow of the contaminant plume toward the downgradient PRB. PRBs can be used for a wide range of organic and inorganic contaminants. In general, PRBs are practical only for contamination that is shallower than 50 ft bgs.

Advantages:

- Passive technology that uses no above ground infrastructure,
- If installed properly, no contaminant migration occurs beyond the barrier,
- Requires no removal, treatment, or aboveground storage of contaminated groundwater,
- Can incorporate different materials to treat a wide range of contaminants, and
- Once the barrier is installed, no further costs are incurred (other than monitoring).

Disadvantages:

- Difficult to properly install in a deep aquifer,
- Emplacement of the barrier can be disruptive to the site,
- The barrier is permanent and the timeframe for contaminated groundwater to pass through the PRB may be long,
- Used as a containment remedy, the source area may remain indefinitely depending on concentration, sorption, and other factors,
- Precipitation of metals and other inorganics may reduce hydraulic conductivity,
- For a biological barrier, generation of biomass may limit the permeability of the barrier, and
- For metal enhanced reduction barriers, reactivity of iron may necessitate periodic replacement or treatment of the iron medium.

References:

- SNL/NM, August 2003, "Survey of Subsurface Treatment Technologies for Environmental Restoration Sites at Sandia National Laboratories, New Mexico," Sandia National Laboratories, Albuquerque, NM, August 2003.
- Strietelmeier, B.A., M.L. Espinosa, M.W. Jones, J.D. Adams, E.M. Hodge, S.D. Ware, P.A. Leonard, P. Longmire, J.P. Kaszuba, and J.L. Conca, March 2001, "Remediation of Nitrate-Contaminated Groundwater Using a Biobarrier," Waste Management 2001 Conference, February 25-March 1, 2001, Tucson, Arizona, http://www.wmsym.org/Abstracts/2001/54/54-2.pdf.

3.2.6 Phytoremediation

Phytoremediation uses plants for groundwater remediation by taking advantage of their natural abilities to take up, accumulate, and/or degrade constituents of their soil and water environments. It is most appropriate for sites where groundwater is within 10 ft of the ground surface and contaminants are found in large areas at low concentration.

Advantages:

- Effective for large areas with low contaminant concentrations,
- Potentially less expensive than an aggressive removal technology,
- Implementation flexibility of location for ex situ application, and
- Plants are used for remediation of contaminants, minimizing worker exposure.

Disadvantages:

- Can only be used at sites with very shallow groundwater (less than 40 ft bgs),
- Monitoring can proceed for an indefinite period, resulting in increased cost,
- May be difficult to implement in an arid environment, and
- Requires land space for plant growth that may not be possible at some sites.

References:

- Ground-Water Remediation Technologies Analysis Center (GWRTAC), 2001, Remediation Technologies, http://www.groundwatercentral.info/.

3.2.7 Pump and Treat

Pump and treat is a broad term used to describe the pumping of contaminated groundwater to the surface where it can be treated. Treated water possibly may be reinjected. Because this is an ex situ treatment, a wide range of contaminants can be treated with a variety of technologies. Designs of pump and treatment systems vary greatly. Systems consist of at least one extraction well used to remove contaminated groundwater for ex situ treatment and a disposition method for the treated water. Disposition of treated water can include injection into the aquifer, onsite reuse (irrigation), misting, disposal to infiltration trenches or surface water bodies, or discharge to a sanitary sewer.

Ex situ treatment of the contaminated groundwater can be performed using a variety of technologies including air stripping, sorption to activated carbon, ion exchange resins, phytoremediation, ex situ bioreactors, and others.

Advantages:

- Because of widespread use, pump and treat is a well developed technology,
- Generally effective in preventing the spread of contamination in the subsurface, and
- Can be used on a wide range of contaminants.

Disadvantages:

- Timeframe for remediation can be long,
- May not be capable of reducing contaminant concentrations to meet cleanup standards,
- Requires extensive site characterization to determine potential for effectiveness,
- Rebound and trailing effects can reduce effectiveness of this remedy,

- Subsurface heterogeneities can reduce contaminant capture efficiency,
- Operation and maintenance costs can be expensive,
- Contaminated groundwater is often too dilute to support an adequate microbial population in ex situ bioreactors,
- Nuisance microorganisms can predominate and reduce treatment effectiveness in ex situ bioreactors, and some intermediate degradation products are more toxic than the original contaminants in bioreactors, and
- Ex situ treatment media may require treatment or disposal.

References:

- EPA, July 1996, "Pump-and-Treat Ground-Water Remediation: A Guide for Decision Makers and Practitioners," EPA/625/R-95/005, Office of Research and Development, Washington D.C., http://www.epa.gov/superfund/health/conmedia/gwdocs/pum_tre.htm, July 1996.
- Center for Public Environmental Oversight, 2000, Technology Tree: Bio-reactors. http://www.cpeo.org/techtree/ttdescript/biorec.htm.

3.3 Initial Technology Screening

The threshold criteria described in Section 3.1 were used in the initial screening described in this section. Initial screening was performed on all technologies identified and described in Section 3.2. Table 3-2 lists all technologies and the four threshold criteria. Evaluation was conducted on a YES/NO basis, as follows:

- YES = the technology meets the threshold criteria.
- NO = the technology does not meet the threshold criteria.

The first threshold criterion, "Protective of Human Health and the Environment," was evaluated based on whether appropriate measures could be taken to ensure that implementation of the technology would be protective of human health and the environment.

The second threshold criterion, "Attain Media Cleanup Standards," was evaluated using the BSG-specific characteristics listed in Table 3-3. Each technology was evaluated to determine if the individual technology would be effective or applicable based on these site-specific characteristics, without consideration of cost and schedule. Evaluation was conducted on a YES/NO basis, as follows:

- YES = the technology will work given this characteristic, or this characteristic is not applicable to the technology.
- NO = the technology will not work given this characteristic.

If a technology received a YES evaluation for all of the technical site-specific characteristics listed in Table 3-3, then a YES was recorded in the "Attain Media Cleanup Standards" location on Table 3-2. If a technology received a NO evaluation for one or more of the characteristics listed in Table 3-3, then a NO was recorded in the "Attain Media Cleanup Standards" location on Table 3-2.

Because nitrate may be released from a non-point source, a NO evaluation for the third criterion, "Source Control," was recorded for technologies designed to aggressively remediate or control a specific point source, because these technologies are not applicable for this dilute plume that has no continuing source. The fourth threshold criterion, "Waste Management Standards Compliance," was evaluated based on whether compliance with all applicable state or federal regulations could be met for all waste generated during the life cycle of the technology.

All technologies that received a YES evaluation for all threshold criteria passed this initial screening. These selected technologies will be carried forward for further evaluation in Section 4 to determine remedial alternatives for cleanup of BSG.

3.4 Initial Technology Screening Results

Based on the results of the initial screening of technologies conducted in Section 3.3, technologies are categorized either as eliminated technologies or as applicable technologies. Eliminated technologies will no longer be considered and applicable technologies will be used in Section 4 to create remedial alternatives.

