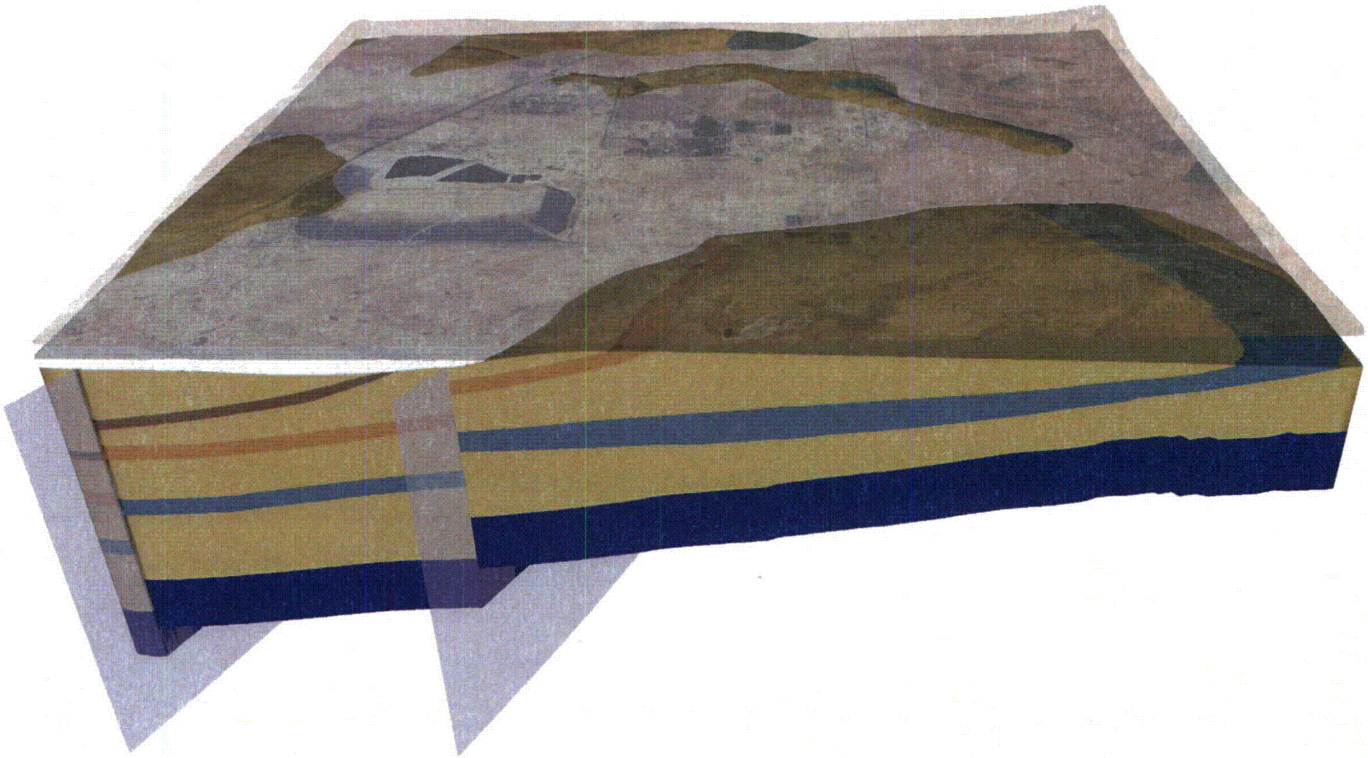
GRANTS RECLAMATION PROJECT
UPDATED CORRECTIVE ACTION PROGRAM (CAP)

Prepared for:

NUCLEAR REGULATORY COMMISSION



Prepared by:

Homestake Mining Company of California

P.O. Box 98 – State Highway 605

Grants, New Mexico 87020

NRC Radioactive Material License SUA-1471

March 2012

GRANTS RECLAMATION PROJECT
UPDATED CORRECTIVE ACTION PROGRAM (CAP)

Prepared for:

NUCLEAR REGULATORY COMMISSION

Prepared by:

HOMESTAKE MINING COMPANY OF CALIFORNIA
P.O. Box 98 – State Highway 605
Grants, NM 87020

MARCH 2012

FSME20
Received
w/o
ltr

LIST OF PREPARERS AND CONTRIBUTORS

Prepared by:

HOMESTAKE MINING COMPANY OF CALIFORNIA
P.O. Box 98 – State Highway 605
Grants, NM 87020

With contributions by:

ARCADIS U.S., INC
630 Plaza Drive
Highlands Ranch, CO 80129
(720) 344-3500

&

HYDRO-ENGINEERING, INC.
4685 East Magnolia St.
Casper, Wyoming 82604
(307) 266-6597

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

ACRONYMS AND ABBREVIATIONS

3-D	three-dimensional
ACOE	U.S. Army Corps of Engineers
AEA	Atomic Energy Act
AEC	U.S. Atomic Energy Commission
AFCEE	Air Force Center for Environmental Excellence
ARAR	Applicable, Relevant, and Appropriate Requirement
AQB	Air Quality Bureau
CAA	Clean Air Act
CAP	Corrective Action Program
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	constituent of concern
CWA	Clean Water Act
DA	Department of the Army
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
DOT	Department of Transportation
DRP	Decommissioning and Reclamation Plan
DWB	Drinking Water Bureau
EC	electrocoagulation

EP-1	Evaporation Pond 1
EP-2	Evaporation Pond 2
EP-3	Evaporation Pond 3
EPA	U. S. Environmental Protection Agency
EVS	Environmental Visualization System
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FS	Feasibility Study
ft/day	feet per day
GHG	greenhouse gas
gpd/ft	gallons per day per foot
gpm	gallons per minute
GQB	Groundwater Quality Bureau
GWPS	groundwater protection standard
GWQB	Ground Water Quality Bureau
HMC	Homestake Mining Company
HMTA	Hazardous Materials Transportation Act
hp	horsepower
HPRO	high pressure reverse osmosis
HWB	Hazardous Waste Bureau
kW	kilowatt
kWh	kilowatt-hour

LPRO	low pressure reverse osmosis
LTP	Large Tailings Pile
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
mg/L	milligrams per liter
MSL	mean sea level
MOU	Memorandum of Understanding
NCP	National Contingency Plan
NEPA	National Environmental Policy Act
NESHAPS	National Emission Standard for Hazardous Air Pollution
NMAC	New Mexico Administrative Code
NMDA	New Mexico Department of Agriculture
NMED	New Mexico Environment Department
NMEIB	New Mexico Environmental Improvement Board
NMEID	New Mexico Environmental Improvement Division
NMOSE	New Mexico Office of State Engineer
NMSA	New Mexico Statutes Annotated
NMSHPO	New Mexico State Historic Preservation Office
NPDES	National Pollutant Discharge Elimination System
NOM	Natural organic matter
NPL	National Priority List

NRC	U.S. Nuclear Regulatory Commission
NSPS	New Source Performance Standard
O&M	operation and maintenance
OHSB	Occupational Health and Safety Bureau
OMM	original mixing model
OPA	Oil Pollution Prevention Act
OSHA	Occupational Safety and health Administration
OU	operable unit
PCB	polychlorinated biphenyl
pCi/L	picoCuries per liter
PMF	probable maximum flood
PMP	probable maximum precipitation
POC	point-of-compliance
RAI	Request for Additional Information
RCRA	Resource Conservation and Recovery Act
RD	remedial design
RI	Remedial Investigation
RO	reverse osmosis
ROD	Record of Decision
RSE	Remediation System Evaluation
SDWA	Safe Drinking Water Act

SOP	Standard Operating Procedure
SOW	Scope of Work
SPCC	Spill Prevention, Control, and Countermeasure
SRT	Sustainable Remediation Tool
STP	Small Tailings Pile
SWB	Solid Waste Bureau
SWDA	Solid Waste Disposal Act
SWQB	Solid Waste Quality Bureau
TDS	Total Dissolved Solids
tpd	tons per day
TSCA	Toxic Substances Control Act
UMTRCA	Uranium Mill Tailings Radiation Control Act
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey
U(VI)	uranyl
WQA	Water Quality Act
WQB	Water Quality Bureau
WQCC	Water Quality Control Commission
W.R.A.P.	Water Resources Allocation Program

DEFINITIONS

Hydraulic Conductivity: A measure of the ability of geologic materials to conduct water through a unit aquifer thickness under a hydraulic or pressure gradient

Secondary Porosity: Voids and associated hydraulic media that form through physical and chemical processes following deposition, including compaction, fracturing, faulting, dissolution, and mineralization

Secondary Permeability: The increased permeability or hydraulic conductivity due to the presence of secondary porosity

Specific Storage: The volume of water that a unit volume of saturated aquifer releases from storage per unit volume of aquifer per unit decline in hydraulic head primarily caused by aquifer compressibility

Specific Yield: The ratio of the volume of water an unconfined aquifer will yield by gravity drainage to the total volume of aquifer

Storage Coefficient or Storativity: The volume of water that a unit volume of a confined aquifer releases from storage per unit decline in hydraulic head, equal to the product of the aquifer thickness and specific storage

Subcrop: The location of an outcrop of sub-unconformity rock formations on the surface of the unconformity; the intersection of two units across an unconformity

Transmissivity: A measure of the ability of an aquifer unit to conduct water under a hydraulic or pressure gradient, equal to the product of the aquifer thickness and the average hydraulic conductivity

Executive Summary

The Grants Reclamation Project (site) is owned and operated by Homestake Mining Company of California (HMC). The site is a former uranium mill located in Cibola County, New Mexico that processed ore from several local mines from 1958 to 1990 (**Figure 1-1**). Currently, the primary activity at the site is the containment and treatment of contaminated groundwater through a groundwater restoration program. The objective of the program is to restore concentrations of the constituents of concern (COCs) to levels that meet the site standards, which have been established for each of the impacted aquifers. The site COCs are uranium, selenium, molybdenum, sulfate, chloride, total dissolved solids (TDS), nitrate, vanadium, thorium-230, and radium-226/-228.

During operation, the Large Tailings Pile (LTP) received 21 million tons of tailings from the mill. At the time of placement, concentrations of the ten COCs in tailings pore water in the LTP were elevated. Pore water seeping from the LTP has impacted shallow groundwater, specifically in the alluvial aquifer beneath and downgradient of the LTP. To limit future contamination potential from the LTP and to inhibit the expansion of the contaminant plume, a groundwater restoration program focusing on both source control and plume remediation was begun in 1977, first under the direction of the New Mexico Environmental Improvement Board until 1986, and later under the direction of the Nuclear Regulatory Commission (NRC).

Active restoration efforts are currently expected to continue through 2020, with final evaporation and site closure and decommissioning continuing through 2022. This represents a 3-year extension of the schedule; the restoration effort was previously expected to be completed by 2017. Two of the primary reasons for the revised schedule were the delay in the issuance of approvals for construction of Evaporation Pond-3 (EP-3) and the New Mexico Environment Department's (NMED's) decision to limit land treatment as a means of managing groundwater generated by the plume control program.

The purpose of this update to the Corrective Action Program (CAP) is to document the status of the current restoration effort and the adaptations necessary for source control and plume remediation. The information presented in this CAP is up-to-date as of its submittal. This CAP is designed to accomplish the following objectives:

- To fulfill the relevant acceptance criteria for groundwater CAPs for the NRC, as detailed in NUREG-1620, Section 4.4.3

- To communicate effectively with all stakeholders about the progress being made in restoring groundwater to established site standards and the anticipated path forward
- To address future modifications to the CAP and predict the required duration for each component
- To compile relevant information available in the annual monitoring reports and NRC license amendments into a single document
- To address the Requests for Additional Information (RAIs) from the NRC after their recent review of the 2006 draft CAP revision
- To address specific comments from the Environmental Protection Agency (EPA) and NMED in letters to the NRC dated December 13, 2011 and November 27, 2011, respectively, to assure that completion of the CAP will satisfy EPA and NMED requirements necessary to delete the site from the National Priorities List (NPL)

HMC is proactively incorporating multi-agency input into its evaluation and operation of the groundwater restoration program. HMC is committed to successfully restoring groundwater to the site standards, and input from all of the stakeholders is valued in achieving this goal.

The CAP includes five major operational components: (1) source control, (2) plume control, (3) reverse osmosis (RO) treatment, (4) evaporation, and (5) land treatment. Source control currently involves flushing of the soluble contaminant mass in the tailings pore water with unimpacted to slightly impacted low contaminant concentration water to expedite the draindown of seepage from the LTP to the groundwater. The plume control program involves the creation and maintenance of a hydraulic barrier downgradient of the LTP to inhibit the flow of contaminated groundwater.

Maintenance of the hydraulic barrier requires pumping of large volumes of groundwater containing relatively low levels of COCs. Since 2000, this water has been managed by land treatment on HMC property. Beginning in 2010, however, NMED began to limit HMC's use of land treatment as part of its remediation strategy. If these land treatment limitations continue, additional delays should be expected, as this strategy is a critical component of the CAP.

Within the groundwater collection area established by the hydraulic barrier, groundwater that contains COCs in excess of the approved cleanup standards is extracted from the aquifer and sent to the RO water treatment plant. RO treatment removes COCs from the water, thereby allowing the treated product water to be used as a source of unimpacted water at the site. Evaporation (which is conducted in three lined ponds) and land treatment are water management strategies that allow HMC to handle inflows and outflows from the other restoration programs to achieve a site-wide water balance. Evaporation and land treatment are essential to the operation of the CAP.

HMC has completed and is currently conducting numerous evaluations to determine if the performance and/or operation of the five existing components of the CAP has been effective or can be further optimized.

HMC conducted a mass removal analysis of dissolved uranium to demonstrate the effectiveness of the plume control program. During this analysis, the total mass of dissolved uranium in the alluvial aquifer plume was calculated for each year from 2001 to 2009. In 2001, the total mass of dissolved uranium in the alluvial plume was estimated to be 80,000 kilograms (kg) and in 2009, the total mass was estimated to be 30,000 kg. These results are consistent with reductions in COC concentrations and plume size observed over the past decade. Furthermore, the results of this analysis directly address EPA and NMED concerns by conclusively demonstrating that the decrease in dissolved uranium concentrations observed in the plume is due to mass removal, not dilution from injected water.

HMC is also in the process of evaluating the condition and performance of the RO plant and identifying strategies to maximize production and treatment efficiency. Preliminary results from this investigation indicate that the RO plant is in generally good condition and can be operated reliably for the next 10 years with some investment in rehabilitation and replacement of equipment as it reaches the end of its useful life. Pretreatment can be optimized to maximize treatment capability and minimize produced waste. Potential improvements include equalization and characterization of influent feed water, physical modifications to address hydraulic capacity constraints, adjusting the locations of chemical feeds, and increasing process water quality monitoring. These improvements will boost the reliability of the plant and increase treatment capacity.

HMC is conducting an investigation in the LTP to evaluate the current source control program. This investigation includes a rebound evaluation to provide a defensible, technically sound prediction of long-term COC leaching behavior in and downgradient of the LTP after flushing ends. The rebound evaluation has three elements: (1) bench-scale tests to evaluate the leaching behavior of uranium, molybdenum, and selenium from tailings solids; (2) a tracer study in a 1.3-acre portion of the LTP to characterize the flow regime and evaluate the connectivity of the well network before discontinuing flushing; and (3) a monitoring program of relevant geochemical parameters after flushing was discontinued in May 2011 in this highly localized area. Continued post-flushing monitoring is planned for at least 1 year in this area of the LTP to further understand rebound potential.

In addition to the source control, plume control, and RO treatment optimization evaluations, HMC is investigating several alternative treatment technologies. If bench- and pilot-scale tests are successful, HMC may implement one or more of these technologies upon receiving appropriate agency approval to enhance groundwater restoration. HMC is currently evaluating three different alternative treatment technologies: *in situ* phosphate treatment, *ex situ* zeolite treatment, and electro-coagulation (EC). Phosphate treatment would be used in a variety of implementation approaches to address dissolved uranium in groundwater *in situ*. Currently, HMC is operating a pilot test of the technology in the LTP after performing extensive bench-scale tests. Both zeolite and EC treatment are pump-and-treat technologies that would be used as additional water treatment strategies to supplement RO treatment. HMC is currently operating an *ex situ* zeolite pad on top of the LTP and is conducting bench-scale EC testing to determine the feasibility of using either or both of these treatment technologies at the site.

The five current components of the CAP work in combination as a proven strategy to achieve source control and plume remediation. The source control program limits future contamination potential from the LTP. The plume control program inhibits the movement of contaminated groundwater and sends highly contaminated groundwater to the RO plant for treatment. Evaporation and land treatment are essential water management practices that allow HMC to achieve target injection, extraction, and treatment rates. Without land treatment, the performance of the source control, plume control, and RO treatment programs is limited, and groundwater restoration will not be achieved on schedule. HMC will continue to evaluate conditions and alternative treatment technologies with the aim of identifying opportunities to enhance the effectiveness of the restoration efforts.

HMC's estimate that active groundwater restoration efforts under the CAP will continue through 2020 is based upon groundwater modeling, observed results from present operating conditions, and predicted future operating conditions. The CAP will be subject to further revisions depending upon operational changes in the five current components of the CAP and/or the implementation of alternative restoration technologies as applicable. However, the current schedule cannot not be met if one or more of the CAP components are impeded.

1.0 INTRODUCTION

The Grants Reclamation Project (site) is owned and operated by Homestake Mining Company of California (HMC). The site occupies approximately 1,085 acres, located 5.5 miles north of Milan, New Mexico, in Cibola County (**Figure 1-1**). The site is a former uranium mill that processed ore from several local mines; milling operations occurred from 1958 to 1990.

HMC manages a groundwater restoration program to restore concentrations of the constituents of concern (COCs) to levels that meet the accepted groundwater site standards for each COC in each aquifer. This program began in 1977 and is projected to continue through 2020 with final site closure scheduled in 2022. The program is implemented using an adaptive, ongoing strategy that includes water management, water treatment, and source control. The groundwater restoration program is authorized and regulated under the U.S. Nuclear Regulatory Commission (NRC) License SUA-1471 and two New Mexico Environment Department (NMED) Discharge Permits.

This update to the Corrective Action Program (CAP) includes detailed information about current site conditions, recent modifications to the groundwater restoration program, and key aspects of the proposed future implementation of the CAP. This update also compiles relevant information from recent annual reports and NRC license conditions into a single document and addresses relevant Requests for Additional Information (RAIs) from the 2006 draft CAP revision.

1.1 Regulatory Context

Regulatory responsibilities for the Grants Reclamation Project (site) are currently shared by the U.S. Nuclear Regulatory Commission (NRC), the U.S. Environmental Protection Agency (EPA), the New Mexico Environmental Department (NMED), and the New Mexico Office of State Engineer (NMOSE). **Tables 1.1-2** and **1.1-3** list the primary federal and state statutes and authorities that potentially apply to the site depending on applicable regulatory authority and future reclamation and decommissioning activities.

1.1.1 Relationship of Regulatory Authorities for CAP and Updated Decommissioning and Reclamation Plan

A primary closure and reclamation activity at the site is to restore concentrations of the COCs in groundwater to levels that meet the site's established groundwater standards (**Table 1.1-1**) as previously approved by NRC, EPA, and NMED. As described in this section, each agency has specific assigned responsibilities for the site.

The CAP is a fundamental component of the Decommissioning and Reclamation Plan (DRP) for the site, and future updates of the CAP will continue to address progress in groundwater restoration. As such, established groundwater standards must be achieved prior to final reclamation and decommissioning of surface assets and environmental media. During decommissioning and demolition of surface facilities in the mid-1990s, some surface assets were left in place to support the source control and groundwater restoration efforts. Groundwater restoration activities began during the active life of the mill; therefore, groundwater restoration plans were developed and implemented in separate but related documentation to final site decommissioning and reclamation.

This CAP is an update to the previous version submitted to the NRC on December 12, 2006 and documents the history of past groundwater restoration activities, the current status of the restoration effort, optimization options for the current restoration activities, and potential alternative treatment technologies to supplement the existing strategy. In addition, this update to the CAP provides a revised schedule and project end date based on our current understanding of source control and groundwater restoration progress.

HMC is currently preparing an updated Decommissioning and Reclamation Plan (DRP) that will supersede the existing HMC Grants Site Reclamation Plan (October 1993) and provide additional detail regarding past site reclamation and decommissioning actions, current reclamation and decommission efforts, and final closure activities that remain to be performed.

The current federal and state licenses, permits, and approvals and major compliance requirements held by HMC for the site are listed in **Table 1.1-4.** The regulatory requirements associated with surface decommissioning and reclamation activities will be addressed in the updated DRP.

HMC is committed to completion of groundwater restoration, site decommissioning, and reclamation to meet the requirements of the NRC, EPA, and NMED. Upon completion of these activities, it is anticipated that the site will be transferred to the U.S. Department of Energy (DOE) Office of Legacy Management for long-term surveillance and maintenance, as mandated by the Uranium Mill Tailings Radiation Control Act of 1978.

1.1.2 Regulatory Authorities

1.1.2.1 Nuclear Regulatory Commission

The NRC is the lead agency responsible for regulating and directing all site closure and remedial activities per the terms of the site Radioactive Materials License SUA-1471.

The principal statutory authorities that govern the NRC's activities at the site are:

- Atomic Energy Act of 1954 (AEA), as amended
- Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA), as amended

NRC regulations are issued under the U.S. Code of Federal Regulations (CFR) Title 10, Chapter 1. The principal NRC regulatory authorities applicable to the site are:

- 10 CFR 40 (domestic licensing of source material), including:

  Appendix A to 10 CFR 40 – Criteria Relating to the Operation of Uranium Mills and the Disposition of tailings or wastes Produced by the Extraction or Concentration of Source Material from Ores Processed Primarily for their Source Material Content

- 10 CFR 20 (standards for protection against radiation)
- 10 CFR 51 (implements the National Environmental Policy Act: environmental protection regulations for domestic licensing and related regulatory functions)

Under the AEA, the NRC has the responsibility of regulation of source material and byproduct material generated from conventional uranium milling operations like the site. NRC regulations for source material facility licensing are found in 10 CFR 40.

Source and Byproduct Material

Under the Atomic Energy Act of 1954 (AEA), the NRC has the responsibility of regulation of source material and byproduct material generated from conventional uranium milling operations such as the Grants site. NRC regulations for source material facility licensing are found in 10 CFR 40.

Source material means:

(a) "Uranium or thorium, or any combination thereof, in any physical or chemical form; or

(b) Ores which contain by weight one-twentieth of 1 percent (0.05 percent) or more of uranium, thorium or any combination of uranium and thorium. Source material does not include special nuclear material."

Byproduct material means:

(a) "The tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content."

The NRC regulates byproduct material located at a site where milling operations are no longer active, if such site is not covered by the remedial action program of Title I of UMTRCA (see discussions below).

Residual Uranium

Radioactive Material License SUA-1471 authorizes only the possession of residual uranium and byproduct material in the form of uranium waste tailings and other byproduct waste generated by the licensee's past milling operations.

Under 10 CFR 20, "regulations in this part establish standards for protection against ionizing radiation resulting from activities conducted under licenses issued by the NRC. These regulations are issued under the AEA, as amended, and the Energy Reorganization Act of 1974, as amended".

It is the purpose of the regulations under 10 CFR 20 "to control the receipt, possession, use, transfer, and disposal of licensed material by any licensee in such a manner that the total dose to an individual (including doses resulting from licensed and unlicensed radioactive material and from radiation sources other than background radiation) does not exceed the standards for protection against radiation prescribed in the regulations in this part. However, nothing in this part shall be construed as limiting actions that may be necessary to protect health and safety."

Environmental Protection

Regulations in 10 CFR Part 51 provide for environmental protection regulations for domestic licensing and related regulatory functions (implements NEPA), while regulations in 10 CFR 20 cover radiation protection standards.

UMTRCA amended the AEA, and established two programs to protect the public health, safety and environment from uranium mill tailing. One program deals with the federal government assuming responsibility for cleanup at abandoned, inactive uranium milling sites (Title I sites) and the second program (Title II sites) which places the responsibility for cleanup of commercially-owned sites with the NRC licensees that were operating in 1978, or licensed by the NRC, or licensed by an Agreement State after 1978.

The Grants Reclamation Project is a Title II site. Title II amended the definition of byproduct material to include mill tailings and added specific authority for the NRC to regulate this new category of byproduct material at licensed sites. Under UMTRCA, the NRC has authority to ensure the site meets applicable standards for protecting human health and the environment, including control of radiological and non-radiological hazards. The EPA has authority to set generally applicable standards for both radiological and non-radiological hazards. Eventually ownership of the site will be conveyed to the DOE under a general license to the NRC.

EPA and DOE regulatory authorities are discussed below.

1.1.2.2 U.S. Environmental Protection Agency

As detailed in Section 1.1.3, the EPA's primary responsibility is as an oversight agency, monitoring all restoration activities and providing reviews and comments directly to the NRC; this oversight role is associated with the EPA retaining responsibility for the site under CERCLA.

The principal statutory authorities that govern the EPA's current regulatory activities at the site are:

- UMTRCA, as amended
- Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA)

UMTRCA

Although the EPA does not license uranium mills, it does establish environmental standards under UMTRCA that must be adopted by the NRC and Agreement States. The current regulations that are applicable to the remediation of both inactive uranium mill tailings and uranium extraction facilities, including active uranium mills, have been issued by the EPA under UMTRCA, as amended. . The EPA regulations in 40 CFR Part 192 apply to remediation of such properties and address emissions of radon, as well as radionuclides and other contaminants, into surface and groundwater. Under both the AEA and UMTRCA, the generally applicable standards that EPA promulgates for non-radiological hazards under UMTRCA are to be consistent with standards that EPA promulgates under the Solid Waste Disposal Act (SWDA) and Resource Conservation and Recovery Act (RCRA) for such hazards. The EPA does so by referencing 40 CFR Part 261 regulations. The NRC adopts these requirements into their requirements of 10 CFR Part 40, Appendix A. EPA groundwater protection standards issued under the authority of UMTRCA are required to be followed the site.

CERCLA

CERCLA, as amended, provides broad federal authority to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment. The National Contingency Plan (NCP) (40 CFR Part 300) is the EPA's implementing regulations for CERCLA. Under the NCP, the site was added to the National Priorities List (NPL) in 1983. As a result, the EPA continues to have regulatory authority at the site due to their regulatory authority under CERCLA (see discussion below as to the shared regulatory responsibilities with the NRC).

1.1.2.3 Department of Energy

For license transfer or termination, HMC must conduct an NRC-approved reclamation of any on-site radioactive waste remaining from uranium-processing operations. HMC is also required to ensure full funding for inspections, and if necessary, ongoing maintenance. The DOE will then accept title to the site for long-term custody and care. The DOE will administer the site under the provisions of a general NRC license granted under 10 CFR Part 40.28, "General License for Custody and Long-Term Care of Uranium or Thorium Byproduct Materials Disposal Sites."

1.1.2.4 State of New Mexico

The State of New Mexico has regulatory authority through a number of environmental statutes and regulations identified in **Table 1.1-3**. The NMED provided the NRC with a listing of state statutory and regulatory authorities that may be applicable to the site (NMED 2011). The major state regulatory agencies involved are the NMED and NMOSE. The NMED consists of a number of bureaus, including the Ground Water Quality Bureau (GWQB), Surface Water Quality Bureau (SWQB), Solid Waste Bureau (SWB), Hazardous Waste Bureau (HWB) and the Air Quality Bureau (AQB), The NMOSE offices that are the primary agency regulatory authorities at the HMC site are the Water Rights Division (water appropriations) and the Dam Safety Bureau (permitting of dams associated with surface ponds). These two agencies are part of the New Mexico Water Resources Allocation Program (W.R.A.P.).

NMED regulatory activities on the CAP are being carried out primarily by the GWQB. The GWQB of the NMED has responsibility for issuance of groundwater discharge permits, other than those related to production and refinement of oil or natural gas, under the authority of the New Mexico Water Quality Act (WQA). The GWQB has issued two groundwater discharge permits to the HMC site (DP-200 and DP-725). These permits are issued pursuant to the New Mexico WQA, NMSA 1978 74-6-1 through 74-6-17 and the New Mexico Water Quality Control Commission (WQCC) Regulations 20.6.2 NMAC. These discharge permits the construction and operations of associated surface ponds (e.g., evaporation ponds) and operation of properly constructed injection/collection/monitor wells.

Other environmental media subject to regulatory control by the NMED include media such as non-radioactive air emissions (e.g., dust) [NMED AQB] and solid and hazardous waste handling and disposal [NMED HWB] (delegated authority from the EPA).

The current state permits and approvals held by HMC for site are listed in **Table 1.1-3.** As groundwater alternative reclamation steps are identified in more detail, additional state and federal regulatory approvals may be required.

1.1.3 Interactions of Regulatory Authorities and Grants

As discussed above, groundwater restoration at the site is currently subject to the regulatory authority of at least two federal agencies (NRC and EPA) and two state agencies (NMED and

NMOSE). Each agency's goal is to protect public health and safety by restoring groundwater, but they have different, specific regulatory roles and requirements. The agencies are committed to resolving regulatory and policy issues to achieve multi-agency consensus on groundwater restoration activities at the site. An overview of past interactions between the NRC, EPA, NMED, and NMOSE in the completion of tasks for the CAP is described in **Figure 1.1-3**. **Table 1.1-5** provides a timeline of regulatory licensing history at the Grants site. Additional information and relevant documents are provided in **Appendix A**; histories of operations and restoration activities are discussed in **Section 2**.

Under CERCLA, the EPA has divided the site remediation activities into three distinct phases or operable units (OUs).

- OU1: restoration of groundwater that is contaminated by tailings seepage.
- OU2: consists of the long-term stabilization of the tailings, surface reclamation, and decommissioning and closure of the mill.
- OU3: addresses indoor and outdoor radon concentrations in residual areas adjacent to the mill site.

The remainder of this section will discuss the respective roles of each of the agencies as they currently apply to these OUs.

1.1.3.1 OU1

OU1 is being conducted through the groundwater restoration program being carried out under NRC License SU-1471, the groundwater CAP, and NMED groundwater discharge plans DP-200 and DP-725. In 1977, the HMC implemented OU1 remedial activities by carrying out an NRC- and state-approved groundwater collection and injection system at the site. The groundwater cleanup standards are established by the NRC under License SUA-1471 and NMED under DP-200. In addition, HMC uses a secondary groundwater collection and land treatment system for the remediation of portions of the contaminant plumes that have migrated beyond the facility's licensed boundary. Although this secondary groundwater system is not required as part of the existing CAP or DP-200, HMC has incorporated this system into the revised CAP as well as into DP-200 as part of a renewal process that is currently under review by the NMED.

Rather than continue to conduct groundwater cleanup activities under the requirements of three competing regulatory programs, it is anticipated that the requirements of this CAP and the updated (pending) DRP will be incorporated into a Remedial Action plan approved by EPA, with NMED and NRC concurrence, under EPA's CERCLA authority and that the state discharge permits could be terminated.

1.1.3.2 OU2

Remedial activities under OU2 are being addressed by the NRC under 10 CFR 40, Appendix A. HMC submitted a DRP for the site in 1993, and this plan is being updated as applicable to address final decommissioning and reclamation activities for NRC approval. The final DRP will be implemented to meet the technical requirements of 10 CFR 40, Appendix A and conform to EPA standards in 40 CFR 192.

1.1.3.3 OU3

A Record of Decision (ROD) for OU3 was signed by the EPA on September 27, 1989, with the final selected remedial action being that no further action was required. However, the decision presented in the ROD did not constitute a finding by the EPA that adequate protection had been achieved within the neighboring subdivisions. Based on sampling of the soils and air in the neighboring subdivisions, the EPA continues to review outdoor monitoring and particulate data collected at the site boundary. Under CERCLA, EPA may reopen the administrative record to include new information. The EPA has been collecting air and soil sampling data in support of the development of a Human Health Risk Assessment, which includes both indoor and outdoor radon samples. A final Human Health Risk Assessment is expected to be issued by the EPA in the spring of 2012 (EPA 2011a). Therefore, determination of the protectiveness of the OU3 remedy will be deferred until the risk assessment report is completed.

1.1.3.4 Removal from NPL

Upon completion of groundwater restoration and site decommissioning and reclamation in compliance with 10 CFR Part 40, per 40 CFR Parts 300.425(e) and 300.515(c)(3) and in consultation with the State of New Mexico, EPA will determine whether required response actions have been implemented to meet CERCLA requirements. The site may then be considered for deletion from the NPL (Meyer 2010).

In order to delete the site from the NPL, the EPA must determine, based on the deletion docket, that one of the following criteria have been met (EPA 2011c):

- The responsible party under CERCLA or other designated party(s) has implemented all appropriate response actions required.
- All appropriate fund-financed response under CERCLA has been implemented, and no further response action by the responsible party is appropriate.
- The Remedial Investigation (RI) has shown that the release poses no significant threat to public health or the environment; therefore, taking of remedial measures is not appropriate.

In order to document that the deletion criteria have been met, the EPA is of the opinion that a ROD will be required for the agency's determination that appropriate response actions have been implemented for OU1 and OU2 (EPA 2011b). The purpose of the ROD is to ensure that CERCLA responses have been adequately followed to arrive at the current remedy in place and that substantive CERCLA standards have been met.

In producing this ROD, the EPA will consider the use of CERCLA-equivalent documents (or information and analysis contained in such documents) for remedial investigation/feasibility study (RI/FS) and remedial design (RD) that HMC may have already generated pursuant to NRC closure requirements (EPA 2011b). If equivalent documents do not exist, the EPA will be required to compile this information to satisfy CERCLA criteria. The EPA has furnished the NRC with their requirements for site deletion at the HMC site (EPA 2011b). It is anticipated that the EPA will delete the site from the NPL when the Groundwater CAP and DRP have been completed and approved by the NRC and the agency agrees that CERCLA requirements have been achieved. As groundwater restoration and reclamation and decommissioning plans evolve, efforts have been made to ensure that information available to the EPA is consistent with the sections of the recommended remedial action report contents and the recommended final close-out report outline identified in the EPA's guidance document for close-out procedures for NPL sites (EPA 2011c). HMC will also use any additional information provided by the NRC and EPA in addressing issues critical to NPL delisting. It is understood that remedial and decommissioning tasks will have to be completed in full compliance with 10 CFR 40, Appendix

A before the EPA, pursuant to 40 CFR Parts 300.425(e) and 300.515(c) (3), and in consultation with the NMED, can determine NPL delisting.

1.1.3.5 Standards

The NRC, EPA, and NMED have agreed upon the groundwater site standards for each COC for each aquifer (Meyer 2010). The site standards were finalized in 2006 after background water quality was evaluated, and set at either background or appropriate drinking water standards. These standards were incorporated into the NRC license through License Amendment No. 39 as "ground water protection standards" (GWPSs). The site standards are summarized in Table **1.1-1**, below. The Chinle Mixing Zone refers to the area adjacent to the subcrop locations where the alluvial water has had an impact on water quality. These site standards must be met at POC wells D1, X, and S4 in the alluvial aquifer and at the proposed POC wells CE2 and CE8 in the Upper Chinle Non-Mixing Zone. The locations of the POC wells are identified on **Figure 1.1-1**. The site standards will be discussed in more detail in **Section 2.4.1**.

