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UMTRA
Ground Water Project

Site Observational Work Plan for the Naturita, Colorado, UMTRA Project Site

May 2002

Prepared by the
U.S. Department of Energy
Grand Junction Office

RECORD

Work Performed Under DOE Contract No. DE–AC13–96GJ87335 for the U.S. Department of Energy
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Appendices

Please e-mail lm.records@lm.doe.gov to request the appendices available on CD

Appendix A Monitoring Well Logs
Appendix B Ground Water Analytical Results (Included on CD)
Appendix C Surface Water Analytical Results (Included on CD)
Appendix D Soil and Sediment Analytical Results (Included on CD)
Appendix E USGS Distribution Coefficient Analysis
Appendix F Contaminant Transport Modeling
Appendix G Data Set Used in Pattern Recognition Modeling

Plate

Plate 1

Acronyms and Abbreviations

ACL	alternate concentration limit
AEC	U.S. Atomic Energy Commission
ASTM	American Society for Testing and Materials
AWQC	ambient water quality criteria
BAF	bioaccumulation factors
BCF	bioconcentration factor
BLRA	Baseline Risk Assessment
CDPHE	Colorado Department of Public Health and Environment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFC	chlorofluorocarbons
CFR	Code of Federal Regulations
cfs	cubic feet per second
COPC	contaminant of potential concern
cm^3	cubic centimeter(s)
DOE	U.S. Department of Energy
EC	electrical conductivity
E-COPC	ecological constituent of potential concern
EHPA	ethylhexyl phosphoric acid
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
ESL	Environmental Sciences Laboratory
FONSI	finding of no significant impact
FR	Federal Register
ft	foot (feet)
ft/day	foot (feet) per day
ft^2/day	square feet per day
g	grams
gal	gallon(s)
gal/day	gallons per day
GCAP	Ground Water Compliance Action Plan
GJO	Grand Junction Office
GMWL	Global Meteoric Water Line
gpm	gallons per minute
HCA	hierarchical cluster analysis
HCl	hydrochloric acid
HI	hazard index
HQ	hazard quotient
IC	institutional control
ICP-MS	inductively coupled plasma–mass spectrometry
i.d.	inside diameter
IRIS	Integrated Risk Information System
K	hydraulic conductivity
K_d	distribution coefficient
kg	kilogram(s)
KPA	kinetic phosphorescence analysis
kW-hr	kilowatt-hour
L	liter

L/s	liter(s) per second
LOAEL	lowest-observed-adverse-effect levels
lb	pounds
LTMP	Long-Term Management Plan
LTSP	Long-Term Surveillance Plan
m	meter(s)
MAP	Management Action Process
MCL	maximum concentration limit
µg/L	micrograms per liter
µm	micrometer(s)
µS/cm	microsiemens per centimeter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mL	milliliter
mL/g	milliliters per gram
mL/min	milliliters per minute
mm	millimeter(s)
mV	millivolts
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no-observed-adverse-effect levels
NRC	U.S. Nuclear Regulatory Commission
NWQL	National Water Quality Lab
O&M	operation and maintenance
ORNL	Oak Ridge National Laboratory
ORP	oxidation-reduction potential
PC	principal component
PCA	principal component analysis
pCi/g	picocuries per gram
pCi/L	picocuries per liter
PEIS	Programmatic Environmental Impact Statement
PeRT	Permeable Reactive Treatment
PVC	polyvinyl chloride
RAP	Remedial Action Plan
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
Rd	distribution ratio
RO	reverse osmosis
ROD	Record of Decision
rpm	revolutions per minute
RRM	residual radioactive material
SDWA	Safe Drinking Water Act
SEE	Site Environmental Evaluation (database)
SOWP	Site Observational Work Plan
SV	similarity value
TAGR	Technical Approach to Ground Water Restoration
TDS	total dissolved solids
TEL	threshold effect levels
U(VI)	mobile uranium-valence plus 6

UCL_{95}	95 percent upper confidence limit
UMTRA	Uranium Mill Tailings Remedial Action (Project)
UMTRCA	Uranium Mill Tailings Radiation Control Act
USC	United States Code
USGS	U.S. Geological Survey
ZVI	zero valent iron

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Executive Summary

This document is the Site Observational Work Plan (SOWP) for the Naturita, Colorado, Uranium Mill Tailings Remedial Action (UMTRA) Project site. The purpose of this report is to document characterization of the site using the observational approach and the proposed strategies for achieving ground water compliance with requirements established in the Uranium Mill Tailings Radiation Control Act (42 *United States Code* 7901 *et seq.*) and the United States Environmental Protection Agency's (EPA's) Health and Environmental Protections Standards for Uranium and Thorium Mill Tailings (Title 40, *Code of Federal Regulations,* Part 192).

The Naturita mill, located about 2 miles north of the town of Naturita along the west side of the San Miguel River, began operation in 1939 for vanadium production. It was converted to include the production of uranium during the Manhattan Project of the early 1940s, and continued to co-produce uranium and vanadium until it closed in 1958. During its life, the mill processed 704,000 tons of ore from the Uravan Mineral Belt. Most of the tailings were purchased by Ranchers Exploration and hauled several miles to another site for heap leaching in the late 1970s. From 1993 to 1998, the UMTRA surface cleanup removed another 771,400 cubic yards of residual radioactive material (RRM) to the Upper Burbank engineered disposal site at Uravan, about 15 miles to the northwest. RRM was left at a number of locations under the application of supplemental standards, especially near Highway 141, along the San Miguel River, and in an adjoining and downgradient vicinity property. Currently, no mill buildings remain, and the site meets the UMTRA surface standards.