3.4.1 Eliminated Technologies

Technologies that did not meet all of the threshold criteria did not pass the initial screening. These technologies were eliminated at this point and were not considered for creating remedial alternatives in Section 4. An explanation of why each technology was eliminated is discussed below.

3.4.1.1 Monolithic Confinement

Monolithic confinement was eliminated because it is an aggressive source control technology that requires constructing barriers to confine groundwater contamination, either by digging a trench or drilling boreholes. Construction of such a barrier at 110 to 320 ft bgs in metamorphic rock would be a difficult task and the technology is more suitable for sites containing a point source. Therefore, it was determined that monolithic confinement is not an applicable technology at this site because it would be difficult to attain cleanup goals.

3.4.1.2 Permeable Reactive Barriers

A PRB would be constructed downgradient of the plume and would need to be large enough to inhibit flow of contaminated groundwater underneath or around the barrier. Construction of such a barrier in metamorphic rock would be a difficult task considering depth to groundwater between 110 and 320 ft bgs. Therefore, it was determined that PRBs are not applicable at this site because it would be difficult to attain cleanup goals.

Table 3-2. Initial screening process for technologies using the Order threshold criteria.

Technologies	Protective of Human Health and Environment	Attain Media Cleanup Standards[1]	Source Control[2]	Waste Management Standards Compliance
Groundwater Monitoring	YES	YES	YES	YES
In Situ Bioremediation	YES	YES	YES	YES
Monitored Natural Attenuation	YES	YES	YES	YES
Monolithic Confinement	YES	NO	NO	YES
Permeable Reactive Barriers	YES	NO	YES	YES
Phytoremediation	YES	NO	YES	YES
Pump and Treat	YES	YES	YES	YES

YES = the technology meets the threshold criteria
NO = the technology does not meet the threshold criteria

1: This threshold criterion was evaluated using the BSG-specific characteristics listed in Table 3-3. If a technology received an evaluation of YES for all of the site-specific characteristics listed in Table 3-3, then YES was recorded in the appropriate location on this table. If a technology received an evaluation of NO for one or more of the characteristics listed in Table 3-3, then NO was recorded in the appropriate location on this table.

2: Since there is non-point source of nitrate release, technologies designed to aggressively remediate or control a point source were evaluated as NO.

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Table 3-3. BSG-specific characteristics for evaluating the threshold criteria: Attain Media Cleanup Standards.

Technologies	**Contamination in a Deep Aquifer**	**Small Groundwater Flux**	**Heterogeneous Subsurface**	**Small Effective Porosity**	**Peak Historic Nitrate Concentration (32.6 mg/L)**
Groundwater Monitoring	YES	YES	YES	YES	YES
In Situ Bioremediation	YES	YES	YES	YES	YES
Monitored Natural Attenuation	YES	YES	YES	YES	YES
Monolithic Confinement	NO	YES	YES	YES	YES
Permeable Reactive Barriers	NO	YES	YES	YES	YES
Phytoremediation	NO	YES	YES	YES	YES
Pump and Treat	YES	YES	YES	YES	YES

YES = the technology will work given this characteristic or this characteristic is not applicable to the technology
NO = the technology will not work given this characteristic

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3.4.1.3 In Situ Phytoremediation

In situ phytoremediation would not require pumping and is most applicable when the groundwater is within 10 ft of the surface. Implementation of this technology for the BSG would be ineffective considering the depth to groundwater, the nature of the subsurface, and the need for irrigation of plants in this arid environment. Therefore, it was determined that phytoremediation is not applicable at this site because it would be difficult to attain cleanup goals.

3.4.2 Potentially Applicable Technologies

Technologies that met all of the threshold criteria passed the initial screening. These technologies or combinations of these technologies will be used in Section 4 to determine remedial alternatives for cleanup of the BSG.

Applicable technologies include:

- Groundwater monitoring,
- ISB,
- MNA, and
- Pump and treat (ex-situ treatment technology to be determined).

4.0 REMEDIAL ALTERNATIVE EVALUATION APPROACH

Technologies that passed the initial screening process in Section 3.0 were used to create remedial alternatives that include combinations of the technologies and strategies for remedy implementation. Considerations of technology capabilities in relation to site-specific characteristics and cleanup goals were used to create a list of remedial alternatives. This section lists and describes each remedial alternative and includes the general description and approach to investigating and evaluating these potential remedies.

Institutional controls will be established based on the characteristics of the implemented remedy for BSG and in accordance with SNL/NM guidance. In September 2006, the DOE and SNL/NM, with input from the public, completed a draft "Long-Term Stewardship Implementation Plan (For Legacy Sites)." The outcome of the draft plan was a listing of issues that need resolution for the success of long-term stewardship (LTS). These issues include the difficulties of maintaining institutional controls inherent in long-term groundwater monitoring. The DOE and Sandia are continuing to address the issues identified in the draft plan (SNL/NM September 2006).

Initial screening of technologies, as conducted in Section 3.3, identified technologies that could be used for remediation of BSG. Possible remedial alternatives were identified using these technologies. These remedial alternatives include:

1. **Groundwater Monitoring.** A groundwater monitoring remedy would track concentrations, distribution, and transport of nitrate during the remedial timeframe. A monitoring plan would be written, based on the Burn Site Current Conceptual Model (SNL/NM March 2008), to identify frequency and duration of sample collection and analysis from an adequate network of monitoring wells.

2. **MNA.** Implementing MNA would allow for attenuation of nitrate in the subsurface by natural processes without active remediation. This alternative would include documenting attenuation mechanisms and attenuation kinetics, and predicting spatial and temporal contaminant concentration trends.

3. **ISB followed by Groundwater Monitoring.** This remedy would begin with implementation of ISB for nitrate. Following concentration reduction, groundwater monitoring would track concentrations, distribution, and transport of nitrate during the remedial timeframe.

4. **ISB followed by MNA.** This remedy would begin with implementation of ISB for nitrate. Following concentration reduction, MNA would be implemented to further reduce nitrate concentrations and confirm that sufficient degradation will take place during the remedial timeframe.

5. **Pump and Treat followed by Groundwater Monitoring.** This remedy would begin with implementation of pump and treat for nitrate. Following concentration reduction, groundwater monitoring would track concentrations, distribution, and transport of nitrate during the remedial timeframe.

6. **Pump and Treat followed by MNA.** This remedy would begin with implementation of pump and treat for nitrate. Following concentration reduction, MNA would be implemented to further reduce nitrate concentrations and confirm that sufficient degradation will take place during the remedial timeframe.

The remedial alternative evaluation approach will involve continued screening of remedial alternatives based on the results of evaluation studies; details are presented in Section 5. The approach is intended to choose a remedy that is protective of human health and the environment. Studies can then focus on demonstrating remedy effectiveness and calculating design parameters. The CME threshold criteria, used in Section 3 during initial screening of technologies, will also be used to screen the remedial alternatives. Remedial alternative evaluation criteria derived from the requirements stated in the Order (NMED April 2004) will be used to quantitatively analyze remedy effectiveness and choose a preferred remedy (see Section 5.1).