Table 1.1-1 – Site Standards

Constituent of Concern	Alluvial Aquifer	Chinle Mixing Zone	Upper Chinle Non-Mixing Zone	Middle Chinle Non-Mixing Zone	Lower Chinle Non-Mixing Zone
Selenium (mg/L)	0.32	0.14	0.06	0.07	0.32
Uranium (mg/L)	0.16	0.18	0.09	0.07	0.03
Molybdenum (mg/L)	0.10	0.10	0.10	0.10	0.10
Sulfate (mg/L)	1,500	1,750	914	857	2,000
Chloride (mg/L)	250	250	412	250	634
Total Dissolved Solids (mg/L)	2,734	3,140	2,010	1,560	4,140
Nitrate (mg/L)	12	15	*	*	*
Vanadium (mg/L)	0.02	0.01	0.01	*	*
Thorium-230 (pCi/L)	0.3	*	*	*	*
Radium-226 + Radium-228 (pCi/L)	5	*	*	*	*

Notes:

* No standard for the constituent in the indicated zone

mg/L = milligrams per liter

pCi/L = picocuries per liter

Table 1.1-2 Federal Statutes and Authorities

Statute	Administering Agency	Permitting and Enforcement Authority	Comments
FEDERAL			
AEA	Atomic Energy Commission (NRC)	NRC	Radioactive Material License
CAA			
Title I (PSD: NSPS, NESHAPS)	EPA (Air Programs)	NMED (AQB)	EPA Oversight
Title V	EPA (Air Programs)	NMED (AQB)	
CWA			
402 [NPDES]	EPA	NMED (WQB)	EPA Oversight
404 [Dredge & Fill]	DA Drinking Water Program	DA	
SDWA			
Drinking Water Supplies • Approved Facilities • Monitoring/Certified Labs	EPA Region VI Drinking Water Program	NMED (DWB)	EPA Oversight
UIC Program	EPA Region VI UIC Program	NMED (GQB)	EPA Oversight
TSCA			
• PCBs	EPA Region VI Toxics and Pesticides Program	NMED (AQB)	EPA Oversight
RCRA)			
• Subtitle C [Hazardous Waste]	EPA Region VI Waste Program	NMED (HWB)	EPA Oversight
• Subtitle D [Solid Waste]		NMED (SWB)	EPA Oversight
FIFRA	EPA Region VI Toxics and Pesticide Program	NMDA	Main issues pertain to use of approved pesticides and herbicides and possible applicator license.
NEPA of 1969	Council on Environmental Quality; applicable federal agency (e.g., NRC)	No Permit Required	NEPA requirements via NRC radioactive material license amendments.
Endangered Species Act	DOI Policy for all federal agencies, e.g., USFWS	Consultation with USFWS	
Bald Eagle & Golden Eagle Protection Act	DOI	DOI	No permit or approvals required unless a nest interferes with resource development and needs to be relocated.

Table 1.1-2 Federal Statutes and Authorities

Statute	Administering Agency	Permitting and Enforcement Authority	Comments
Migratory Bird Treaty Act	USFWS	USFWS – coordination through NEPA	Law implements international treaty that protects birds that migrate across national borders.
River and Harbors Act • Dredge and fill • Protection of navigable waters, e.g., streams downgradient from HMC Site	ACOE	DA	Could be applicable for any water diversions.
Occupational Safety & Health Act	OSHA	New Mexico OHSB	OSHA has authority for surface operations (no mining activities).
HMTA	DOT	DOT delegates enforcement authorities to other federal agencies. Shared and overlapping authorities for shipments.	Act preempts state and local requirements unless requirements offer equal or greater levels of protection.
HMTA Uniform Safety Act	DOT	DOT	Purpose is to clarify maze of conflicting local, state, and federal requirements.
Pollution Prevention Act	EPA Region VI Pollution Prevention Program	EPA Region VI	Non-delegable to states.
OPA • Facility Response Plans • SPCC Plan Upgrades	EPA Region VI	EPA Region VI	Non-delegable to states. Supplements requirements in the CWA.
CERCLA	EPA Region VI	EPA Region VI	Cleanup of sites contaminated with hazardous substances under MOU with NRC. Reporting of releases of hazardous substances.
Executive Order 12898 Federal Actions to address environmental justice in minority populations and low-income populations.	EPA Office of Environmental Justice	Coordinate lead agency's efforts to integrate environmental	Fair treatment and meaningful involvement of all people regardless of

Table 1.1-2 Federal Statutes and Authorities

Statute	Administering Agency	Permitting and Enforcement Authority	Comments
		justice into all policies, programs, and activities.	race, color, national origin, or income with respect to development, implementation, and enforcement of environmental laws, regulations, and policies.

Notes:
ACOE – U.S. Army Corps of Engineers
AEA – Atomic Energy Act
AQB – Air Quality Bureau
CAA – Clean Air Act
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
CWA – Clean Water Act
DA – Department of Army
DOI – Department of Interior
DWB – Drinking Water Bureau
DOT – Department of Interior
EPA – Environmental Protection Agency
FIFRA – Federal Insecticide, Fungicide, & Rodenticide Act
GQB – Groundwater Quality Bureau
HMTA – Hazardous Materials Transportation Act
HWB – Hazardous Waste Bureau
MOU – Memorandum of Understanding
NEPA – National Environmental Policy Act
NESHAPS – National Emission Standards for Hazardous Air Pollutants
NMDA – New Mexico Department of Agriculture
NMED – New Mexico Environment Department
NPDES – National Pollutant Discharge Elimination System
NRC – Nuclear Regulatory Commission
NSPS – New Source Performance Standard
OSHA – Occupational Safety and Health Administration
OHSB – Occupational Health and Safety Bureau
OPA – Oil Pollution Prevention Act
PCBS – polychlorinated biphenyls
RCRA – Resource Conservation and Recovery Act
SDWA – Safe Drinking Water Act
SPCC – Spill Prevention Control and Countermeasures
SWB – Solid Waste Bureau
TSCA – Toxic Substances Control Act
UIC – Underground Injection Control
USFWS – U. S. Fish and Wildlife Service
WQB – Water Quality Bureau

Table 1.1-3 State of New Mexico Statutes and Authorities

Table 1.1-3 State of New Mexico Governing Statutes and Authorities			
New Mexico Environmental Act and Regulation and Administrative Code			
Standard, Requirement, Criterion, or Limitation	**NMAC Citation**	**Title/Media**	**Description**
NEW MEXICO WATER QUALITY ACT	Title 20	Environmental Protection	--
New Mexico Water Quality Control Commission Regulations Ground and Surface Water Protection	20.6.2	Groundwater and Surface Water Protection	--
	20.6.2.1203	Groundwater	Notice of Discharge-Removal
	20.6.2.2101	Surface Water	General NPDES Discharge Requirements
	20.6.2.3101	Groundwater	Protection of groundwater with concentration of 10,000 mg/l or less TDS.
	20.6.2.3103	Groundwater	Establishment of Contaminant-Specific Standards for groundwater of 10,000 mg/l or less TDS.
	20.6.2.3104	Groundwater	Discharge permit required for into groundwater in compliance with 20.6.2.3111 NMAC.
	20.6.2.4101	Groundwater and Surface Water	Prevention and abatement of water pollution.
	20.6.2.4103 A-D	Groundwater and Surface Water	Abatement Standards and Requirements
	20.6.2.4111	Groundwater and Surface Water	Abatement Plan Modification
	20.6.2.5000 through 20.6.5299	Groundwater	Underground Injection Control
New Mexico Water Quality Control Commission Regulations Standards for Interstate and Intrastate Surface Waters	20.6.4.8.A(1)	Surface Water	Anti-degradation Policy and Implementation Plan for Surface Water
New Mexico Water Quality Control Commission	20.6.4.12	Surface Water	Compliance with Water Quality Standards
	20.6.4.13.A-L	Surface Water	General Surface Water Criteria

Table 1.1-3 State of New Mexico Statutes and Authorities

Table 1.1-3 State of New Mexico Governing Statutes and Authorities

Standard, Requirement, Criterion, or Limitation	**NMAC Citation**	**Title/Media**	**Description**
New Mexico Environmental Act and Regulation and Administrative Code			
Regulations Standards for Interstate and Intrastate Surface Waters	20.6.4.122	Surface Water	Rio Grande Basin (San Mateo Creek Basin) Designated Water Use and Criteria
	20.6.4.900.A, C,D,F,G,H2	Surface Water	Criteria Applicable to Existing, Designated, or Attainable Uses Unless Otherwise Specified In 20.6.4.97 through 20.6.4.899.
OFFICE OF THE STATE ENGINEER – UNDERGROUND WATER			
New Mexico Rules and Regulations Governing Well Driller's Licensing; Construction, Repair. and Plugging of Wells	19.27.4	Groundwater	Well driller's licensing; construction, repair, and plugging of wells and boreholes.
Statutes Governing the Appropriation and Use of Groundwater	NMSA 1978, 72-2-8, 72-2-12, 72-13-4	Groundwater	Article 1-17; Application for Pollution Plume Control Wells and Pollution Recovery Wells; Article 1-18; Requirements for Metering of Groundwater Withdrawal. Applicable for new groundwater wells.
NEW MEXICO WATER SUPPLY SYSTEMS			
New Mexico Regulations for Public Drinking Water Systems	20.7.10.100	Drinking Water Systems	Health-based standards for public drinking water systems (MCLs and MCLGs).
NEW MEXICO AIR QUALITY CONTROL ACT			
New Mexico Air Quality Regulations	20.2	Air	Air Quality Regulations
	20.2.6	Air	Open burning restrictions
	20.261	Air	Smoke and visible emissions restrictions
NEW MEXICO HAZARDOUS WASTE ACT			
New Mexico Hazardous Waste Regulations	20.4.1.300	Hazardous Waste	Standards for Generators of Hazardous Waste.
	20.5	Petroleum Storage Tanks	Aboveground fuel storage tank(s) and remediation of spills and leaks.

Table 1.1-3 State of New Mexico Statutes and Authorities

Table 1.1-3 State of New Mexico Governing Statutes and Authorities

New Mexico Environmental Act and Regulation and Administrative Code			
Standard, Requirement, Criterion, or Limitation	**NMAC Citation**	**Title/Media**	**Description**
NEW MEXICO SOLID WASTE ACT			
New Mexico Solid Waste Regulations	20.9.2.10	Solid Waste	Special general provisions – prohibited acts
Maximum Size, Sizing Criteria, Design Criteria	20.9.4.9	Solid Waste	Special waste (i.e., asbestos)
NEW MEXICO PREHISTORIC AND HISTORIC SITES			
New Mexico Cultural Properties Act	NMSA 1978, 18-6-1 through 18-6-27	Historic Building Structure Sites or Artifacts	Preservation, protection, and enhancement of structures, sites, and objects of historical significance within the state.
New Mexico Prehistoric and Historic Sites Preservation Act	NMSA 1978, 18-8-1 through 18-8-8.	Prehistoric or Historic Sites	Acquisition, stabilization, restoration, or protection of significant prehistoric or historic sites.
New Mexico Prehistoric and Historic Sites Regulations	4.10.12	Prehistoric or Historic Sites	Provides for implementation of the Act; sites are discovered and may be impacted.
NEW MEXICO WILDLIFE CONSERVATION ACT, ENDANGERED PLANT SPECIES ACT, AND NOXIOUS WEED CONTROL ACT			
New Mexico Wildlife Conservation Act	NMSA 1978, 17-2037 through 17-2-46	Threatened and Endangered Species	Regulation and protection of threatened and endangered species.
New Mexico Endangered Plant Species Act	NMSA 1978, 75-6-1	Threatened and Endangered Species	Regulation and protection of threatened and endangered species.
New Mexico Endangered Plants Regulations	19.21	Threatened and Endangered Plants	Protection of threatened and endangered flora.

Notes:
MCLs – Maximum Contaminant Levels
MCLGs – Maximum Contaminant Level Goals
mg/l – milligrams per liter
NMAC – New Mexico Administrative Code
NMSA – New Mexico Statutes Annotated
NPDES – National Pollutant Discharge Elimination System
TDS – total dissolved solids

Table 1.1-4 Current Licenses, Permits, and Approvals

Regulatory Agency	License, Permits, and Approvals	Regulatory Authority
FEDERAL		
U.S. NRC	NRC License SUA-1471	Atomic Energy Act of 1954, as amended Energy Reorganization Act of 1974 (Public Law 93-438) Applicable parts of Title 10, CFR, Chapter I, Parts 19, 20, 30, 31, 32, 33, 34, 35, 36, 39, 40, 51, 70, and 71
EPA	CERCLA ID NM007860935	Comprehensive Environmental Response, Compensation and Liability Act of 1980, as amended 10 CFR 300 National Oil and Hazardous Substances Pollution Contingency Plan
	SPCC Plan	Oil Pollution Act of 1970 10 CFR 40 Part 112 Oil Pollution Prevention
	EPA oversight of NMED delegated authority	As per applicable NMED regulations
STATE OF NEW MEXICO		
NMED	Discharge Permit 725 (regulates discharges to 3 evaporation ponds and 2 collection ponds)	NMSA 1978, 74-6-1 through 74-6-17 New Mexico Water Control Commission Ground and Surface Water Protection NMAC Title 20.6.2
	Discharge Permit 200 (regulates injection of contaminated alluvial groundwater to tailings piles and extraction and reverse osmosis system)	NMSA 1978, 74-6-1 through 74-6-17 New Mexico Water Control Commission Ground and Surface Water Protection NMAC Title 20.6.2
NMED HWB	Hazardous Waste Generator ID NMD007860935	NMSA 1978, 74-4-1 through 74-4-14 New Mexico Water Control Commission Hazardous Waste Bureau NMAC 20.4.1
NMOSE	NMOSE Permits for Construction and Operations of: • Collection Ponds (2) • Evaporation Ponds (3) • Large Tailings Pile • Small Tailings Pile	NMSA 1978, 72-5 Office of State Engineer NMAC 19.25.12 Dam Design, Construction, and Dam Safety
	NMOSE Water Appropriations	NMSA 1978, 72-12 (Underground Waters)

Table 1.1-4 Current Licenses, Permits, and Approvals

Regulatory Agency	License, Permits, and Approvals	Regulatory Authority
	Permits	Office of State Engineer NMAC 1978, 19-27-1 (Underground Water - General Provisions) NMAC 1978, 19-27-24 (Bluewater Basin)
	NMOSE Permits for Collection/Injection Wells/Monitor Wells	NMSA 1978,72-12 (Underground Waters) Office of State Engineer NMAC 19-27-4 (Well Driller Licensing; Construction, Repair, and Plugging of Wells)
New Mexico Historic Preservation Division NMSHPO	New Mexico Archaeological Permits (a number issued for undisturbed areas subject to disturbance)	NMSA 1978, 18-6-1 through 18-6-27, 18-8-1 through 18-8-8 NMSHPO NMAC 4.10-1 through 4.10-17
State OSHA	Workers safety program	NMSA 1978, 50-9-1 through 50-9-25 New Mexico Environment Department New Mexico OHSB NMAC 11-15-1 through 11-5-4 (New Mexico Plan

Notes:
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
CFR – Code of Federal Regulations
EPA – Environmental Protection Agency
HWB – Hazardous Waste Bureau
NMAC – New Mexico Administrative Code
NMED – New Mexico Environment Department
NMOSE – New Mexico Office of State Engineer
NMSA – New Mexico Statutes Annotated
NMSHPO – New Mexico State Historic Preservation Office
NRC – Nuclear Regulatory Commission
OHSB – Occupational Health and Safety Bureau
SPCC – Spill Prevention Control and Countermeasures

Table 1.1-5 provides a timeline of regulatory licensing history at the site.

Table 1.1-5 Regulatory Licensing History at the Site

Licensing Authority	Event Description
AEC 1958-1974	The AEC administered the original radioactive materials license for the site from 1958 to 1974, when the State of New Mexico became an NRC Agreement State, granting it the authority to regulate uranium milling activities. The NMEIB and the NMEID assumed regulatory authority over the original AEC license, including its renewal.
State of New Mexico 1974-1986	The State of New Mexico was responsible for licensing and regulating uranium milling operations at the site from 1974 to 1986, when it relinquished its authority back to the NRC.
	In 1976, the NMEID and United Nuclear-Homestake Partners, the owners of the site at the time, signed an agreement that established a groundwater injection and collection system to contain seepage from the tailings piles (Section 2.4). This groundwater containment program was the first restoration activity at the site, and eventually evolved into a key component of the current CAP.
	The site was placed on the EPA's Superfund NPL in September 1983 at the request of the State of New Mexico due to elevated selenium concentrations in the alluvial aquifer near the site. As a result, the site's groundwater restoration activities are also being overseen under the EPA's Superfund Program, in accordance with CERCLA.
	When the site was placed on the NPL, the EPA did not require additional response actions to remediate the groundwater because HMC was already implementing a groundwater containment program under the 1976 agreement with the State of New Mexico.
NRC 1986-present	The NRC regulates site activities specifically under a Source and Byproduct Material License (License No. SUA 1471), issued in accordance with CFR10 CFR Part 40. The current NRC license, as amended, authorizes HMC to possess residual uranium and by-product material generated by past milling operations in accordance with approved license conditions. Currently, the two principal licensed activities are the implementation of the CAP and decommissioning and closure of the remaining assets at the site.
	On September 15, 1989, HMC submitted a CAP for groundwater remediation to the NRC. The program was approved by the NRC via License Amendment No. 8 (dated July 20, 1990) by adding the requirement for implementation of the CAP as License Condition 35 (Appendix A).
	The previously mentioned groundwater containment program, in place since 1977 during milling operations, was converted to a groundwater restoration program in 1990, when the mill was shut down.

Table 1.1-5 Regulatory Licensing History at the Site

Licensing Authority	Event Description
NRC 1986 present (continued)	Due to overlap in the regulatory requirements of the NRC and EPA Region VI, the two agencies signed an MOU in December 1993, defining the regulatory roles and responsibilities for each federal agency. Under the MOU, the NRC is the designated lead agency for the radioactive materials disposal, reclamation, and closure activities, while the EPA is responsible for overseeing all reclamation activities carried out under the NRC's authority to ensure these actions will allow attainment of ARARs under CERCLA.
	A revised CAP was submitted by HMC to the NRC on December 12, 2006. The revised CAP was prepared to document modifications to the groundwater corrective action operations over the past 20 years.
	On February 4, 2010, the NRC submitted RAIs regarding the 2006 CAP. In 2010, the NRC also requested an update of the CAP that would address modifications to the restoration program and future CAP activities. This document provides the requested update. In addition, it includes relevant information from the annual reports and license conditions and addresses the relevant RAIs from the 2006 CAP (Appendix A).
DOE (post-closure)	Once EPA removes the site from the NPL list and NRC approves completion of the reclamation and decommissioning and HMC's funding provision for post-closure long-term monitoring and ongoing routine maintenance, the license will be transferred to the DOE under UMTRCA for long-term custody and care of the site.

Notes:
AEC – U.S. Atomic Energy Commission
ARARs – Applicable, relevant, and appropriate requirements
CAP – Corrective Action Program
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
CFR – Code of Federal Regulations
DOE – Department of Energy
EPA – Environmental Protection Agency
HMC – Homestake Mining Company
MOU – Memorandum of Understanding
NMEIB – New Mexico Environmental Improvement Board
NMEID – New Mexico Environmental Improvement Division
NPL – National Priority List
NRC – Nuclear Regulatory Commission
RAIs – Requests for Additional Information
UMTRCA – Uranium Mill Tailings Radiation Control Act

1.2 Objectives

This updated CAP has several primary objectives, including:

- To fulfill NRC License requirements for groundwater CAPs based upon the acceptance criteria detailed in NUREG-1620, Section 4.4.3
- To communicate effectively with all stakeholders about the progress made restoring groundwater thus far and the anticipated path forward
- To document current groundwater restoration activities at the site
- To outline anticipated future modifications to the CAP and predict the duration for each component of the CAP
- To compile relevant information available in the annual monitoring reports and NRC license amendments into a single document
- To address specific comments from the EPA and NMED in letters to the NRC dated December 13, 2011 and November 27, 2011, respectively, to ensure that completion of the CAP will satisfy EPA and NMED requirements necessary to delete the site from the NPL.

1.3 CAP Structure

The information included in the CAP follows NRC NUREG-1620 guidance. Section 4.4.3 of NUREG-1620 details the acceptance criteria for a groundwater corrective action program. This document provides guidance on necessary information, but does not specify a required format. **Table A-1** in **Appendix A**, attached, references the relevant section of the CAP that addresses each NUREG-1620 acceptance criterion.

The 2012 CAP is organized differently than the previous CAP submitted to the NRC in 2006. Detailed information has been tabulated from the text and, where appropriate, has been moved into appendices; thus, the most relevant and important information is provided in the main text of the CAP and details are summarized in the appendices.

The site, various site components, and operational history are described in **Section 2**. The geologic and hydrogeologic setting of the site is described in **Section 3.0,** and more detailed information is provided in **Appendices C** and **D**. Groundwater quality, including both background water quality and characteristics of the contaminant plume, is described in **Section 4,** and more detailed information is provided in **Appendix E**. The existing CAP is described in **Section 5,** and detailed operational information is tabulated in **Appendix F**. The Revised CAP and the schedule are described in **Section 6,** and detailed operational information is tabulated in **Appendix I**. The groundwater monitoring program is described in **Section 7,** and more detailed information is provided in **Appendices K** and **L**. HMC's financial surety is summarized in **Section 8**.

2.0 SITE DESCRIPTION

The site is owned and operated by HMC. The site location and climate, surrounding land and groundwater use, operational history, and groundwater remediation history are discussed in this section.

2.1 Site Location and Climate

The site is located approximately 5.5 miles north of Milan, New Mexico in Cibola County, primarily in Section 26, Township 12 North, Range 10 West (**Figure 2.1-1**). The site license boundary occupies an area of approximately 1,085 acres, including the 185-acre Evaporation Pond 3 (EP-3) site, which was added to the existing license boundary in 2010. The site is located near the confluence of the ephemeral Lobo Creek and San Mateo Creek drainages, both tributaries to the Rio San Jose. The site is located in a semi-circular valley defined by a series of mesas that are approximately 7,000 to 8,000 feet above mean sea level (MSL) and is approximately 10 miles in diameter. The site is approximately 6,600 feet MSL, and the local topography is generally flat with some low, rolling hills and shallow arroyos.

The site has an arid to semi-arid, temperate climate typical of the high desert. The average precipitation is 10.4 inches per year, and the average pan evaporation is 54.6 inches per year. The majority of annual precipitation typically occurs during thunderstorms in July, August, and September. Average precipitation for the remainder of the year is about 0.5 inch per month. **Figure 2.1-2** presents the total yearly precipitation for the site from 1997 through 2010. Evaporation is highest in May, June, and early July; the onset of the rainy season, usually in mid-July, reduces evaporation in the latter summer months.

2.2 Surrounding Land and Groundwater Use

NRC License Condition No. 42 requires the submittal of a land use survey with the annual report; the most recent detailed Land Use Review/Survey is provided as Appendix E of the 2010 Annual Report (HMC and Hydro-Engineering 2011). HMC owns a substantial amount of property around the site. Most of this land that is not within the site boundary is used for livestock grazing through a lessor/lessee tenant arrangement. No grazing is allowed in the areas adjacent to the tailings and evaporation facilities. Land treatment, which is an integral part of the water balance of the CAP, also occurs on adjacent land owned by HMC. This land treatment is used for crop production and/or livestock grazing, and the total farm field area is 394 acres, although not all of this area is irrigated every year. **Section 5.3.5** describes the existing land treatment program in greater detail.

There are five residential subdivisions near the site: Felice Acres, Broadview Acres, Murray Acres, Pleasant Valley Estates, and Valle Verde. HMC began providing four of these subdivisions with a potable water supply system in 1986, as an extension of the Village of Milan water supply, to address concerns about the quality of groundwater for domestic use. The Land Use Review/Survey in the 2010 Annual Report investigated whether residents in the subdivisions used Milan water during 2010 by consulting a residential customer database. There were two residences in and adjacent to the Valle Verde subdivision that were not connected to the Village of Milan water supply system. One resident hauled water to the residence for domestic use and did not use a private well; the other is currently on a private well but plans are to connect this resident to the Milan water supply system soon. There are three other pending residential hookups to the Village of Milan water supply system located in proximity to Highway 605; approvals to complete these hookups are presently underway.

The radiation dose to the public associated with land treatment has been modeled and is presented in the 2000-2010 Irrigation Evaluation Report (HMC et al. 2011), which is also included as **Attachment J-1** in **Appendix J**. In the worst-case scenario, the radiation dose is less than 1 percent of the dose from natural background and medical exposures.

2.3 Operational History

Uranium milling operations occurred at the site from 1958 to 1990. There were originally two separate mills operated as two distinct partnerships: the larger mill was organized under Homestake-Sapin Partners, with a nominal milling capacity of 1,750 tons per day (tpd). The smaller mill was organized under Homestake-New Mexico Partners, with a nominal milling capacity of 750 tpd. They operated independently, and each had separate tailings piles. The two milling facilities were combined and expanded in 1961 for a total nominal milling capacity of 3,400 tpd. The surviving organization was Homestake-Sapin. Both mills were designed to be alkaline leach-caustic precipitation processes for concentrating uranium oxide from ores with average grades of 0.05 to 0.30 percent U_3O_8. A detailed summary of the mill operation, including process chemistry and tailings characteristics, is provided in **Appendix B**.

In 1968, United Nuclear Corporation acquired an interest in the partnership, and the operation became known as United Nuclear-Homestake Partners. United Nuclear Corporation's interest was purchased by HMC in March 1981, and the operation became Homestake Mining Company-Grants. In 2001, HMC merged with Barrick Gold Corporation as a wholly-owned subsidiary.

Two tailings piles were developed on the site. The first and smaller of the two piles is called the Small Tailings Pile (STP) and the larger is called the Large Tailings Pile (LTP). The STP contains tailings from ore milled under contracts with the federal government. The total quantity of tailings placed in the STP was 1.22 million tons. Tailings deposited within this pile were contained entirely by an embankment composed of compacted natural soils. The embankment was compacted by heavy equipment and raised to a height of 20 to 25 feet. The crest was a minimum of 10 feet wide and the base approximately 40 feet wide. The STP covers an area of about 40 acres. In 1990, an evaporation pond (EP-1) was constructed within the footprint of the STP to assist in the dewatering of the LTP and to hold water pumped from the collection wells associated with the CAP. More recently, this evaporation pond, along with other lined ponds constructed nearby, have been used to evaporate the brine from the reverse osmosis (RO) water treatment plant and other wastewater generated as part of the CAP. The evaporation component of the CAP is discussed in **Section 5.3.4**.

The LTP contains tailings from ore milled under both federal government and commercial contracts for a total of 21.05 million tons of tailings; 11.41 million tons was generated under U.S. Atomic Energy Commission (AEC) contracts, and 10.89 million tons from commercial contracts. Originally, HMC deposited tailings into only one cell of the LTP. In 1966, HMC added a cell adjacent to and west of the existing cell. From 1966 until 1990, tailings disposal alternated between the two cells to maintain optimal operating conditions. The starter dike for the LTP was constructed in compacted 6-inch lifts of natural soils excavated from within the tailings pile area. The starter dike was constructed to a height of approximately 10 feet and a width of approximately 10 to 15 feet at the crest and 25 to 30 feet at the base. The perimeter dike was raised using the centerline method until 1981, when an inboard offset of the embankment was made to improve stability. Subsequent lifts were added to the offset perimeter dike by the centerline method. The LTP covers approximately 234 acres, and the top varies between 70 feet to 90 feet above the toe of the LTP.

The tailings piped to the LTP were separated by the cyclone method and deposited through spigotting throughout most of the milling operation. Cycloning separated the coarse fraction (sands), as the underflow, from the fine fraction (slimes), as the overflow. The sands were deposited downstream of the dike crest along the centerline to raise the pile, and the slimes were deposited upstream of the dike crest toward the pond center of each cell. Detailed information about the grain size and geotechnical characteristics of the tailings is included in **Appendix B**. The tailings liquid was recovered through two decant towers for reuse as mill process water. When production rates were low during the latter stages of mill operations, cyclone separation was not used; the tailing slurry was discharged directly across the beaches into the tailings pond. This method of operation confined disposal to a single pond at a time, with the other pond used for evaporation as needed. Milling and deposition of tailings ended in 1990.

Interim reclamation of the LTP was completed in 1995, with the side slopes graded to a 5:1 horizontal to vertical slope and covered with 3 feet of compacted radon barrier material (sandy clay) and 8 inches of rock for erosion control. The top surface of the LTP was covered with a minimum of 0.5 foot of interim cover. Final reclamation of the LTP will be completed once the wells in the tailings pile are no longer needed, and a final determination is made concerning acceptable tailings consolidation and settlement. In addition, an interim cover was placed on the top portion of the STP not covered by EP-1, with final reclamation to be completed as part of the final closure of EP-1.

2.4 Groundwater Remediation History

HMC manages a groundwater restoration program authorized by NRC License SUA-1471 and two NMED Discharge Permits (HMC and Hydro-Engineering 2010a). This program is an adaptive, ongoing strategy that began in 1977 and is scheduled to be completed in 2020 with final reclamation and site closure occurring in 2022. The ultimate goal of the program is to restore the concentration of COCs to levels that meet the accepted groundwater site standards for each constituent in aquifer (**Section 1.1**; **Table 1.1-1**).

When the Grants mills were built, the surrounding area was remote ranch land. In the 1960s and 1970s, several subdivisions were constructed in the vicinity of the mill, primarily by families working at the mill or in the area mines. Many of the original residence owners used domestic wells that were completed in aquifers in which the natural water quality was generally poor (MFG 2006).

In the 1950s, the AEC began to require monitoring of uranium recovery facilities for groundwater protection. Sampling was performed quarterly at the site and was reviewed by the AEC. While the AEC monitoring did not show any increases in radioactive materials in the water through the 1970s, the New Mexico State Engineers Office observed and reported groundwater contamination in the early 1960s (Chavez 1961, EPA 2006, USPHS 1962).

In 1974, the U.S. Congress passed the Safe Water Drinking Act (SDWA) to protect the nation's public water supply. In 1975, the New Mexico Environmental Improvement Division (NMEID; now the NMED) requested that the EPA study the impacts of uranium mining and milling activities in the Grants Mineral Belt on local groundwater and surface water (EPA 1989). The EPA study determined that groundwater in the alluvial aquifer, which was being used for domestic use in one of the neighboring subdivisions downgradient of the site, had elevated selenium levels. At that time, HMC undertook a more comprehensive groundwater monitoring program. Several residential wells in two subdivisions south of the HMC site were subsequently found to also exhibit elevated levels of selenium, the source of which was uncertain. Possible sources included: (a) groundwater from Poison Canyon, an area with selenium-rich soils that are known to impact background water quality; (b) seepage from the tailings piles, as the carbonate leach process causes some of the selenium in the tailings to be soluble; and (c) discharges from other mines and mills in the area.

As a result of the findings of the 1975 EPA sampling program, a Groundwater Protection Plan was signed in August 1976 between the NMEID and United Nuclear-Homestake Partners, which was the owner of the site at that time (NMEID and UN-HP 1976). This plan established a groundwater injection and collection system with an associated monitoring program and initiated a program to provide domestic bottled water to downgradient residents upon request. This groundwater injection and collection system allowed United Nuclear-Homestake Partners to control seepage from the STP and LTP.

In 1976, United Nuclear-Homestake Partners determined that there was a contaminant plume in the alluvial aquifer that originated from the LTP and was moving off site to the south and west (HMC and Hydro-Engineering 2010a). United Nuclear-Homestake Partners installed and operated a line of groundwater injection wells along the southern site boundary between the LTP and the downgradient subdivisions beginning in 1977. This line of injection wells created a hydraulic barrier that inhibited the movement of the contaminant plume across the site boundary and pushed the contaminated groundwater back towards the facility (MFG 2006). A series of groundwater collection wells was also installed between 1977 and 1982 near the tailings piles and evaporation ponds to collect seepage (EPA 2006, CH2MHill 2001, HMC and Hydro-Engineering 2006).

In 1983, the site was placed on the NPL. As a result, HMC and the EPA signed an Agreement and Stipulation that required HMC to provide an extension to the Village of Milan municipal water system to four residential subdivisions (Broadview Acres, Felice Acres, Murray Acres, and Pleasant Valley Estates) located south and southwest of the mill site, which were in the area affected by groundwater contamination (EPA 2006). In addition, under this agreement, HMC was required to pay for residents' use of the water supply for a period of 10 years. At that time, the EPA did not require additional response actions to remediate the groundwater because HMC was already implementing a state-approved plan. Residences were connected to the Village of Milan's water supply system in 1985, and HMC paid for this water use until 1995 (EPA 2006). HMC has since been released from its obligations under this Agreement, and residences have permanent connections to alternate water supplies.

Groundwater remediation has continued and has been modified in response to monitoring results. A bullet summary of the key milestones of the groundwater restoration program, which evolved into HMC's CAP, is included in **Appendix A**.

On September 15, 1989, HMC submitted a CAP to the NRC (Hydro-Engineering 1989). The CAP was approved by the NRC via License Amendment No. 8, dated July 20, 1990, and the requirement to implement the CAP was added to the license as License Condition 35 (NRC 1990). The original hydraulic barrier program was converted to a groundwater restoration program after the mill was shut down in 1990. A Revised CAP was submitted by HMC to the NRC on December 12, 2006 (MFG 2006), which documented modifications to restoration operations since 1989 as the hydrologic and geochemical responses of each aquifer to restoration activities were observed.

This update includes relevant information from the annual reports and license conditions into a single document, and addresses the relevant RAIs recently requested from the 2006 CAP submittal.

2.4.1 Site Standards

The NRC, EPA, and NMED have agreed upon the groundwater site standards for each COC in each aquifer (Meyer 2010). There are ten COCs for the site, but not all ten apply to every aquifer. The COCs are selenium, uranium, molybdenum, sulfate, chloride, total dissolved solids (TDS), nitrate, vanadium, thorium-230, and radium-226/-228. These site standards were finalized in 2006 after background water quality was evaluated, and are set at background or appropriate drinking water standards. Background concentrations were calculated using data from 1995 through 2004. These standards were incorporated into the NRC license through License Amendment No. 39 as GWPSs. The site standards are summarized in **Table 1.1-1** in **Section 1.1**.

All three Chinle aquifers subcrop with the overlying alluvial aquifer (**Section 3.2**). The Chinle Mixing Zone refers to the areas adjacent to the subcrop locations where the alluvial water has had an impact on water quality in the Chinle aquifers. In these subcrop locations, there is hydraulic communication between the aquifers. The non-mixing zones for each Chinle aquifer are not affected by the alluvial aquifer. These site standards must be met at the three POC wells D1, X, and S4 in the alluvial aquifer and at the proposed POC wells CE2 and CE8 in the Upper Chinle Non-Mixing Zone (**Figure 1.1-1**). License Condition No. 39, including the method used to determine the site standard for each COC, is included in **Appendix A**.

2.4.2 Remediation Operational History

The current CAP includes five restoration strategies to meet the site standards, including a hydraulic barrier, an RO plant, a source control program, evaporation ponds, and a land treatment program. The CAP is explained in detail in **Section 5**.