The U.S. Department of Energy (DOE) began collecting data about the ground water contamination during the surface program and published a Baseline Risk Assessment in 1995. Section 6 of this SOWP updates that risk assessment. DOE has worked with the U.S. Geological Survey to collect and analyze data from an additional 26 monitoring wells and 16 surface locations during 2000 and 2002. Results indicate that three contaminants of potential concern—arsenic, uranium, and vanadium—pose a potential risk to human health, and vanadium poses a potential risk to ecological receptors.

Hydrologic tests, water age determinations, and chloride analysis of the uppermost aquifer, the alluvial aquifer, indicate that the system receives most of its recharge from the San Miguel River south of the site and transmits water from south to north. Other sources of recharge are the intermittent streams from uplands to the west and from rainfall. Subsurface flow is slower along the western side of the site away from the San Miguel River. Water containing uranium contamination also exists on the east side of the San Miguel River, across the river from the adjoining downgradient vicinity property. Additionally, these analyses suggest that water is being lost to evaporation from the ground water system due to excavations down to the ground water surface in an adjoining gravel pit operation on the upgradient side of the site. If this continues, and the operation is expected to expand, the volume of ground water entering the site may diminish and the estimated flushing rates may also diminish. Therefore, the rates of flushing in the ground water model may not be conservative. The bedrock below the alluvial aquifer consists of mudstones, siltstones to sandstones, and shales of the Brushy Basin Member of the Morrison Formation. Hydrologic tests indicate that the Brushy Basin sediments create an effective aquitard for downward migration of surface contamination and also limit upward migration of water from sandstone units below it. Therefore, only the alluvial aquifer is contaminated at Naturita.

Ground water flow and transport modeling indicates that arsenic will flush to the UMTRA maximum concentration limit (MCL) of 0.05 mg/L within 10 years. Only two wells had arsenic levels slightly above the MCL and both show a trend of decreasing concentrations; and the area containing these elevated values is small. However, uranium and vanadium have higher concentrations, are more widespread, and do not flush within the 100-year regulatory timeframe. Modeling predicts 135 years will be required for uranium to flush to 0.044 mg/L (the UMTRA MCL) and more that 1,000 years will be required for vanadium to flush to 0.33 mg/L (a health-based risk concentration).

Two compliance strategies are proposed for the site: (1) natural flushing with institutional controls (ICs) and continued monitoring for arsenic, and (2) no remedial action with the application of alternate concentration limits (ACLs) for uranium and vanadium, and with ICs and continued monitoring as a best management practice. U.S. Nuclear Regulatory Commission's guidance for ACL applications was prepared for Title II UMTRA sites, but this guidance can also be followed for Title I sites if modifications are made to accommodate the differences between Title I and Title II sites.

Natural flushing for arsenic is expected to require 10 years or less. The most recent sampling round showed concentrations of arsenic slightly below the 0.05 mg/L in the two wells that had previous hits slightly above this MCL. If this trend continues for three sampling rounds, arsenic will be removed from the list of potential contaminants.

ACLs for uranium and vanadium are proposed because modeling has show that neither contaminant will naturally flush to acceptable concentrations within the 100 years permitted for natural flushing. Uranium is expected to require 135 years to attenuate to the UMTRA standard of 0.044 mg/L and vanadium could require more than 1,000 years to attenuate to 0.33 mg/L, a human-health based standard.

ACL, point of compliance (POC) values, are 3 mg/L for uranium and 6 mg/L for vanadium. These points apply to any location within the IC boundary and are action levels. If monitoring shows that these levels are exceeded in the future, appropriate corrective action will be investigated and enacted. These values were selected because human health and environmental risks were shown to be acceptable for these concentrations, which are slightly more than current maximum concentrations for these constituents anywhere inside this IC area. The current maximum concentrations are located within the footprint of the former millsite.

Points of Exposure (POEs) are any points located along the San Miguel River where the river contacts the former millsite and any point downgradient of the millsite along the river for approximately 3,750 feet, as shown by the IC boundary. A dilution calculation was performed for the San Miguel River using the maximum concentrations of uranium and vanadium ever recorded at the site, which are greater than the proposed ACL values, and using a 20-year low flow for the river. The calculation shows that the river dilutes uranium and vanadium seepage of ground water into the river system by 3,000 to 5,000 times. This demonstrated a sufficient dilution of vanadium to be protective of aquatic life in the river if ACLs are maintained at the POCs. ICs will be established to protect humans from ingesting ground water.

As part of the ACL application, a corrective action assessment was performed. The assessment addressed practicable corrective actions, technical feasibility of corrective actions, corrective action costs and benefits, and selection of a practicable action that would achieve hazardous

constituent concentrations that are as low as reasonably achievable. Section 8 of this SOWP presents details of this assessment. Because no one or no ecological system is currently being harmed by the contamination, the assessment showed that remedial action would cause more potential environmental harm and be potentially more dangerous to workers than leaving it in place and implementing ICs. Costs would also be unreasonably high for the benefits gained.

An IC boundary is proposed for the site that includes an area from the upgradient end of the former millsite to a point on both sides of the San Miguel River 3,750 feet downgradient. This area includes all possible portions of the alluvial aquifer that are currently contaminated or might be contaminated by plume migration due to milling related activities. Because the site is wholly in private ownership, DOE would seek an IC to prevent anyone from drinking contaminated water from within this IC boundary. The IC will be in the form of an environmental covenant for perpetuity between the Colorado Department of Public Health and Environment and the three affected landowners. DOE will be a third party beneficiary to this agreement. In addition to excluding anyone from drinking contaminated water inside the IC boundary, the covenant would also require radon mitigation of future dwellings; compliance with state uranium mill tailings regulations for any excavation or construction activities in surface program supplemental standards areas; continued allowance of monitoring wells on their properties; and access to their properties with prior notification for inspection purposes.