5.0 REMEDIAL ALTERNATIVE EVALUATION PLAN

This section provides guidance on activities and evaluation criteria to be used for evaluating the remedial alternatives presented in Section 4. This includes evaluation criteria and potential activities for remedy evaluation that can be carried out to gather data.

5.1 Plan Description

The remedial alternative evaluation includes activities conducted to gather and evaluate data for each remedy using threshold and remedial alternative evaluation criteria. The remedial alternative evaluation will be conducted to optimize data gathering activities. Data evaluation is ongoing during data gathering to screen out any remedial alternative that fails to meet the evaluation criteria.

Data gathering activities are carried out in a staged process beginning with a paper study or Data Gaps Review (Stage 1). In addition to the paper study, data gathering activities may include gathering field data and numerical modeling. These activities provide site-specific data necessary to evaluate the remedies, provide a recommendation, and calculate design parameters. Many of the activities for the Remedial Alternative Evaluation Plan have already been conducted and were presented in the IMWP (SNL/NM September 2005). If necessary, additional work will be performed and the results will be reported in the CME Report as attachments.

5.2 Evaluation Criteria

The evaluation criteria provide a basis for comparing the data collected to evaluate each remedial alternative. Evaluation criteria will be used, as specified in the Order (Section VII.C.3, CME Criteria [NMED 2004]). The remedial alternative evaluation will select the best remedy for implementation as the corrective measure for BSG. During the evaluation, each remedial alternative will be compared to the threshold criteria and the remedial alternative evaluation criteria identified here. Comparison to remedial alternative evaluation criteria will be a quantitative process, while comparison to threshold criteria will be qualitative. A numerical value will be assigned based on comparison to remedial alternative evaluation criteria, which will be detailed in the CME Report. If a remedy does not meet a threshold criterion, it will be eliminated. If a remedy is significantly less effective than other remedies based on the remedial alternative evaluation criteria, it will also be eliminated.

5.1.1 Threshold Criteria

Threshold criteria were used in the initial evaluation to screen out technologies that cannot be implemented for the BSG (see Section 3). All of the technologies used to create the remedial alternatives met the threshold criteria. However, site-specific data gathered during the remedial alternative evaluation may demonstrate that a remedial alternative cannot reasonably meet one of the threshold criteria. Therefore, each remedial alternative will be evaluated following each data gathering activity to assure that it can meet the threshold criteria. The following threshold criteria will be evaluated:

- **Protective of human health and the environment.** Any proposed remedy must be protective of human health and the environment. As stated in the RCRA Corrective Action Plan, "Remedies may include those measures that are needed to be protective, but are not directly related to media cleanup, source control, or management of wastes" (EPA May 1994). Components of remedies considered for BSG include evaluating protection of human health and the environment for potential formation of hazardous degradation products, any hazards associated with operations and maintenance of the remedy, and remediation within an appropriate timeframe.

- **Attain media cleanup standard or alternative, approved risk-based cleanup goals.** Any proposed remedy must attain groundwater cleanup standards or goals. As stated in the RCRA Corrective Action Plan, "Remedies will be required to attain media cleanup standards set by the implementing agency, which may be derived from existing state or federal regulations (e.g., groundwater standards) or other standards. The media cleanup standards for a remedy will often play a large role in determining the extent of, and technical approaches to, the remedy" (EPA May 1994). The cleanup goals and objectives for BSG are described in Section 2. If a remedy cannot meet any one of these goals or objectives, it will no longer be considered.

- **Comply with standards for management of wastes.** Any proposed remedy must comply with all applicable state or federal regulations. As stated in the RCRA Corrective Action Plan, "Waste management activities will be conducted in compliance with all applicable state or federal regulations (e.g., closure requirements, land disposal restrictions)" (EPA May 1994). For remedial alternatives considered for BSG, waste could be generated during the life cycle of the remedy in the form of contaminated groundwater brought to the surface and laboratory and field sampling wastes, and at the completion of the remedy during final decommissioning of the remedy system.

Source control is a fourth criterion outlined in the Order, but will not be considered as part of the CME because technologies specifically designed for source control are not applicable at this site. As discussed in the Burn Site Current Conceptual Model (SNL/NM March 2008), groundwater contamination may have resulted from a non-point source of nitrate. One of the recommended CME activities is an evaluation of potential for a continuing source of contaminants to groundwater from this source.

If a remedial alternative does not meet one of the threshold criteria, then it will be eliminated from further evaluation. The threshold criteria will be evaluated using a matrix similar to the example in Table 5-1. Evaluation will be conducted on a YES/NO basis. A remedy will be eliminated if a NO evaluation is given for any of the threshold criteria.

Table 5-1. Example remedial alternative evaluation using the Order threshold criteria.

Remedial Alternative	Protective of Human Health and Environment	Attain Media Cleanup Standards	Waste Management Standards Compliance
Groundwater Monitoring			
MNA			
ISB followed by Groundwater Monitoring			
ISB followed by MNA			
Pump and Treat followed by Groundwater Monitoring			
Pump and Treat followed by MNA			

ISB = in situ bioremediation
MNA = monitored natural attenuation
NO = the remedy does not meet the threshold criteria
YES = the remedy meets the threshold criteria
Note: The threshold criterion, "Source Control," is not included since release of nitrate is from a non-point source.

5.1.2 Remedial Alternative Evaluation Criteria

Remedial alternative evaluation criteria will be evaluated for each remedy. A summary of this comparison will be included in a matrix, as shown in the example in Table 5-2. Numerical values will be assigned to each criterion for the factors that are described in the following sections. These remedial alternative evaluation criteria will be evaluated several times following data gathering activities. If at any time it is determined that a remedy is significantly less effective than the other remedies, then it will no longer be considered. The criteria and considerations for evaluating each remedy are described below.

- **Long-term reliability and effectiveness.** In general, this criterion will evaluate the reliability of the remedy to meet cleanup standards and reduce risk. As stated in the Order, "Each remedy shall be evaluated for long-term reliability and effectiveness. This factor includes consideration of the magnitude of the risks that will remain after implementation of the remedy; the extent of long-term monitoring or other management that will be required after implementation of the remedy; the uncertainties associated with leaving contaminants in place; and the potential for failure of the remedy. A remedy that reduces risks with little long-term management, and that has proven effective under similar conditions, shall be preferred" (NMED April 2004). This criterion will include defining the institutional controls to be established at the BSG area for each remedy.

Table 5-2. Example CME evaluation using the Order corrective measures remedial alternative evaluation criteria.

Remedial Alternative	Long-Term Reliability and Effectiveness	Reduction of Toxicity, Mobility, or Volume	Short-Term Effectiveness	Feasibility	Cost
Groundwater Monitoring					
MNA					
ISB followed by Groundwater Monitoring					
ISB followed by MNA					
Pump and Treat followed by Groundwater Monitoring					
Pump and Treat followed by MNA					

ISB = in situ bioremediation.
MNA = monitored natural attenuation.