A detailed, bulleted history of the groundwater remediation operations is included in **Appendix A**. The major events are summarized here:

- 1977 – The hydraulic barrier is created between the LTP and the subdivisions through the injection of clean water on the north side of Broadview Acres.
- 1978 – Active tailings seepage collection system started.
- 1980 – Alluvial groundwater collection in Murray Acres began.
- 1990 – EP-1 was constructed and operations commenced.
- 1992 – Toe drains were installed around the perimeter of the LTP to collect seepage.
- 1995 – Dewatering of the LTP was tested; EP-2 was constructed.
- 1996 – Groundwater was collected from the Upper Chinle aquifer for reinjection into the alluvial aquifer where COC concentrations were elevated.
- 1999 – The RO plant was constructed and used to treat water for injection into the alluvial aquifer.
- 2000 – Flushing of the tailings for the source control program in the LTP and the land treatment program (initially 270 acres) began.
- 2002 – Second RO unit was added to treatment plant (RO capacity increased from 300 to 600 gallons per minute [gpm]); the full-scale source control program was implemented.
- 2010 – EP-3 was constructed.

2.4.3 Groundwater Monitoring

As remedial operations have continued at the Grants site, the CAP has been repeatedly modified to optimize performance. Groundwater monitoring, which began in 1975, has been used to characterize the contaminant plume, to evaluate the performance of the restoration strategies, and to demonstrate progress made in restoring groundwater to meet site standards.

Starting in 1983, annual groundwater monitoring reports have been submitted to the NRC. The most recent monitoring report is the 2010 report, submitted to the NRC in March 2011 (HMC and Hydro-

Engineering 2011). These annual monitoring reports summarize operations during the previous year and provide water quality information for the five affected aquifers.

HMC currently samples approximately 80 wells to meet license and permit requirements and voluntarily samples several hundred additional wells to assess the performance of the restoration strategies and to monitor any changes in the groundwater plume.

HMC plans to evaluate the monitoring program to determine if it can be further focused and optimized. The evaluation of the monitoring program will be an ongoing activity for HMC; the monitoring program will co-evolve with the CAP to ensure that accurate, relevant water quality data can be used to guide modification of the CAP. This process is discussed in more detail in **Sections 5.5.6** and **7.3** and in **Appendix K**. It will include the following steps:

1) Identify site wells that are currently being used or may be used as monitoring wells (both for license and permit compliance as well as CAP performance evaluation).

2) Determine the monitoring objective the well would fulfill if included in the monitoring program.

3) Evaluate historic water quality data from the well to determine whether continued or additional sampling would provide relevant information.

4) Based on this evaluation, determine the appropriate parameter list and sampling frequency for the well.

Historical data will be analyzed using simple statistical methods and a rule-based decision process to determine whether continued or additional sampling will provide relevant data to characterize operation performance and/or the contaminant plume. This decision-making process is illustrated on **Figure 2.4.3-1**.

2.4.4 Mass Removal Analysis

The plume control program at the site began in 1977. This strategy presently maintains a hydraulic barrier around the site: approximately 115 injection wells and infiltration lines are used to control the local hydraulic gradient to inhibit the flow of contaminated groundwater. Additionally, extraction wells upgradient from the hydraulic barrier collect contaminated groundwater from the plume, which is then sent to the RO plant for treatment or to the evaporation ponds for isolation and consolidation (**Section 5.3.3**). COC concentration decreases have been observed across the plume, and particularly within the groundwater collection area established by the hydraulic barrier. Although unimpacted water is used for the injections, COC concentration decreases are not due to dilution; rather, they are primarily due to the large amount of COC mass that has been removed by the extraction wells within in the hydraulic barrier. If reductions were due primarily due to dilution, the total dissolved uranium mass within the plume would have remained relatively unchanged.

Based on a mass removal analysis, the estimated dissolved uranium mass remaining in the plume in 2009 (30,000 kg) was less than 40 percent of the dissolved mass in the plume in 2001 (80,000 kg) due to the restoration program. The results of the mass removal analysis are presented graphically on **Figure 2.4.4-1**. The methodology and assumptions of the dissolved uranium mass reduction analysis are detailed in **Section 4.2.4** and in **Appendix E**. This analysis quantifies the removal of dissolved uranium mass over the past decade and further demonstrates the benefits of the plume control strategy employed at the site.

The short-term increase in dissolved uranium mass observed from 2002 to 2003 is associated with the implementation of the full-scale source control program in the LTP in 2002. The source control program, which involves flushing the LTP with unimpacted water (**Section 5.3.1**), increased the injection rate from 61 gpm in 2001 to more than 300 gpm in 2002, an increase of nearly 500 percent, which increased the seepage and uranium loading rates to the alluvial aquifer. It has been estimated that the source control program has removed approximately 75,000 kg of dissolved uranium from the LTP itself from 2002 to 2009.

3.0 GEOLOGIC AND HYDROGEOLOGIC SETTING

3.1 Geologic Setting

Significant effort has been made over the past 40 years to understand the regional and local geologic conditions of the site. Much of that information is summarized in the Background Water Quality Evaluation of the Chinle Aquifer report (HMC and Hydro-Engineering 2003). **Figure 3.1-1** presents a portion of the geologic map of the Grants quadrangle (Dillinger 1990). This map shows the extent of bedrock, deposited from the Permian through the Tertiary, and overlying Quaternary alluvial deposits and volcanic flows. In general, progressively older units of Cretaceous through Permian bedrock outcrop from northeast to southwest as a result of regional deformation and subsequent erosion. The overlying Tertiary units consist predominantly of widely scattered Middle Tertiary (Pliocene and Miocene) andesite and basalt surficial flows related to the Mt. Taylor volcanic field cap. The Quaternary units consist of localized andesite and basalt flows and widespread alluvium, which is composed of eroded bedrock materials in the vicinity.

The site is located in the southeastern part of the Colorado Plateau physiographic province and is mostly on the south flank of the San Juan Basin. Regional structural features are shown on **Figure 3.1-2**. This region experienced a minor degree of structural deformation (regional folding and block uplift) associated with formation of the Zuni Uplift, which is characterized by a northwest-trending anticline composed of Precambrian crystalline basement rocks overlain by Permian to Jurassic sedimentary rocks. These sedimentary rocks were uplifted during the Laramide Orogeny near the end of the Late Cretaceous through the Eocene, approximately 80 to 40 million years before present (Cooley et al. 1969; Anderson et al. 2003; Lorenz and Cooper 2003). Bedrock units at the site consist of the Glorietta Sandstone (Early Permian), San Andres Limestone (Early Permian), and Chinle Formation (Late Triassic). As a result of Laramide deformation, these bedrock units have a shallow northeastern dip direction of approximately 3 to 10 degrees (Kelley 1967).

The development of more recent northeast-trending, high-angle normal faulting associated with the Rio Grande Rift resulted in minor fault displacements in this part of New Mexico. The large northeast-striking San Mateo normal fault located northeast of the site has a vertical displacement of as much as 450 feet (Santos 1970), as shown on **Figure 3.1-2**. Two small-scale normal faults in the vicinity of the site (known as the West Fault and East Fault) are shown on the U.S. Geological Survey (USGS) geologic map of the Grants quadrangle (**Figure 3.1-1**). Evaluation of lithologic and geophysical logs from drilling investigations at the site indicate these two fault are located slightly farther to the west and to the east, respectively, than the locations shown on the USGS quadrangle map. Structural offset generally increases to the north along both faults (NRC 2004). In general, these two faults are approximately vertical, exhibit an east-side-down sense of shear, and act as impermeable barriers to groundwater flow within the permeable units of the Chinle Formation in the vicinity of the site. However, the East Fault entirely loses slip displacement immediately south of the Felice Acres subdivision (i.e., aquifer units are not vertically offset, as shown on **Figure 3.1-3** [HMC and Hydro-Engineering 2010b]). With the exception of the southern terminus of the East Fault, structural offset within the Chinle Formation has resulted in the juxtaposition of permeable sandstones with relatively impermeable mudstones and siltstones across the two faults. The magnitude of structural offset of the underlying San Andres-Glorietta regional aquifer is much lower than the vertical thickness of the unit and does not appear to significantly affect groundwater flow.

Depictions of the three-dimensional geology and hydrogeology at the site are illustrated on **Figure 3.1-3**. The Quaternary alluvium directly overlies the Chinle Formation and San Andres Limestone above a pronounced angular unconformity. As a result, sandstone units within the underlying Chinle Formation are abruptly truncated at the base of the alluvium. The Chinle Formation sandstone units are laterally continuous and separated by thick sections of low permeability shale. These geologic and hydrogeologic relationships are depicted in detailed hydrogeological cross-sections A-A' through E-E' (**Figures 3.1-4** through **3.1-8**).

Kelly (1963) and Rautman (1980) present the details of uranium ore-bearing rocks and uranium production in this area. Production of uranium started in the 1950s in the underground mines in the Ambrosia Lake area, which represented the majority of uranium ore production from this region. The ore-bearing rocks in this area consist primarily of Jurassic units, including the Westwater Canyon Sandstone Member of the Morrison Formation and the Todilto Limestone at the base of the Wanakah Formation. Both of these units outcrop to the north of the site within the San Mateo Creek and Lobo Creek alluvial drainages (**Figure 3.1-1**). The Quaternary alluvial materials at the site area were partly derived from the erosion of ore-bearing bedrock. As a result, the alluvium contains significant concentrations of naturally occurring uranium, as well as selenium and molybdenum, which are typically present in uranium deposits.

3.2 Hydrogeologic Setting

The site is located within the San Mateo Creek, Lobo Creek, and Rio San Jose drainages (**Figure 3.2.1-1**). The Lobo Creek is a tributary to the San Mateo Creek (both ephemeral drainages), which in turn is a tributary to the Rio San Jose drainage. The San Mateo Creek drainage basin occupies approximately 240 square miles and includes the Grants site. The Lobo Creek drainage area occupies approximately 56 square miles and borders the eastern side of the Grants site. Lobo Creek joins San Mateo Creek at the site, but neither creek has a well-defined channel near the site and surface flow is infrequent. The Rio San Jose drainage borders the western side of the site and encompasses approximately 2,530 square miles, a much larger area than the San Mateo and Lobo Creek drainages combined. The gridlines on **Figure 3.1-1** represent 1 square mile.

The City of Grants in Cibola County is included within the Bluewater Underground Water Basin, which falls under District I (Albuquerque) of the New Mexico Office of the State Engineer. The shallow unconfined aquifer in the area, the alluvial aquifer, includes the Quaternary Alluvium and surficial volcanic flows. Deeper confined aquifers include three aquifers within the Chinle Formation and a regional aquifer in the San Andres Limestone and the Glorietta Sandstone. In general, the San Andres Limestone and the Glorietta Sandstone are considered to be a single aquifer in the Grants area (San Andres-Glorietta aquifer). Each of the aquifer units is described below.

3.2.1 Surface Water and Groundwater Interactions

The regional climate of western New Mexico is an arid to semi-arid, temperate continental climate. Precipitation is limited, and most of the annual precipitation generally occurs during thunderstorms in the late summer to early autumn. Precipitation data for the site are included in **Table D-1** in **Appendix D**. Because of the climate of the site, surface water in the vicinity is limited to small, ephemeral stream courses that flow only in response to significant storm events. No perennial streams exist within the NRC license boundary (**Figure 3.2.1-1**). This drainage map also includes the local USGS stations.

The site lies partially within the broad, flat floodplain of the San Mateo Creek. The natural land surface gradients of the site are usually less than 1 percent; the average grade is 0.1 percent. Surface drainage across the site is predominantly directed to the southwest, although there are generally no established drainage courses or signs of active erosion. Ponding occurs after significant precipitation events, but this water either evaporates or infiltrates the alluvium. Recharge and evaporation rates are provided in **Appendix D** in **Table D-1**. Surface flow on and near the site occurs only after extreme precipitation events, and is generally limited to reaches of the local San Mateo and Lobo Creeks (Hydro-Engineering 1993).

There are no permanent surface water bodies within the NRC license boundary, nor are there any impacts from site contamination on regional surface water bodies. These include the San Mateo Creek and the Rio San Jose. The San Mateo Creek is part of the Rio Grande drainage basin, draining into the Rio San Jose near Milan. In its lower reach, the San Mateo Creek is ephemeral. Losing conditions exist along the entire ephemeral stretch of the San Mateo Creek in the vicinity of the site. The Arroyo del Puerto is an ephemeral tributary stream to the San Mateo Creek; the confluence is approximately 10 miles north of the site. Detailed information about the Arroyo del Puerto, the San Mateo Creek, and the Rio San Jose is compiled in **Appendix D**. The information includes (Hydro-Engineering 1993; Byrd et al. 2003; Roca Honda Resources 2009):

- Watershed drainage area and other dimensional information
- Mean monthly and mean daily streamflow data (**Figures D-1, D-2, D-3,** and **D-4** for the San Mateo Creek, Arroyo del Puerto, and Rio San Jose)

Although no streams exist on the site, the site employs a variety of strategies to limit or manage groundwater interaction with both stormwater and water used in CAP operations. Two of these strategies are designed to limit potential contamination of groundwater by surface water. Two other controls are designed to control stormwater.

- A flood diversion levee in the northeast corner of the site, complete with an erosion protection cover, was installed in June 1995 to divert San Mateo and Lobo Canyon flood flows to the north and west of the LTP and STP.
- The LTP, STP, and ground surface in the former mill area were recontoured and regraded to minimize slope gradients; additionally, 8 feet of sand and rock were placed along the toe of the north and west side slopes of the LTP to protect against erosion in case of flooding
- The five ponds in use at the site (three evaporation ponds and two collection ponds) during CAP operations are lined to limit seepage of pond water into the groundwater (discussed in detail in **Section 5.3.4**)
- Land treatment, discussed in detail in **Section 5.3.5**, is used in four areas. **Table F-5** in **Appendix F** includes a summary of land treatment operations, including the total water application per year from 2000 to 2010. Land treatment is modeled using LEACHP (**Appendix J**) to demonstrate the limited impact of land treatment water on groundwater.

More detailed information about stormwater control, including modeling using the Probable Maximum Precipitation (PMP) storm and Probable Maximum Flood (PMF), is included in **Appendix D**. More information about land treatment modeling is provided in **Appendix J**.

All surface water at the site evaporates, infiltrates the alluvium, or runs off downstream. Evaporation and recharge rates are included in **Table D-1** in **Appendix D**.

3.2.2 Alluvial Aquifer

The alluvial aquifer near the site consists of three distinct but connected alluvial systems: the San Mateo, Rio San Jose, and Lobo alluvial systems, which represent the uppermost aquifer in the groundwater system (**Figure 3.2.2-1**). The aquifer is composed of Quaternary-age alluvium deposited unconformably on the eroded surface of the Chinle Formation (**Figure 3.1-3**). Quaternary andesite and basalt flows are distributed in all directions around the Town of Grants and are interbedded with the alluvial deposits. The alluvial aquifer extends from northeast of the site to the south and southwest, eventually joining with the more extensive Rio San Jose alluvial system. In the immediate vicinity of the site, the alluvial system follows the San Mateo drainage, which directly underlies the LTP (**Figure 3.2.2-1**). The average total thickness of the saturated and unsaturated portions of the alluvium near the site is approximately 95 feet, with a maximum thickness of approximately 120 feet. HMC has drilled more than 900 wells at the site and nearby downgradient locations (**Figure 3.2.2-1**). The corresponding geophysical and lithologic logs were combined with information from residential wells not owned by HMC to define the base of the alluvium (**Figure 3.2.2-2**). The deepest portion of the alluvial aquifer is present below the western side of the LTP, while the shallowest portion of the alluvial aquifer is present in an area extending from the eastern Murray Acres subdivision to the STP (**Figure 3.2.2-2**).

The thickness and extent of the saturated portion of the alluvial aquifer is shown on **Figure 3.2.2-3**. The boundaries of the alluvial aquifer are defined by the intersection of the base of the alluvium with the groundwater surface. Extensive areas of zero saturation exist to the east and west of the site where the bedrock elevation is greater than the groundwater surface elevation and represent the margins of the aquifer system within the San Mateo drainage. A significant area of zero saturation also exists within the alluvial aquifer, which extends west and northward from the southern Felice Acres subdivision toward the Valley Verde subdivision. This location coincides with a bedrock high composed of the underlying Chinle Formation. Fifteen data points were used to define the area of zero saturation in this area. Saturated thickness ranges from zero to 80 feet thick with an average thickness of approximately 35 feet near the site.

Figure 3.2.2-4 presents the hydraulic conductivity of the alluvial aquifer at the site and adjacent properties. Measured hydraulic conductivity values are relatively high, ranging from approximately 10 to more than 200 feet per day (ft/day) (HMC and Hydro-Engineering 2010b). A hydraulic conductivity in excess of 20 ft/day is typical of the central axis of the San Mateo alluvial system near the site. However, hydraulic conductivity values increase to more than 200 ft/day between the Pleasant Valley Estates subdivision and the Rio San Jose alluvial system in the western portion of Section 27.

Figure 3.2.2-5 presents the transmissivity of the alluvial aquifer at the site and adjacent properties. Like hydraulic conductivity, transmissivity is a measure of an aquifer's ability to transmit water and is defined as the product of the average hydraulic conductivity and saturated aquifer thickness. Estimated transmissivity values range three orders of magnitude from approximately 500 to more than 40,000 gallons per day per foot (gpd/ft) (HMC and Hydro-Engineering 2010b). The San Mateo alluvial channel typically exhibits transmissivity values in excess of 10,000 gpd/ft to the north and west of the LTP. Transmissivity values decrease toward the margins of the alluvial channel (**Figure 3.2.2-3**) due to aquifer thinning. Coinciding with the observed increase in hydraulic conductivity values, transmissivity increases to more than 50,000 gpd/ft between the Pleasant Valley Estates subdivision and the Rio San Jose alluvial system. A localized zone of reduced transmissivity exists between the eastern Murray Acres subdivision and the STP as a result of reduced saturated thickness and generally low permeability of the alluvial aquifer material.

The alluvial aquifer generally behaves as an unconfined aquifer and, based on the results of aquifer testing, specific pumping tests, specific yields range from 0.038 to 0.28. A specific yield of 0.2 is assumed to best represent the alluvial aquifer at the site. A more detailed summary of the aquifer properties for the alluvial aquifer is presented in Hydro-Engineering (1983 and 1996).

The water level elevations and well locations for the alluvial aquifer are shown on **Figure 3.2.2-6**. Groundwater elevations within the alluvial aquifer ranged from approximately 6,427 to 6,604 feet MSL during December 2010 (**Figure 3.2.2-6**). Groundwater flows in the alluvial aquifer near the Grants site are highly variable; however, flow directions at the site are generally to the southwest (**Figure 3.2.2-6**).

Bedrock high locations composed of the underlying Chinle Formation represent groundwater flow boundaries and define distinct alluvial flow channels (**Figures 3.2.2-1** and **3.2.2-2**). Downgradient of the Grants site, the majority of groundwater flow in the San Mateo alluvial system is directed to the west through the Murray Acres and Pleasant Valley subdivisions into a narrow alluvial channel, as a result of a prominent bedrock high flow boundary (zone of zero saturation). The remaining groundwater flow from the Grants site flows south and joins the Lobo alluvial system immediately east of the Felice Acres subdivision, where flow is directed to the southwest into a narrow alluvial channel. Westward groundwater flow from both alluvial channels eventually converges with the Rio San Jose alluvium system. Flow within the San Jose alluvium is directed to the southeast as a result of confinement of the saturated portion of the alluvial aquifer between bounding bedrock high locations. Locally, flows have been reversed between the injection and collection systems due to the mounds and depressions imposed on the piezometric surface related to ongoing groundwater restoration activities (**Figure 3.2.2-6**).

Annual recharge to the alluvial aquifer in the form of direct infiltration from precipitation is limited. The annual precipitation of 12 inches on site in 2010 is above the normal precipitation for Grants (HMC and Hydro-Engineering 2011). Additional site-specific discharge and recharge locations in the context of the aquifer dynamics between the alluvial and Chinle Formation aquifers are discussed in the subsequent sections describing the geology and hydrogeology of the Chinle Formation.

Hydraulic gradient, hydraulic conductivity, and porosity all affect the groundwater flow velocity. The groundwater upgradient of the LTP is moving at an average rate of 0.5 foot per day based on a gradient of 0.0033 ft/ft, a hydraulic conductivity of 30 ft/day, and an assumed effective porosity of 0.2. Southwest of the Murray Acres injection system, groundwater is estimated to be moving at an average rate of 0.7 foot per day.

The flow of the San Mateo alluvial system north of the Grants site has been estimated at approximately 63 gpm, based on transmissivity values and aquifer width segments (**Appendix C**). Under the injection conditions that have existed for more than 20 years, the quantity of water moving southwest and west from the Grants mill site is estimated at approximately 260 gpm and approximately 78 gpm for the area to the southeast of Broadview Acres (**Appendix C**). This indicates that a total of approximately 338 gpm is moving downstream of the Grants site. A minimum of approximately 70 gpm of the total estimated flow from the Grants site flows through the narrow alluvial channel south of the Felice Acres subdivision, based on the estimated flow southeast of the Broadview Acres subdivision.

3.2.3 Chinle Formation Aquifers

The Chinle Formation is the shallowest bedrock unit in the vicinity of the Grants site. In general, the Chinle Formation is approximately 850 feet thick and consists of very low permeability, massive shale that greatly restricts vertical groundwater flow. The abundant shale serves as a competent aquitard between the surficial alluvial aquifer and underlying San Andres-Glorietta regional aquifer in this area (HMC and Hydro-Engineering 2010b). Within the Chinle Formation are three hydraulically isolated and uniformly distributed aquifer units (Upper Chinle, Middle Chinle, and Lower Chinle aquifers), each bounded by overlying and underlying low permeability shale. Each aquifer unit subcrops at the base of the alluvium, where hydraulic connectivity occurs in areas of alluvium saturation (**Figure 3.2.3-1**).

The West and East Faults, previously described in more detail in **Section 3.1** of this report, act as impermeable barriers to groundwater flow within the Chinle Formation aquifers in the vicinity of the Grants site (**Figure 3.2.3-1**). However, the East Fault entirely loses slip displacement immediately south of the Felice Acres subdivision, where water levels and pump test results suggest adequate hydraulic connectivity across the southernmost portion of this fault (HMC and Hydro-Engineering 2010b).

The aquifer properties for each of the Chinle Formation aquifers are summarized in Hydro-Engineering (1983 and 1996).

3.2.3.1 Upper Chinle Aquifer

The Upper Chinle aquifer is a northeast-dipping, confined aquifer composed of a laterally continuous sandstone unit. The areal extent of the Upper Chinle aquifer is shown on **Figure 3.2.3.1-1**. Structural elevation contours of the top of the Upper Chinle aquifer indicate minor variations in the steepness of the northeasterly dip, particularly in the area immediately to the south of the LTP. Available information indicates that the average thickness of the sandstone is approximately 35 feet. The aquifer unit is hydraulically bounded from other Chinle Formation aquifer units by competent overlying and underlying shale and has been structurally offset by the West and East Faults at the site (**Figures 3.1-3** through **3.1-8**).

The Upper Chinle aquifer subcrops at the base of the alluvium on both sides of the East Fault, most notably at the base of the western side of the LTP (**Figure 3.2.3-1**). However, the sandstone subcrop does not occur west of the West Fault in the vicinity of the Grants site. Rather, the subcrop was offset farther north beyond the extent shown in **Figure 3.2.3.1-1** as a result of the most recent high-angle normal faulting and the northeast-dipping bed surface. Due to the structural separation across the faults, the aquifer can be viewed as two hydraulically isolated aquifer systems across the West Fault. However, because the East Fault terminates south of the Felice Acres subdivision, where the sandstone unit is laterally continuous across the fault trace, the aquifer is considered a single aquifer system across the East Fault with a groundwater flow barrier to the north of the Felice Acres subdivision.

The Upper Chinle aquifer is an important groundwater system at the Grants site because of the direct hydraulic communication with groundwater in the alluvial aquifer. Continuous hydraulic connectivity occurs between the alluvial aquifer and the Upper Chinle aquifer along the entire length of the subcrop near and south of the LTP, with the exception of the bedrock high located south of the Felice Acres subdivision where the alluvium is unsaturated (**Figure 3.2.3.1-1**). Though differences in hydraulic head between the alluvial aquifer and underlying Upper Chinle aquifer along the length of the subcrop are often indistinguishable, the alluvial aquifer discharges to the Upper Chinle east of the East Fault and in the vicinity near and north of the LTP (discussed in more detail below). As a result of this direct hydraulic communication, the water quality of the Upper Chinle aquifer is influenced by the water quality of the alluvial aquifer, particularly beneath the western side of the LTP.

Aquifer properties vary significantly within the bedrock units due to the effects of secondary permeability; specifically, fracturing of the sandstone related to faulting. As a result, a narrow band (several hundred feet wide) of elevated transmissivity exists on both sides of the East Fault (**Figure 3.2.3.1-2**). Estimated transmissivity values along the western side of the East Fault between the LTP and the Felice Acres subdivision exceed 10,000 gpd/ft (HMC and Hydro-Engineering 2010b). Estimated transmissivity on the eastern side of the East Fault north of Felice Acres along Highway 605 exceeds 2,000 gpd/ft, but generally ranges between approximately 100 to 2,000 gpd/ft at other locations (HMC and Hydro-Engineering 2010b). In contrast, estimated transmissivity values are much lower in the region between the West and East Faults, where the aquifer unit is not fractured and finer grain size was noted, particularly beneath the western side of the LTP (e.g., approximately 500 gpd/ft). The hydraulic conductivity of the Upper Chinle ranges from less than 0.1 ft/day to more than 100 ft/day (HMC and Hydro-Engineering 2010b). The storage coefficient for this confined aquifer is estimated to be approximately 5×10^{-5} (HMC and Hydro-Engineering 2010b).

Well locations and groundwater elevations for the Upper Chinle aquifer are identified on **Figures 3.2.3.1-3 and 3.2.3.1-4**. Groundwater elevations within the aquifer ranged from approximately 6,456 to 6,540 feet MSL during December 2010. The saturated thickness of the aquifer ranges from 15 to 65 feet thick with an average thickness of approximately 35 feet near the site. The naturally occurring flow direction in the Upper Chinle aquifer on the western side of the East Fault is from north to south. However, due to groundwater pumping and fresh water injection across the site, flow directions are spatially variable; gradient reversals have been observed south of the Grants site. Injection of fresh water into the Upper Chinle aquifer on the northern side of Broadview Acres is causing localized radial groundwater flow and gradient reversal within this portion of the Upper Chinle aquifer, effectively forcing groundwater from this area northward toward the STP. The resulting southward flow discharges to the alluvial aquifer at the subcrop area on both the north and south sides of the bedrock high location south of the Felice Acres subdivision (**Figure 3.2.3.1-4**). This discharge is limited to the west side of the East Fault. The Upper Chinle aquifer is recharged on the east side of the East Fault and in the vicinity near and north of the LTP.

In contrast, the Upper Chinle aquifer is recharged by the alluvial aquifer along the subcrop location on the east side of the East Fault. In general, flow directions on the eastern side of the East Fault are predominantly to the northeast along the length of the fault (**Figure 3.2.3.1-4**).

3.2.3.2 Middle Chinle Aquifer

Similar to the Upper Chinle aquifer, the Middle Chinle aquifer is an east to northeast-dipping, confined aquifer composed of laterally continuous sandstone. The aquifer unit is also hydraulically bounded from other Chinle Formation aquifer units by competent overlying and underlying shale (**Figures 3.1-3** through **3.1-8**). The Middle Chinle aquifer is generally the thickest of the sandstone units in the Chinle Formation. The saturated thickness of the aquifer ranges from 10 to 80 feet thick with an average thickness of approximately 44 feet near the Grants site. The elevation contours for the top of the sandstone aquifer unit on each side of the two faults are provided on **Figure 3.2.3.2-1**. North of the Broadview Acres subdivision, the Middle Chinle aquifer dips predominantly toward the east on each side of both faults. However, south of the Broadview Acres subdivision, a northeast-plunging syncline (i.e., dipping fold axis) changes the bedding dip abruptly toward the northeast.

In the immediate vicinity of the Grants site, multi-well pumping tests indicate that the three sandstone units of the Middle Chinle aquifer exist as three fault-bound groundwater systems separated by the East and West Faults (**Figure 3.2.3.2-1**) (HMC and Hydro-Engineering 2010b). The southernmost portion of East Fault south of the Felice Acres subdivision exhibits no fault offset. At this location, the two sandstone units are laterally continuous and in hydraulic communication across the fault (HMC and Hydro-Engineering 2010b).

All three systems for the Middle Chinle aquifer subcrop at the base of the alluvium (**Figure 3.2.3.2-1**). The subcrops on either side of the West Fault have been laterally offset by approximately 5,400 feet due to fault slip along the West Fault. Hydraulic connectivity with the overlying alluvial aquifer exists on the west side of the West Fault northeast of the Pleasant Valley subdivision. Hydraulic connectivity also exists with the alluvial aquifer between the West and East Faults at an isolated subcrop location within a confined alluvial channel south of the Felice Acres subdivision. Though this subcrop is located a considerable distance (approximately 8,800 feet or 1.7 miles) from the Grants site, detectable impacts to the Middle Chinle aquifer in the vicinity of the subcrop have been observed as a result of the direct communication with the alluvial aquifer.

Similar to the Upper Chinle aquifer, the hydraulic properties of the Middle Chinle aquifer vary significantly due to the effects of reduced permeability associated with faulting (**Figure 3.2.3.2-2**) (HMC and Hydro-Engineering 2010b). In the region between the West and East Faults, transmissivity values range between approximately 5,000 and 7,000 gpd/ft. However, a narrow band of reduced transmissivity values less than 500 gpd/ft exists along the West and East Faults. The zone of localized reduced transmissivity in the vicinity of wells CW46 and CW45 is likely related to a reduction in permeability resulting from the termination of the East Fault (**Figure 3.2.3.2-2**). The average hydraulic conductivity of the Middle Chinle aquifer near the Grants site is approximately 25 ft/day. A storage coefficient of $3x10^{-5}$ is thought to best represent the Middle Chinle aquifer (HMC and Hydro-Engineering 2010b).

Well locations and groundwater elevations for the Middle Chinle aquifer are shown on **Figures 3.2.3.2-3 and 3.2.3.2-4**. Groundwater elevations within the aquifer ranged from approximately 6,438 to 6,541 ft MSL during December 2010. Due to groundwater pumping and fresh water injection across the site and flow barrier boundaries associated with local faulting, flow directions in the Middle Chinle aquifer are spatially variable. The head in the Middle Chinle aquifer on each side of the two faults is significantly different from the head between the two faults, which demonstrates that the groundwater is not readily connected across fault boundaries. Based on December 2010 water levels, the West Fault represents a significant barrier to groundwater flow within the Middle Chinle aquifer, with up to 110 feet of hydraulic head difference across the fault in the area west of the LTP (**Figure 3.2.3.2-4**). Similar reduced connectivity exists across the East Fault on the eastern side of the LTP, where more than 50 feet of hydraulic head difference was observed during fall 2010. There is no evidence of a barrier to flow across the southernmost portion of the East Fault south of the Felice Acres subdivision.

Groundwater flow on the west side of the West Fault is predominantly directed to the southwest with the exception of a minor gradient reversal due to local fresh water injection into the overlying alluvial aquifer near the subcrop location (**Figure 3.2.3.2-4**). In general, December 2010 water levels indicate that the Middle Chinle aquifer discharges into the alluvial aquifer (i.e., upward flow) at the subcrop location on the west side of the West Fault (HMC and Hydro-Engineering 2010b). The Middle Chinle aquifer between the East and West Faults is recharged by the alluvial aquifer at the subcrop locations (i.e., downward flow) south of the Felice Acres subdivision (**Figure 3.2.3.2-4**). Flow directions in this central portion of the Middle Chinle aquifer are predominantly directed to the northeast toward the LTP, partly due to the fresh water injection and localized groundwater mounding near the Felice Acres subdivision. However, the flow direction north of the LTP has also historically been reversed due to the pumping from Middle Chinle wells CW1 and CW2. A naturally occurring gradient reversal southwest of the LTP was also observed during December 2010 in the vicinity of CW6 (**Figure 3.2.3.2-4**). Flow direction is also northeast on the east side of the East Fault, indicating that this portion of the aquifer is also recharged by the alluvial aquifer.

3.2.3.3 Lower Chinle Aquifer

The confined Lower Chinle aquifer is the deepest permeable zone within the Chinle Formation and is generally located approximately 200 feet above the geologic contact with the San Andres limestone (**Figures 3.1-3** through **3.1-8**). The aquifer is hydraulically isolated from the overlying Middle Chinle aquifer and underlying San Andres-Glorietta regional aquifer. In contrast to the continuous sandstones of the overlying Chinle aquifers (the Upper Chinle and Middle Chinle aquifers), the Lower Chinle aquifer is composed of shale with enough developed secondary permeability to behave as a limited aquifer (HMC and Hydro-Engineering 2010b). The permeability of the aquifer is not consistently high enough to serve as a viable aquifer, and areas exist where the aquifer is effectively absent.

The extent of the Lower Chinle aquifer is shown on **Figure 3.2.3.3-1**. This zone experienced a higher degree of tectonic folding than any other aquifer unit at the Grants site. Elevation contours for the top surface of the aquifer indicate that the unit dips predominantly to the east at locations north of the residential subdivisions. However, south of the residential subdivisions, an eastward-plunging syncline (i.e., dipping fold axis) changes the bedding dip abruptly toward the northeast (**Figure 3.2.3.3-1**).

The Lower Chinle aquifer subcrops at the base of the alluvium on either side of the West Fault, which has been laterally offset by approximately 3,000 feet due to slip displacement along the West Fault (**Figure 3.2.3.3-1**). Direct hydraulic connectivity with the overlying alluvial aquifer exists in the area between the West and East Faults southwest of the Felice Acres subdivision and immediately west of the Valley Verde and Pleasant Valley subdivisions on the west side of the West Fault. The Lower Chinle aquifer is presumed to be laterally continuous immediately south of the terminus of the East Fault, where the aquifer functions as a single hydrologic unit. The potential for impacts to the Lower Chinle aquifer is significantly reduced due to the distance of the subcrop locations from the Grants site.

The hydraulic properties of the Lower Chinle aquifer are highly variable and largely dependent on secondary permeability within the shale (i.e., fractured or altered shale). The ability of the Lower Chinle aquifer to produce water is much lower and less consistent than in the overlying Middle and Upper Chinle sandstone aquifers. Hydraulic conductivity ranges from 0.1 to more than 50 ft/day (HMC and Hydro-Engineering 2010b). Hydraulic conductivity approximately 1 mile north of the subcrop areas is thought to be less than 0.10 ft/day (HMC and Hydro-Engineering 2010b). Estimated transmissivity values for the Lower Chinle aquifer are generally higher than 100 gpd/ft near subcrop locations (**Figure 3.2.3.3-2**) (HMC and Hydro-Engineering 2010b). However, selected areas near subcrop locations exceed 1,000 gpd/ft. These locations include the area immediately south of the Valley Verde subdivision on the west side of the West Fault and south of the Felice Acres subdivision near the southern terminus of the East

Fault. Measured storage coefficients for the confined Lower Chinle aquifer vary from 3.4×10^{-5} to 1.2×10^{-4}.

Much less pumping and injection infrastructure has been installed in the Lower Chinle aquifer due to the deeper occurrence beneath the Grants site and reduced transmissivity. Other than the HMC wells, only two or three wells completed in the Lower Chinle aquifer are actively used. The natural water quality of the aquifer is poor due to the low permeability of the shale and the associated long residence time for groundwater. Therefore, there is generally less use of this aquifer for water supply. In general, the Lower Chinle aquifer is only viable as a water resource near the subcrop locations in connection with the alluvial aquifer, where adequate secondary permeability has likely resulted from weathering and faulting.