No one is currently drinking ground water from the site, and no one is anticipated to be using it for drinking water. One family is living downgradient in the contaminant plume and inside the IC boundary. They currently haul drinking water from another source. DOE plans to drill a water well into a sandstone aquifer below their property that contains potable water and provide drinking water to their cistern. The well will be cased off to prevent any possible cross contamination from overlying water-bearing intervals.

Future samples will be collected from river and monitor well locations upgradient, onsite, and downgradient of the former millsite to ensure that humans and the environment will remain safe and until the levels of contamination fall below MCLs or risk-based levels. Samples will be analyzed for arsenic, uranium, and vanadium annually for the first 5 years after the Ground Water Compliance Action Plan is accepted and every 3 years thereafter for the next 30 years, or until contamination falls below MCLs or risk based levels for three consecutive samplings. The monitoring plan will be reevaluated periodically to determine if changes are required.

End of current text

1.0 Introduction

1.1 Purpose and Scope

The Naturita UMTRA Project site is a former uranium and vanadium ore processing facility located about 2 miles northwest of the town of Naturita, Colorado, along Colorado State Highway 141 (Figure 1–1). The Naturita site is bounded by the San Miguel River on the east and the highway on the west. Private property borders the northern, downgradient edge of the site and the southern, upgradient portion of the site. The City of Naturita owns the central portion of the site; Chemetall Foote Corp, a German company, owns the northern and southern parts of the site.

The former tailings pile at the site was removed to a heap-leach reprocessing plant along State Highway 90, about 3 miles southeast of the intersection of Highways 90 and 1241 at Coke Oven during 1977 to 1979. After being reprocessed, the tailings were stabilized at that location with 2 to 10 feet (ft) of cover. The DOE completed surface remediation in 1997. A significant amount of residual contaminated soils and other materials that remained at the Naturita site were removed and transported to the disposal cell at Uravan; however, some contaminated materials were left in place through the application of supplemental standards. After the remedial action, the site was backfilled with clean fill material and recontoured. The land was seeded, but vegetation remains somewhat sparse.

DOE's goal is to implement a cost-effective compliance strategy that is protective of human health and the environment at the Naturita site. The proposed compliance strategies to clean up the alluvial ground water at the site are (1) no ground water remediation of constituents with concentrations that do not pose a potential risk and do not exceed EPA standards, and (2) natural flushing of ground water in combination with the application of supplemental standards for constituents with concentrations that pose a potential risk or exceed EPA standards. Institutional controls will prohibit some ground water uses during the natural flushing period, and DOE will conduct ground water monitoring to observe progress of remediation.

This SOWP documents the strategy that will allow DOE to comply with EPA ground water standards at the Naturita site and provides a mechanism for stakeholder participation and review. Site-specific data are presented that support the proposed strategy.

Compliance requirements for meeting the regulatory standards at the Naturita site are presented in Section 2.0. Site background information, including an overview and history of the former milling operation and current water and land use, are reviewed in Section 3.0. Results of the field investigations conducted at the site from 1998 through 2001 are presented in Section 4.0. Site-specific characterization of the geology, hydrology, geochemistry, and ecology are synthesized in the site conceptual model in Section 5.0. Potential human health and ecological risks associated with ground water contamination are summarized in Section 6.0, and the proposed compliance strategy to clean up the ground water and a brief analysis of alternatives are presented in Section 7.0 and Section 8.0, respectively.