- **Reduction of toxicity, mobility, or volume.** This criterion is intended to evaluate the effectiveness of the remedy at reducing nitrate concentrations in the BSG. As stated in the Order, "Each remedy shall be evaluated for its reduction in the toxicity, mobility, and volume of contaminants. A remedy that more completely and permanently reduces the toxicity, mobility, and volume of contaminants shall be preferred" (NMED April 2004).

- **Short-term effectiveness.** In general, short-term effectiveness applies to the ability of the remedy to reduce risks during the remediation process. These risks include reducing exposure to contaminants during remedy implementation and risks and hazards introduced by remedy implementation. As stated in the Order, "Each remedy shall be evaluated for its short-term effectiveness. This factor includes consideration of the short-term reduction in existing risks that the remedy would achieve; the time needed to achieve that reduction; and the short-term risks that might be posed to the community, workers, and the environment during implementation of the remedy. A remedy that quickly reduces short-term risks, without creating significant additional risks, shall be preferred" (NMED April 2004).

- **Feasibility.** As stated in the Order, "Each remedy shall be evaluated for its feasibility, or the difficulty of implementing the remedy. This factor includes consideration of installation and construction difficulties; operation and maintenance difficulties; difficulties with cleanup technology; permitting and approvals; and the availability of necessary equipment, services, expertise, and storage and disposal capacity. A remedy that can be implemented quickly and easily and poses fewer and lesser difficulties shall be preferred" (NMED April 2004).

- **Cost.** As stated in the Order, "Each remedy shall be evaluated for its cost. This factor includes a consideration of both capital costs and operation and maintenance costs. Capital costs shall include, without limitation, construction and installation costs; equipment costs; land development costs; and indirect costs including engineering costs, legal fees, permitting fees, startup and shakedown costs, and contingency allowances. Operation and maintenance costs shall include, without limitation, operating labor and materials costs; maintenance labor and materials costs; replacement costs; utilities; monitoring and reporting costs; administrative costs; indirect costs; and contingency allowances. All costs shall be calculated based on their net present value. A remedy that is less costly, but does not sacrifice protection of health and the environment, shall be preferred" (NMED April 2004).

6.0 CORRECTIVE MEASURES EVALUATION REPORT

The results of the CME will be presented in the CME report. This report will provide the technical basis for the recommended corrective measure and will include technical and functional requirements of implementation of the preferred remedy. The key components of the CME report are designated requirements from the Order (NMED April 2004). Guidelines of the RCRA Corrective Action Plan (EPA May 1994) were also considered. The following is an outline of the key components of the CME report:

I. Title Page and Signature Block
II. Abstract
III. Table of Contents
IV. Introduction
V. Background Information
    a. Site Conditions
        i. A summary of surface, subsurface, and groundwater conditions as appropriate.
        ii. A brief summary/discussion of any new information since the field investigation.
    b. Potential Receptors
        i. Including discussion of sources, pathways, and receptors.
VI. Evaluation of Remedial Alternatives
    a. Overview of CME
    b. Identification and Descriptions of Remedial Alternatives
    c. Evaluation Criteria and Approach
        i. Threshold Criteria.
        ii. Remedial Alternative Evaluation Criteria.
    d. Selection of a Preferred Corrective Measure
        i. Demonstrate that the corrective measure will protect human health and the environment.
        ii. Demonstrate that the corrective measure will attain media cleanup standards.
        iii. Demonstrate that the corrective measure will comply with any applicable standards for waste management.
        iv. Demonstrate that the corrective measure is effective in other factors.
VII. Remedial Alternative Design Criteria to Meet Cleanup Goals and Objectives
VIII. Corrective Measures Implementation Plan
    a. Outline
    b. Schedule
IX. Appendices.

7.0 PROJECT MANAGEMENT PLAN

This section presents the Project Management Plan (PMP) for the CME for BSG. This includes the overall approach, the project organizational structure, project schedule and deliverables, project budget, and the project assumptions.

7.1 Project Approach

The corrective measures process that is being undertaken for BSG, by requirement of the Order (NMED April 2004) and under the direction of the RCRA Corrective Action Plan (EPA May 1994), is a phased approach illustrated in Figure 7-1. This approach will be used to determine and implement the selected remedy as the corrective measure for meeting the cleanup standards, objectives, and requirements for BSG. The process includes the following five steps:

1. Protect human health and the environment (IMWP),
2. Defining the problem (CME Work Plan and Current Conceptual Model),
3. Remedy evaluation (CME Report),
4. Long-term corrective measures planning (CMI Plan), and
5. Corrective measures implementation (CMI Report).

Following each step will be a decision point to obtain concurrence from the NMED before proceeding with the next phase of the process.

In conjunction with the BSG Current Conceptual Model (SNL/NM March 2008), this CME Work Plan is represented in Figure 7-1 under the problem definition step. Following agency approval of this CME Work Plan, the CME will proceed. The CME will result in recommendations for the corrective measure, which will be presented in the CME Report.

This process will define the cleanup approach and document understandings and agreements between SNL and the regulatory agency regarding corrective measure execution. The approach being developed will determine the most cost- and schedule-effective corrective measure that can gain public and regulatory acceptance. An important aspect of this approach, and an objective of this work plan, is outlining and defining all of the goals, objectives, requirements, and other criteria that must be addressed in order to design and implement a corrective measure. It is feasible that the team of regulators and technical staff that developed the cleanup approach will change during the corrective measure implementation timeframe. For continuity in achieving the project goals and objectives, well-documented requirements and implementation strategies will help future parties execute the cleanup approach in the manner envisioned by the initial project team. The overall goal of developing this document base is to provide clear direction for implementing and attaining the regulatory standards, periodic reporting requirements, and the scope, schedule, and budget, with all leading toward site closure in accordance with pre-determined requirements.