Well locations and groundwater elevations for the Lower Chinle aquifer are shown on **Figures 3.2.3.3-3 and 3.2.3.3-4**. Groundwater elevations for the aquifer ranged from approximately 6,426 to 6,488 feet MSL during December 2010 (HMC and Hydro-Engineering 2010b). Flow directions are predominantly to the northeast across the area, with the exception of northwesterly flow in the south portion of the Lower Chinle aquifer between the West and East Faults. The northwest-directed flow in this area indicates that the flow of some Lower Chinle groundwater is uninterrupted by the West Fault in the area west of the Broadview Acres subdivision, which is consistent with the interpreted natural flow pattern for this region between the two faults.

In general, hydraulic head is higher in the alluvial aquifer than in the Lower Chinle aquifer with the exception of the subcrop locations, where the hydraulic communication between the two aquifers results in very similar heads. Across the site, the head differential indicates that communication between the alluvial and Lower Chinle aquifers is restricted to the isolated subcrop areas, where the alluvial aquifer most likely recharges the Lower Chinle aquifer on both sides of the West Fault.

3.2.4 San Andres-Glorietta Regional Aquifer

The San Andres-Glorietta aquifer is the most important regional aquifer in the Grants area. The aquifer consists of the San Andres Limestone and Glorietta Sandstone, with a total thickness that exceeds 200 feet (HMC and Hydro-Engineering 2010b). Similar to the Chinle Formation aquifers, the regional aquifer is mildly folded and dips to the east and northeast as a result of regional tectonic deformation (**Figure 3.2.4-1**). The aquifer has been used as the source for unimpacted water injection into the alluvial aquifer and Chinle Formation aquifers at the Grants site.

The alluvial aquifer and the San Andres-Glorietta regional aquifer are separated by a very thick (approximately 800 feet) aquitard at the HMC tailings site (**Figures 3.1-3** through **3.1-8**). The regional aquifer is in direct hydraulic communication with the overlying alluvial aquifer at the subcrop location near Highway 122, west of the area (**Figure 3.2.4-1**) (HMC and Hydro-Engineering 2010b). Direct hydraulic communication also exists with the Rio San Jose alluvial system upgradient of the Grants site and on the west side of Milan (Dillinger 1990).

Single-well pump tests in the San Andres-Glorietta aquifer suggest a range of estimated transmissivity from 222,000 to 460,000 gpd/ft (Gordon 1961 and Hydro-Engineering 1996). The USGS suggested an average transmissivity of 374,000 gpd/ft, as used in Baldwin and Anderholm (1992) and Frenzel (1992). Estimated storage coefficients for the aquifer from multi-well pump tests conducted in 1956 range from 4.2×10^{-4} to 1.4×10^{-3} (Gordon 1961).

The rate of groundwater movement in the San Andres-Glorietta aquifer is governed by hydraulic conductivity, gradient, and effective porosity of the unit. An average groundwater velocity of 4 ft/day is estimated based on a hydraulic conductivity of 615 ft/day, a gradient of 0.00086 ft/ft, and an assumed effective porosity of 0.1 (HMC and Hydro-Engineering 2010b). The groundwater velocity is likely to vary greatly in this type of aquifer due to a very wide variation of hydraulic conductivity and effective porosity.

The quantity of water moving in the San Andres-Glorietta aquifer in the area of the HMC facility can be estimated using the transmissivity, groundwater gradient, and a selected width of groundwater flow. An estimate of 1,900 gpm (approximately 998,640,000 gallons annually) was calculated from a transmissivity of 460,000 gal/day/ft, a gradient of 0.0006 ft/ft, and a flow width of 10,000 feet (HMC and Hydro-Engineering 2010b).

Well locations and groundwater elevations for the San Andres-Glorietta aquifer are identified on **Figures 3.2.4-2 and 3.2.4-3**. Groundwater elevations for the aquifer ranged from 6,420 to 6,433 feet MSL during December 2010 (HMC and Hydro-Engineering 2010b). Flow directions are nearly uniformly directed to the east-southeast. The difference in hydraulic head between the alluvial aquifer and the San Andres-Glorietta aquifer ranges from approximately 80 to 100 feet, which confirms that the flow between the two aquifer systems is restricted by the limited permeability of the Chinle Formation (HMC 2009). The slip displacement along the faults is not large enough to completely offset the entire thickness of the aquifer system. However, an increase in hydraulic gradient is generally observed in the vicinity of the Grants site, indicating reduced transmissivity that may be the result of faulting (HMC 2009). Based on the observed depression of the alluvial water table surface in the vicinity of the San Andres-Glorietta aquifer subcrop, the alluvial aquifer likely recharges the regional aquifer (**Figure 3.2.2-6**).

4.0 GROUNDWATER QUALITY

Groundwater monitoring at the site has been required in some capacity since the late 1950s. Several regulatory agencies have overseen the monitoring program since then. The AEC required quarterly monitoring of both groundwater and air at the site through 1974, when the NMIB and NMEID assumed regulatory authority over the AEC license. The State of New Mexico relinquished its authority to the NRC in 1986, and it remains the lead agency for the site (**Section 1.1**).

In 1975, the NMEID requested that the EPA conduct a study of the impacts of uranium mining and milling operations in the Grants Mineral belt on local groundwater and surface water (EPA 1989) in response to the passing of the SDWA. The EPA study found elevated concentrations of selenium in the alluvial aquifer downgradient of the site, which was being used for domestic water supply in one of the neighboring subdivisions. As a result of the EPA study, United Nuclear-Homestake Partners (the site owners at the time) undertook a more comprehensive groundwater monitoring program, which subsequently identified several additional residential wells south of the site that exhibited elevated concentrations of selenium. The source of the selenium was unknown. Possible sources included (a) groundwater from Poison Canyon, an area with selenium-rich soils known to impact background water quality; (b) seepage from the LTP and/or STP; and (c) discharges from other local mines and mills. In 1976, United Nuclear- Homestake Partners determined that there was a contaminant plume in the alluvial aquifer originating from the LTP and moving outside of the license boundary to the south and west (HMC and Hydro-Engineering 2010a), prompting the implementation of the plume control program (**Section 2.4**).

4.1 Background Water Quality

An evaluation of background water quality was completed in 2006, using data from 1995 through 2004 (HMC and Hydro-Engineering 2003). The focus of this evaluation was the ten COCs for the site: selenium, uranium, molybdenum, sulfate, chloride, TDS, nitrate, vanadium, thorium-230, and radium-226/-228.

In 2006, after evaluation of background water quality and extensive negotiations among the stakeholders, the NRC, EPA, and NMED have agreed upon groundwater site standards for the ten COCs that would be applied to specified POC wells. These standards were finalized in 2006 after an evaluation of background water quality and were incorporated into the NRC license through License Amendment No. 39 (**Attachment A-1** in **Appendix A**). These standards were set at either background levels or appropriate drinking water standards. These site standards are included in **Table 1.1-1** for the alluvial aquifer, the three Chinle formation aquifers, and the Chinle Mixing Zone (areas adjacent to the Chinle subcrop locations where the alluvial aquifer has an impact on the water quality of the Chinle aquifers; **Figure 3.2.3-1**).

It is recognized that upgradient impacts to the alluvial aquifer may affect background water quality in the future. It will be necessary to continue to monitor upgradient water quality to determine whether background water quality is changing. HMC is currently monitoring upgradient wells P and Q (**Section 7.2.1**).

4.2 Contaminant Plume

The contaminant plume is addressed at the site through the plume control program, one of the five components of the CAP. This program began in 1977 and has continuously grown and adapted since then. It is discussed in detail in **Section 5.3.2**. The program uses injection wells and infiltration lines to establish a hydraulic barrier to the west, south, and east (downgradient) of the LTP, thereby inhibiting the movement of contaminated groundwater. The plume control program also uses extraction wells to collect highly contaminated groundwater from the alluvial aquifer and send this water to the RO plant for treatment or to the three lined evaporation ponds. The area within the hydraulic barrier is referred to as the groundwater collection area. The plume control program thus inhibits expansion of the groundwater plume and removes contaminant mass from it.

4.2.1 Characterization

The site COCs that are of the greatest concern are uranium, selenium, molybdenum, TDS, sulfate, and chloride. Site standards for all COCs are listed in **Table 1.1-1**. The annual monitoring reports provide detailed information about the results of the previous year's monitoring and should be consulted for the most detailed information; the 2010 report (HMC and Hydro-Engineering 2011) is the most recent monitoring report available. **Table E-1** in **Appendix E** summarizes the results of the 2010 monitoring report (HMC and Hydro-Engineering 2011), including exceedances in 2010 of the relevant site standards and where these exceedances occurred.

4.2.2 Extent

Table E-1 in **Appendix E** summarizes results from 2010 monitoring where site standards were exceeded. These results demonstrate that the areas of greatest concern are directly underneath the LTP, within the groundwater collection area to the southwest of the LTP, and in a few isolated surrounding areas. Dissolved concentrations of uranium that exceed 1.0 milligram per liter (mg/L) have generally been confined to the immediate vicinity of the tailings, west of the LTP, and in the southern portion of the Felice Acres subdivision.

4.2.3 Attenuation

The general long-term trend of COC concentrations at the site is decreasing. Detailed information, including raw data and concentration-time plots, is available in the annual monitoring reports for all COCs in all five aquifers at the site. The general, site-wide decrease of COC concentrations can be attributed to the successful implementation of the CAP, especially the plume control program.

Dissolved uranium concentrations in the alluvial aquifer in 1998, 2003, 2007, and 2010 are shown on **Figures 4.2.3-1** through **4.2.3-4**, and concentration trends are summarized on **Figure 4.2.3-5**. **Figures 4.2.3-6** through **4.2.3-9** depict uranium concentrations in the Upper Chinle aquifer in 1998, 2003, 2007, and 2010. These dissolved uranium distribution maps are used to determine changes in the plume distribution over time. They were generated by evaluating concentrations of dissolved uranium for the 4 specific years from the site database using the Environmental Visualization System (EVS). EVS is a three-dimensional (3-D) software package that combines analytical results from soil and water analyses with lithologic data to develop a comprehensive site conceptual model. Because spatial integrity and expert interpretations of geologic, hydrogeologic, and geochemical processes are preserved in the model, it is a powerful tool to interpret spatial variability in site conditions. EVS was used to generate figures for Section 3 to clearly communicate with stakeholders about the geologic and hydrogeologic setting of the site and the nature and extent of the contaminant plume.

The wells used to generate the dissolved uranium distribution maps were selected based on wells that are sampled frequently with available concentration data throughout this time period. This subset of wells includes the three POC wells (D1, X, and S4) for the alluvial aquifer. The complete list of wells used in the generation of these figures is included in **Table E-2** in **Appendix E**. Uranium results used for contouring represent the maximum result detected for a given calendar year at each well location. Concentration data were initially hand contoured for each representative year. The contours were subsequently incorporated with available concentration data for spatial interpolation (kriging) using EVS. The resulting contaminant distributions were then limited to concentrations above the site standard for uranium in the alluvial aquifer (0.16 mg/L).

Prior to the full-scale initiation of the source control program in 2002, dissolved concentrations above the site standard (0.16 mg/L) extended into the Rio San Jose Alluvial System west of the Pleasant Valley Estates subdivision (**Figure 4.2.3-1**). The furthest downgradient extent of dissolved uranium concentrations in the alluvial aquifer in excess of the site standard has progressively retreated toward the site between 1998 and 2010 (**Figures 4.2.3-1** through **4.2.3-4**). In general, exceedances of the site standard are currently absent in the Rio San Jose Alluvial System, with the exception of an isolated well location (Well 0541) that yielded a concentration of 0.21 mg/L in 2010 following a decade of concentrations below the exceedance level.

Following initiation of the LTP flushing program in 2002, increased concentrations of dissolved uranium were observed in two distinct portions of the dissolved plume to the immediate west and southeast of the tailings near EP-2 (**Figure 4.2.3-2**). While measured concentrations at alluvial wells beneath the LTP generally decreased in 2003, uranium concentrations increased slightly (within the same order of magnitude) at well locations on the southwest side of the LTP (MQ, M6, and M9), as evidenced by the expanded 1.0 mg/L contour beginning in 2003. On the southeast side of the LTP, contaminant mass had migrated from the LTP to the vicinity of the evaporation ponds as a result of the flushing program. However, the southward extent of the plume along Highway 605 has steadily decreased in size and concentration between 1998 and 2010 and is currently limited to a narrow zone between wells L and L6.

The areal extent and concentrations of disconnected portions of the dissolved uranium plume that exceed site standards at two locations (Murray Acres and Felice Acres subdivisions) have continually decreased during the 1998 to 2010 time period (**Figures 4.2.3-1** through **4.2.3-4**). Dissolved uranium concentrations in the Murray Acres subdivision at Well 0802 have decreased an order of magnitude from approximately 2 mg/L in 1998 to only slightly exceeding the site standard at 0.4 mg/L in 2010. A plume of concentrations above the site standard in the vicinity of the Felice Acres subdivision has decreased by approximately 50 percent between 1998 and 2010. Fresh water injection on the northeast side of both subdivisions continues to hydraulically isolate these two locations from the main plume to the north (**Figure 3.2.2-6**).

Figure 4.2.3-5 presents concentration trends for dissolved uranium at four wells representing key areas of the alluvial aquifer plume (C6, CW44, L10, and S4) between 1998 and 2011. Strongly decreasing trends are observed at all four locations, indicating that the current remedy has been effective at reducing alluvial aquifer concentrations since the start of the program.

An integral part of the plume control program is the injection of unimpacted to slightly impacted water into the alluvial aquifer. To demonstrate that the success of the plume control program in reducing COC concentrations is not due to dilution, HMC analyzed dissolved uranium mass removal, detailed in **Sections 2.4.4**, **4.2.4**, and **5.5.2.1** and in **Appendix E**. The results of this analysis confirm that the restoration program has removed a significant amount of uranium mass and that reductions in uranium concentrations are not primarily due to dilution.

4.2.4 Total Dissolved Plume Mass

As described in **Section 2.4.4** and **Appendix E**, HMC analyzed dissolved uranium mass removal to demonstrate the effectiveness of the plume control program at the site in removing dissolved uranium from the alluvial aquifer. A detailed description of the analysis is provided in **Appendix E**. In summary, the results show that dissolved uranium mass in the plume decreased approximately 60 percent from approximately 80,000 kg in 2001 to approximately 30,000 kg in 2009 because of the plume control program. The mass of dissolved uranium remaining in the plume between 2001 and 2009 is presented on **Figure 2.4.4-1**; the temporary increase in 2003 is attributed to the full-scale implementation of the source control program in the LTP.

To perform this analysis, a data query identified wells in the site database that had more than 6 years of dissolved uranium concentration data for years 2000 to 2011. The groundwater well network used in the mass removal analysis was then limited to locations within an estimated composite plume boundary representative of the maximum spatial extent of dissolved uranium concentrations greater than 0.16 mg/L during the 2001-2009 timeframe (**Figure 4.2.4-1**). This network was further screened to only include individual sample locations with no more than two missing (non-consecutive) sample years. Values for missing sample years were estimated from the arithmetic mean of previous or preceding yearly data to create representative uranium concentrations for the mass removal analysis. If multiple samples were available for a given year, the maximum dissolved uranium concentration was used. The final selected well locations and maximum yearly dissolved uranium concentrations are detailed in **Table E-1** in **Appendix E**. A plan view map of the selected well network and composite plume boundary is shown on **Figure 4.2.4-2**.

Other data inputs for the mass removal analysis include total porosity, saturated aquifer thickness, and the estimated area of influence for each individual well location (**Table E-1**). The total porosity value of 20 percent, representative of a typical porosity for mixed sand and gravel sediments, was used for each well (e.g., Fetter 2001). The saturated aquifer thickness in feet at individual sampling points was estimated using a geologic model of the saturated extent of the alluvial aquifer. Thiesson polygons were then generated using ArcGIS and used to define the individual regions of influence associated with each sampling point (monitoring well). The area of each polygon in square feet was then estimated using ArcGIS (**Figure 4.2.4-2**).

5.0 EXISTING CAP

The objective of the CAP is to restore the concentrations of the ten COCs at the site to the standards established for each aquifer (**Table 1.1-1**); this objective is termed "groundwater restoration." Groundwater restoration depends on both source control and plume treatment. The CAP uses several strategies to achieve this objective and is continuously evolving and adapting to optimize performance in response to both progress and challenges. This adaptive approach allows HMC flexibility in restoring groundwater as conditions at the site change.

The CAP has five main components to restore groundwater: (1) source control, (2) plume control, (3) RO treatment, (4) evaporation, and (5) land treatment. Source control is currently achieved through flushing of tailings pore water to expedite the mass flux of COCs from the LTP, resulting in a manageable, controlled source to groundwater over the long term. Plume control relies on a hydraulic barrier to limit the movement of contaminated groundwater. RO treatment removes COC mass from groundwater upgradient of the hydraulic barrier and allows treated water to be used as a source of clean, non-potable water at the site. Evaporation and land treatment are both water management strategies that handle excess water to maintain a site-wide water balance of inflows and outflows of the various CAP components.

Each restoration component is discussed in **Section 5.3,** and detailed, tabulated operational information is summarized in **Appendix F**. The focus of **Section 5.3** is to provide the objectives of and justification for each restoration strategy and to explain how each strategy is managed.

HMC is currently evaluating several alternative treatment technologies to determine whether one or more of these options would be appropriate to supplement the current CAP; these technologies are discussed in **Section 5.4**. Because the success of the CAP depends upon its adaptive approach, HMC continually focuses on operation management by evaluating and adjusting each restoration component to optimize performance. **Section 5.5** describes the objectives and procedures for the evaluation and optimization processes HMC is currently pursuing, which may allow HMC to potentially improve the performance of one or more CAP components. Results from the evaluation of alternate treatment technologies and from the optimization evaluations are too preliminary to present in this document, but relevant details will be reported in future updates to the CAP and under separate cover, as appropriate.

The CAP is evaluated by using a numerical groundwater flow model (MODFLOW) and associated solute transport model (MT3DMS). This modeling effort, described in **Section 5.1** and in further detail in **Appendix G**, allows HMC to (1) evaluate the progress of the CAP, (2) adjust the CAP to changing conditions, and (3) estimate when groundwater restoration will be complete.

A site-wide water balance that depicts the major operational flows in 2010 is described in **Section 5.2** and detailed in **Appendix H**. This depiction includes all five CAP components and all five aquifers at the site.

The CAP has changed significantly since restoration began in 1977. The evolution of the CAP is summarized in **Section 2.4.2** and detailed in **Appendix A**. The Annual Monitoring Reports submitted to the NRC include information about the operation of the CAP components and should be consulted for the most detailed information, but relevant information from the 2010 annual report is included in **Section 5.3** and **Appendix F**.

The anticipated future operation of the CAP is discussed in **Section 6.0** and **Appendix I**.

5.1 Groundwater Modeling

Detailed information about the groundwater modeling for the site is provided in **Appendix G**. This appendix includes all relevant information to fulfill the NUREG-1620 acceptance criteria for groundwater corrective action and compliance monitoring plans.

The objectives of groundwater modeling for the site are (1) to evaluate the progress made in restoring groundwater to the site standards, (2) to assist in selection of appropriate modifications to the CAP to optimize performance and adapt to changing conditions at the site, and (3) to estimate when groundwater will be restored to background concentrations and the CAP completed. In order to meet these objectives, the main focus of the modeling effort is to simulate the effects of seepage from the LTP into the alluvial aquifer and predict the performance of site restoration activities.

Groundwater modeling is performed using the widely used modeling codes MODFLOW-96 (MODFLOW) and MT3DMS. MODFLOW is the USGS' Modular 3-D finite-difference model that solves the groundwater flow equation and thus simulates groundwater movement (Harbaugh and McDonald 1996). MT3DMS simulates contaminant transport (Zheng and Wang 1999). MODFLOW and MT3DMS are coupled, and references to MODFLOW in this document should be interpreted to include MT3DMS transport modeling unless otherwise specified.

Seepage from the LTP is treated as an independent input to the groundwater model; specifically, seepage from the LTP is incorporated into the groundwater model using 27 injection points that are evenly distributed over the base of the LTP (**Figure 5.1-1**). The seepage simulation includes both the COC concentrations in the seepage and the predicted seepage rate. The predicted future COC concentrations in the seepage were modeled using a spreadsheet-based water and mass balance. Historically, the mass balance has been referred to as the original mixing model (OMM); it has been recently revised to account for the recapture of COC mass when the piezometric surface in the LTP rises. The mass balances of the sands and slimes in the LTP are modeled separately in the OMM.

The predicted rate of seepage was modeled using the two-dimensional, partially saturated flow model VADOSE/W, adapted for the LTP. By adjusting the thickness of individual cells within the model to proportionally represent the corresponding plan area of the tailings, the model is therefore considered quasi 3-D. In general, the tailings seepage rate is proportional to the head and volume of the water contained within the tailings (**Figure 5.1-2**).

The incorporation of the various site restoration activities and schedules in the predictive simulations are described in further detail in **Appendix G**. Based on these model simulations, the time to completion of the CAP has been updated, and the schedule is detailed in **Section 6.2**. The endpoints for various CAP components are later than previously reported because restoration progress has been limited recently due to constraints on water disposal and treatment capacity, but the 2010 construction and operation of EP-3 has helped address this deficiency. The actual schedule may be shorter than this predicted timeframe if alternative treatment technologies are implemented (pending favorable feasibility test results and required agency approval); alternatively, restoration may take longer if land treatment capacity is limited or there are other constraints that do not allow the simulated restoration activities and schedules to be achieved.

Overall, the model simulations show that the site standards will be met at the POC wells by 2020 if active flushing of the LTP continues until the average uranium concentrations within the tailings is 2 mg/L or less and active groundwater treatment is continued. Final physical site closure and reclamation is scheduled to add 2 more years out to 2022.

5.2 Major Operational Flows

The five components of the CAP depend on an extensive site-wide water management program. Waters from the alluvial, Upper Chinle, Middle Chinle, Lower Chinle, and San Andres aquifers, as well as from the LTP and RO plant, are conveyed across the site through a network of aboveground piping and extraction and injection wells. **Figure 5.2-1** depicts the relationship between the five restoration strategies. A site-wide depiction of the major operational flows in 2010 is presented on **Figure 5.2-2**. In this figure, flow rates are presented as annual averaged flows (i.e., total annual volumes were averaged over the entire year and expressed as gpm on the diagram) for comparative purposes. Flow values were obtained from both direct measurements and flow-balance calculations. This figure is an approximate water balance; although major flows are quantified, minor flows are not continuously monitored, and these flows are therefore not accounted for in this depiction. Water movement illustrated on **Figure 5.2-2** is represented by the five site restoration components:

- *Source Control* – groundwater with relatively low concentrations of contaminants is injected into the LTP to hydraulically force contaminated tailings pore water to toe drains and extraction wells to expedite the natural draindown process of COC mass from the LTP.

- *Plume Control* - groundwater with relatively low concentrations of contaminants and treated water from the RO plant are re-injected to reverse local hydraulic gradients, thereby creating a hydraulic barrier to the migration of contaminated groundwater and hydraulically forcing COCs in the aquifer to collection/extraction wells.

- *Reverse Osmosis Treatment* - alluvial water with elevated contaminant levels is sent to the RO plant for treatment. Better quality LTP water has historically also been sent to the RO plant, but this was not done in 2010. Treated product water is re-injected in the alluvial aquifer, and the process brine stream is sent to the evaporation ponds. Collection ponds are used to store miscellaneous RO plant overflows and plant process water (blowdown), which can be recycled to the RO plant influent streams for treatment or, alternatively, pumped to the evaporation ponds.

- *Evaporation* - LTP draindown water and the RO plant process brine are sent to evaporation ponds for concentration of contaminants. Precipitation and evaporation rates control the effectiveness of this strategy and are accounted for in the water balance.

- *Land Treatment* - water from all aquifers was applied on a reduced basis to the land treatment system in 2010. The land treatment system consists of two flood land treatment units occupying 120 and 24 acres each. There are also two center-pivot land treatment units occupying 100 acres and 150 acres each. Not all acreage was used for land treatment in 2010 compared to previous years (2000 – 2009).

The historical operation of the CAP is summarized on **Figure 5.2-3** and is tabulated in **Appendix F**. The site-wide operation of the CAP changes annually, and so the 2010 operational flows **(Figure 5.2-2)** should not be used to extrapolate past and future performance.

Figure 5.2-2 demonstrates how the five CAP components are interrelated by illustrating how water is managed on site. Specifically, the water balance highlights the importance of evaporation and land treatment to the CAP. These two components allow HMC to handle outflow water from source control, plume control, and RO treatment. Without these water management options, HMC would not be able to make significant progress in restoring groundwater.

5.3 Summary of Remedial Actions

The site map (**Figure 5.3-1**) depicts the layout of the CAP infrastructure. The endpoints for groundwater restoration for each aquifer, the site standards, are provided in **Table 1.1-1**. The activities conducted under the CAP are regulated by NRC License SUA-1471 and NMED Discharge Permits DP-200 and DP-725; DP-200 applies to the groundwater restoration for the site generally and DP-725 applies to the three evaporation ponds related to wastewater management. More information about these requirements is available in **Section 1.1**.

5.3.1 Source Control

The primary source of contamination at the site is draindown from the LTP, which consists of gradual seepage of pore water from the tailings as they consolidate and drain after deposition. This tailings pore water contains high concentrations of uranium as a result of the alkaline leach process used in the mill. This impacted water moves from the bottom of the LTP into the partially saturated zone of the alluvial aquifer directly beneath the LTP. Achieving site standards requires a sufficient decrease in COC loading from the LTP to the alluvial aquifer (**Section 5.1**, **Appendix G**). To remove COC mass from the LTP and to reduce the long-term loading to the alluvial aquifer, thereby reducing the amount of time that the LTP would act as the contaminant source, HMC has implemented the source control program, also known as the tailings flushing program.

Source control began in 1995, when HMC initiated a tailings dewatering program in the LTP to remove tailings pore water, thereby reducing the potential for further contamination. In 2000, this extraction effort was coupled with water injections in a pilot test. The full-scale implementation of the flushing program began in 2002. The flushing program involves the injection of unimpacted to slightly impacted water into the LTP and the subsequent extraction of tailings pore water using a network of interconnected injection and extraction wells screened through the entire thickness of the LTP.

The injected water hydraulically drives tailings pore water to the extraction wells for removal from the LTP. A significant portion of the injected water seeps out through the bottom of the LTP into the partially saturated alluvial zone directly beneath it, which pushes the water with the highest concentrations of uranium and other COCs in this zone to collection wells to the south and west of the LTP, where it is removed. This controlled seepage process is termed "alluvial flushing". The remainder of the injected water is captured via collection wells in the LTP.

The source control program enhances or accelerates the removal of the COC mass that is the source for groundwater contamination. It is estimated that the source control program has removed approximately 75,000 kg of uranium through 2009; this mass is therefore no longer present to leach into the alluvial aquifer and exacerbate groundwater impacts (**Section 2.4.4**). This strategy relies on the understanding that the majority of uranium in the tailings solids in the LTP is present as soluble uranium in pore water, and thus can be hydraulically forced out of both high and low permeability zones and removed by extraction wells.

There are approximately 190 injection wells installed in the LTP that injected 193 gpm in 2010 using water sourced from the alluvial, Upper Chinle, and Middle Chinle aquifers. The contribution of water from each aquifer is detailed on **Figure 5.2-1**. There are approximately 150 extraction wells installed in the LTP that extracted a total average flow of 25 gpm in 2010. The extracted water was routed directly to the evaporation ponds. Historically, some of the water collected from the tailings extraction wells has been sent to the RO plant for treatment, but the immoderate chemistry of pore water in the LTP inhibited effective treatment via RO operation. Toe drains, installed along the perimeter of the LTP, collected a total average flow of approximately 35 gpm in 2010, and this water was also directly routed to the evaporation ponds. Historical injection and extraction rates in the source control program are summarized in **Table F-3** in **Appendix F**. The remainder of this water (approximately 133 gpm in 2010) is either stored in the LTP or seeps into the alluvial aquifer. It is estimated that 13 gpm were stored in the LTP in 2010 and approximately 120 gpm seeped into the partially saturated zone of the alluvial aquifer directly beneath the LTP. This water moves contaminated water to the groundwater collection area upgradient of the hydraulic barrier (**Section 5.3.2**) for subsequent removal and treatment.

5.3.2 Plume Control

The plume control program is the original restoration strategy employed at the site, and also the most complex. The program began in 1977 and has evolved continuously. Unimpacted or slightly impacted water is injected into the alluvial, Upper Chinle, and Middle Chinle aquifers to control the local hydraulic gradient in order to inhibit movement of the contaminant plume (discussed in detail in **Section 4.2**). This water has the additional benefit of hydraulically driving more contaminated water to extraction wells, where it is removed and sent to the RO plant for treatment or sent to land treatment (discussed in **Section 5.3.5**). This hydraulic barrier in the alluvial aquifer is created and maintained with 115 injection wells and more than 6,000 linear feet of infiltration lines. The injected water used in the plume control program is from RO plant product water, less contaminated areas of the alluvial aquifer, the Middle Chinle aquifer, and the San Andres aquifer. An annual average flow of 1,230 gpm was used for plume control in 2010 in the alluvial aquifer.

The alluvial aquifer injection wells and infiltration lines establish a hydraulic barrier and groundwater collection area zone downgradient of the LTP. Groundwater flowing underneath the LTP, as well as seepage from the LTP, is eventually captured by the collection system. This collected water primarily reported to the RO plant for treatment. In 2010, 240 gpm of water were collected from the alluvial aquifer. The Upper Chinle collection system, consisting of five extraction wells, produced approximately 106 gpm in 2010. The upgradient alluvial collection system, which reduces the amount of water flowing under the LTP, operated at approximately 57 gpm in 2010.

The list of wells involved in the plume control program is included in **Table F-1** in **Appendix F**; these wells are also depicted on **Figure 5.3.2-1**. Information about these wells, including location, construction details, and pumping rates, is tabulated in **Appendix M**.

The plume control program was evaluated by calculating the total dissolved mass of uranium in the plume (**Section 4.2.4**) and the mass of uranium removed by collection/extraction wells (**Section 2.4.4**). These analyses demonstrate the efficacy of the program and are used in conjunction with capture zone evaluation to optimize performance (**Section 5.5.2**).

5.3.3 Reverse Osmosis Treatment

The RO plant is used to treat water from the alluvial aquifer (from wells designated RO collection wells) and recycled water from the collection ponds. It is possible to send water from the LTP to the RO plant, but water extracted from the LTP was not treated by the RO plant in 2010. Plant influent feed water is composed primarily of groundwater from the alluvial aquifer (approximately 90 percent) and West Collection Pond water (approximately 10 percent). The West Collection Pond receives water from the RO plant including: clarifier blowdown, filter backwash, and RO sump water (miscellaneous overflows). Influent RO plant flow rates typically range from approximately 250 to 400 gpm and have reached 500 gpm in recent years.

In 2010, the RO plant influent averaged 266 gpm, approximately 240 gpm coming from the alluvial aquifer collection wells and 26 gpm from the West Collection Pond. RO plant production rates averaged approximately 166 gpm of RO product water that was re-injected into the alluvial aquifer and 59 gpm brine waste sent to the evaporation ponds. Approximately 62 gpm was sent to the West Collection Pond as miscellaneous overflow.

As indicated on **Figure 5.3.3-1**, the RO plant treatment process includes lime clarification and sand filtration as pre-treatment to the RO treatment units. There are two RO treatment trains. The first is a low pressure reverse osmosis #1 (LPRO#1) skid (300 gpm capacity) that also has a high pressure reverse osmosis (HPRO) skid (75 gpm capacity) to treat the brine from LPRO#1. The second train, LPRO#2, only has an LPRO treatment skid (300 gpm). The clarifier, sand filters, LPRO#1, and HPRO treatment systems were originally designed and constructed in 1999 for a 300 gpm treatment capacity. With the addition of LPRO#2 in 2003, the overall RO plant treatment capacity goal was set at 600 gpm.

5.3.4 Evaporation

Evaporation is a water management strategy that allows HMC to achieve a site-wide water balance; evaporation capacity is vital to handling excess water from other components of the CAP. The evaporation system predominantly receives contaminated water from the extraction wells in the LTP and brine from the RO plant. Increasing the evaporative capacity of the system therefore allows HMC to increase both the amount of water treated in the RO plant and the amount of water that can be extracted from the LTP.

There are two lined collection ponds (West Collection Pond and East Collection Pond) and three lined evaporation ponds (EP-1, EP-2, and EP-3) in use at the site. The locations of the collection and evaporation ponds to the south of the LTP are shown on **Figure 5.3-1.** EP-1 was constructed in the STP, initially to assist with the tailings dewatering program in the early 1990s. The two collection ponds began operation in October 1986; EP-1 began operation in November 1990, EP-2 began operation in March 1996, and EP-3 began operation in December 2010.

There are two types of evaporation techniques in use at the site: passive evaporation from the surface of the ponds and forced or active evaporation as water is pumped through spray nozzles. The passive evaporation capacity is dependent upon the total surface area of the evaporation ponds, which is approximately 70 acres after the construction of EP-3. Forced evaporation capacity was increased in 2004 with the purchase of four Turbomister™ units, which enhance the base evaporation rate from passive evaporation. In 2010, net evaporation from the evaporation system (excluding EP-3 for the majority of the year, as it was under construction) was approximately 146 gpm. The evaporation pond system received approximately 63 million gallons (equivalent to 120 gpm) of water from the tailings extraction wells and brine from the RO plant, in addition to 15 million gallons (equivalent to 28 gpm) of natural precipitation. The historic evaporation performance is summarized in **Table F-4** in **Appendix F**.

5.3.5 Land Treatment

Land treatment, historically referred to as irrigation or land application, is used to manage extracted groundwater to achieve a site-wide water balance for the groundwater remediation program. Past and ongoing land treatment operations are utilized to manage large volumes of slightly impacted groundwater located in two alluvial aquifer zones located west and south of the mill site. Ongoing groundwater cleanup in these areas requires the active removal of impacted water and selective injection of hydraulic barrier water to assure that these impacted zones do not migrate further downgradient in the alluvial aquifer and to achieve groundwater aquifer restoration within these locations. The land treatment system consists of two flood land treatment units (120 and 24 acres each) and two center-pivot land treatment units (100 and 150 acres each). The locations of these areas are shown on **Figure 5.3-1**. Land treatment was approved as a restoration strategy by the NRC and NMED through letter authorizations prior to initiation of the program in 2000. Detailed information regarding the land treatment program can be found in the recent report Evaluation of Years 2000 through 2010 Irrigation with Alluvial Ground Water (Homestake, Hydro-Engineering, ERG, and RIMCON 2011).

Uranium is present in the extracted groundwater predominantly as dissolved uranium in an oxidized chemical form (U[VI]) and in association with bicarbonate. Upon application to the land surface, a number of processes can immobilize it within the soil column, including 1) precipitation of uranyl (U[VI]) mineral phases, 2) uptake by plants, 3) biological reduction of the more soluble U(VI) species to U(IV) and subsequent precipitation as uraninite, and 4) sorption to the surfaces of minerals and solid phase natural organic matter (NOM). Selenium treatment in the soil column is controlled by a combination of sorption to soil and plant uptake. Additional details on treatment mechanisms are provided in **Appendix J**.