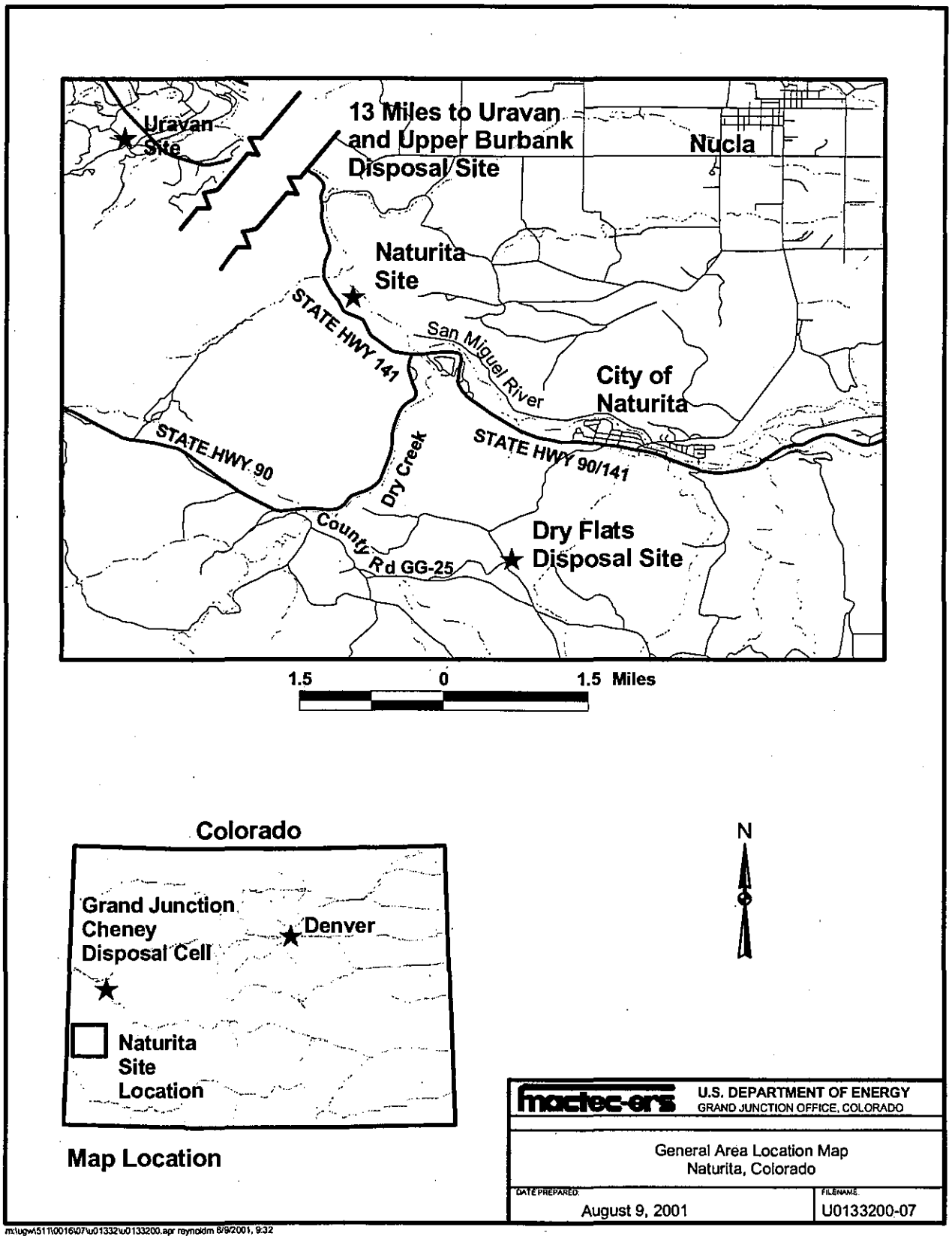

Figure 1–1. Site Location Map

1.2 UMTRA Ground Water Project Programmatic Documents

Programmatic documents that guide the SOWP include the *UMTRA Ground Water Project Management Action Process* (MAP) *Document* (DOE 2001), the *Final Programmatic Environmental Impact Statement for the Uranium Mill Tailings Remedial Action Ground Water Project* (PEIS) (DOE 1996), and the *Technical Approach to Groundwater Restoration* (TAGR) (DOE 1993a). The MAP states the mission and objectives of the UMTRA Ground Water Project and provides a technical and management approach for conducting the project. The PEIS is the programmatic decision-making framework for conducting the UMTRA Ground Water Project. DOE will follow PEIS guidelines to assess the potential programmatic impacts of the UMTRA Ground Water Project, to determine site-specific ground water compliance strategies, and to prepare site-specific environmental impact analyses more efficiently. Technical guidelines for conducting the ground water program are presented in the TAGR.

1.3 Relationship to Site-Specific Documents

The surface Remedial Action Plan (RAP) (DOE 1998a) provides some site characterization information regarding the geology and ground water hydrology. This information was supplemented in developing the SOWP to strengthen the site conceptual model. After a ground water compliance strategy is selected for this site, a Ground Water Compliance Action Plan (GCAP) will be prepared to document the remediation decision. The GCAP will serve as a stand-alone modification of the RAP.

A baseline risk assessment (BLRA, DOE 1995) was prepared to identify potential public health and environmental risks at the site. Potential risks identified in the risk assessment are considered and updated in this SOWP to ensure that the proposed compliance strategy is protective of human health and the environment.

After a proposed compliance strategy is identified in the SOWP and described in the GCAP, a site-specific National Environmental Policy Act (NEPA) document (e.g., an environmental checklist or environmental assessment) will be prepared, if required by the NEPA process, to determine the potential effects, if any, of implementing the proposed compliance strategy.

End of current text

2.0 Regulatory Framework

A ground water compliance strategy is proposed for the Naturita site (see Section 7.0) to achieve compliance with EPA ground water standards applicable to Title I UMTRA Project sites. This section identifies the requirements of the Uranium Mill Tailings Radiation Control Act (UMTRCA), the EPA ground water protection standards promulgated in Title 40 Code of Federal Regulations (CFR) Part 192 Subpart B, NEPA, and other regulations that are applicable to the UMTRA Ground Water Project.

2.1 UMTRCA

The United States Congress passed the UMTRCA (42 USC 7901 *et seq.*) in 1978 in response to public concerns about potential health hazards from long-term exposure to uranium mill tailings. UMTRCA authorized DOE to stabilize, dispose of, and control uranium mill tailings and other contaminated materials at inactive uranium-ore processing sites.

UMTRCA has three titles that apply to uranium-ore processing sites. Title I designates 24 inactive processing sites to undergo remediation. Title I authorizes EPA to promulgate standards and mandates remedial action in accordance with those standards. This Title also directs remedial action to be selected and performed with the concurrence of the U.S. Nuclear Regulatory Commission (NRC) in consultation with affected states and Indian tribes, authorizes DOE to enter into cooperative agreements with the affected states and Indian tribes, and directs NRC to license the disposal sites for long-term care. Title II applies to active uranium mills, and Title III applies to specific uranium mills in New Mexico. The UMTRA Ground Water Project has responsibility for administering only Title I of UMTRCA.

In 1988, Congress passed the Uranium Mill Tailings Remedial Action Amendments Act (42 USC 7922 *et seq.*), authorizing DOE to extend without limitation the time needed to complete ground water remediation activities at the processing sites.

2.2 EPA Ground Water Protection Standards

UMTRCA requires EPA to promulgate standards for protecting public health and the environment from radiological and nonradiological hazards associated with uranium-ore processing and the resulting residual radioactive materials (RRM). On January 5, 1983, EPA published standards (40 CFR Part 192) for RRM disposal and cleanup. The standards were revised and a final rule was published January 11, 1995 (60 FR 2854). This rule states that the standards established under Title I provide protection that is consistent, to the maximum extent practicable, with the requirements of the Resource Conservation and Recovery Act (RCRA).