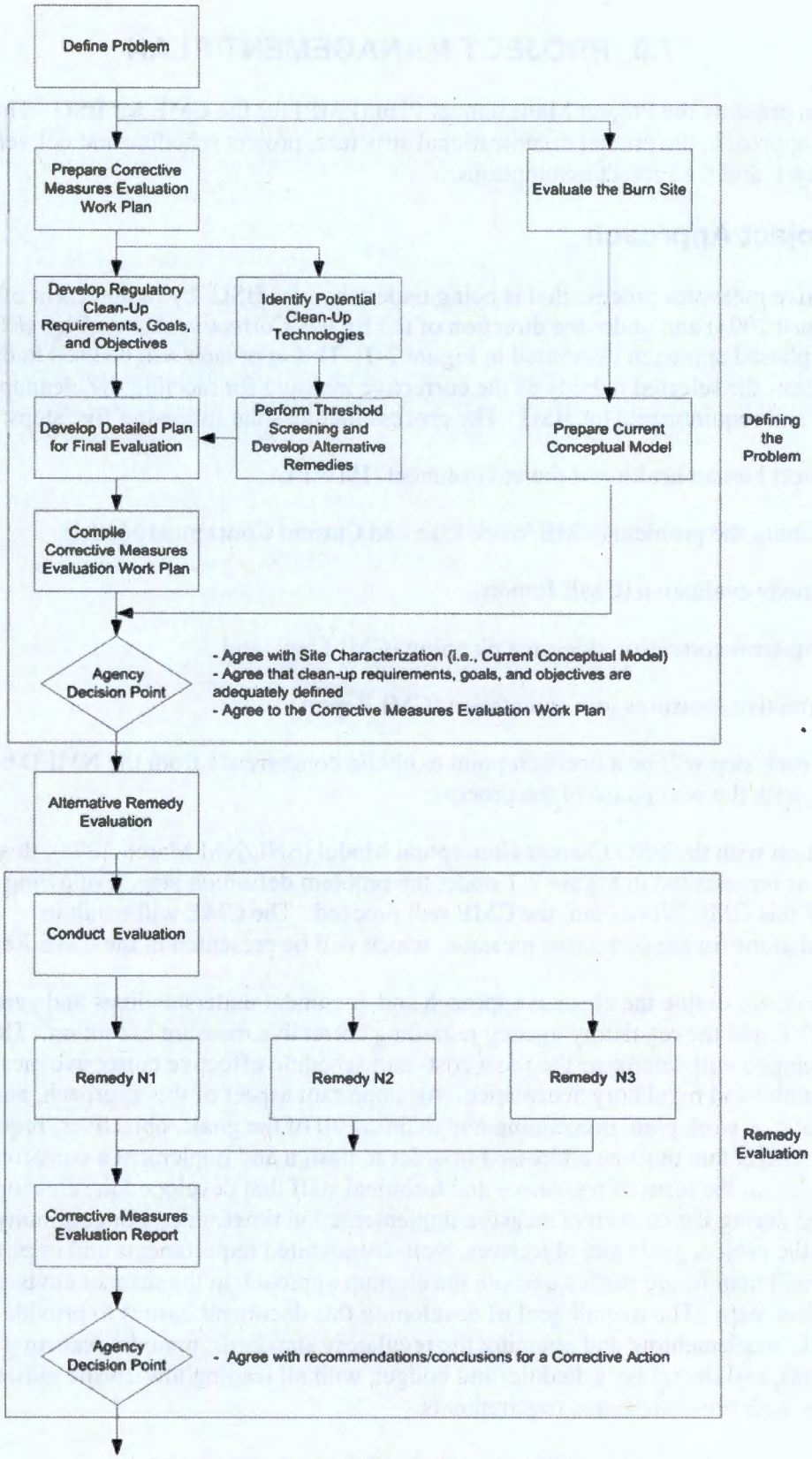


Figure 7-1. Logic diagram for the BSG project.

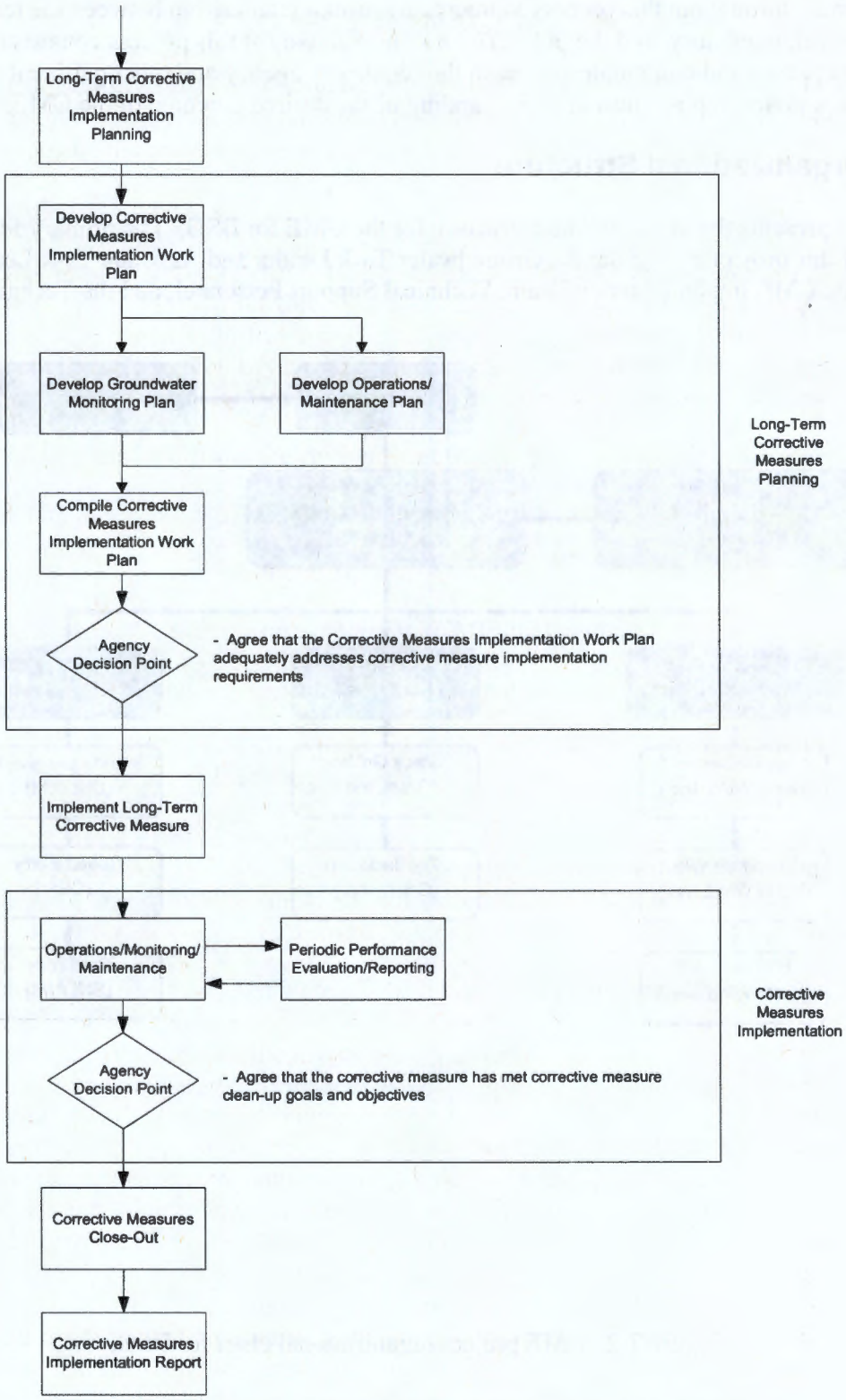


Figure 7-1. Logic diagram for the BSG project (concluded).

It is important throughout this process to maintain a strong relationship between the team (i.e., technical, regulatory, and the public). An important part of this process consists of scheduled reviews and communication with the regulatory agency and other pertinent stakeholders to develop a common understanding of the desired outcome of the CME.

7.2 Organizational Structure

Figure 7-2 presents the organizational structure for the CME for BSG. The primary functional entities of this project are the Sandia Groundwater Task Leader and Assistant Task Leader, the NMED, the CME Implementation Team, Technical Support Personnel, and the Technical Peer Review Panel.