The groundwater used for land treatment has slightly elevated concentrations of COCs, but the land treatment supply water meets the land treatment standards set by the NRC and NMED. From 2000 to 2009, the maximum allowable concentration was 0.44 mg/L for uranium and 0.12 mg/L for selenium. HMC is proposing updated concentration limits for land treatment water, which will be more stringent than the above referenced standards to address concerns associated with ensuring that re-contamination of the alluvial aquifer is avoided in the four land treatment units. These proposed limits are summarized in **Table 6.3.5-1**. Groundwater from all five aquifers is used in the land treatment program; contaminated groundwater that does not meet the land treatment standards is blended with unimpacted water to dilute uranium and selenium concentrations in order to comply with these standards before land treatment application. The land treatment program is essential for managing water that must be addressed through restoration efforts and to increase the amount of water that can be used for plume control and source control, thus accelerating restoration at the site.

Land treatment is typically limited to 7 to 8 months each year during the summer growing season, when the water is used for crop production. The crops grown using the slightly impacted water are not for direct human consumption, have very little impact on environmental exposure pathways, and thus the radiation dose to the public is extremely limited. The radiation dose to the public attributable to land treatment is modeled and evaluated in the 2000-2010 irrigation report (HMC et al. 2011), included as **Attachment J-1** in **Appendix J**. In the worst-case scenario, the radiation dose from land treatment is less than 1 percent of the dose from natural background and medical exposures. In 2010, a total of 201 acre-feet of water from all five aquifers was applied to the land treatment units over 4 months. The historic land treatment performance is summarized in **Table F-5** in **Appendix F,** and the land treatment program and associated data are detailed in **Appendix J**.

Soil samples from the land treatment units are analyzed annually to characterize the percentage of uranium and selenium from applied water that remains within the soil profile. These analyses allow HMC to characterize the impact of land treatment. Uranium and selenium concentrations were measured in soil samples from land treatment areas in 1999 (prior to irrigation) and after each of the 2000 through 2010 irrigation seasons. Additional parameters were also measured or calculated for the samples for evaluation of soil health. Background samples were taken from 2000 through 2010 at varying locations to further define the mean background values for each depth shown on **Figures 5.3.5-1** through **5.3.5-6**. The establishment of background constituent concentrations allows the computation of the changes in COC soil concentrations as a result of the land treatment program.

Figure 5.3.5-1 presents the uranium concentrations with depth for the Section 34 Flood land treatment area and mean background concentrations for 2009 and 2010. The shaded distance between these two lines is the gain in uranium concentration. The green shaded area shows where uranium has been added in the Section 34 soils to a depth of 4 feet with only one gain below this depth. The uranium concentration gain between 9 and 11 feet did not exist in this area in 2009, and the significance of this gain is questionable unless future sampling indicates a continued gain or trend. The amount of gain in the soil profile was 95 and 100 percent (wt. %) in 2009 and 2010, respectively, of the total amount of uranium applied in the Section 34 land treatment area. This indicates that essentially all of the uranium applied in Section 34 is still in the soil profile.

A comparison of the results obtained from 2009 and 2010 indicates that selenium has accumulated in the upper 3 feet of the soil profile of the land treatment area of Section 34 (see **Figure 5.3.5-2**). The two small selenium concentration gains at depths greater than 5 feet are attributed to sampling or analytical variation pending confirmation with future sampling. The amount of gain in selenium concentrations within the soil profile in the Section 34 land treatment area was 89 and 67 percent in 2009 and 2010, respectively, of the amount applied. Therefore, a large percentage of the selenium applied is still in the soil profile.

The Section 28 treatment area 2009 and 2010 uranium gain profiles are shown on **Figure 5.3.5-3**. The profile shows that the uranium accumulation has been primarily in the upper 7 feet with gains of 102 percent for each of these 2 years, confirming that virtually all uranium applied in the irrigation water is retained in the soil profile.

Figure 5.3.5-4 presents a plot for the selenium soil concentration gains versus depth for both 2009 and 2010 relative to the 2010 mean background. This figure shows some gain in selenium concentration over the entire sampled soil profile. The red shaded area shows the 2010 gain in selenium concentration in the Section 28 soils while the 2009 gain is shown with the black pattern. The amount of gain in selenium in 2009 and 2010 was 77 and 94 percent, respectively, of the amount of selenium applied, showing that a large percentage of the selenium applied to the Section 28 land treatment area is still in the upper 17 feet of the soil profile.

Figure 5.3.5-5 shows the 2009 and 2010 gain in uranium in Section 33 with essentially all of the gain during 2010 from the surface to the 5 to 7 foot interval except for a small gain in the 13 to 17 foot depth. The very small gain at the greater depths in 2010 conflicts with the larger gains measured in 2009 at the greater depths. The 2010 data indicate that significant quantities of uranium have not migrated past a depth of 7 feet in Section 33.

The Section 33 selenium gain profile is presented on **Figure 5.3.5-6** showing the 2009 and 2010 gains in soil concentrations. The red pattern shows that the majority of the 2010 gain is above a depth of 7 feet, while some small gain was observed in 3 of the 5 lower intervals. Some selenium has likely migrated through the upper 17 feet of soil, but the majority of the selenium applied is still within the upper 17 feet of soil column.

As demonstrated by this series of figures, the percentage of the uranium in the soil profile in relation to the amount that was applied to the fields indicates that essentially all of the applied uranium is still in the soil profile. The percentage of the selenium retained in the soil profile is lower than uranium, but also indicates that a large percentage of the selenium applied to the fields is still in the upper soil profile.

5.4 Evaluation of Alternative Treatment Technologies

The five groundwater restoration components currently in use at the site have had a demonstrated history of success at reducing the impact of contamination and limiting the potential for future contamination.

Since groundwater restoration began in 1977, the CAP has continuously evolved to address changing site conditions, and HMC is committed to proactively investigating and implementing other technologies to augment the existing CAP. To accomplish this end, HMC is currently evaluating three technologies that, if demonstrated to be feasible and effective, may be implemented in the future pending appropriate agency approval.

5.4.1 *In Situ* Phosphate Treatment

In situ phosphate treatment is an emerging technology currently under evaluation at the site. This technology has been used in bench- and field-scale tests by the DOE at the Hanford site to reduce uranium concentrations in impacted groundwater (Vermeul et al. 2009). A source of phosphate is injected directly into the aquifer, and the phosphate reacts and complexes with dissolved uranium to form uranium phosphate mineral precipitates. These minerals include chernikovite ($H[\{UO_2\}\{PO_4\}].4H_2O$), autunite hydrates ($Ca[\{UO_2\}\{PO_4\}]_2.xH_2O$), as well as apatite ($Ca_5[PO_4]_3[F,Cl,OH]$). These uranium phosphate minerals have very low solubility under ambient aquifer conditions (Wellman et al. 2005). In the presence of excess phosphate, additional apatite is formed, which provides long-term treatment capacity as upgradient contaminated water passes through (Hamdy et al. 2008). The oxidation state of uranium is not changed by this technology, so there is no possibility of re-oxidation and resulting re-mobilization. Effective uranium removal is thereby achieved without the possibility of rebounding concentrations. This approach has been evaluated for application at the Hanford site through injection technologies, including aqueous and foam injection (Mattigod et al. 2010). The application of this technology through an aqueous injection-based approach at the Grants sites may provide a means of *in situ* groundwater treatment that can result in the direct precipitation of uranium as well as the establishment of a reactive treatment barrier. In addition, the *in situ* approach may provide the opportunity to minimize the time, energy, and infrastructure investment required by more traditional pump-and-treat systems.

HMC conducted bench-scale tests of this technology in 2010 and 2011. Two sources of phosphate were investigated: orthophosphate (an immediately available source) and polyphosphate (a slowly hydrolyzing source) to provide a gradual source of phosphate. Because orthophosphate reacts immediately to remove uranium, injecting it into an aquifer would limit the area that could be treated before precipitation. Polyphosphate hydrolyzes and releases orthophosphate gradually, meaning that it could be injected into an aquifer and be transported much farther before it reacts completely, thus treating a much larger area than phosphate. Residual phosphate is expected to react with calcium in groundwater and in aquifer solids, forming apatite and limiting the orthophosphate concentration in the groundwater. In bench tests, both sources of phosphate successfully removed uranium (95 to 99 percent removal) from tailings pore water and from water from the impacted area of the alluvial aquifer. Based on these results, HMC is currently implementing a pilot test of polyphosphate injections in a small area of the LTP to evaluate uranium removal under *in situ* test conditions.

If results from the pilot test indicate that uranium can successfully be removed *in situ* using this technology, HMC will evaluate plans for a field-scale test in the alluvial aquifer with requisite regulatory approval. The full-scale conceptual design of implementing this technology involves supplementing the hydraulic barrier with lines of wells injecting a phosphate source to create permeable reactive barriers of apatite. As contaminated groundwater flows through the area, uranium will react and precipitate; the result will be *in situ* treatment of dissolved uranium in groundwater between injection and collection wells. This technology could potentially also be implemented within and/or underneath the LTP to treat seepage.

5.4.2 *Ex Situ* Zeolite Treatment

HMC is currently operating a pilot-scale zeolite pad on top of the LTP. Zeolites are microporous aluminosilicates used as adsorbents, desiccants, catalysts, and for ion exchange. Industrial processes use both naturally occurring (e.g., clinoptilolite $[\{Na,K, Ca\}_{2\text{-}3}Al_3\{Al,Si\}_2Si_{13}O_{36}.12H_2O]$) and synthesized zeolites. Because of their ion exchange properties, zeolites are commonly used in water purification, usually as a polishing treatment (Xu et al. 2007).

The pilot-scale zeolite pad is treating slightly impacted water from the Upper Chinle aquifer. Dilute sulfuric acid is used to recharge (regenerate) the zeolite. If results from the pilot test are positive, full-scale zeolite treatment may be implemented to treat slightly impacted groundwater as a polishing step for water treatment, to supplement the RO plant or other remediation techniques in use or to be used in the future.

5.4.3 Electrocoagulation

HMC is currently conducting bench-scale tests for electrocoagulation (EC). EC is an electrochemical process commonly used for wastewater treatment to remove a variety of organic and inorganic pollutants. Metals such as arsenic and chromium that can be difficult to remove using other treatment technologies are successfully removed using EC. Uranium, molybdenum, and selenium can be removed by EC, and thus this technology may be appropriate for the site.

An EC reactor consists of one anode and one cathode. Iron and aluminum are common electrode materials, but other metals can be used. When the unit is connected to an external power source, the anode is oxidized and corrodes, while the cathode is reduced. Electrolysis produces metal hydroxide flocs by reaction at the anodes; contaminants sorb to these flocs that subsequently aggregate and can be removed once they settle (Kobya et al. 2003). Factors that influence the removal of metals include the electrode material, the pH of the solution, electrolysis time, current input, and the level of dissolved oxygen.

Bench-scale tests are evaluating the effect of these factors on COC removal for several samples of contaminated water from the site. EC will be implemented in a pilot-scale test if the bench tests demonstrate efficient COC removal with a reasonable demand for electricity. If used at full scale, EC may be an additional water treatment strategy that could supplement other remediation technologies in use currently or in the future at the site.

5.5 Existing CAP Evaluation and Optimization

The five components that constitute the CAP are continuously monitored and re-evaluated so HMC can make operational adjustments to optimize their performance. HMC occasionally supplements these minor modifications with major evaluation efforts to determine whether the groundwater restoration strategy is on the right track or needs to be re-evaluated.

5.5.1 Source Control

HMC is currently pursuing two evaluations of the source control program. The first is a rebound evaluation to address concerns that COC concentrations in the LTP will increase, or rebound, after active flushing ends. The second is a tracer study to more fully characterize horizontal and vertical pore water transport mechanisms in the LTP.

5.5.1.1 Rebound Evaluation

In their December 2010 Review of Specific Remediation Issues (ACOE 2010), the U.S. Army Corps of Engineers (ACOE) recommended the collection of data from additional geochemical parameters of the groundwater beneath and downgradient of the LTP to characterize conditions induced by the source control program. HMC has initiated the pilot-scale rebound evaluation to demonstrate that the source control program has no negative long-term effects.

The objective of the rebound evaluation is to support the prediction of long-term COC leaching behavior in and downgradient of the LTP after flushing ends. To accomplish this objective, HMC identified a 1.3-acre area in the west-central part of the LTP where the source control program has significantly reduced COC concentrations. HMC has taken the following steps:

- Evaluated leaching behavior of uranium, molybdenum, and selenium from tailings solids in bench-scale tests

- Conducted a tracer study in a portion of the LTP to characterize the flow regime and evaluate the connectivity of the well network before discontinuing flushing
- Monitored relevant geochemical parameters after flushing was discontinued (May 2011) in the test area of the LTP

Monitoring is tentatively scheduled to continue for 1 year after flushing was discontinued. When HMC has collected the complete field data set, both the field and bench results from the rebound evaluation will be submitted for review. Preliminary results from the bench-scale tests indicate that leaching of uranium, molybdenum, and selenium from tailings solids is extremely limited, even when using aggressive extraction solutions. These COCs are in non-labile forms that are resistant to dissolution and subsequent mobilization. Preliminary results from the tracer study suggest that pore water flow is rapid in high permeability, coarse-grained zones, and that there is limited diffusive mass transfer between low and high permeability zones. If these preliminary results are substantiated, HMC believes that this evaluation will demonstrate that rebound of COCs upon completion of flushing is highly unlikely.

5.5.1.2 Tracer Study

The basis of the source control program is the conceptual model for the LTP: the majority of uranium in the LTP is present in a soluble form in the pore water, and thus can be hydraulically forced out and removed by flushing. The performance of the flushing program is influenced by local variations in hydraulic conductivity: more permeable zones are more easily accessed by injected water, so decreases in COC concentrations are thus more easily achieved in preferential flow paths. Because of the depositional processes that deposited the materials in the LTP, there is significant horizontal and vertical heterogeneity that impacts the flow of injected and extracted water used in the source control program.

HMC is planning to conduct an additional tracer study to evaluate the performance of the source control program and identify potential options for improvement. This tracer study will be conducted in a portion of the LTP where the success of the source control program has been more limited. Three potential areas in the east-central portion of the LTP have been identified as options for this tracer study. A single injection well will be used so the results can be used in mass balance calculations; additionally, monitoring wells discretely screened at specific depth intervals (including in the alluvial perched zone beneath the LTP) will be used to evaluate vertical flux. Results from this tracer study will allow HMC to further characterize contaminant transport horizontally and vertically within the LTP.

5.5.2 Plume Control

The efficacy of the plume control can be demonstrated by several independent analyses. The first, a mass removal analysis, calculates the mass of dissolved uranium removed by the operation of the hydraulic barrier. The second, a capture zone evaluation, compares the capture zone achieved by the hydraulic barrier to the target capture zone. The mass removal analysis conducted in 2010 on data from 2001 to 2009, discussed below, clearly confirms significant dissolved uranium mass removal within the target capture zone and that observed concentration reductions are due to mass removal, not dilution. This analysis is described in detail in **Sections 2.4.4** and **4.2.4** and in **Appendix E.** A capture zone evaluation, which has not yet been conducted, may provide an opportunity to confirm that the plume control program is meeting hydraulic capture objectives; furthermore, it may provide the basis for future operational changes to support system optimization.

5.5.2.1 Mass Removal Analysis

HMC performed a mass removal analysis for dissolved uranium in the alluvial aquifer to demonstrate the effectiveness of the plume control program. The mass of dissolved uranium remaining in the alluvial aquifer within the bounds of the analysis decreased from 80,000 kg in 2001 to 30,000 kg in 2009 (**Figure 2.4.4-1**). The methodology and assumptions are described in **Sections 4.2.4** and in **Appendix E**.

The results of this analysis clearly demonstrate that the observed concentration decreases for the COCs are not due to dilution from the injection of unimpacted water. If dilution was the primary reason for the concentration decrease, the total mass of dissolved uranium would have remained unchanged. Rather, the extraction wells upgradient or adjacent to existing hydraulic barriers effectively remove COC mass.

5.5.2.2 Capture Zone Evaluation

The ACOE submitted the Focused Review of Specific Remediation Issues on December 23, 2010 (ACOE 2010) as an addendum to the Remediation System Evaluation (RSE). This review was conducted on behalf of the EPA. Part of their Scope of Work (SOW), finalized on August 20, 2009, was to evaluate the adequacy of horizontal and vertical plume control in the alluvial and three Chinle aquifers, using the recent EPA guidance document on capture analysis (EPA 2008a). This evaluation is described in more detail in **Appendix F**.

The EPA guidance document defines a capture zone as equivalent to a “zone of hydraulic containment.” Capture zone analysis is thus the process of using hydraulic head and groundwater quality data to interpret the achieved capture zone to determine if capture is sufficient to meet the target. An important point made in this guidance is the distinction between horizontal and vertical capture zones (**Figure**

5.5.2.2-1): plumes are three-dimensional, and capture efforts must include sufficient horizontal and vertical components to be effective.

The EPA guidance document includes six steps for a systematic evaluation of capture zones:

1) Review site data, the site conceptual model, and remedy objectives.
2) Define the site-specific Target Capture Zone(s).
3) Interpret water levels.
    - Potentiometric surface maps (horizontal capture).
    - Water level difference maps (vertical capture).
    - Water level pairs (gradient control points).
4) Perform relevant calculations
    - Estimated flow rate
    - Capture zone width
    - Drawdown
    - Analytical or numerical modeling to simulate water levels, in conjunction with particle tracking and/or transport modeling
5) Evaluate concentration trends
6) Interpret actual capture based on Steps 1 through 5, compare to the Target Capture Zone(s), and assess uncertainties and data gaps.

The ACOE did not fully follow the EPA guidance document in their assessment of hydraulic capture at the site. Their analysis is incomplete, and thus their conclusion that concentration reductions are due primarily to dilution, rather than mass removal, is inaccurate. The mass removal analysis conducted by HMC (discussed in **Section 5.5.2.1**) is conclusive and quantifies the significant reduction in dissolved uranium mass within the plume. If concentration reductions were due primarily due to dilution, the total dissolved uranium within the plume would have remained unchanged. The ACOE evaluation included the following steps:

- Plotting and hand-contouring water levels measured during two monitoring events in 2009 (one in March and April, the other in June and July) for a limited subset of wells
- Plotting concentration trends for selected wells and parameters (plots are only presented for ten wells in the alluvial aquifer for dissolved uranium; one plot for dissolved sulfate is included)
- Qualitative evaluation of groundwater flux from the injection wells associated with the hydraulic barrier
- Qualitative evaluation of the groundwater model regarding the simulation of seepage from the LTP

While the mass removal analysis (**Section 5.5.2.1**) demonstrates that the hydraulic barrier is effective at containing and removing contaminant mass, HMC is considering using the EPA capture zone analysis guidance document to determine whether the performance of the hydraulic barrier can be improved or further optimized. Performing this analysis may allow HMC to compare the capture zone achieved by the current operation of the barrier wells to the target capture zone.

5.5.3 Reverse Osmosis Treatment

HMC has taken several steps to evaluate the condition and performance of the RO plant and identify strategies to maximize production and treatment efficiency. Ongoing studies are being performed to accomplish the following objectives:

- Determine the remaining useful life of RO plant assets.
- Identify and correct any hydraulic bottlenecks.
- Characterize influent and effluent product and waste streams.
- Optimize pretreatment processes to reduce downstream disturbances.
- Identify improvements to the RO system to minimize operations and maintenance (O&M) costs and increase membrane life.

Final results from these evaluations are forthcoming, though some process improvements are already underway. Preliminary findings include:

- The RO plant is in generally good condition and can be operated reliably for the next 10 years with some investment in rehabilitation/replacement of equipment as it reaches the end of its useful life.

- Pretreatment can be further optimized to maximize treatment capabilities and minimize wastes produced from the RO plant. Examples of anticipated improvements include equalization and characterization of influent feed water, physical modifications to address hydraulic capacity constraints, adjusting chemical feed locations, and increasing process water quality monitoring.

- The RO treatment system can be further optimized to improve the reliability of treatment performance, and increase throughput, resulting in reduced operating costs.

5.5.4 Evaporation

HMC plans to conduct a review of the condition of the forced spray system design and condition of the equipment to determine if the forced evaporation capacity can be improved. The addition of EP-3 has increased passive evaporation capacity, and it may be beneficial to supplement it with increased active evaporation capacity.

5.5.5 Land Treatment

HMC plans to update the unsaturated zone modeling effort to characterize the impact of land treatment on soil and groundwater quality to reflect the most recent observed monitoring information. Additionally, HMC is proposing lower water quality parameter limitations for water applied to the land treatment units (**Table 6.3.5-1**). More information about the land treatment program at the site is provided in **Appendix J**.

5.5.6 Monitoring Program Optimization

The monitoring program is discussed in detail in **Section 7**, and the optimization of the program in **Section 7.3**. Because the monitoring program provides the data necessary to operate and optimize every component of the CAP, HMC is committed to ensuring that the monitoring program will provide sufficient, relevant, and accurate data.

6.0 REVISED CAP

In 2010, the NRC requested information about the future of the CAP. This section presents the anticipated path forward for the CAP; the schedule for the future of the CAP is included in **Section 6.2**. The actual future operations of the CAP may be modified from this discussion, depending upon the results of the ongoing evaluation and optimization activities that HMC is pursuing, as well as future CAP regulatory approvals (**Section 5.5**).

6.1 Estimated Water Balance

The current site-wide operation of the CAP is discussed in detail in **Section 5.2** and in **Appendix H**; the relationship among the five restoration strategies is illustrated on **Figure 5.2-1,** the 2010 site-wide operational flow depiction is included as **Figure 5.2-2,** and historical flows are summarized on **Figure 5.2-3**. The site-wide operation flow depiction allows HMC and stakeholders to understand how water is managed at the site and how the five CAP components are interrelated. It clearly demonstrates the importance of evaporation and land treatment as water management strategies that thereby allow the effective operation of the source control, plume control, and RO treatment strategies.

HMC has predicted flow rates for each component of the CAP for the duration of the anticipated schedule (**Section 6.2**). These predicted flow rates are shown on **Figure 6.1-1** for each major process stream and are grouped by major strategy on **Figure 6.1-2**. As discussed in **Section 6.2**, a number of factors may influence the future operation of the CAP and the predicted future water balance and schedule are subject to change.

6.1.1 Predicted Groundwater Concentrations

Results from the groundwater model, which are discussed in detail in **Section 5.1** and in **Appendix G,** indicate that the site standards will be met at the POC wells if the average uranium concentration in the LTP is 2 mg/L or less. **Appendix G** also includes detailed information about the groundwater modeling effort.

6.2 Schedule for Revised CAP

It is anticipated that the CAP will continue through 2020, with evaporation continuing through 2022, to achieve the restoration goals. The schedules for the CAP specify the duration of each component. These schedules were developed employing groundwater modeling (described in detail in **Section 5.1** and in **Appendix G**) to predict when COC concentrations at the POC wells would be achieved, based upon anticipated operational parameters. These operational parameters include the amount of water available for plume control, the treatment capacity of the RO plant, the amount of water available for source control, the evaporation capacity, and the land treatment capacity. If CAP operations proceed as anticipated in the modeling effort, groundwater restoration will be achieved within this schedule. The anticipated schedule will be modified in future updates to the CAP if 1) the performance of any or all of the CAP components is compromised or delayed (restoration will be achieved more slowly than predicted) or 2) if one or more of the CAP components is optimized or an alternative treatment technology is implemented (restoration therefore might be achieved more quickly than predicted).

Modifications to these operational parameters will be documented and reported in the annual monitoring reports as required under the NRC license.

Figure 6.2-1 depicts the schedule for the CAP.

- Plume control will continue through 2020, although some components of the program will be phased out beginning in 2015.
- RO treatment will continue through 2020.
- Source control will continue through 2016, although injections into the LTP will cease after 2014.
- Water will be sent to the evaporation ponds through 2020, where it will be allowed to evaporate through 2022.
- Land treatment will continue through 2020.

6.3 Summary of Evolved Remedial Actions

Detailed information about the current operations of the five CAP components used at the site is included in **Section 5.3** and **Appendix F**. HMC is in the process of evaluating and optimizing each restoration component (discussed in detail in **Section 5.5**); the results from these efforts may impact the CAP in terms of specific groundwater restoration program elements. Projected operation parameters for the CAP components are discussed in this section and in **Appendix I**.

6.3.1 Source Control

The source control program consists of flushing the LTP with unimpacted to slightly impacted water to hydraulically force highly contaminated pore water to extraction wells, where it can be collected and sent either to the RO plant for treatment or to the lined evaporation ponds for isolation and consolidation (**Section 5.3.1**). Injection of water into the LTP will continue through 2014, and extraction of water from the LTP will continue through 2016 if target injection and extraction rates (300 gpm and 120 gpm, respectively) are achieved through this period (**Figure 6.2-1**). Predicted future operation of the source control program is summarized in **Table I-3** in **Appendix I**.

6.3.2 Plume Control

Unimpacted to slightly impacted water is injected into the alluvial aquifer to reverse local hydraulic gradients and create a hydraulic barrier to inhibit the flow of contaminated groundwater (**Section 5.3.1**). The collection of water from upgradient wells is expected to be phased out of the CAP beginning in 2015, and the collection for reinjection is expected to be phased out beginning in 2016. The fresh water injection portion of the plume control program is expected to be phased out of the CAP beginning in 2019 into the Upper and Middle Chinle aquifers, but fresh water injection will continue into the alluvial aquifer through 2020. Injection and RO treatment of extracted water are expected to continue through 2020 (**Figure 6.2-1**).

HMC is considering adding wells to supplement the plume control program. The number of proposed wells and their locations are listed in **Table I-1** in **Appendix I**. These proposed wells include a series of wells named the B series on the south and southwest sides of the LTP and a series of wells named the S series on the west side of the LTP. The B and S series collection/injection wells would either be used in the plume control program or potentially for the implementation of an *in situ* alternative treatment technology, such as *in situ* phosphate treatment (**Section 5.4.1**)

Currently, San Andres wells #1, #2, 943, and 951 and Upper and Middle Chinle wells CW18 and CW28 are the sources of unimpacted water for the plume control program. HMC is evaluating whether the San Andres wells are adequately sealed. If HMC determines that these wells need to be abandoned, other San Andres wells will be used. These proposed supply wells are also included in **Table I-1**.

6.3.3 Reverse Osmosis Treatment

It is anticipated that the RO plant operations will be optimized and that the plant will be operated near design capacity (600 gpm) in the future. RO treatment is expected to continue through 2020 (**Figure 6.2-1**). The RO plant will treat highly contaminated water from the alluvial aquifer, and may also treat water that is extracted from the LTP as part of the source control program.

HMC may update the operation and maintenance of the RO plant based upon the recommendations suggested in **Section 5.5.3**, which would improve the performance of the plant and allow operations to be maximized through 2020.

6.3.4 Evaporation

The three lined evaporation ponds (EP-1, EP-2, and EP-3) will continue to be used in the same capacity as they are presently. They will receive brine from the RO plant, some fraction of the water extracted from the LTP, and some of the contaminated water extracted from the alluvial aquifer. It is anticipated that the evaporation ponds will be used through 2022, although water will not be sent to the ponds after 2020 (**Figure 6.2-1**). HMC is also planning to continue evaluating the condition of the spray evaporation equipment and may replace the Turbomister™ units and other forced evaporative spray systems if necessary to improve performance.

6.3.5 Land Treatment

It is anticipated that land treatment will continue through 2020 (**Figure 6.2-1**). HMC has proposed reduced water quality standards for water applied to the land treatment areas. These proposed land treatment concentration limits are summarized in **Table 6.3.5-1** below. The lowered standards are being proposed to address NMED concerns associated with ensuring that re-contamination of the alluvial aquifer is avoided in the four land treatment units, though soil sampling has indicated that COCs are being retained in the soil profile.

Table 6.3.5-1: Proposed Land Treatment Supply Upper Limits for Uranium, Selenium, TDS, and Sulfate, and Anticipated Land Treatment Amount

	Maximum Concentration Applied (mg/L)				Anticipated Land Treatment (feet of water)		
Year	Uranium	Selenium	Total Dissolved Solids	Sulfate	Section 34 Flood	Section 28 Pivot	Section 33 Pivot and Flood
2011 (actual data)	0.14	0.03	1410	610	2.5	2.5	0
2012	0.16	0.1	2000	900	2.5	2.5	0
2013	0.16	0.1	2000	900	2.5	2.5	0
2014	0.16	0.1	2000	900	2.5	2.5	0
2015	0.16	0.1	2000	900	2.5	2.5	0
2016	0.16	0.1	2000	900	2.5	2.5	0
2017	0.16	0.1	2000	900	2.5	2.5	0
2018	0.16	0.1	2000	900	2.5	2.5	0
2019	0.12	0.08	2000	900	2.5	2.5	0
2020	0.03	0.05	2000	900	2.5	2.5	0

Note:
mg/L – milligrams per liter

6.3.6 Alternative Treatment Technologies

Depending upon the results of the preliminary bench- and pilot-scale investigations HMC is currently pursuing (**Section 5.4**), one or more alternate treatment technologies may supplement the five existing restoration components. If determined to be effective at COC treatment, one or more of these alternative treatment technologies would likely be used as "polishing" options for final treatment of moderately to slightly impacted water. Currently, HMC is actively evaluating *in situ* phosphate treatment (**Section 5.4.1**), *ex situ* zeolite treatment (**Section 5.4.2**), and EC (**Section 5.4.3**). In the past, HMC has also considered bioremediation, organo-sulfide reductant remediation, and ion exchange treatment. Bioremediation would be accomplished by the *in situ* addition of a carbon source to stimulate microbial activity. The *in situ* addition of a reductant would reduce sulfate to sulfide and result in the co-precipitation of sulfide minerals with COC metals. If HMC determines that one or more of these alternative treatment technologies might be appropriate for use at the site, they may be implemented after obtaining necessary agency approval.

Potential areas for implementation of alternative treatment technologies include the L series wells, the B series wells, the S series wells, the T series wells, the M series wells, the WR series wells, and potentially in the west off-site and south off-site alluvial aquifer groundwater restoration areas. The L series wells are to the southeast of the STP. The B and S series wells are to the southwest and west of the LTP. The M and WR series wells are to the west of the S infiltration lines. The specific location, use, and status of these wells are included in the 2010 Annual Monitoring Report/Performance Review (HMC and Hydro-Engineering 2011). All of these areas have relatively low COC concentrations, and thus may be appropriate for the full-scale implementation of one or more alternative treatment technologies.

7.0 GROUNDWATER MONITORING PROGRAM

The groundwater monitoring program is a vital part of the CAP. Groundwater monitoring began in 1975, and annual monitoring reports have been submitted to the NRC since 1983. The most recent monitoring report was submitted to the NRC in March 2011 (HMC and Hydro-Engineering 2011). These annual monitoring reports provide a summary of operations during the previous year, as well as updated aquifer water quality information.

The monitoring program has evolved with the CAP to ensure that relevant, accurate data are available to provide HMC with the information needed to modify operations and adapt to changing site conditions. Therefore, the monitoring program must be comprehensive and have clearly defined objectives. HMC currently samples approximately 80 wells to meet federal and state license and permit requirements and voluntarily samples several hundred additional wells to assess the performance of the CAP components and to monitor any changes in the groundwater plume.

7.1 Objectives

The ultimate purpose of the groundwater monitoring program is to provide HMC with relevant, accurate data necessary to modify CAP operations as needed to achieve groundwater restoration. Towards this end, there are several objectives of the monitoring program:

- To characterize the contaminant plume
- To evaluate the performance of the five restoration strategies that are part of the CAP
- To demonstrate progress made in restoring groundwater to meet site standards
- To comply with all federal and state permits and license requirements

7.2 Procedure

More detailed information about the monitoring program is provided in the annual monitoring reports; the most recent monitoring report is for 2010 operations (HMC and Hydro-Engineering 2011). The well network, monitoring frequency, and analytical suites are summarized here and in **Appendix L**.

7.2.1 Network

Five POC wells are designated for the site (**Figure 1.1-1**). D1, X, and S4 are the POC wells for the alluvial aquifer, and CE2 and CE8 are the POC wells for the Upper Chinle aquifer. Additionally, wells P and Q are used to monitoring upgradient site background water quality.

There are no POC wells for the Middle and Lower Chinle aquifers because they subcrop with the alluvial aquifer outside of the NRC license boundary (**Figure 3.2.3-1, Figure 5.3-1**). Groundwater from the edge of the tailings must migrate in either the alluvial or Upper Chinle aquifers for more than a mile before reaching the subcrops of the Middle and Lower Chinle aquifers, where impacted water could potentially enter these aquifers. Therefore, monitoring for the Middle and Lower Chinle aquifers can be accomplished using the existing POC monitoring wells.

In addition to the POC and background wells, HMC regularly monitors approximately 80 additional wells to comply with all federal and state licenses and permits and voluntarily samples several hundred more to assess the performance of the CAP. The compliance monitoring wells, along with their sampling frequencies, are listed in **Table 7.2.2-1**. The network of the voluntary performance monitoring wells evolves to stay relevant to current CAP operations and varies from year to year.

7.2.2 Frequency and Analytical Suite

The monitoring frequency of the performance monitoring wells, like the well network, is variable, depending upon the data needed to assess CAP performance. The monitoring frequency for the compliance monitoring wells is specified by relevant project site permits or license. The well network, monitoring frequency, and parameter list for the compliance monitoring program are summarized in **Table 7.2.2-1**.

Table 7.2.2-1 – Compliance Monitoring Program

Well	Parameter List Code*	Frequency of Monitoring
Point-of-Compliance Wells		
Point-of-Compliance Wells D1, X, S4, CE2, CE8	B, F H	Annual Semiannual
Background Wells P, Q	B, F H	Annual Semiannual
Compliance Monitoring Wells		
Alluvial Wells		
Broadview Acres wells SUB1, SUB2, SUB3	B, F G	Annual Semiannual
Felice Acres wells 490, 491, 496	G	Semiannual
Murray Acres well 802	G	Semiannual
Pleasant Valley wells 688, 846	G	Semiannual
Section 34 Land treatment wells 844, 845, 555, 556, 557	H	Semiannual
Section 28 Land treatment wells 881, 882, 884, 886, 893	H	Semiannual
Section 33 Land treatment wells	H	Semiannual

Well	Parameter List Code*	Frequency of Monitoring
551, 553, 554, 647, 649, 650, 658		
Regional wells 541, 631, 657, 869, 920, 942	G	Semiannual
Site monitoring wells F, FB, GH, GN, MO, MR, MX, R, S2	G	Semiannual
Collection system wells	Total Volume	Monthly
Injection system wells	Total Volume	Monthly
Reversal wells B, BA, KZ, DZ, SM, SN, S2, S5	Water level	Weekly
	Chinle Wells	
Broadview Acres well CE9	G	Semiannual
Felice Acres wells 493, 494, CW45	G	Semiannual
Regional wells CW18, CW29, CW42	G	Semiannual
Site monitoring wells CW 2, CW25, CW50	G	Semiannual
	San Andres Wells	
#1 Deep, #2 Deep, 943, 951	D G	Semiannual

Note:
* See **Table 7.2.2-2** below.

Table 7.2.2-2 provides the parameter list codes and the parameters included in each list for each category of monitoring well listed in **Table 7.2.2-1**.