The standards in 40 CFR 192.02 (c)(1) require that the Secretary of Energy determine which constituents listed in Appendix I are present in, or reasonably derived from, RRM. Those standards also require the Secretary to determine the areal extent of ground water contamination by listed constituent. Section 6.0, "Summary of Human Health and Ecological Risk", of this document, complies with these requirements and identifies the constituents of concern at the Naturita site.

2.2.1 Subpart B: Standards for Cleanup of Land and Buildings

The regulations allow the option of complying with four general standards. Three are numerical standards and are set forth in 40 CFR 192.02 (c)(3) as follows:

- Background level—Concentrations of constituents in the uppermost aquifer in an area that were not affected by ore-processing activities.
- Maximum Concentration Limit (MCL)—EPA defined maximum concentrations for certain hazardous constituents in ground water; these limits are specific to the UMTRA Project. The MCLs for inorganic constituents that apply to UMTRA Project sites are given in Table 1 to Subpart A, 40 CFR 192.04 and are presented in Table 2–1 of this document.
- Alternate Concentration Limit (ACL)—An ACL may be applied to a hazardous constituent if it does not pose a substantial present or future risk to human health or the environment, as long as the limit is not exceeded. An ACL may be applied after considering options to achieve background levels and MCLs.

Table 2–1. Maximum Concentration Limits of Inorganic Constituents in Ground Water at UMTRA Project Sites

Constituent	Maximum Concentration Limit[a]
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chromium	0.05
Lead	0.05
Mercury	.002
Molybdenum	0.1
Nitrate (as N)	10.0[b]
Selenium	0.01
Silver	0.05
Combined radium-226 and radium-228	5 pCi/L
Combined uranium-234 and uranium-238	30 pCi/L[c]
Gross alpha-particle activity (excluding radon and uranium)	15 pCi/L

[a]Concentrations reported in milligrams per liter (mg/L) unless otherwise noted.
[b]Equivalent to 44 mg/L nitrate as NO_3.
[c]Equivalent to 0.044 mg/L, assuming secular equilibrium of uranium-234 and uranium-238.
pCi/L = picocuries per liter.

Reference: 60 FR 2854.

2.3 Natural Flushing Standards

Subpart B also allows the use of natural flushing to meet EPA standards. Natural flushing allows natural ground water processes to reduce the contamination in ground water to acceptable standards (background levels, MCLs, or ACLs). Natural flushing must allow the standards to be met within 100 years. In addition, institutional controls and an adequate monitoring program must be established and maintained to protect human health during the period of natural flushing. Institutional controls would prohibit inappropriate uses of the contaminated ground water. The

ground water also must not be a current or projected source of drinking water for a public water system during the period of natural flushing, and beneficial uses of ground water must be protected.

2.3.1 Subpart C: Implementation

Subpart C provides guidance for implementing methods and procedures to reasonably ensure that standards of Subpart B are met. Subpart C requires that the standards of Subpart B are met on a site-specific basis using information gathered during site characterization and monitoring. The plan to meet the standards of Subpart B must be stated in a site-specific GCAP. The plan must contain a compliance strategy and a monitoring program, if necessary.

2.4 Supplemental Standards

Under certain conditions, DOE may apply supplemental standards to contaminated ground water in lieu of background levels, MCLs, or ACLs (40 CFR Part 192). Supplemental standards may be applied if any of the following conditions are met:

- Remedial action necessary to implement Subpart A or B would pose a significant risk to workers or the public.
- Remedial action to meet the standards would directly produce health and environmental harm that is clearly excessive compared to the health and environmental benefits of remediation now or in the future.
- The estimated cost of remedial action is unreasonably high relative to the long-term benefits, and the RRM does not pose a clear present or future hazard.
- There is no known remedial action.
- The restoration of ground water quality at any processing site is technically impracticable from an engineering standpoint. Guidance for what is deemed technically impracticable is provided by EPA (1993b, 1996b, 2000b).
- The ground water is classified as limited-use ground water. Subpart B of 40 CFR 192 defines limited-use ground water as ground water that is not a current or potential source of drinking water because the concentration of total dissolved solids (TDS) exceeds 10,000 milligrams per liter (mg/L); there is widespread ambient contamination that cannot be cleaned up using treatment methods reasonably employed in public water systems; or the quantity of water available to a well is less than 150 gallons (gal) per day. When limited-use ground water applies, supplemental standards ensure that current and reasonably projected uses of the ground water are preserved (40 CFR Part 192).
- Radiation from radionuclides other than radium-226 and its decay products is present in sufficient quantity and concentration to constitute a significant radiation hazard from RRM.

If supplemental standards are applied, the regulations in 40 CFR 192.22 (c) also require DOE to inform anyone affected by the hazardous constituents and to solicit their comments.

One of the four cleanup standards (i.e., background, MCLs, ACLs, or supplemental standards) is selected on the basis of risk to human health and the environment. The methods available to achieve compliance include active remediation, natural flushing, no remediation, or any combination of the methods. Section 5.0, "Site Conceptual Model," presents a summary of the geology, hydrology, and geochemistry of the site. This information provides the basis to select the compliance strategy. Section 7.0, "Ground Water Compliance Strategy," presents a discussion of the proposed compliance strategies and includes a justification for selecting a natural flushing to MCL remediation strategy for arsenic, supplemental standards for vanadium and uranium, and monitoring and institutional controls (ICs) for all three constituents.