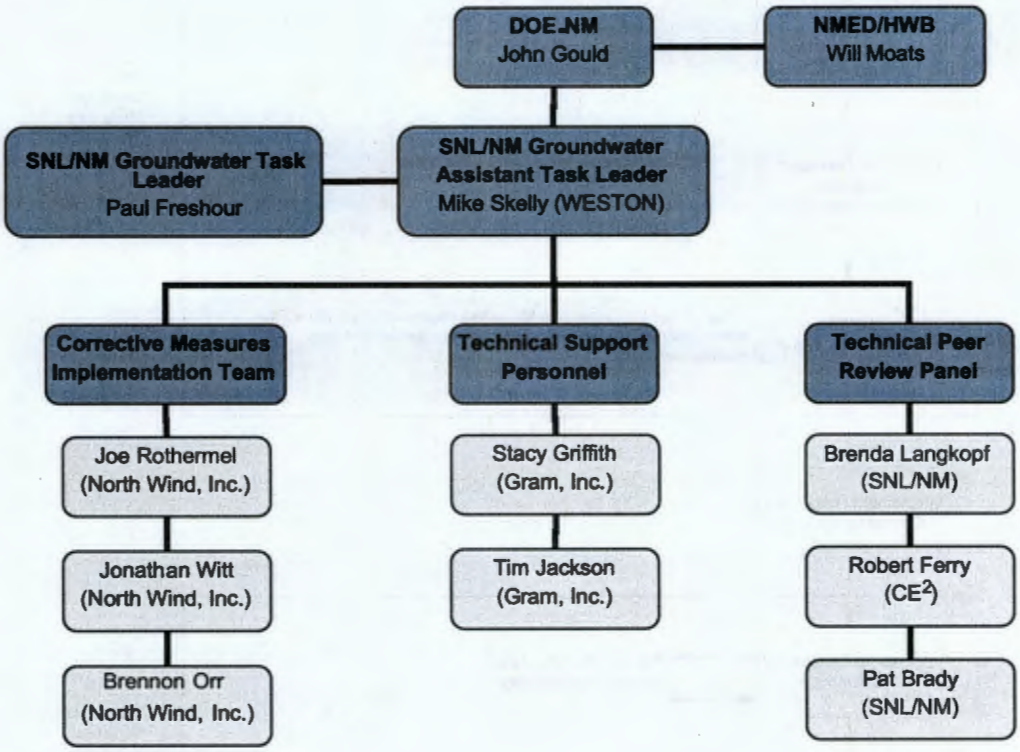


Figure 7-2. CME project organizational chart for BSG.

The Sandia Groundwater Task Leader is responsible for the overall project (i.e., scope, schedule, and budget). This position is responsible to implement the Order (NMED April 2004) for BSG and to meet regulatory requirements, milestones, and objectives. This position also serves as an interface between the Corrective Measures Implementation Team, Technical Support Personnel, Technical Peer Review Panel, and the NMED. The Sandia Groundwater Task Leader and Assistant Task Leader identify and acquire technical and operational resources to complete the project scope.

NMED is the regulatory agency responsible for enforcing the requirements identified in the Order for the CME for BSG. SNL/NM is owned by the National Nuclear Security Administration (NNSA) and is operated by Sandia Corporation.

The CME Implementation Team reports to the Sandia Groundwater Task Leader and works with technical support personnel. The primary function of the CME Implementation Team is to lead the screening and evaluation of potential technologies and remedial alternatives that will meet cleanup standards for BSG. This includes execution of individual technical tasks as well as overall responsibility for the technical direction of the project. The CME Implementation Team is responsible for interpreting all technical data and for making decisions based on these interpretations.

Technical support personnel report to the Sandia Groundwater Task Leader and work with the CME Implementation Team. They are responsible for performance and oversight of all onsite field activities that are conducted in support of the CME for BSG. This may include groundwater monitoring and analysis, well installation, data compilation, and report writing. Technical support personnel also provide site historical and process knowledge as it pertains to the CME for BSG.

A Technical Peer Review Panel may be utilized to ensure that the project is executed in the most technically rigorous and defensible manner possible. This panel includes recognized experts in the field of groundwater characterization and remediation, and would be used to review work plans, technical documents, and project reports. The members of the panel may also serve as technical resources for other members of the project team.

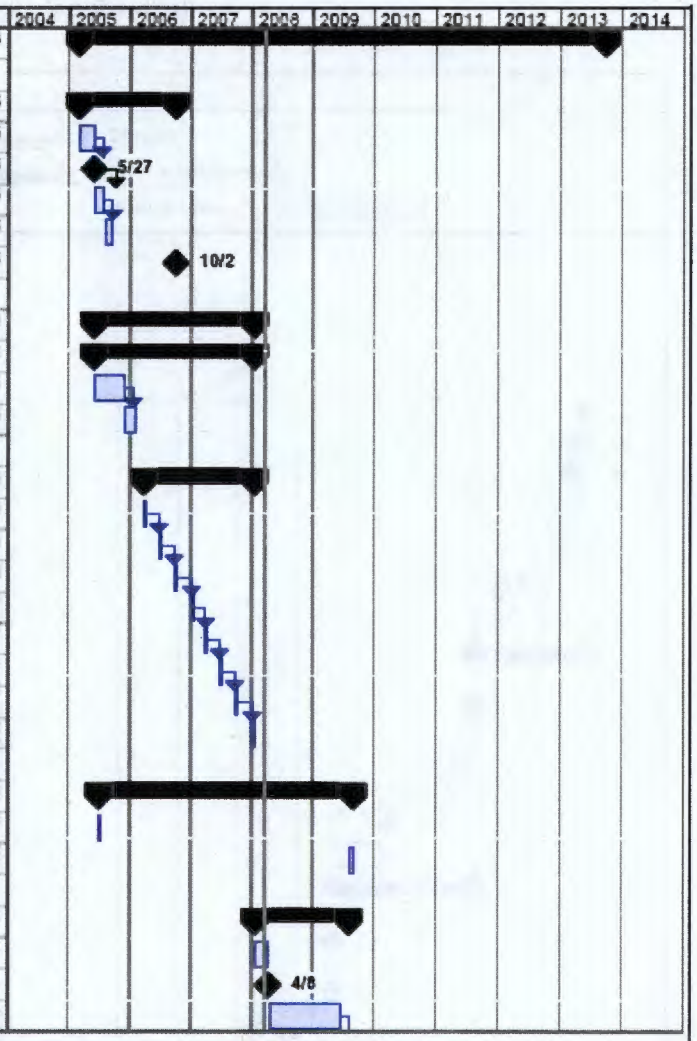
7.3 Schedule

The corrective measures schedule has been derived through development of the project requirements. The basis for the schedule is the logical development of project tasks and activities, which will support the corrective measure under the Order. This schedule will include corrective measure commitments, milestones, and NMED decision points. Certain documents require NMED review and approval. These documents are identified deliverables, which are identified within the project schedule as such, and have clearly defined NMED review/comment and comment resolution periods.