Table 7.2.2-2 – Site Analytical Suites

Parameter List Code	Included Parameters (Dissolved)
B	Water level pH Total dissolved solids (TDS) Sulfate (SO_4) Chloride (Cl) Bicarbonate (HCO_3) Carbonate (CO_3) Sodium (Na) Calcium (Ca) Magnesium (Mg) Potassium (K) Nitrate (NO_3) Uranium (U) Selenium (Se) Molybdenum (Mo) Radium-226 (Ra-226)
D	pH TDS

Table 7.2.2-2 – Site Analytical Suites

Parameter List Code	Included Parameters (Dissolved)
	SO_4 Cl HCO_3 CO_3 NO_3 U Se Mo Aluminum (Al) Arsenic (As) Barium (Ba) Cadmium (Cd) Cobalt (Co) Copper (Cu) Cyanide (CN) Fluorine (F) Iron (Fe) Lead (Pb) Manganese (Mn) Mercury (Hg) Nickel (Ni) Silver (Ag) Zinc (Zn)
F	Vanadium (V) Radium-228 (Ra-228) Thorium-230 (Th-230)
G	Water Level TDS SO_4 U Se Mo
H	Water Level TDS SO_4 U Se Mo Cl

7.2.3 Methodology

The HMC standard operating procedure (SOP) for sample collection and preparation methodology that must be followed for all monitoring events is provided in **Attachment L-1** in **Appendix L**. Procedures in the SOP are followed for every sampling event performed by site staff and consultants.

7.3 Optimization

HMC continually re-evaluates the monitoring program to determine whether it can be further optimized. The monitoring program must evolve with the CAP to ensure that accurate, relevant water quality data can be used to modify the CAP. This process is also discussed in **Sections 2.4.3** and **5.5.6** and in more detail in **Appendix K**. It will include the following steps:

1) Identify site wells that are currently being used or may be used as monitoring wells to evaluate the performance of the CAP in a comprehensive table and collect relevant data.

2) Determine the monitoring objective the well would fulfill if included in the monitoring program.

3) Evaluate historical water quality data from the well to determine whether continued or additional sampling would provide relevant information. Suitable lines of evidence for this evaluation include the number of samples collected since installation, frequency of detection in recent sampling events, maximum detected concentrations, concentration-time profiles, magnitude of annual concentration change compared to the site standards, and variability of the concentrations over time.

4) Based on this evaluation, determine the appropriate parameter list and sampling frequency for the well. This information should prove useful to HMC; there is no added benefit to sampling a well for more parameters or more often if doing so does not provide any additional information.

The final recommendations are subject to a detailed geochemical review to ensure that the proposed sampling program will meet CAP needs and related permit and license requirements. In summary, historical data will be analyzed using simple statistical methods and a rule-based decision process to determine whether continued or additional sampling will provide relevant data to characterize CAP performance and/or the contaminant plume. This decision-making process is illustrated on **Figure 2.4.3-1**.

7.4 Compliance

The compliance monitoring program was specified by NRC License Amendment No. 34 in August 1999. **Attachment L-1** of **Appendix L** includes detailed information on groundwater data submitted to the NRC and the NMED. These groundwater data are required by NRC License SUA-1471 and NMED Discharge Permits DP-200 and DP-725 (discussed in detail in **Section 1.1**).

7.4.1 Point-of-Compliance Wells

The five POC wells (D1, X, and S4 in the alluvial aquifer and CE2 and CE8 in the Upper Chinle aquifer; **Figure 1.1-1**) are the locations at which the site standards (**Table 1.1-1**) must be met to comply with the

NRC license and to demonstrate that groundwater restoration objectives have been met. There are no POC wells for the other aquifers, as discussed previously.

7.4.2 CAP Status Wells

HMC voluntarily monitors several hundred wells additional to the ones listed in **Table 7.2.2-1** to assess the performance of the CAP. These wells are sampled as needed to provide real-time data that allows HMC to modify CAP operations to enhance performance. HMC is considering formalizing the CAP performance monitoring into an established program with specified analyte lists and monitoring frequencies, but this is not required by any involved agency and will be implemented only if determined to be beneficial for further optimizing current CAP operation monitoring activities.

7.5 Quality Assurance

A comprehensive field and laboratory quality control program is used to ensure that the data are high-quality and appropriate for achieving monitoring objectives. This program is presented in **Appendix L** as **Attachment L-1**. It is anticipated that this program will be followed for the duration of the CAP.

8.0 FINANCIAL SURETY

Comprehensive financial surety evaluations are required by NRC License Condition No. 28. The latest cost estimate/surety evaluation was approved by the NRC on December 20, 2011 via License Amendment 44 (**Attachment M-2**). These cost estimate update evaluations are completed annually as specified by license provisions and cover identified site remediation costs through completion of the site remediation and closure program.

This latest evaluation included a detailed cost estimate for the implementation of the on-site reclamation tasks under the existing approved CAP, which was expected to be completed by 2017. The total present value cost estimate for site reclamation in the financial surety submittal was $41,093,194. This estimate includes a 15 percent contingency and a Long-Term Maintenance/Surveillance Fee, as required by the NRC. An annual cost estimate update is due by March 31, 2012 as required under License Condition No. 28; that cost estimate will include the time extension for CAP completion out to 2022, as described and outlined in **Section 6**. Changes and updating of the cost estimate will continue annually per license condition or as dictated by changes in the CAP as ground water restoration, reclamation and site decommissioning plans and activities proceed.

9.0 CONCLUSIONS

This update to the CAP documents the status of the groundwater restoration effort at the site and the anticipated path forward, including the predicted duration of each component of the CAP. HMC is committed to successfully restoring groundwater to the established site standards, and input from all of the stakeholders is valued in achieving this goal. Thus, HMC is proactively incorporating multi-agency input into its evaluation and operation of the groundwater restoration program. This update to the CAP compiles relevant information from the annual monitoring reports and NRC license amendments into a single document, so that the information presented in this update is complete and up to date. It fulfills the relevant NRC acceptance criteria for groundwater CAPs and addresses the RAIs from the NRC's recent review of the 2006 update. Relevant comments and recommendations from the EPA and the NMED are also addressed in this update.

The CAP began at the site in 1977 and is now expected to continue through 2020, with final evaporation and site closure and decommissioning continuing through 2022. Factors contributing to this extension to the CAP schedule include the 3-year delay in obtaining the necessary approval to construct EP-3 coupled with recent limitations on land treatment. There are five current operational components of the CAP: (1) source control, (2) plume control, (3) RO treatment, (4) evaporation, and (5) land treatment. HMC continues to evaluate these strategies and has undertaken several evaluations to determine if the performance and/or the operation of these five components can be optimized.

HMC is conducting a rebound evaluation in the LTP to evaluate the current source control program. This investigation will provide a defensible, technically sound prediction of long-term COC leaching behavior in and downgradient of the LTP after flushing ends. The rebound evaluation includes bench-scale tests to evaluate leaching behavior from the tailings solids, a dissolved gas tracer study to characterize the flow regime in the LTP, and monitoring relevant geochemical parameters in a 1.3-acre area of the LTP where flushing was discontinued in May 2011. Post-flushing monitoring will be performed for at least 1 year to characterize and verify rebound characteristics.

A dissolved uranium mass removal analysis verified the efficacy of the plume control program. Between 2001 and 2009, approximately 50,000 kg of dissolved uranium were removed from the alluvial aquifer. This analysis demonstrates that the plume control program removes COC mass through the extraction wells within the site hydraulic barrier and aquifer plume areas; observed decreases in COC concentrations are attributable to mass removal, not dilution. In addition, from 2002 to 2009, approximately 75,000 kg of dissolved uranium were removed from the LTP itself.

HMC is currently evaluating the condition and performance of the RO plant and is identifying strategies to increase treatment capacity, improve reliability, and reduce operating costs. These potential improvements include equalization and characterization of influent feed water, physical modifications to address hydraulic capacity constraints, adjustment of chemical feed locations, and increasing process water quality monitoring. The preliminary results of this evaluation indicate that the RO plant is in generally good condition and can be operated reliably for the next 10 years with some investment in rehabilitation and replacement of equipment as required extending the plant's useful life.

In addition to source control, plume control, and RO treatment optimization evaluations, HMC is also investigating several alternative treatment technologies. If bench- and pilot-scale tests are successful, HMC may implement one or more of these technologies upon receiving appropriate agency approval to enhance groundwater restoration for the five existing CAP components. Currently, HMC is evaluating three different alternative treatment technologies: *in situ* phosphate treatment, *ex situ* zeolite treatment, and EC. Phosphate treatment would be used in a variety of implementation approaches to remove uranium *in situ*. HMC is operating a pilot test of the technology in the LTP after performing extensive bench-scale tests. Both zeolite and EC treatments are pump-and-treat technologies that have the potential to supplement RO treatment. HMC is currently operating an *ex situ* zeolite pad on top of the LTP and is conducting bench-scale EC testing.

In conclusion, the five current components of the CAP work in combination to achieve source control and plume remediation. These have demonstrated success in making progress towards achieving the HMC site standards. HMC will continue to seek opportunities to improve the performance of these CAP components. The proposed 2020 schedule can only be met if the performance of the CAP strategies, including proposed land treatment, are not compromised or delayed.

References

Anderson, O.J., Maxwell, C.H and S.G. Lucas. 2003. Geology of Fort Wingate Quadrangle, McKinley County, New Mexico. Open file report 473. New Mexico Bureau of Geology and Mineral Resources, September.

Baldwin, J.A. and S.K. Anderholm. 1992. Hydrogeology and Ground-Water Chemistry of the San Andres-Glorietta Aquifer in the Acoma Embayment and Eastern Zuni Uplift, West-Central New Mexico, U.S. geological Survey, Water-Resources Investigation Report 91-4033.

Byrd, D., Allen, H.R., and M. Montano. 2003. Water Resources Data, New Mexico, Water Year 2003. Water Data Report NM-03-1.

Chavez, E.A. 1961. Progress report on contamination of potable ground water in the Grants-Bluewater area, Valencia County, New Mexico. New Mexico State Engineer's Office, Roswell, New Mexico. Citation from: Kaufman, R.F. et al. [EPA]. 1976. Cibola Beacon. 2011. News article: Superfund site presentation raises more questions Ortega: Homestake Mining Company's 'Broken Promises'. May 5.

CH2M Hill. 2001. Homestake Mining Company Superfund Site Five-Year Review Report, September 2001. Volumes 1 and 2.

Cooley, M.E., J.W. Harshbarger, J.P. Akers, W.F. Hardt, and O.N. Hicks. 1969. Regional Hydrogeology of the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah. United States Geological Survey Professional Paper 521-A. 68 pages.

Dillinger, J.K. 1990. Geologic Map of the Grants 30' x 60' Quadrangle, West-Central New Mexico. United States Geological Survey Coal Investigations Map C-118-A.

Elkington, J. 1994. Towards the sustainable corporation: Win-win-win business strategies for sustainable development. California Management Review 36, no. 2: 90-100

Fetter, C.W. 2001. Applied Hydrogeology: Fourth Edition. Prentice Hall.

Frenzel, P.F. 1992. Simulation of Ground-Water Flow in the San Andres-Glorietta Aquifer in the Acoma Embayment and Eastern Zuni Uplift, West-Central New Mexico, U.S. Geological Survey Water-Resources Investigation Report 91-4099.

Gordon, E.D. 1961. Geology and Ground-Water Resources of the Grants-Bluewater Area, Valencia County, New Mexico, with a section on aquifer characteristics by H.L. Reeder, and with a section and chemical quality of the ground water by J.J. Kunkler. New Mexico State Engineer Technical Report 20, 109 pp.

Hamdy, H., El-Naby, A., and Y.H. Dawood. 2008. Natural attenuation of uranium and formation of autunite at the expense of apatite within an oxidizing environment, south Eastern Desert of Egypt. *Applied Geochemistry* 23(12): 3741-3755.

Harbaugh, A.W. and M.G. McDonald. 1996. User's Documentation for MODFLOW-96, an update to the U.S Geological Survey Modular Finite-Difference Ground-Water Flow Model: U.S. Geological Survey Open – File Report 96-485, 56 p.

HMC and Hydro-Engineering. 2003. Grants Reclamation project, Background Water Quality Evaluation of the Chinle Aquifers. Consulting Report for Homestake Mining Company of California.

HMC and Hydro-Engineering. 2006. Grants Reclamation Project, 2005 Annual Monitoring Report/Performance Review for Homestake's Grants Project Pursuant to NRC License SUA-1471 and Discharge Plan DP-200. Consulting Report for Homestake Mining Company, Grants, New Mexico.

HMC and Hydro-Engineering. 2009. 2008 Annual Monitoring Report, Performance Review for Homestake's Grants Project, Pursuant to NRC License SUA-1471 and Discharge Plan DP-200. March 2009.

HMC and Hydro-Engineering. 2010a. 2009 Annual Monitoring Report/Performance Review for Homestake's Grant Project Pursuant to NRC License SUA-1471 and Discharge Plan DP-200. Prepared for Homestake Mining Company of California. March.

HMC and Hydro-Engineering. 2010b. Ground-Water Hydrology, Restoration and Monitoring at the Grants Reclamation Site for NMED DP-200. Prepared for the New Mexico Environment Department. February.

HMC and Hydro-Engineering. 2011. Grants Reclamation Project, 2010 Annual Monitoring Report/Performance Review for Homestake's Grants Project Pursuant to NRC License SUA-1471 and Discharge Plan DP-200. Consulting Report for Homestake Mining Company, Grants, New Mexico.

Homestake, Hydro-Engineering, ERG, & RIMCON. 2011. Evaluation of Years 2000 through 2010 Irrigation with Alluvial Ground Water. Consulting Report for Homestake Mining Company, Grants, New Mexico.

Hydro-Engineering. 1983. Ground-Water Monitoring for Homestake Mill's Discharge Plan, DP-200. Consulting Report for Homestake Mining Company, Grants, New Mexico.

Hydro-Engineering. 1989. Corrective Action Plan for Homestake's Tailings, Consulting Report for Homestake Mining Company, Grants, New Mexico. September 15.

Hydro-Engineering. 1993. Reclamation Plan, Revision 10/93, Homestake Mining Company of California Grants Operation, Volume 1. Consulting Report for Homestake Mining Company of California.

Hydro-Engineering. 1996. Ground-Water Monitoring for Homestake's Grants Project, NRC License SUA-1471, and Discharge Plan DP-200. Consulting Report for Homestake Mining Company of California.

Kelley, V.C. 1967. Tectonics of the Zuni-Defiance Region, New Mexico and Arizona. In: F.D. Trauger (ed.), Guidebook of Defiance-Zuni-Mt. Taylor Region, Arizona and New Mexico. Eighteenth Field Conference, October 19, 20, and 21 1967. Pp. 27-32.

Kelly, W.C. 1963. Geology and Technology of the Grants Uranium Region. New Mexico Bureau of Mines and Minerals Resources. Memoir 15.

Kobya, M., Can, O.T., and M. Bayramoglu. 2003. Treatment of Textile Wastewaters by Electrocoagulation Using Iron and Aluminum Electrodes. Journal of Hazardous Materials, p. 163-178.

Lorenz, J.C. and S.P. Cooper. 2003. Tectonic Setting and Characteristics of Natural Fractures in Mesaverde and Dakota Reservoirs of the San Juan Basin. New Mexico Geology. New Mexico Bureau of Geology and Mineral Resources, v. 25, n. 1, p.3-14.

Mattigold, S., Zhong, L., Jansik, D., Foote, M., Hart, A., and D. Wellman. 2010. Reactant Carrier Microfoam Technology for In-Situ Remediation of Radionuclide and Metallic Contaminants in Deep Vadose Zone. Proceeding of Waste Management 2010.

Meyer, M. 2010. U.S. Nuclear Regulatory Commission. Complexities of Decommissioning a Uranium Mill Site. NRC ADAMS ML100560341. August 05.

MFG Consulting Scientists and Engineers (MFG). 2006. Grants Reclamation Project Groundwater Corrective Action Program (CAP) Revision. December 12, 2006.

New Mexico Environment Department (NMED). 2011. Letter from Jerry Schoeppner, Acting Ground Water Quality Bureau Chief, NMED to John Buckley, Decommissioning and Uranium Recovery Licensing Directorate, USNRC Regarding Transmittal of New Mexico requirements pertaining to completion of remedial activities, Homestake Mining Company Superfund Site (CERCLIS ID NMD0007860935), Cibola County, New Mexico. November 22.

New Mexico Environmental Improvement Agency (NMEID) and United Nuclear-Homestake Partners (NMEID and UN-HP). 1976. Groundwater Protection Plan. August 18, 1976.

Rautman, C.A. 1980. Geology and Mineral Technology of the Grants Uranium Region 1979. New Mexico Bureau of Mines and Mineral Resources, Memoir 38.

Roca Honda Resources, LLC. 2009. Baseline Data Report. Phase II Permit Application for a New Mine Application. November 20.

Santos, E.S. 1970. Stratigraphy of the Morrison Formation and Structure of the Ambrosia Lake District, New Mexico. Ore-bearing strata and tectonic features in a major uranium-mining district in northwestern New Mexico. Contributions to Economic Geology. Geological Survey Bulletin 1272-E. U.S. Government Printing Office, Washington, D.C.

Stone, W.J., Lyford, F.P., Frenzel, P.F., Mizell, N.H., and E.T. Padgett. 1983. Hydrogeology and water resources of San Juan Basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources Hydrologic Report 6.

U.S. Army Corps of Engineers (ACOE). 2010. Focused View of Specific Remediation Issues, An Addendum to the Remediation System Evaluation for the Homestake Mining Company (Grants) Superfund Site, New Mexico. Final Report. December 23.

U.S. Environmental Protection Agency (EPA). 1989. EPA Superfund Record of Decision: Homestake Mining Company, EPA ID NMD007860935; Operable Unit 1. September 27, 1989. EPA/ROD/R06-89/050.

EPA. 2006. Second Five-year Review Report. For Homestake Mining Company Superfund Site, Cibola County, New Mexico. September.

EPA. 2008a. A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-08/003.

EPA. 2008b. Green Remediation: Incorporating Sustainable Environmental Practices into Remediation of Contaminated Sites. EPA 542-R-08-002. April.

EPA. 2009. EPA Region 6 Green and Clean Policy. Retrieved on December 2, 2011 from http://www.clu-in.org/greenremediation/docs/R6GRPolicy.pdf.

EPA. 2011a. EPA Region VI. Third Five-Year Review Report. Homestake Mining Company Superfund Site (EPA ID: NMD007860935) Cibola County, New Mexico. September.

EPA. 2011b. Letter from Coleman, Samuel, Director, Superfund Division, USEPA Region VI to Larry Camper, Decommissioning and Uranium Recovery Licensing Directorate, USNRC Regarding CERCLA Requirements for Homestake Mining Company Site, NM. December 13.

EPA. 2011c. Close Out Procedures for National Priorities List Sites. OSWER Directive 9320.2-22. May.

U.S. Nuclear Regulatory Commission. (NRC). 1990. Letter from R.E. Hall, Director, NRC Field Office to M. Hiles, Grants Project, Homestake Mining Company Regarding Amendment No. 8 to License SUA-1471. July 20, 1990.

NRC. 2004. Grants Reclamation Project Background Water Quality Evaluation of the Chinle Aquifers. License SUA-1470. October 2003. Revised June 2004. 105 pages.

U.S. Public Health Service (USPHS). 1962. Process and Waste Characteristics at Selected Uranium Mills. W62-17. Robert B. Taft Sanitary Engineering Center, Cincinnati, Ohio.

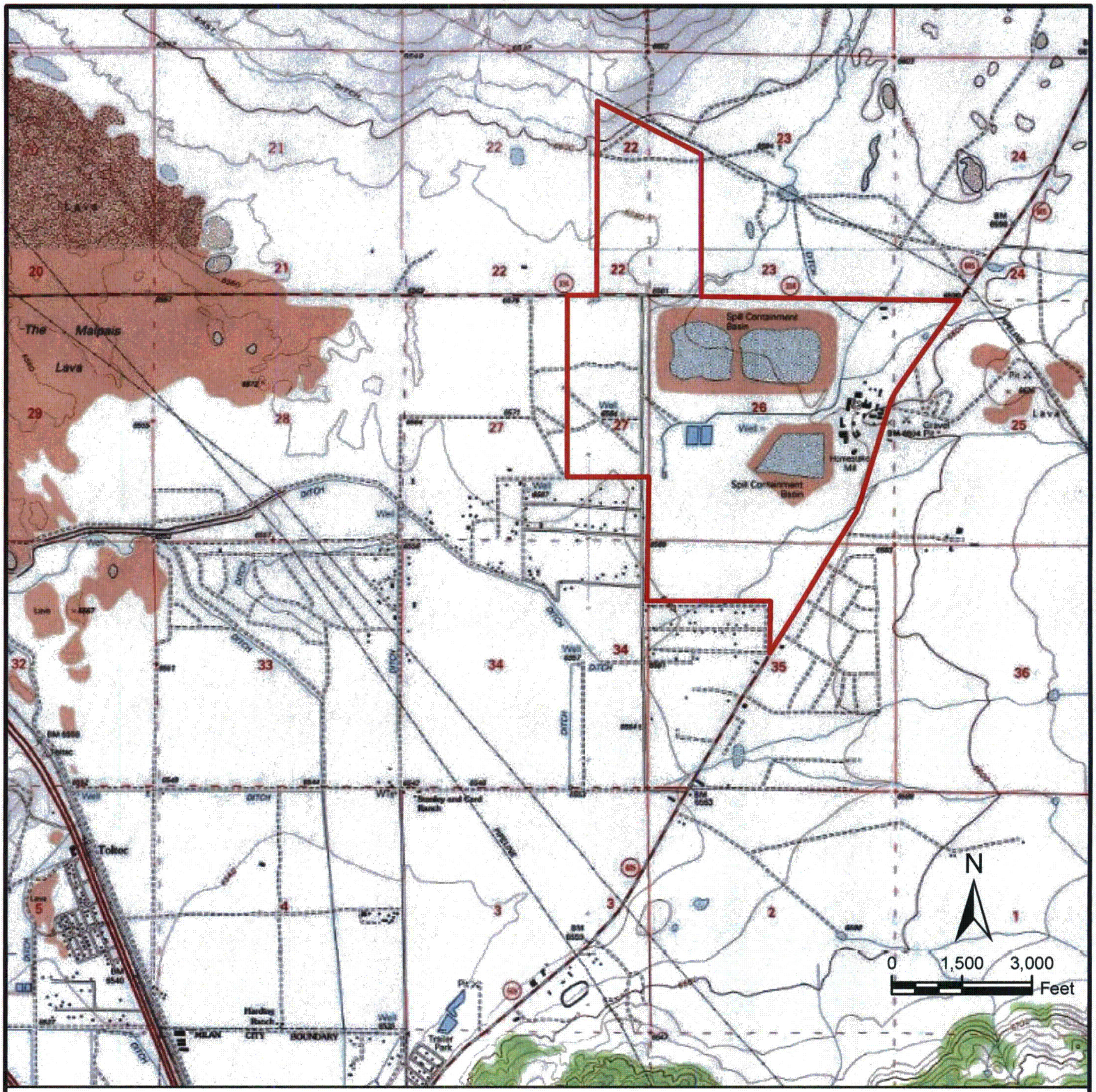
Vermeul, V.R., Bjornstad, B.N., Fritz, B.G., Fruchter, J.S., Mackley, R.D., Mendoza, D.P., Newcomer, D.R., Rockhold, M.L., Wellman, D.M., and M.D. Williams. 2009. 300 Area Uranium Stabilization through Polyphosphate Injection: Final Report. Pacific Northwest National Library. PNNL-18529. June.

Wellman, D.M., Icenhower, J.P., Pierce, E.M., McNamara, B.K., Burton, S.D., Geiszler, K.N., Baum, S.R., and B.C. Butler. 2005. Polyphosphate Amendments for In-Situ Immobilization of Uranium Plume. Proceedings of the Third International Conference on the Remediation of Contaminated Sediments. PNNL-SA-43638.

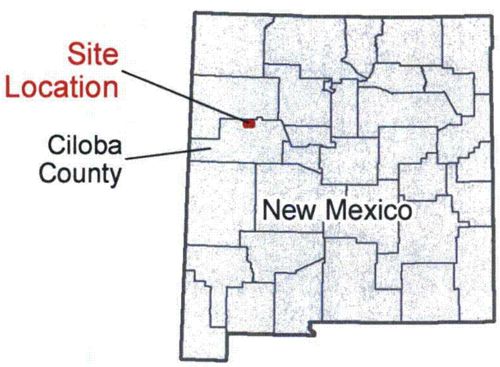
Xu, R., Pang, W., Yu, J., Huo, Q., and Chen, J. 2007. Chemistry of Zeolites and Related Porous Materials: Synthesis and Structure. Hoboken, NJ: John Wiley and Sons. 679 pp.

Zheng, C. and P.P. Wang. 1999. MT3DMS: A Modular Three-dimensional Multispecies Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems; Documentation and User's Guide.

K:\AO000120-Grants\GIS\ArcMaps\Revised CAP\Figure 1-1 Site Location Map.mxd - 11/7/2011 @ 11:51:49 AM



Source: USA Topo Maps, serviced by ESRI ArcGIS Online



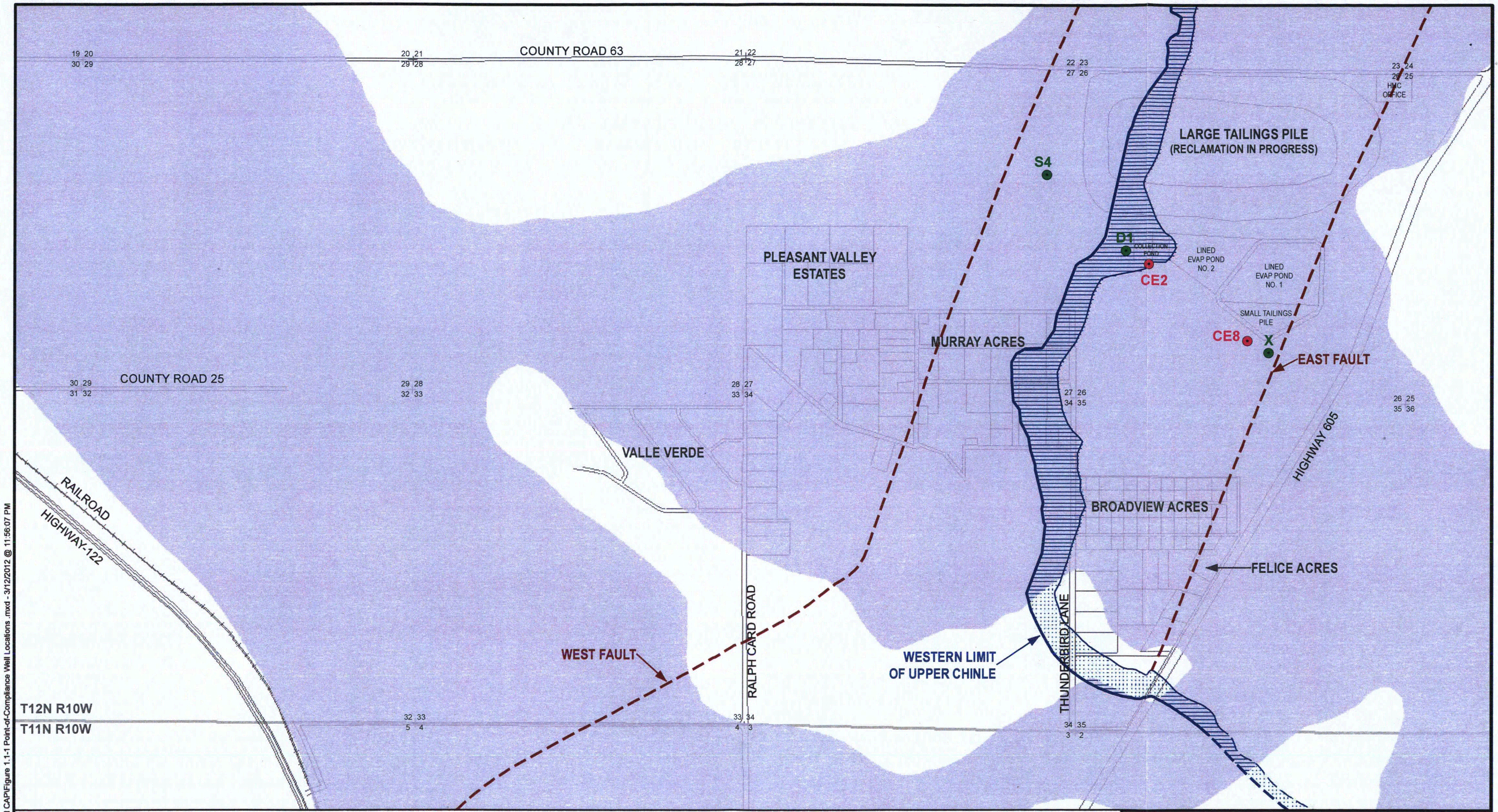
LEGEND:

NRC License Boundary

GRANTS RECLAMATION PROJECT

Updated Corrective Action Program (CAP)

FIGURE 1-1
SITE LOCATION MAP



CITY: Boulder, CO DRAFTER: J. CHEN
K:\AO00120-Grants\GIS\ArcMaps\Revised CAP\Figure 1.1-1 Point-of-Compliance Well Locations.mxd - 3/12/2012 @ 11:56:07 PM

LEGEND:

Point-of-Compliance Wells

- Wells in Alluvium Aquifer
- Wells in Upper Chinle Mixing Zone
- Fault
- Alluvial Aquifer

Subcrop of Upper Chinle Alluvium Overlies Sandstone

(Boundary dashed where inferred)

- Saturated Alluvium
- Unsaturated Alluvium

N

0 750 1,500 Feet

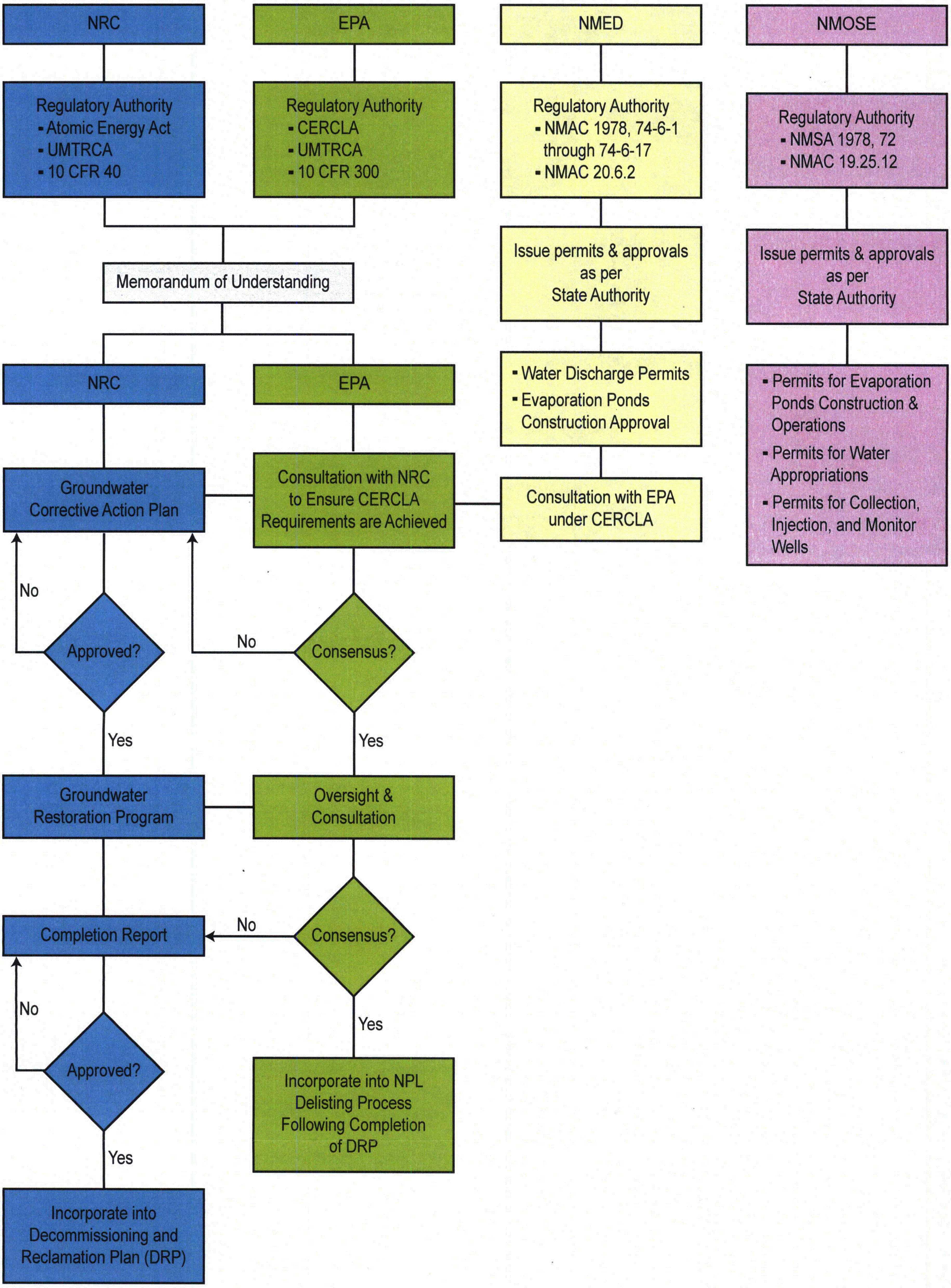
Basemap features from: Hydro-Engineering, LLC, 2011

GRANTS RECLAMATION PROJECT

Updated Corrective Action Program (CAP)