2.5 Cooperative Agreements

UMTRCA requires that compliance with the ground water standards be accomplished with the full participation of states that are paying part of the costs, and in consultation with Indian tribes on whose lands uranium mill tailings are located. UMTRCA also directs DOE to enter into cooperative agreements with the states and Indian tribes. DOE entered into a ground water cooperative agreement with the Colorado Department of Public Health and Environment (CDPHE) in March 1998.

2.6 National Environmental Policy Act

UMTRCA is a major federal action that is subject to the requirements of NEPA (42 USC 4321 *et seq.*). Regulations of the Council on Environmental Quality (to implement NEPA) are codified in 40 CFR Part 1500; these regulations require each federal agency to develop its own implementing procedures (40 CFR 1507.3). DOE-related NEPA regulations are in 10 CFR Part 1021, "National Environmental Policy Act Implementing Procedures". DOE guidance is provided in *Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements* (DOE 1993b).

Pursuant to NEPA, in 1994 DOE drafted a PEIS for the UMTRA Ground Water Project. The PEIS document was made final in October 1996. The purpose of the PEIS was to analyze the potential impacts of implementing four programmatic alternatives for ground water compliance at the designated processing sites. The preferred alternative for the UMTRA Ground Water Project was published in a Record of Decision in 1997. All subsequent action on the UMTRA Ground Water Project will comply with the Record of Decision.

2.7 Other Regulations

In addition to UMTRCA, EPA ground water standards, and NEPA, DOE must also comply with other federal regulations and executive orders that may be relevant to the UMTRA Project sites. Examples include regulations that require protection of wetlands and floodplains, threatened or endangered species, and cultural resources. Other regulations, for which the state may be delegated authority, include requirements for water discharge and waste management. Executive orders include those related to pollution prevention and environmental justice.

2.8 State Regulations

DOE must comply with state regulations where federal authority has been delegated to the state. These include compliance with state permits required for drilling, completing, and decommissioning monitoring wells; water discharge; and waste management.

2.9 DOE Orders

Several environmental, health and safety, and administrative DOE orders apply to the work being conducted under the UMTRA Ground Water Project. DOE orders prescribe the manner in which DOE will comply with federal and state laws, regulations, and guidance, and the manner in which DOE will conduct operations that are not prescribed by law. DOE guidance for complying with federal, state, and tribal environmental regulations are in DOE Order 5400.1 series, partially superseded by DOE Order 231.1. DOE Order 5400.5 requires protection of the public from radiation hazards. DOE guidance pertaining to NEPA is contained in DOE Order 451.1, and specific guidance pertaining to environmental assessments is provided in *Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements* (DOE 1993b).

End of current text

3.0 Site Background

The Naturita UMTRA Project site is in western Colorado, Montrose County, approximately 2 miles north of the city of Naturita (Figure 1–1). It is situated on an elongate north-south section of floodplain between Colorado State Highway 141 on the west and the San Miguel River on the east. The site is the location of a former vanadium and uranium mill that operated intermittently from 1939 until 1958. The historical site area, a boundary used during the surface remedial action, enclosed 53 acres. The current site area is expanded to include property owned by the City of Naturita and Chemetall-Foote and now consists of 79 acres (Plate 1). This section presents an overview of the site's physical setting and climate, a history of the former milling operation and remedial actions, a summary of previous investigations, and the City of Naturita's current land use plan.

3.1 Physical Setting and Climate

The former millsite is located in the northeastern part of the Colorado Plateau Physiographic Province at the eastern edge of canyonlands country. Incised streams and large structural warps producing ridges and intervening basins characterize the area. Major physiographic features near the site include the valley occupied by the San Miguel River at an elevation of 5,355 ft and Sawtooth Ridge to the west and southwest that is slightly over 6,000 ft high.

The region has an arid to semiarid climate with high evaporation, low precipitation, low humidity, and large temperature variations. The average annual rainfall is about 13 inches per year (DOE 1995). Rainfall occurs during the summer and fall in high-intensity, short-duration, late afternoon thunderstorms that are conducive to runoff. Precipitation occurs in the winter as snowfall. Temperatures show considerable diurnal and seasonal variations. Winters are cold; average monthly temperatures are typically below freezing in December and January. Summers are warm; average monthly temperatures are in the 70s °F from June to August.

3.2 Site History

3.2.1 Milling History

Rare Metals Company built the Naturita vanadium mill about 1930 with a loan of $427,000 from the Vanadium Corporation of America (VCA). As collateral for the loan, VCA held the mortgage to the mill, and when Rare Metals failed in the mid-1930s, VCA foreclosed, performed improvements, and finally reopened the mill in 1939 (Shumway 1970). A salt-roast water-leaching process was used initially, but this was altered in 1942 to include recovery of uranium for the Manhattan Engineering District project. The ore was salt roasted and quenched in a carbonate solution, followed by carbonate leaching. Residues from this process were acidified with sulfuric acid to extract extra metals. These solutions were neutralized with excess sodium carbonate, and sludges were recirculated to reclaim additional uranium and vanadium. The carbonate leach liquor, containing uranium and vanadium, was treated with sulfuric acid and boiled to expel carbon dioxide. A filtrate containing the metals was fused with a reducing mixture of salt, soda ash, and either sawdust or fuel oil. After fusion, the ash was water-leached, dissolving vanadium and leaving the uranium. Additional steps concentrated vanadium as "red cake" (Merritt 1971).