7.3.1 Description

The anticipated corrective measures schedule is presented in Figure 7-3. This schedule identifies the logical progression of tasks and activities aimed at achieving the corrective measures cleanup objectives. This schedule covers development of site characterization knowledge, delineation and preparation of the Corrective Measures Work Plan, technology development and evaluation, the Corrective Measures Report, and development and implementation of the corrective measure.

Task Name	Duration	Start	Finish
Burn Site Groundwater (BSG) Corrective Measures	**2239 days**	**Tue 3/1/05**	**Mon 9/30/13**
BSG Interim Measures Work Plan (IMWP)	**414 days**	**Tue 3/1/05**	**Mon 10/2/06**
Prepare Draft IMWP	64 days	Tue 3/1/05	Fri 5/27/05
Submit IMWP to NMED for Approval	0 days	Fri 5/27/05	Fri 5/27/05
NMED Review IMWP	45 days	Mon 5/30/05	Fri 7/29/05
Address NMED Comments	30 days	Mon 8/1/05	Fri 9/9/05
Receive NMED Approval for IMWP (Pending)	0 days	Mon 10/2/06	Mon 10/2/06
Interim Measures Implementation	**688 days**	**Wed 6/1/05**	**Fri 1/18/08**
Additional Well Installation	**688 days**	**Wed 6/1/05**	**Fri 1/18/08**
Obtain Permits for Well Drilling (NEPA,etc.)	130 days	Wed 6/1/05	Tue 11/29/05
Drill and Develop Additional Wells	45 days	Wed 11/30/05	Tue 1/31/06
Groundwater Monitoring	**475 days**	**Mon 3/27/06**	**Fri 1/18/08**
Groundwater Sampling Event #1	10 days	Mon 3/27/06	Fri 4/7/06
Groundwater Sampling Event #2	10 days	Mon 6/26/06	Fri 7/7/06
Groundwater Sampling Event #3	10 days	Mon 9/25/06	Fri 10/6/06
Groundwater Sampling Event #4	10 days	Mon 1/8/07	Fri 1/19/07
Groundwater Sampling Event #5	10 days	Mon 4/2/07	Fri 4/13/07
Groundwater Sampling Event #6	10 days	Mon 6/25/07	Fri 7/6/07
Groundwater Sampling Event #7	10 days	Mon 9/24/07	Fri 10/5/07
Groundwater Sampling Event #8	10 days	Mon 1/7/08	Fri 1/18/08
Institutional Controls	**1092 days**	**Fri 7/1/05**	**Mon 3/7/09**
Locks Placed on Existing Wells	5 days	Fri 7/1/05	Thu 7/7/05
Warning Signs Placed on Existing Wells	20 days	Tue 8/11/09	Mon 9/7/09
Update BSG CCM	**407 days**	**Mon 1/21/08**	**Tue 8/11/09**
Prepare Updated Draft CCM for Peer Review	57 days	Mon 1/21/08	Tue 4/8/08
Submit BSG CCM to NMED	0 days	Tue 4/8/08	Tue 4/8/08
NMED Review BSG CCM	306 days	Mon 4/21/08	Mon 6/22/09



Project: BSG Schedule
Date: Thu 3/20/08

Task | Split | Progress | Milestone | Summary | Project Summary | External Tasks | External Milestone | Deadline

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Figure 7-3. Burn Site Groundwater schedule.

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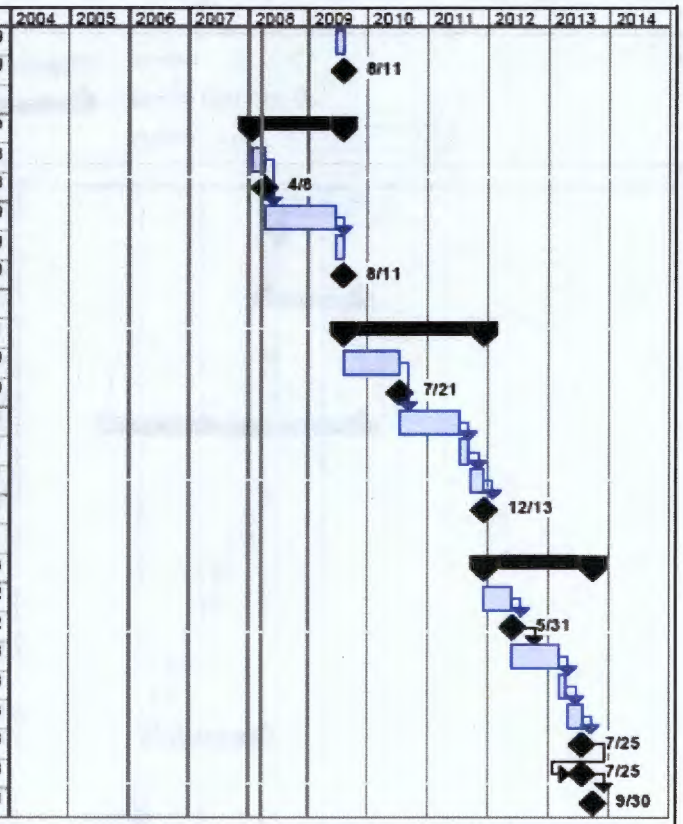
Task Name	Duration	Start	Finish
Address NMED Review Comments	36 days	Tue 6/23/09	Tue 8/11/09
Receive NMED approval BSG CCM	0 days	Tue 8/11/09	Tue 8/11/09
Update BSG CME Work Plan	**407 days**	**Mon 1/21/08**	**Tue 8/11/09**
Prepare Updated Draft CME WP for Peer Review	57 days	Mon 1/21/08	Tue 4/8/08
Submit CME WP to NMED for Approval	0 days	Tue 4/8/08	Tue 4/8/08
NMED Review BSG CME WP	314 days	Wed 4/9/08	Mon 6/22/09
Address NMED Comments on BSG CME WP	36 days	Tue 6/23/09	Tue 8/11/09
Receive NMED Approval BSG CME WP	0 days	Tue 8/11/09	Tue 8/11/09
CME Report (Estimated Dates)	**610 days**	**Wed 8/12/09**	**Tue 12/13/11**
Prepare Draft of CME Report	246 days	Wed 8/12/09	Wed 7/21/10
Submit CME Report to NMED for Approval	0 days	Wed 7/21/10	Wed 7/21/10
NMED Review BSG CME Report	261 days	Thu 7/22/10	Thu 7/21/11
Address NMED Comments on BSG CME Report	41 days	Fri 7/22/11	Fri 9/16/11
NMED Review Responses to BSG CME Report	62 days	Mon 9/19/11	Tue 12/13/11
Receive NMED Approval BSG CME Report	0 days	Tue 12/13/11	Tue 12/13/11
CM Implementation Plan (Estimated Dates)	**468 days**	**Wed 12/14/11**	**Mon 9/30/13**
Prepare Draft CMIP	122 days	Wed 12/14/11	Thu 5/31/12
Submit BSG CMIP to NMED	0 days	Thu 5/31/12	Thu 5/31/12
NMED Review BSG IP	203 days	Fri 6/1/12	Tue 3/12/13
Address NMED Comments BSG CMIP	30 days	Wed 3/13/13	Tue 4/23/13
NMED Review Responses BSG CMIP	66 days	Wed 4/24/13	Wed 7/24/13
Receive NMED Approval BSG CMIP	0 days	Thu 7/25/13	Thu 7/25/13
Submit Final Interim Measures Report	0 days	Thu 7/25/13	Thu 7/25/13
Implement BSG Corrective Action	0 days	Mon 9/30/13	Mon 9/30/13



Project: BSG Schedule
Date: Thu 3/20/08

Task | Milestone | External Tasks
Split | Summary | External Milestone
Progress | Project Summary | Deadline

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Figure 7-3. Burn Site Groundwater schedule (concluded).