FIGURE 1.1-1
POINT-OF-COMPLIANCE
WELL LOCATIONS

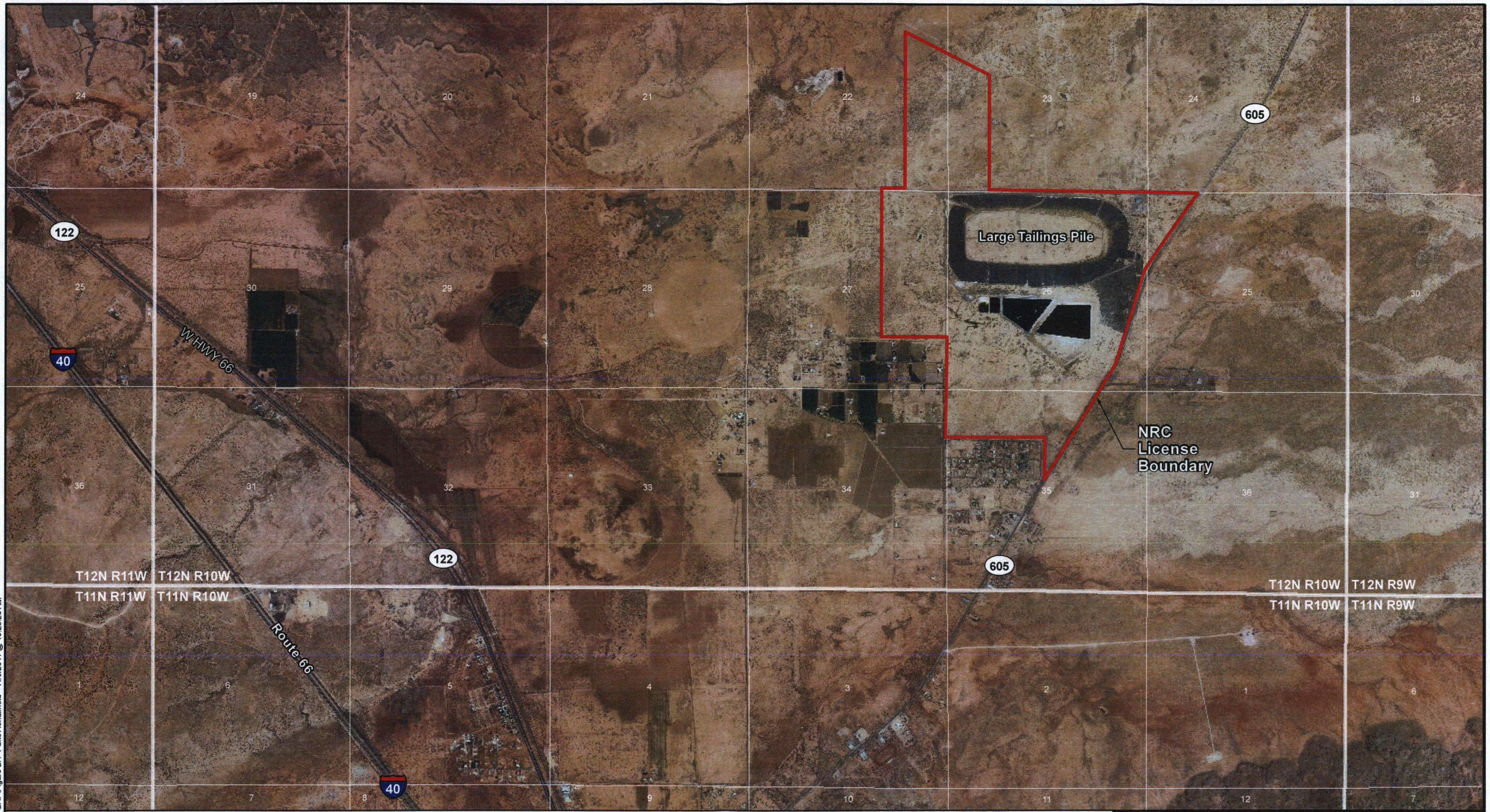
K:\AO000120_Grants\Illustrators\Figure 1.1-2 Interactions of nrc epa nmed nmose.ai @ 03/13/2012 PREPARED BY: JC



GRANTS RECLAMATION PROJECT

Updated Corrective Action Program (CAP)

FIGURE 1.1-2
INTERACTIONS OF THE NRC, NMED, AND NMOSE IN THE COMPLETION OF THE GROUNDWATER CORRECTIVE ACTION PROGRAM



N

0 1,250 2,500 Feet

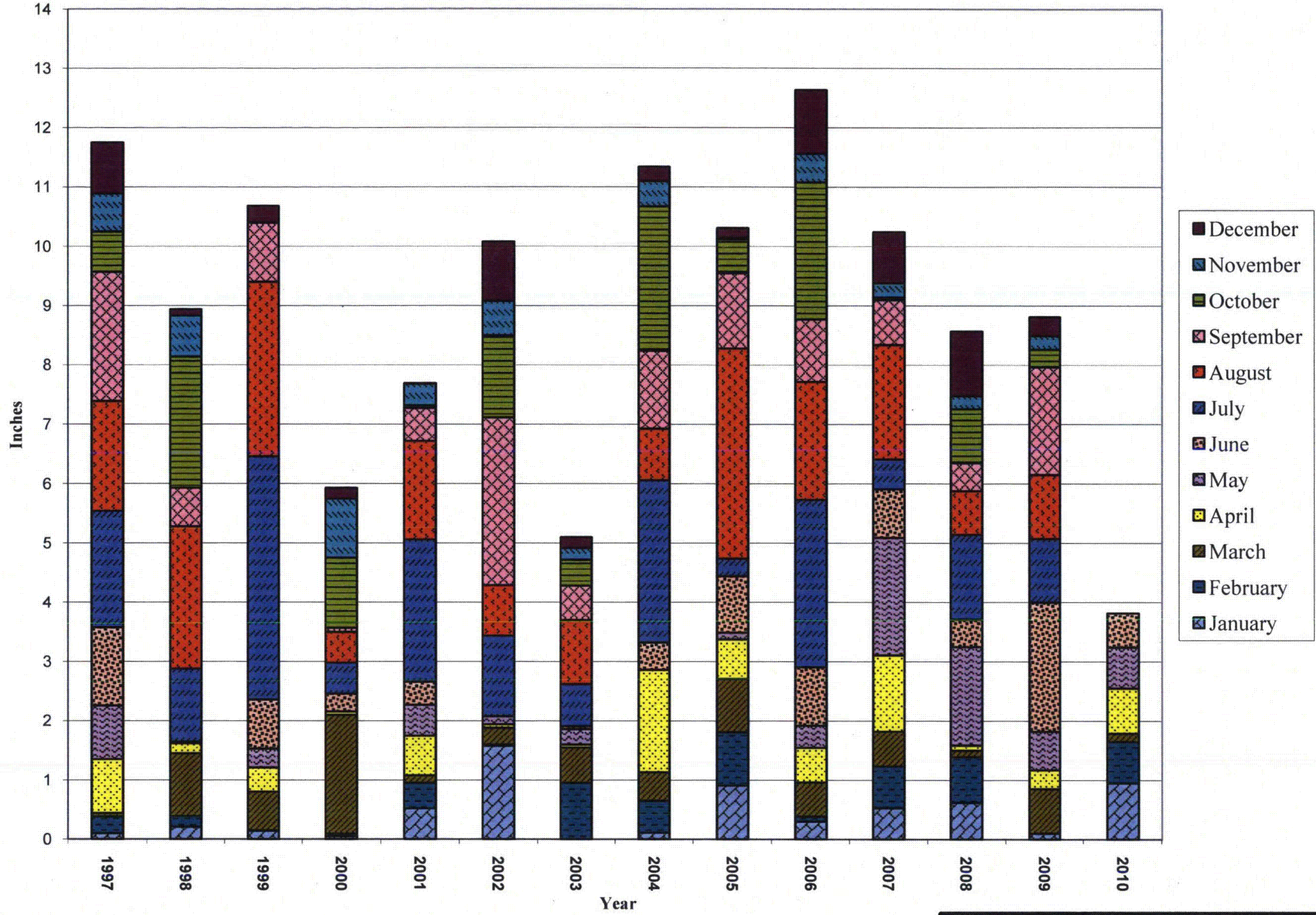
Aerial: NAIP 2009.

GRANTS RECLAMATION PROJECT

Updated Corrective Action Program (CAP)

FIGURE 2.1-1
SITE AERIAL

CITY: Boulder_CO DRAFTER: J. CHEN
K:\AO000120-Grants\GIS\ArcMaps\Revised CAP\Figure 2.1-1 Site Aerial.mxd - 11/9/2011 @ 10:25:25 AM



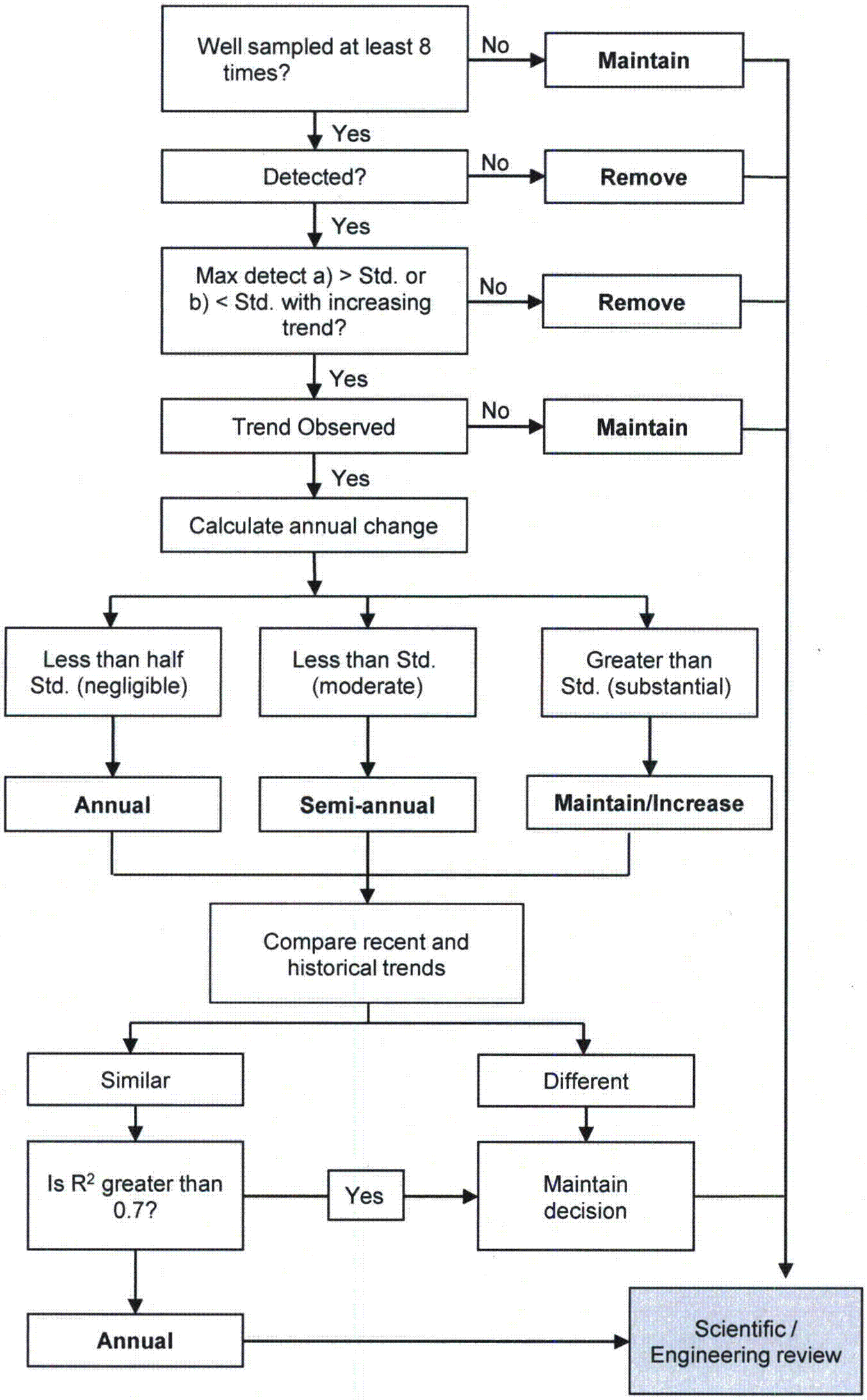
Annual Average Rainfall = 10.48"

GRANTS RECLAMATION PROJECT

Updated Corrective Action Program (CAP)

FIGURE 2.1-2
TOTAL SITE PRECIPITATION DATA
1997 - 2010

K:\AO000120-Grants\Illustrators\Figure 2.1-2 Total Site Precipitation Data 1997-2010 .ai @ 11/07/2011 PREPARED BY: JC



Evaluate recent data for wells.

If concentrations have been below detection for the most recent eight events, consider removing well/analyte from program.

If concentrations are below the Std. and not increasing, consider removing well/analyte from program.

When data are above the Std. with no detectable trend, continue current sampling frequency.

When data are above the Std. and exhibit a detectable trend, calculate the annual concentration change.

When the annual change is less than the Std., the change is slow with respect to the Std.

When the annual change is substantial (> Std.), consider monitoring at least semi-annually.

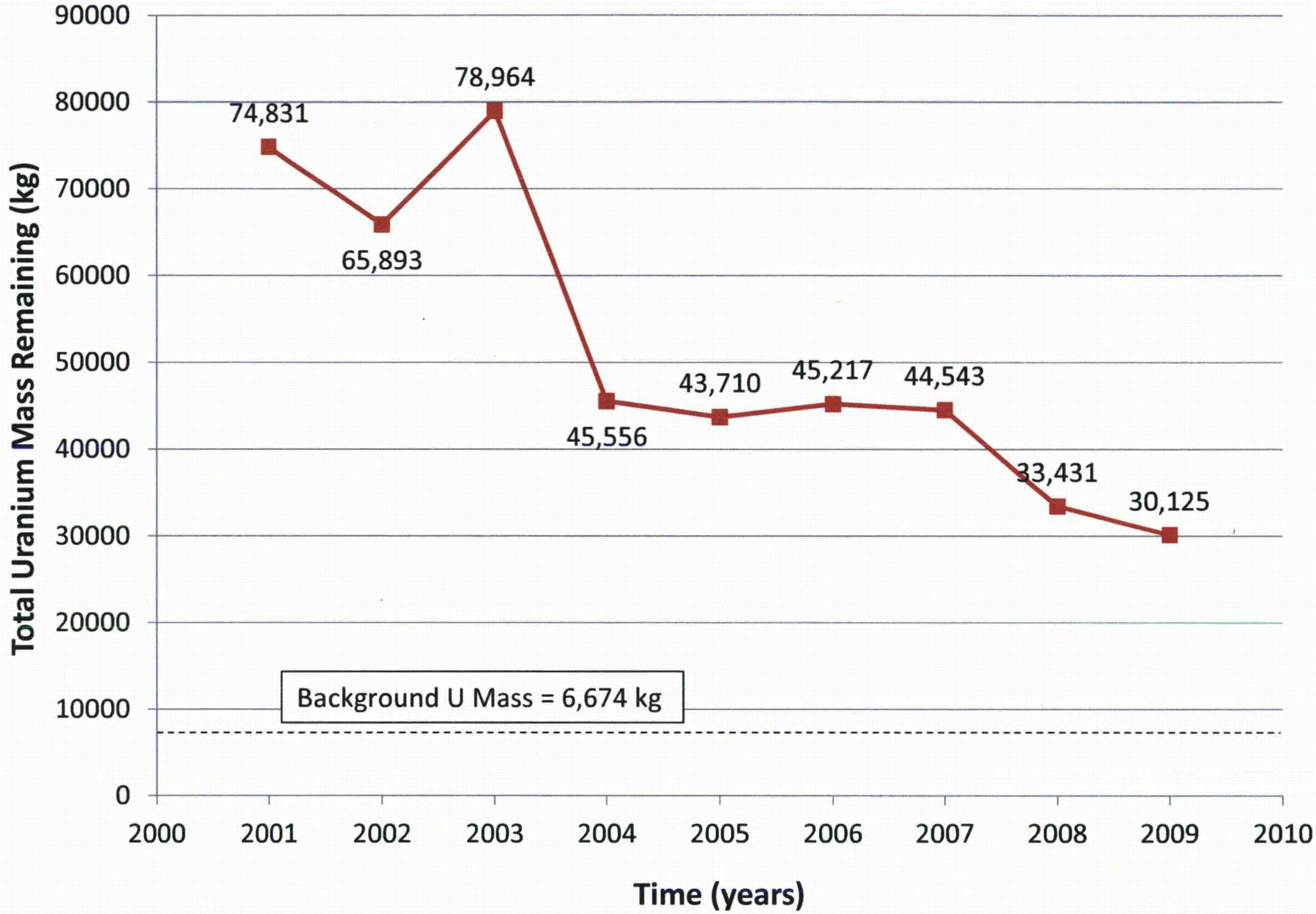
After making recommendations based on recent data, evaluate the recent data compared to the historical data.

If recent and historical trends are similar and concentrations are strongly correlated with time (R^2 >0.7), then consider decreasing frequency since concentrations are generally predictable over time.

After preliminary frequency is suggested by the system, recommendations are reviewed scientifically with respect to site knowledge, well purpose, proximity to potential receptors, etc.

GRANTS RECLAMATION PROJECT
Updated Corrective Action Program (CAP)

FIGURE 2.4.3-1
MONITORING PROGRAM OPTIMIZATION PROCESS



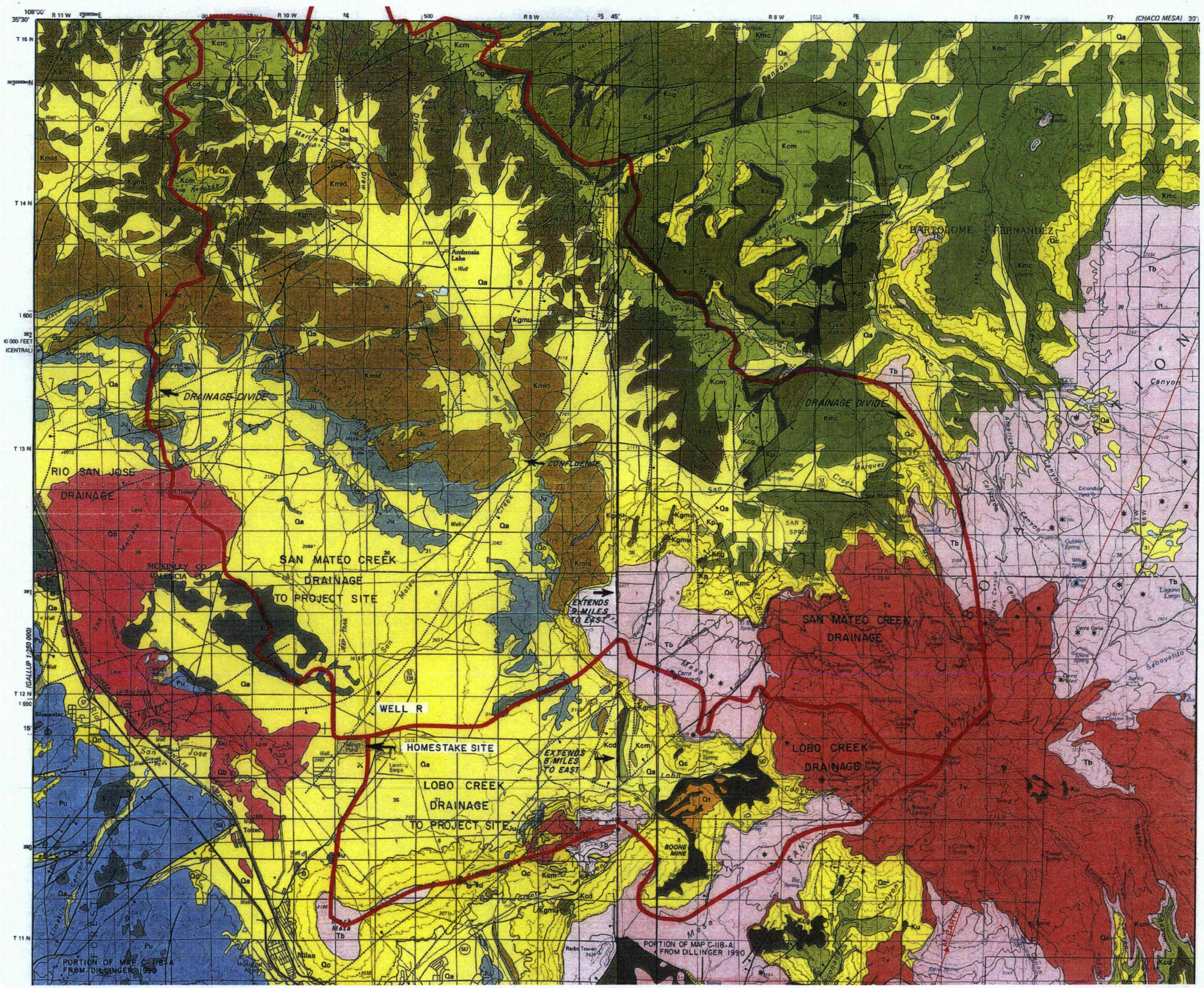
Note:

Estimate of background mass of dissolved uranium determined using the estimated volume of the 1998-2010 composite plume used for the mass reduction analysis (1,473,021,793 ft^3) for the Alluvial Aquifer and a background concentration of 0.16 mg/L. See related discussions in Section 4.2.4 and Appendix E for more details of the methodology and assumptions of the dissolved uranium mass reduction analysis.

GRANTS RECLAMATION PROJECT

Updated Corrective Action Program (CAP)

FIGURE 2.4.4-1
TOTAL DISSOLVED URANIUM MASS REMAINING (ALLUVIAL AQUIFER)



LEGENDS: Correlation of Map Units

Alluvium Colluvium and Terrace Gravel	Qa, Qc, Qt	Holocene and Pleistocene	QUATERNARY
Basalt Flows	Qb, QTb		QUATERNARY OR TERTIARY
Basalt Flows	Tb, Tv	Pliocene	TERTIARY
Santa Fe Formation	Ts	Pliocene and Miocene	TERTIARY
UNCONFORMITY			
Cleary Coal Member and Gibson Coal Member	Kmfc, Kmc, Kp, Kcd	Upper Cretaceous	CRETACEOUS
Dilco Coal Member	Kcm, Kcd	Upper Cretaceous	CRETACEOUS
Gallup Sandstone	Kg, Kgmu	Upper Cretaceous	CRETACEOUS
Mancos Shale	Kmdu, Kmld	Upper Cretaceous	CRETACEOUS
Dakota Sandstone	Kdm	Upper Cretaceous	CRETACEOUS
UNCONFORMITY			
Morrison Formation, Eolian Sandstone, Wanakah Formation, Entrada Sandstone	Ju		JURASSIC
UNCONFORMITY			
Chinle Formation, Moenkopi Formation	Tu		TRIASSIC
UNCONFORMITY			
San Andres Limestone, Glorieta Sandstone, Yeso Formation, Abo Formation	Pu	Lower Permian	PERMIAN
UNCONFORMITY			
Precambrian Granite	pCg		PRECAMBRIAN

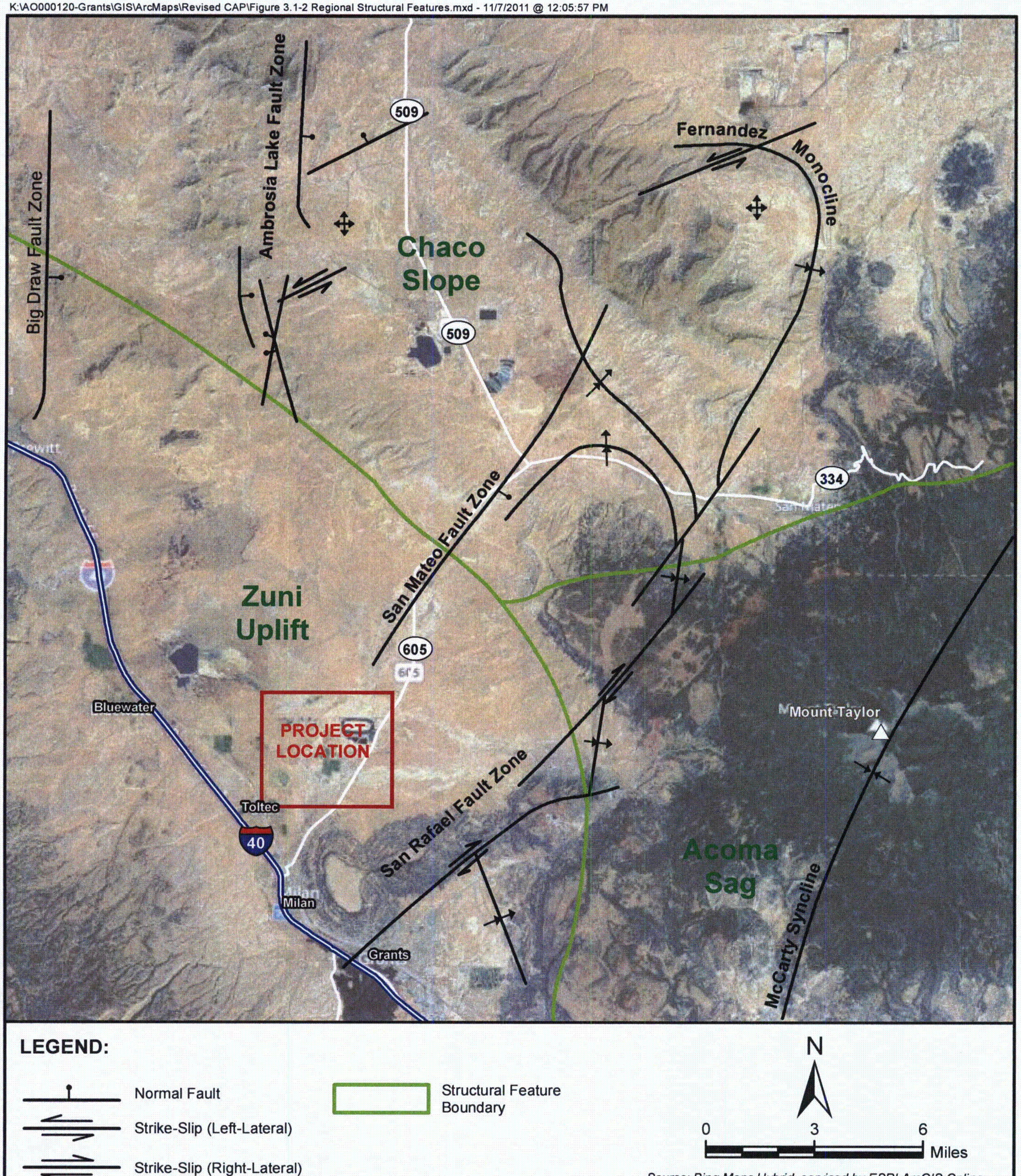
Source:
Dillinger, J.K., 1990, Geologic map of the Grants 30' x 60' quadrangle, west-central New Mexico: U.S. Geological Survey, Coal Investigation Map C-118-A, scale 1:100,000.

GRANTS RECLAMATION PROJECT

Updated Corrective Action Program (CAP)

FIGURE 3.1-1
BEDROCK GEOLOGY

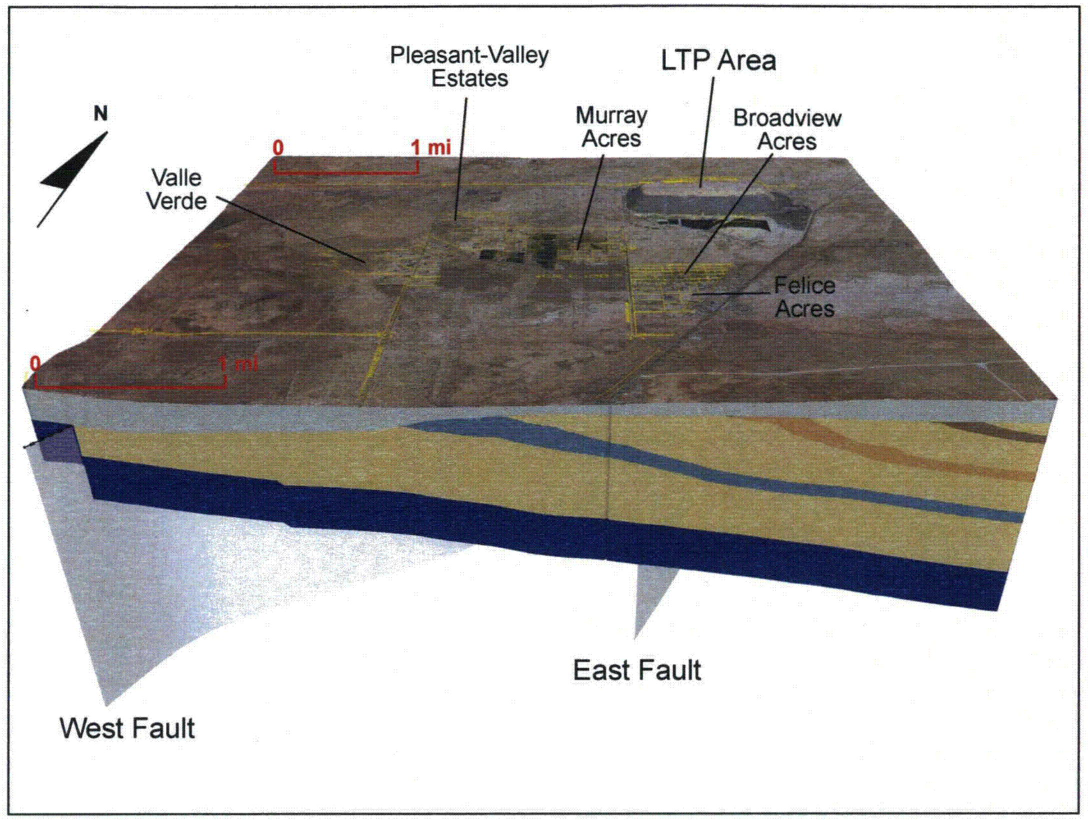
K:\AO000120_Grants\Illustrators\Figure 3.1-1 Bedrock Geology Map.ai @ 11/07/2011 PREPARED BY: JC



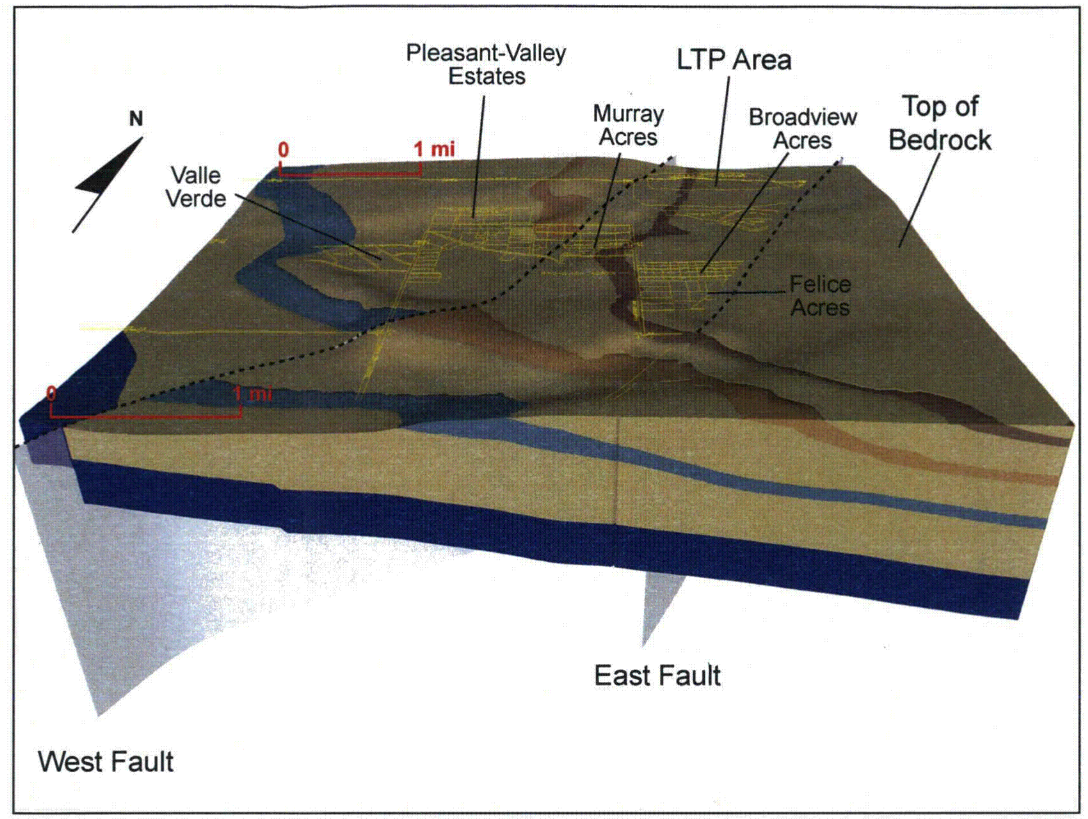
Source: Bing Maps Hybrid, serviced by ESRI ArcGIS Online

GRANTS RECLAMATION PROJECT
Updated Corrective Action Program (CAP)

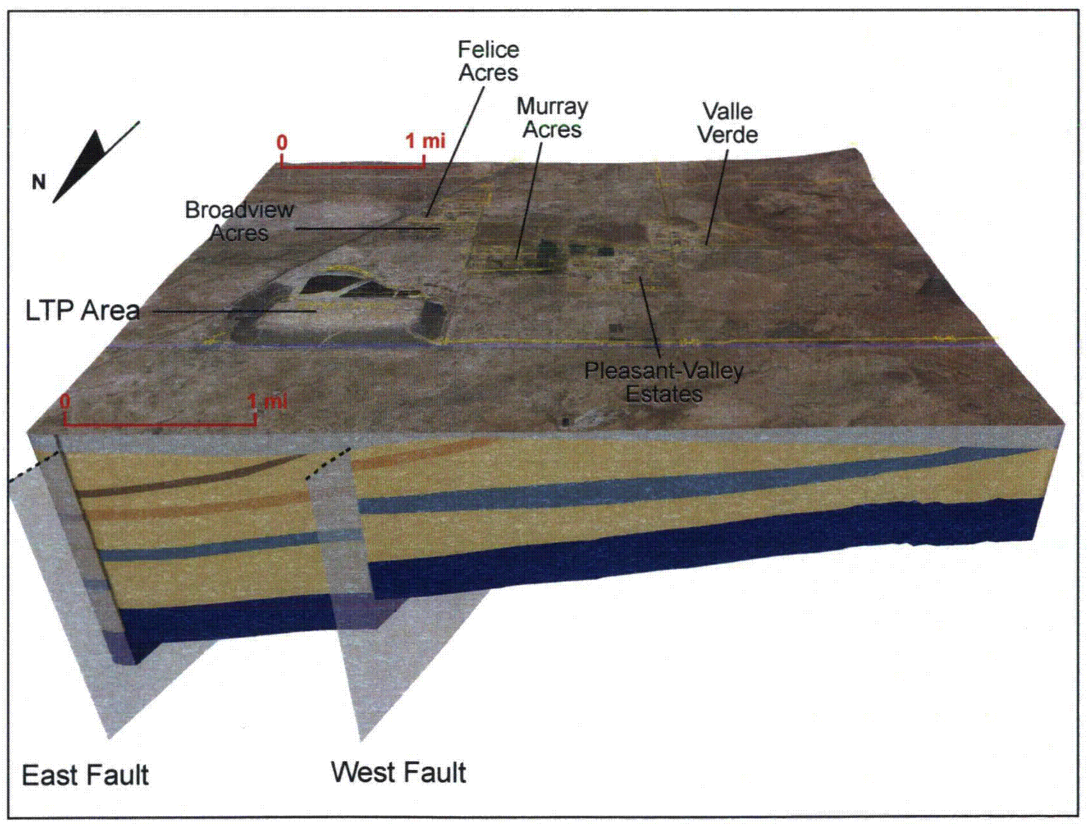
FIGURE 3.1-2
REGIONAL STRUCTURAL FEATURES