The mill was originally designed to operate at about 150 tons per day capacity but was increased in 1954 to 350 tons per day. An overhead aerial photograph of the millsite taken in 1954 shows the mill and a large area of tailings located along the San Miguel River (Figure 3–1). The ore storage area on the west side of Colorado Highway 141 was already in use. The river shows a prominent distributary channel meandering across the vicinity property (Maupin Property) to the north. Tailings may have eroded off the millsite and may have been deposited in and along this channel. The mill closed in 1958 when the contract with the Atomic Energy Commission (AEC) expired. During the life of the mill, approximately 704,000 tons of ore was processed (Ford, Bacon, & Davis Utah 1981).

Ores for the mill were mined predominantly from the Salt Wash Member of the Morrison Formation from the Uravan Mineral Belt. Uranium and vanadium minerals were predominantly carnotite and tyuyamunite. About 51 percent of the ores came from contractor-controlled properties; the remaining 49 percent came from independent producers (Albrethsen and McGinley 1982). From 1961 to 1963, VCA operated an upgrader plant at the site, and concentrates were sent to their operations at Durango, Colorado, for further treatment. From 1963 to 1978, the millsite was used as a general headquarters for the downsizing VCA. They brought mining and milling equipment from all over the Colorado Plateau to the Naturita site and sold it to other mining interests (DOI 1994). Figure 3–2 is an overhead aerial photograph of the millsite in 1966 showing the maximum areal extent of the tailings pile. The distributary channel meandering across the vicinity property to the north is still apparent.

In the fall of 1969, Foote Mineral and the Colorado Department of Health tried to stabilize the tailings that were next to the San Miguel River by covering them with topsoil and seeding, fertilizing, and watering the surface to allow the grass to root. This was done in part because tailings were eroding from the site during flood periods of the San Miguel River (DOI 1994). This stabilization apparently met with only limited success, because a 1974 overhead aerial view of the site shows barren tailings (Figure 3–3). The photograph was taken during spring or summer (trees are green), so any vegetation on the tailings should be visible. Buildings along Highway 141 are being used (a car is in front), and the tailings pile shows lineations, probably from the reclamation efforts. At the time approximately 704,000 tons of tailings are located on the site (Ford, Bacon, & Davis Utah 1981). A road or dike or both appear along the eastern side of the tailings pile where it contacts the San Miguel River. The distributary channel in the vicinity property has been modified and now cuts across the property farther north. The oval feature on the vicinity property was a local racetrack (named "Little Indy Speed Way") constructed by a family member of the property owner. The distributary channel has apparently deposited sediments and water in the eastern interior of the racetrack and could have deposited tailings on the vicinity property during this time.

By the 1970s, the price of uranium was attractive again, and in 1975, Foote Mineral leased a part of the millsite to the Nuclear Division of General Electric as a buying station for uranium ore. This continued into the 1980s. In 1976, Ranchers Exploration and Development Corporation bought 24 acres of tailings located on the site and removed an estimated 360,000 tons of tailings to a new location 4 miles to the south up Dry Creek. From 1977 to 1979, Ranchers heap-leached the tailings and recovered an additional 380,000 pounds of uranium and 1,840,000 pounds of vanadium (DOI 1994). In 1978 VCA merged with Foote Mineral, and the downsizing of all former VCA operations accelerated.

N

1100 0 1100 Feet

Approximate Scale

U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION OFFICE, COLORADO

1954 Aerial Photo
Naturita, CO

DATE PREPARED: September 24, 2001

FILENAME: U0138400-01

m:\ugw\511\0016\07\u01384\u0138400.apr smithw 9/24/2001, 14:41

Figure 3-1. Overhead Aerial Photograph Taken in 1954

N

1100 0 1100 Feet

Approximate Scale

macTec-ers	U.S. DEPARTMENT OF ENERGY GRAND JUNCTION OFFICE, COLORADO
1966 Aerial Photo Naturita, CO	
DATE PREPARED: September 24, 2001	FILENAME: U0138400-02

m:\ugw\511\0016\07\u01384\u0138400.apr smithw 9/24/2001, 21:04

Figure 3-2. Overhead Aerial Photograph Taken in 1966

N

630 0 630 Feet

Approximate Scale

U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION OFFICE, COLORADO

1974 Aerial Photo
Naturita, CO

DATE PREPARED: September 24, 2001

FILENAME: U0138400-03

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Figure 3-3. Overhead Aerial Photograph taken in 1974