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7.3.2 Deliverables

The documents to be submitted to the NMED as deliverables, with the corresponding submittal dates in accordance with the Order requirements, are presented in Table 7-1. Projected due dates for the out years (beyond 2008) are estimates only. Additional documents and delivery dates may be identified in subsequent documents as the work progresses. The corrective measures schedule may be revised from time to time to reflect these changes.

Table 7-1. Deliverable documents.

Deliverable	Submittal Date (Actual or Anticipated)
BSG Interim Measures Work Plan	May 27, 2005
Updated BSG Current Conceptual Model	April 8, 2008
Updated BSG CME Work Plan	April 8, 2008
BSG CME Report	July 21, 2010
BSG CMI Plan	May 31, 2012
Final BSG Interim Measures Report	July 25, 2013
BSG CMI Report	At remedy completion

BSG = Burn Site Groundwater.
CME = Corrective Measures Evaluation.
CMI = Corrective Measures Implementation.

7.4 Budget

Table 7-2 presents the current BSG budget, based on the SNL/NM Environmental Restoration (ER) Project Life-Cycle Baseline calculated to 2070 and approved through 2009. It is broken down by project management activities, technology evaluation costs, and site technical services for Fiscal Year (FY) 2004 through FY 2013. A lump sum that assumes a FY 2013 implementation of the final corrective measure is presented for long-term operations.

Table 7-2. Estimated budget for the BSG CME.

Category	Timeframe (Fiscal Year)	Amount ($)
Overall Project Management (Sandia Project Office Costs)[1]	2004 through 2013	1,026,000
Technology Evaluation (Current Conceptual Model, CME Work Plan, Evaluation, Implementation Documents)[1]	2004 through 2013	1,326,000
Site Technical Services (Field Sampling, Analytical Review, etc.)[1]	2004 through 2013	1,051,000
Long-Term Operations[2]	2013 through 2070 (lump sum based on 2006 CMI)	9,600,000

1. Based on the SNL/NM ER/LTS Project Life-Cycle Baseline calculated to 2070 and approved through 2009.
2. Currently based on groundwater monitoring operations, but will require re-baselining based on outcome of the CME.

CME = Corrective Measures Evaluation.
CMI = Corrective Measures Implementation.

7.5 Assumptions

The BSG project will be managed as part of the SNL/NM ER Project until it transitions to the SNL/NM LTS Program. The funding targets listed above for the BSG depend on funding for the entire ER and LTS Projects. As such, the relevant assumptions for the entire ER Project, as well as those for the BSG, are listed below.

7.5.1 General Assumptions

ER Program Assumptions are as follows:

- The ER Project mission, objective, and scope are stable and will proceed as represented by the project documents delivered to the DOE and the baseline from FY 2004 through FY 2009,
- SNL/NM and DOE management will support ER/LTS project management as necessary to meet project and regulatory objectives, as described in the project documents developed under the Order and delivered to DOE,
- The current DOE working and teaming relationships with SNL/NM will be maintained and streamlined to conform with implementation of the project goals, and
- No catastrophic events will occur that would significantly delay the project schedule or significantly increase the project scope.

7.5.2 Financial Assumptions

This funding profile is based on the following assumptions:

- DOE will provide funding necessary to implement the corrective measures evaluation as enumerated in the approved CME Work Plan for BSG through the completion of the CME Report, and

- DOE will provide funding for additional scope resulting from the realization of programmatic risk.

7.5.3 Regulatory Assumptions

- The Order will be the governing document for enumerating the requirements for this corrective action. Changes to the requirements for the corrective measure will be done in accordance with the process for change outlined in the Order.

- The documents that are required under the Order are enumerated in Section 7.3.2 of this document. These documents comprise the project team basis and implementation requirements, as required by the Order, for the execution of the CME for BSG. If one or more parties to the Order change a project requirement, either through a modification of the Order, a change to a law, permit or statute, or a change in the site conditions, then the documents which govern the project implementation basis and requirements are required to be modified. This may include some (or all) of the scope, schedule and budget.

- The NMED will have adequate resources to provide regulatory decisions and document reviews in support of the schedule.

- NMED regulatory review periods will not increase and the document approval backlog will steadily decrease through time.

- Positive relationships and cooperation with the NMED will continue and administrative requirements will not increase.

7.5.4 Project Scope Assumptions

- Project scope will not change significantly from that which is currently incorporated in the baseline,

- Unforeseen circumstances will allow the extension of the completion milestone beyond FY 2009, and

- Final stewardship requirements will not significantly increase baseline scope above the level that is currently anticipated.

The monitoring assumptions specific to the Burn Site are as follows:

- Nitrate is the only COC,
- Conventional sampling methods will be used (e.g., Bennett pumps). Budget estimates are based on 2005 labor hours and sampling costs, and
- Waste management requirements or disposition costs will not change significantly from those currently in place (e.g., purge water volumes will continue to be about four drums or less per well). It will always be possible to discharge the purge water to a nearby drain connected to a publicly owned treatment works (POTW).

7.5.5 Project Schedule and Planning Assumptions

- The project schedule outlined in this document (Figure 7-3) is the basis for the implementation of the CME. This schedule is based upon the requirements of the Order and BSG IMWP. As stated in Section 7.5.4 above, changes to the CME documents Order or BSG IMWP will require modification of the schedule.
- The schedule presented in this document (Figure 7-3) represents the CME schedule for achieving the delivery date of the CME Report as outlined in the BSG IMWP (SNL/NM 2005). This schedule illustrates NMED review periods projected to achieve the evaluations and preparation of the report.

7.5.6 Technical Assumptions

- The current technical direction of the project will not change significantly. All stakeholders and regulatory authorities will reach a common consensus through their review, recommendation, and/or approval authority on the current technical direction.
- Sufficient independent technical review will be utilized to ensure that approaches are technically sound.
- Proven and tested technologies will be utilized and no technology development activities will be required that would delay planned activities.

7.5.7 Public Involvement Assumptions

- The results of actions or recommendations by the public will not increase project scope or schedule, and
- Working groups with public representation will continue to serve as the mode for close involvement of stakeholders in the corrective-action process.

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