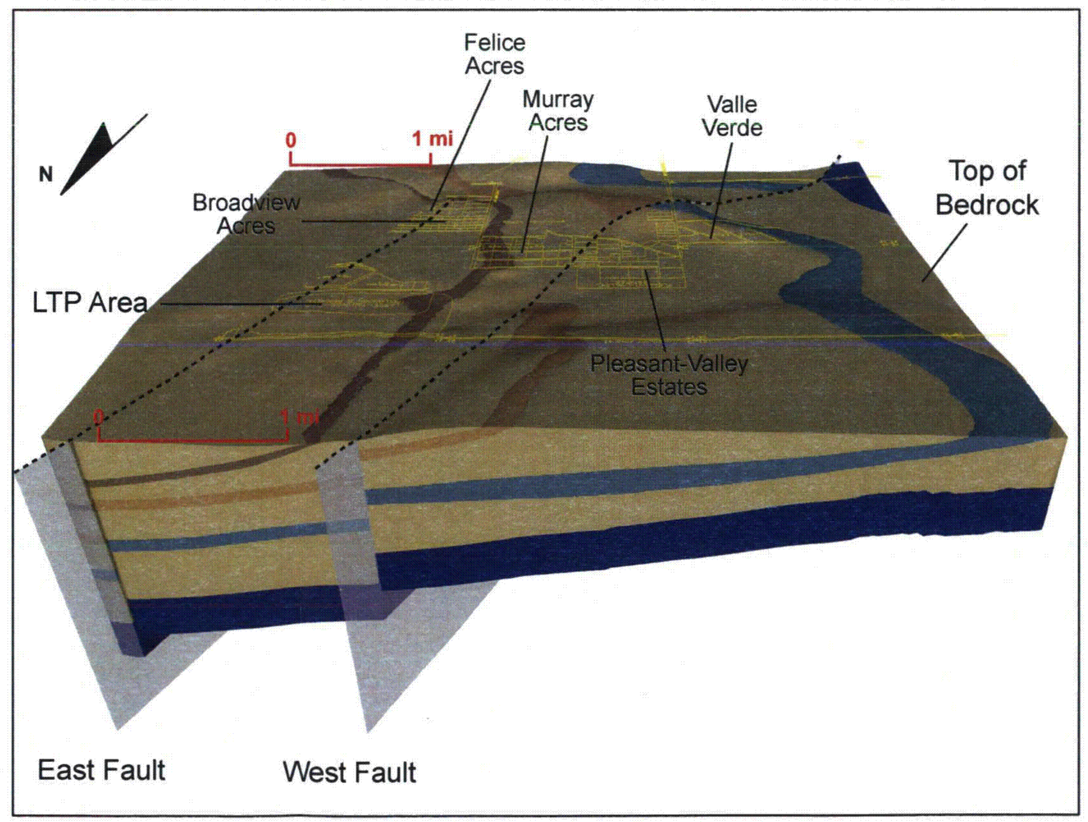
1. ALLUVIUM AND BEDROCK BLOCK MODEL – FACING NORTH



2. BEDROCK BLOCK MODEL DEPICTING CHINLE AND SAN ANDRES-GLORIETTA AQUIFER SUBCROP LOCATIONS – FACING NORTH



3. ALLUVIUM AND BEDROCK BLOCK MODEL – FACING SOUTH



4. BEDROCK BLOCK MODEL DEPICTING CHINLE AND SAN ANDRES-GLORIETTA AQUIFER SUBCROP LOCATIONS – FACING SOUTH

LEGENDS:

BEDROCK HYDROSTRATIGRAPHY

- ALLUVIUM
- CHINLE SHALE
- UPPER CHINLE AQUIFER
- CHINLE SHALE
- MIDDLE CHINLE AQUIFER
- CHINLE SHALE
- LOWER CHINLE AQUIFER
- CHINLE SHALE
- SAN ANDRES-GLORIETTA AQUIFER

NOTES:

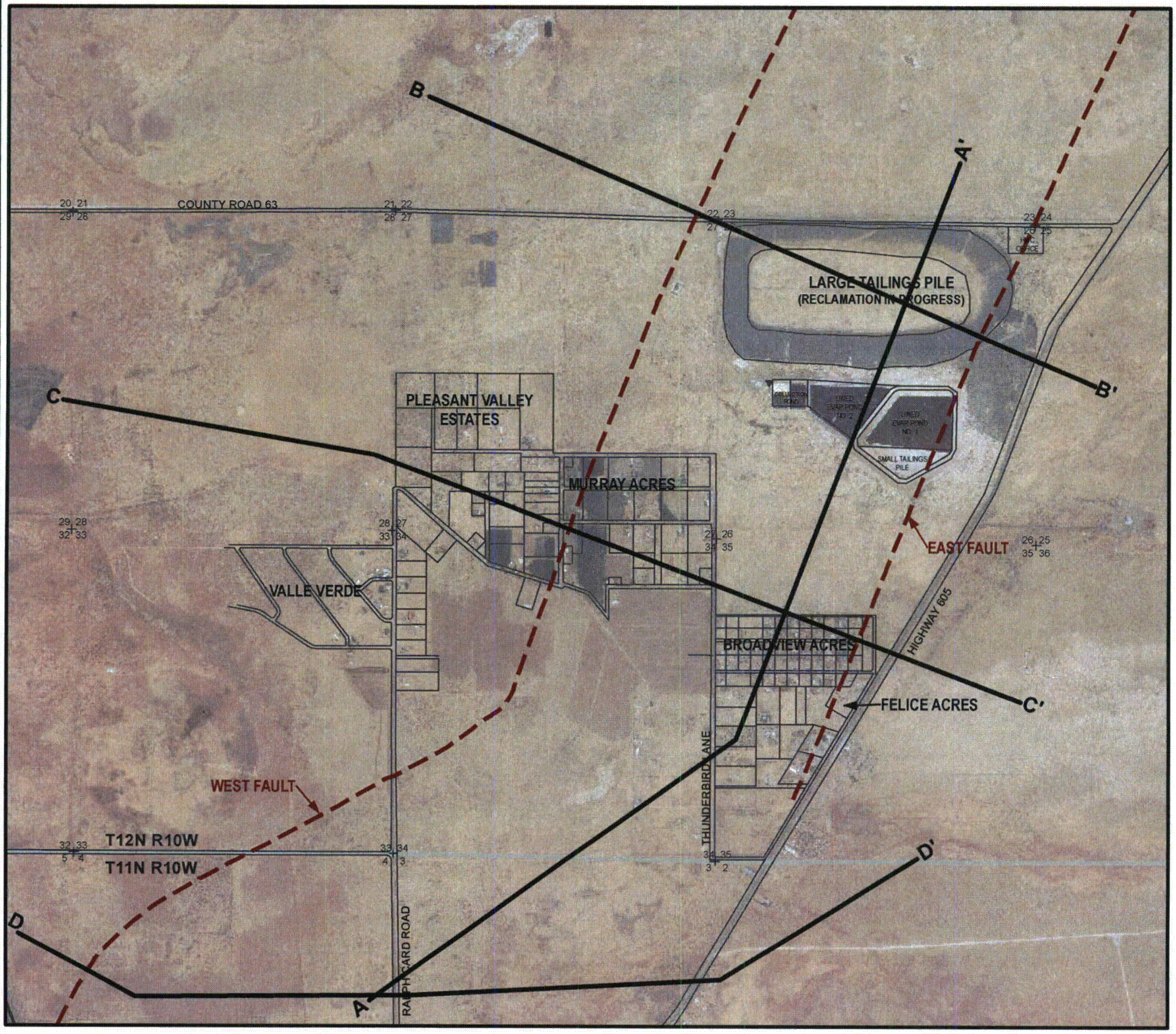
1. 3D model output depicted at 5x vertical exaggeration.

GRANTS RECLAMATION PROJECT

Updated Corrective Action Program (CAP)

FIGURE 3.1-3
3D HYDROGEOLOGY
GRANTS SITE

K:\AO000120_Grants\Illustrators\Figure 3.1-3 3D Hydrogeology-Grants Site.ai @ 11/07/2011 PREPARED BY: JC



LEGEND:

- Hydrogeologic Cross Section Line
- Fault

N

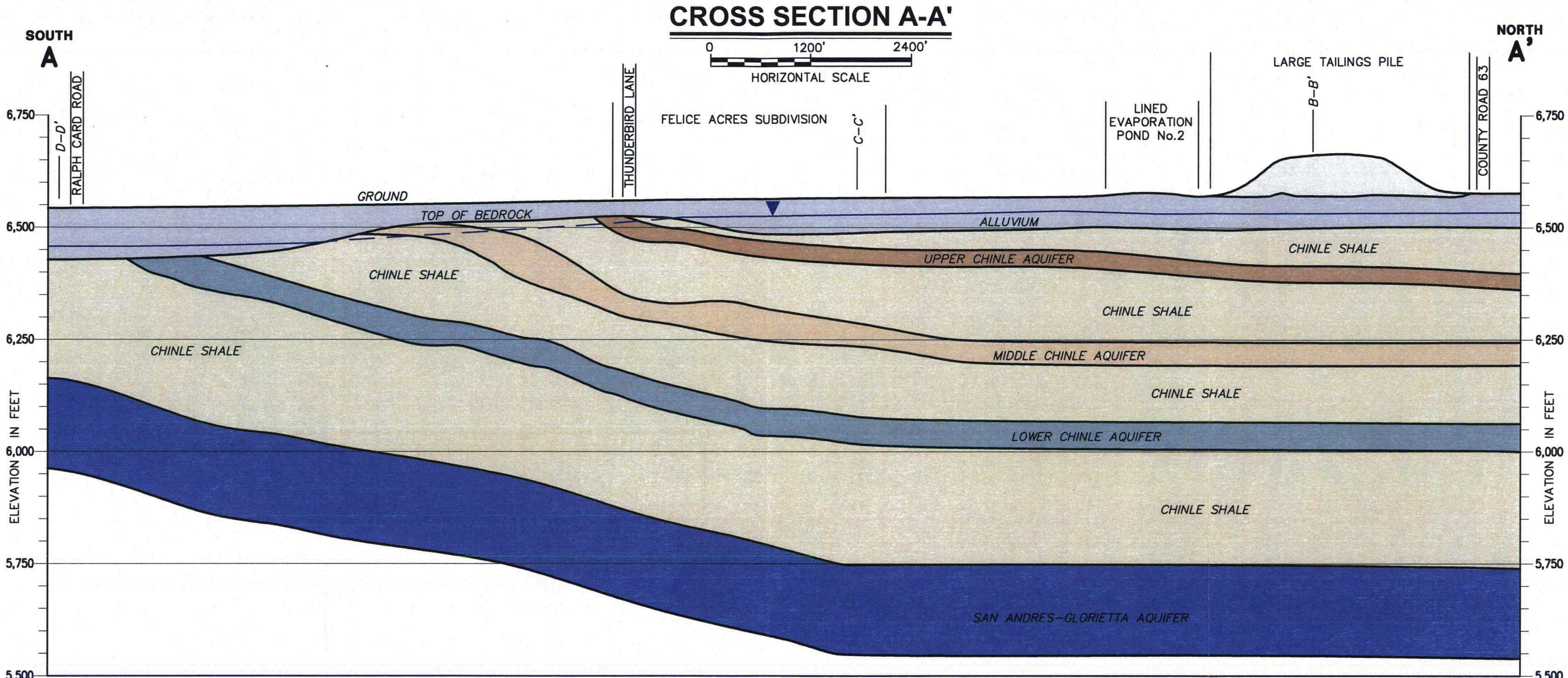
0 1,250 2,500 Feet

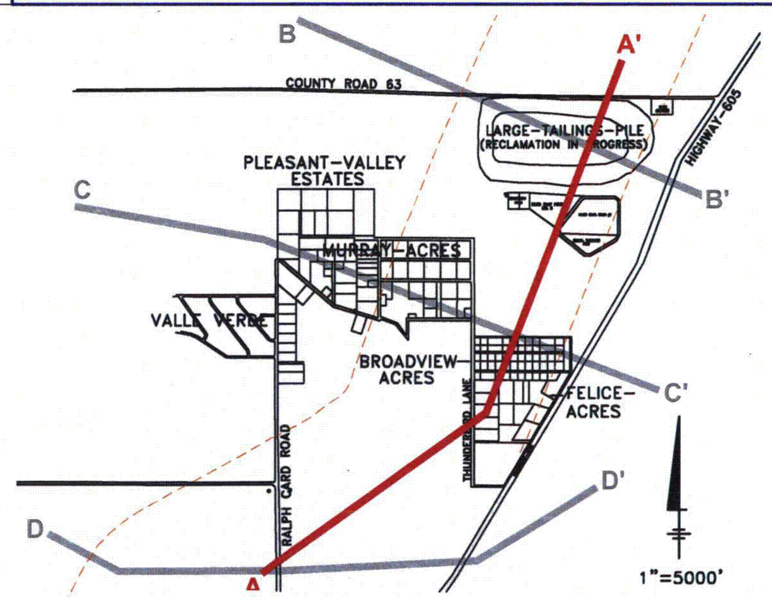
Source: NAIP 2009.

GRANTS RECLAMATION PROJECT
Updated Corrective Action Program (CAP)

FIGURE 3.1-4
HYDROGEOLOGIC CROSS SECTION LOCATION MAP

CROSS SECTION A-A'





LOCATION MAP

NOTE:

1. THREE–DIMENSIONAL MODEL OUTPUT DEPICTED AT 5X VERTICAL EXAGGERATION.

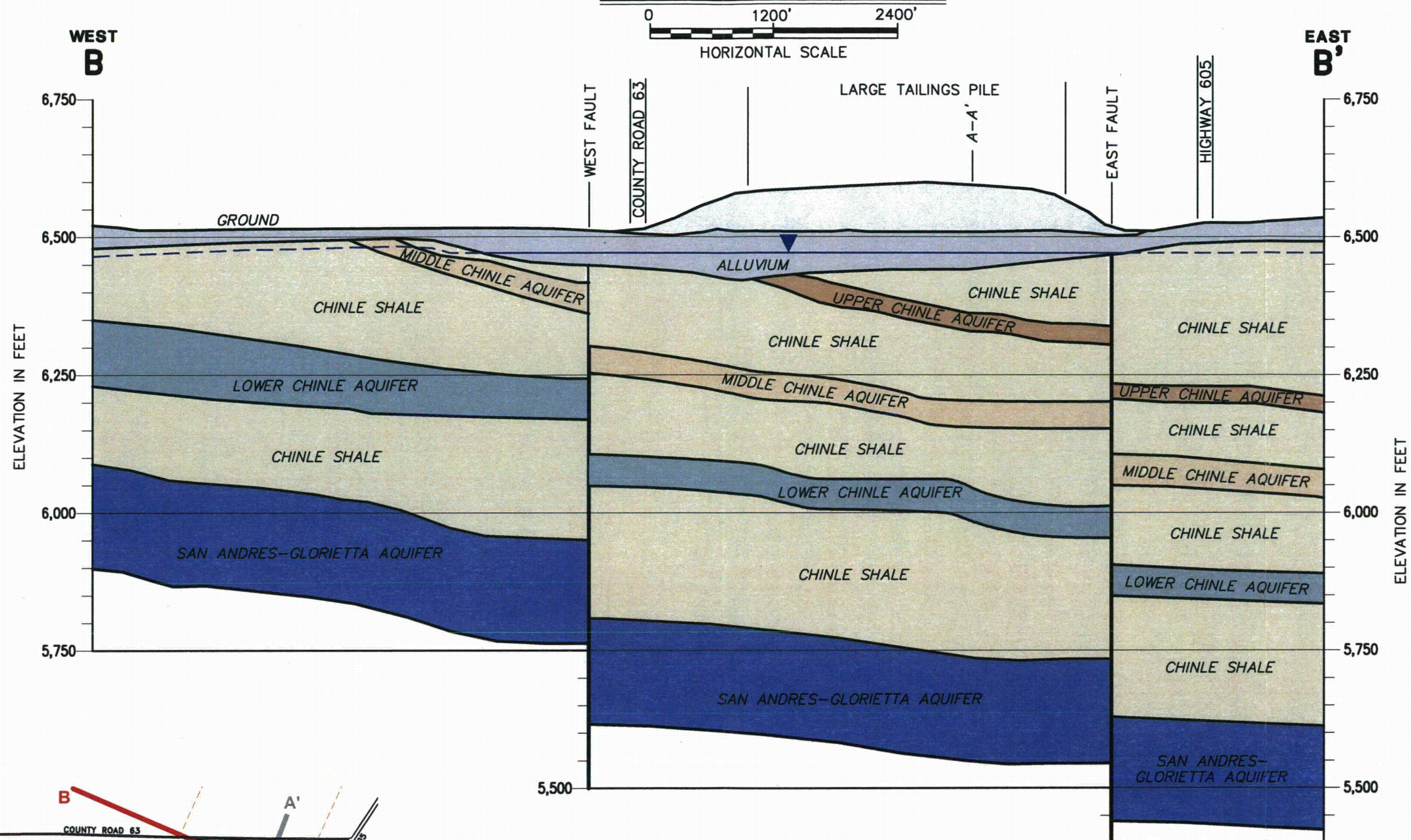
LEGEND:

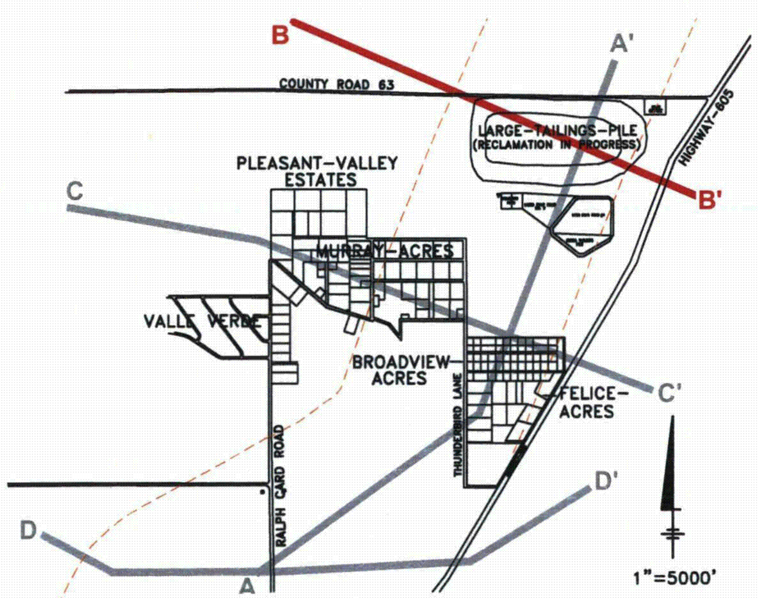
- LARGE TAILINGS PILE
- ALLUVIUM
- CHINLE SHALE
- UPPER CHINLE AQUIFER
- MIDDLE CHINLE AQUIFER
- LOWER CHINLE AQUIFER
- SAN ANDRES–GLORIETTA AQUIFER
- WATER TABLE

GRANTS RECLAMATION PROJECT
Updated Corrective Action Program (CAP)

FIGURE 3.1-5
HYDROGEOLOGICAL CROSS SECTION A - A'

CROSS SECTION B-B'





LOCATION MAP

NOTE:

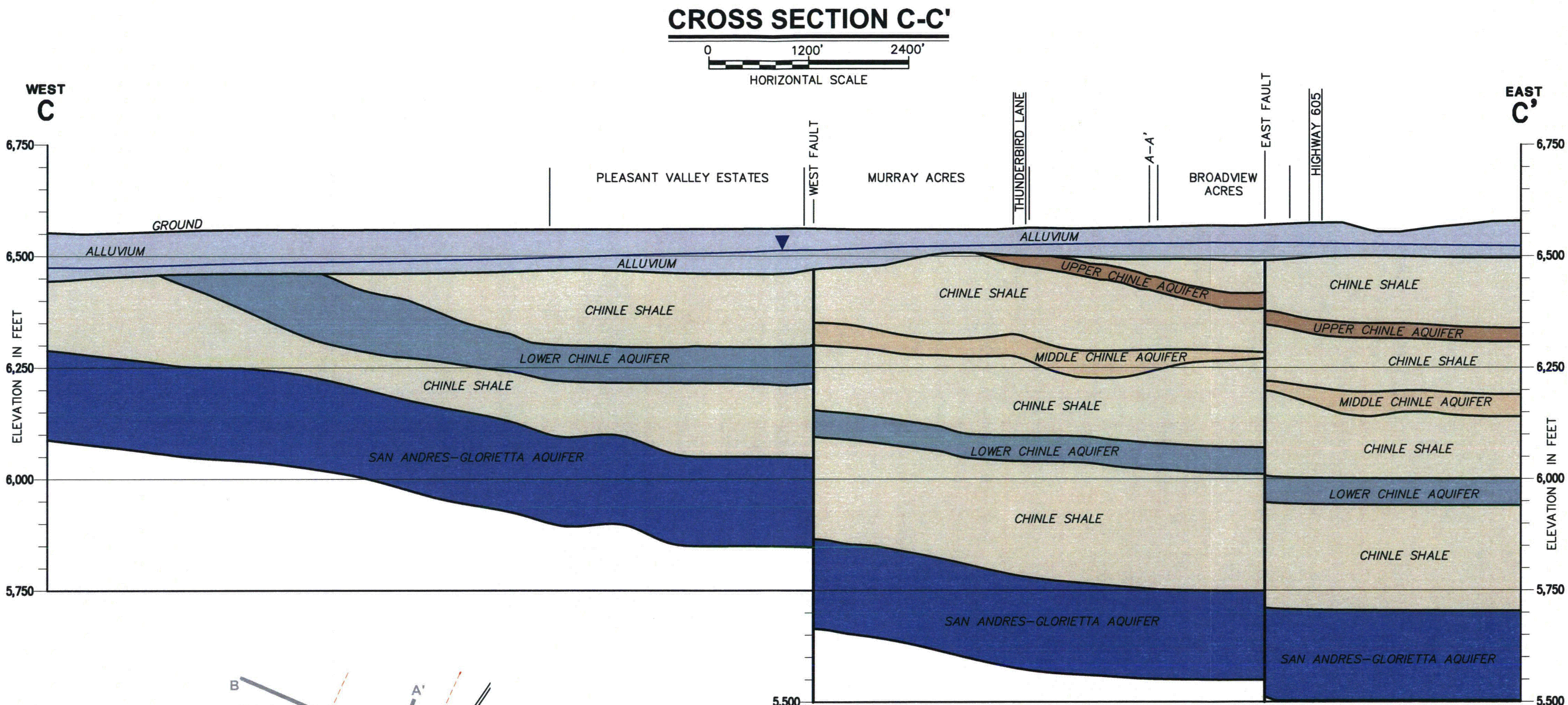
1. THREE-DIMENSIONAL MODEL OUTPUT DEPICTED AT 5X VERTICAL EXAGGERATION.

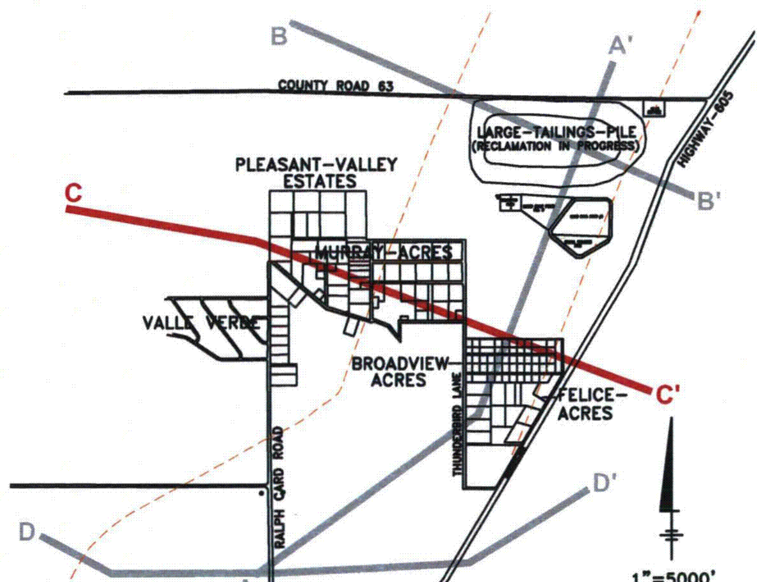
LEGEND:

- LARGE TAILINGS PILE
- ALLUVIUM
- CHINLE SHALE
- UPPER CHINLE AQUIFER
- MIDDLE CHINLE AQUIFER
- LOWER CHINLE AQUIFER
- SAN ANDRES-GLORIETTA AQUIFER
- WATER TABLE

GRANTS RECLAMATION PROJECT
Updated Corrective Action Program (CAP)

FIGURE 3.1-6
HYDROGEOLOGICAL CROSS SECTION B - B'





LOCATION MAP

NOTE:

1. THREE-DIMENSIONAL MODEL OUTPUT DEPICTED AT 5X VERTICAL EXAGGERATION.

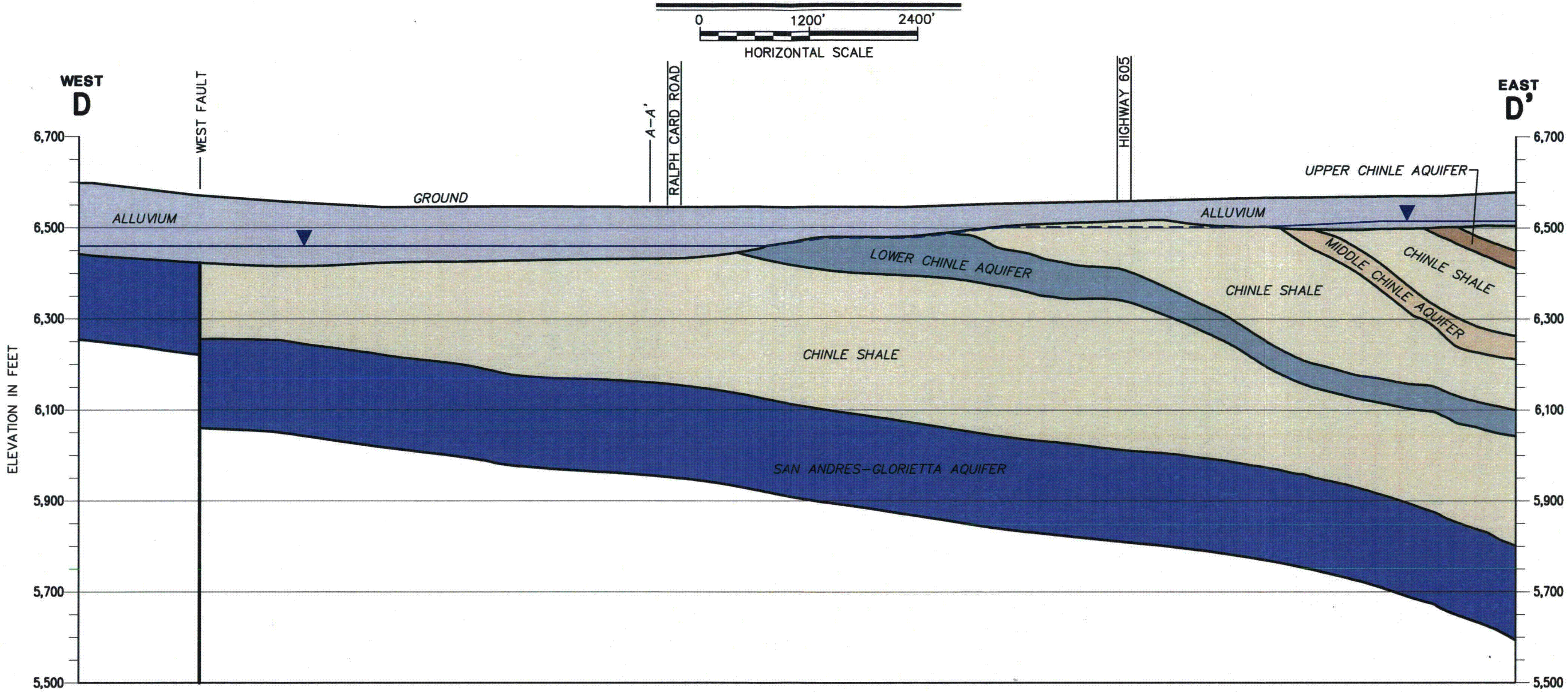
LEGEND:

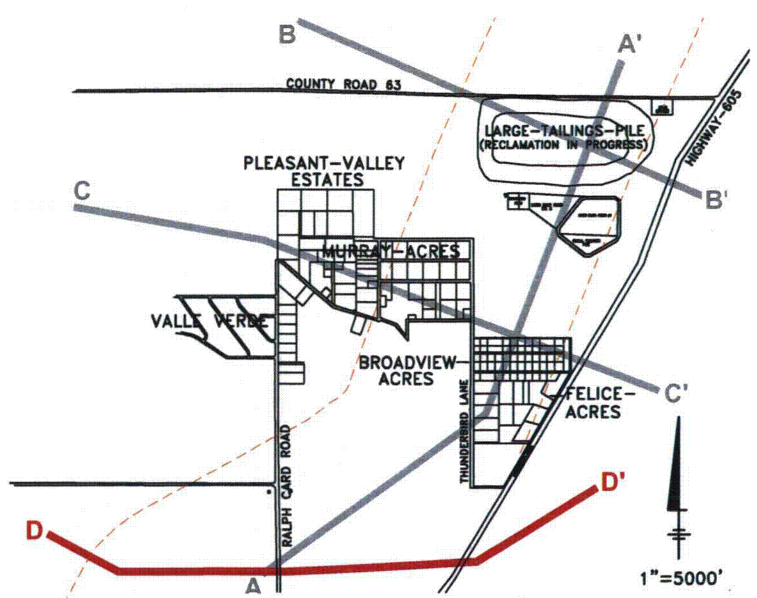
- LARGE TAILINGS PILE
- ALLUVIUM
- CHINLE SHALE
- UPPER CHINLE AQUIFER
- MIDDLE CHINLE AQUIFER
- LOWER CHINLE AQUIFER
- SAN ANDRES-GLORIETTA AQUIFER
- WATER TABLE

GRANTS RECLAMATION PROJECT
Updated Corrective Action Program (CAP)

FIGURE 3.1-7
HYDROGEOLOGICAL CROSS SECTION C - C'

CROSS SECTION D-D'





LOCATION MAP

NOTE:

1. THREE–DIMENSIONAL MODEL OUTPUT DEPICTED AT 5X VERTICAL EXAGGERATION.

LEGEND:

- LARGE TAILINGS PILE
- ALLUVIUM
- CHINLE SHALE
- UPPER CHINLE AQUIFER
- MIDDLE CHINLE AQUIFER
- LOWER CHINLE AQUIFER
- SAN ANDRES–GLORIETTA AQUIFER
- WATER TABLE

GRANTS RECLAMATION PROJECT
Updated Corrective Action Program (CAP)

FIGURE 3.1-8
HYDROGEOLOGICAL CROSS SECTION D - D'

LEGEND:

- Gauging Station*
- Roca Honda Mine
- HMC Grants Project Area
- Urban Area
- County Boundary
- Arroyo
- Interstate Highway
- U.S. Route
- State Highway

* The location of the Rio San Jose discharge gauging station (#08343000) is approximate.

Source: Strees and Shaded Relief, serviced by ESRI ArcGIS Online.

N

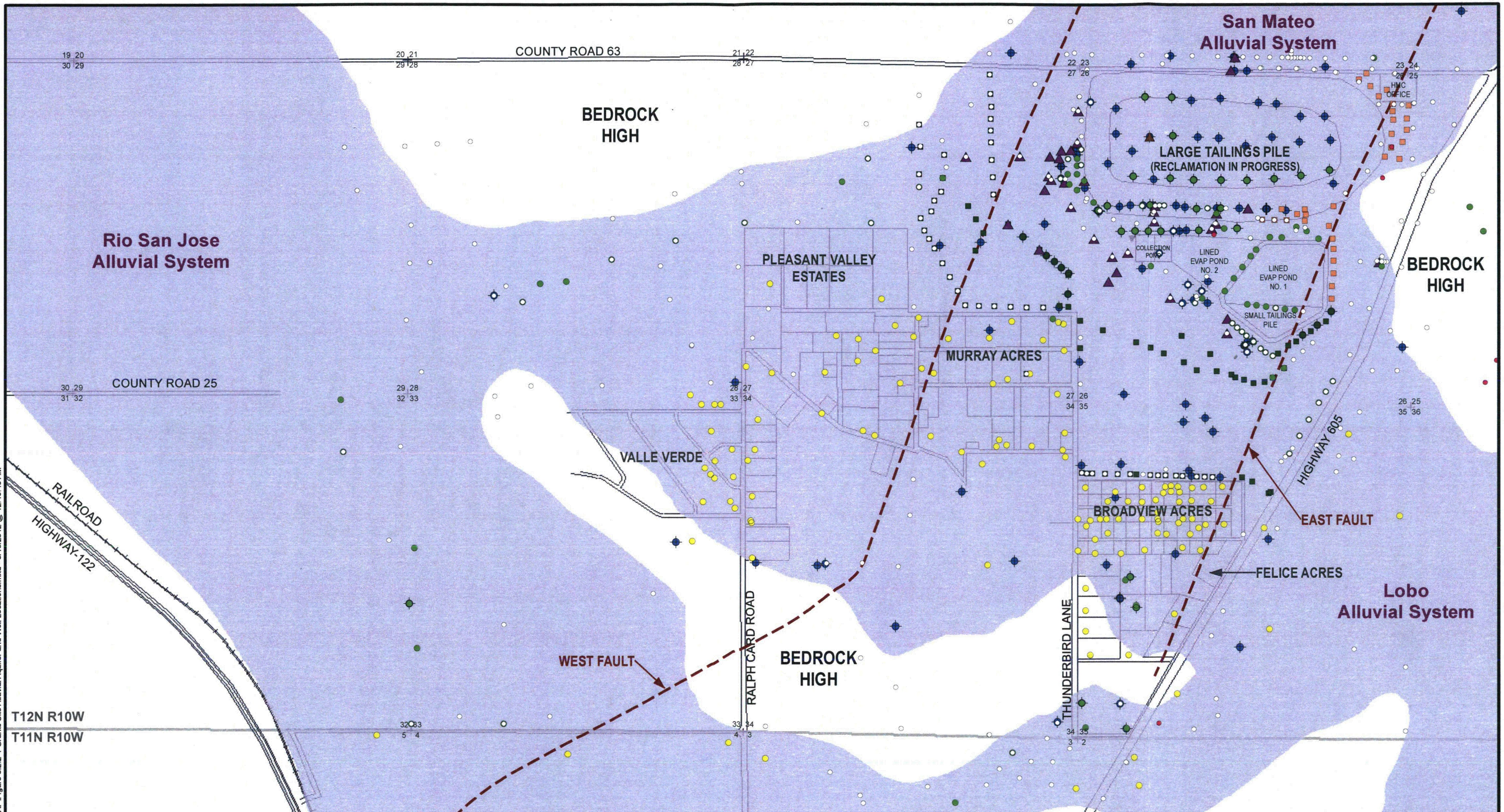
0 5 10 Miles

GRANTS RECLAMATION PROJECT

Updated Corrective Action Program (CAP)

FIGURE 3.2.1-1
DRAINAGE MAP OF THE VICINITY SURROUNDING GRANTS, NM

K:\AO000120-Grants\GIS\ArcMaps\Revised CAP\Figure 3.2.1-1 Drainage Map of the Vicinity Surrounding Grants.mxd - 11/7/2011 @ 12:30:56 PM



LEGEND:

Alluvial Wells by Use

- Collection
- Domestic
- Industrial
- Injection
- Monitor
- Piezometer
- Re-Injection
- Reversal
- Unknown/Unassigned
- Fault
- Alluvial Aquifer

N

0 750 1,500 Feet

Basemap features from: Hydro-Engineering, LLC, 2011

GRANTS RECLAMATION PROJECT

Updated Corrective Action Program (CAP)

FIGURE 3.2.2-1
GRANTS SITE ALLUVIAL AQUIFER AND WELL LOCATIONS

CITY: Boulder, CO DRAFTER: J. CHEN
K:\AO000120-Grants\GIS\ArcMaps\Revised CAP\Figure 3.2.2-1 Grants Site Alluvial Aquifer and Well Locations.mxd - 3/13/2012 @ 12:40:40 AM