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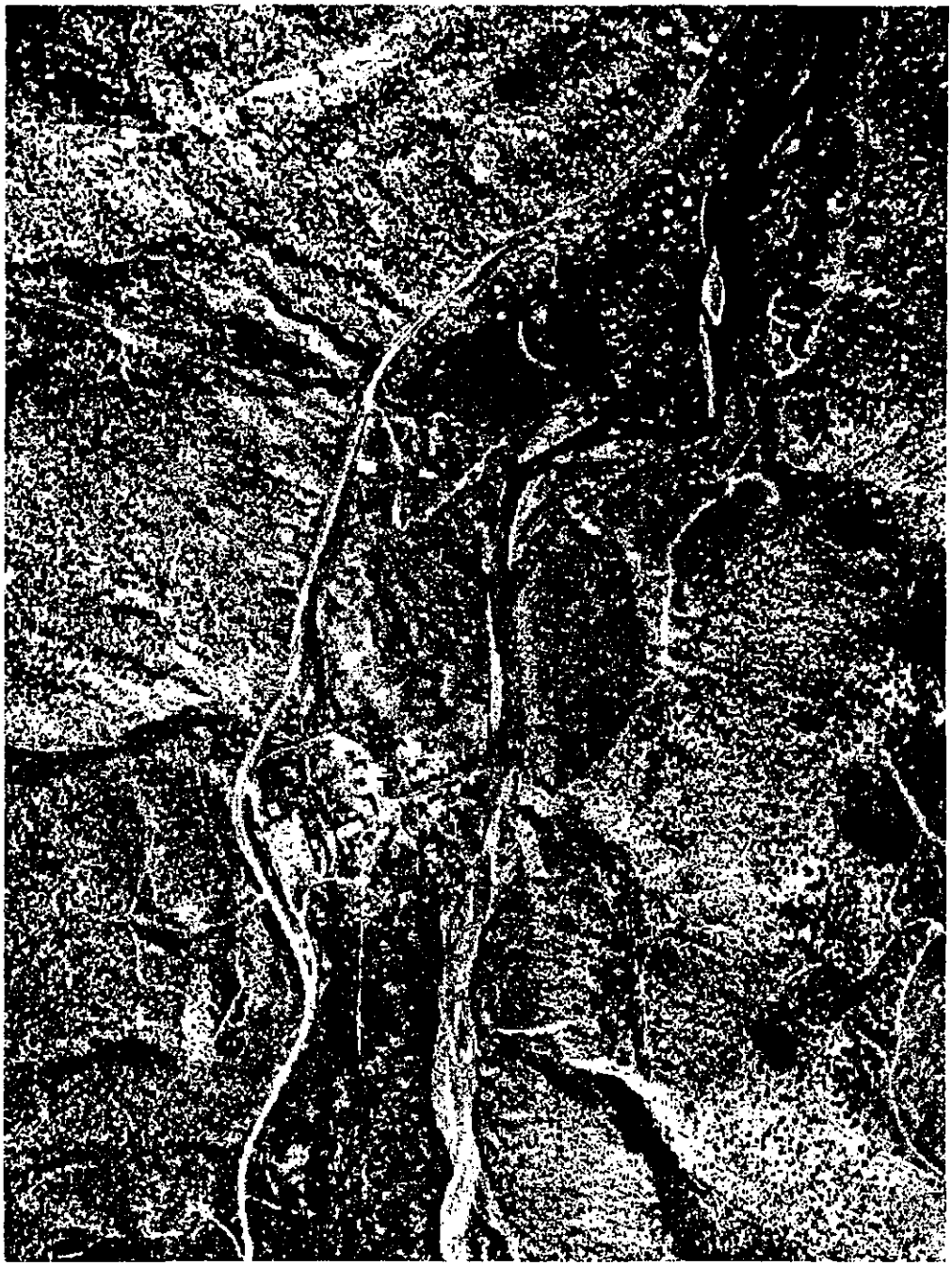
3.2.2 Remedial Action History

Ford, Bacon, and Davis Utah performed an engineering assessment of the site for DOE in 1981 and proposed remedial actions with associated cost estimates. In 1984 and 1985, DOE again evaluated the radiological contamination at the site and supplied information to be used in the proposed remedial action that started in 1994. Figure 3–4 is an overhead aerial photograph of the millsite from 1986 that shows the former tailings pile with considerable vegetative cover. The San Miguel River has established its present course and no longer has a distributary channel crossing the vicinity property to the north and displays the unusual 90-degree turn from east to north in this area. A sand bar east of the former racetrack began to form and became vegetated with small willow saplings in the next decade. The former river channel scarp is the source for surface location 0538 (sometimes referred to as a spring).

During this time, the ownership of the mill changed several times. Foote Minerals was purchased by Cyprus Mining, who merged with Amax mining company to form Cyprus-Amax Minerals Corporation, who owned the site in 1994. Cyprus-Amax later became Cyprus-Foote, which was purchased by the German company, Chemetall, who formed the new company and became the current landowner, Chemetall Foote Corporation. Another previous landowner, Hecla Mining, who bought Ranchers Exploration in 1984, sold their property to the City of Naturita for one dollar (personal communication with Greg Hall, Naturita mayor, March 2001). Plate 1 shows the current land status for the site; Chemetall Foote owns north and south parcels and the City of Naturita owns the central portion.

The UMTRA Project surface remedial action at the site occurred between January 1993 and September 1998 (DOE 1998a). During this time, 771,400 cubic yards (yd^3) of RRM were removed from the site. The approximate breakdown is 315,520 yd^3 from the former mill yard, 10,340 yd^3 from the former ore storage area, 209,880 yd^3 from windblown areas, 225,490 yd^3 from the former tailings area, and 10,170 yd^3 from stockpiled demolition debris. In addition, a contiguous vicinity property to the north (NT-065, the Maupin property) underwent remedial action, and 93,602 yd^3 of material was removed (DOE 1998b). All material was hauled by truck to the Upper Burbank disposal cell about 15 miles to the northwest near the townsite of Uravan, Colorado. Figure 3–5 is an oblique aerial photograph from July 1994 of the mill yard before buildings were razed. It shows the former office buildings, the semicircular concrete pad used during the ore-buying era, and new trailers and equipment moved to the site to begin demolition. Figure 3–6 is an oblique aerial photograph from July 1996 of the mill yard showing the demolition of all buildings, construction of the retention pond for the decontamination pad, and an associated retention dike along the lower side of the site. Figure 3–7 is an overhead aerial photograph from May 1998 showing the final grade for the site. The RRM has been removed from the entire site, and considerable material has been removed from the vicinity property to the north, including the area of the old racetrack. Large cottonwood trees around the river bend were left at the owner's request. Figure 3–8 is an oblique aerial photograph showing the site in March 2001. Reseeding efforts have met with limited success, and another attempt will be made to address this in the fall of 2001.



820 0 820 Feet

Approximate Scale

N

U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION OFFICE, COLORADO

1986 Aerial Photo
Naturita, CO

DATE PREPARED: September 24, 2001

FILENAME: U0138400-04

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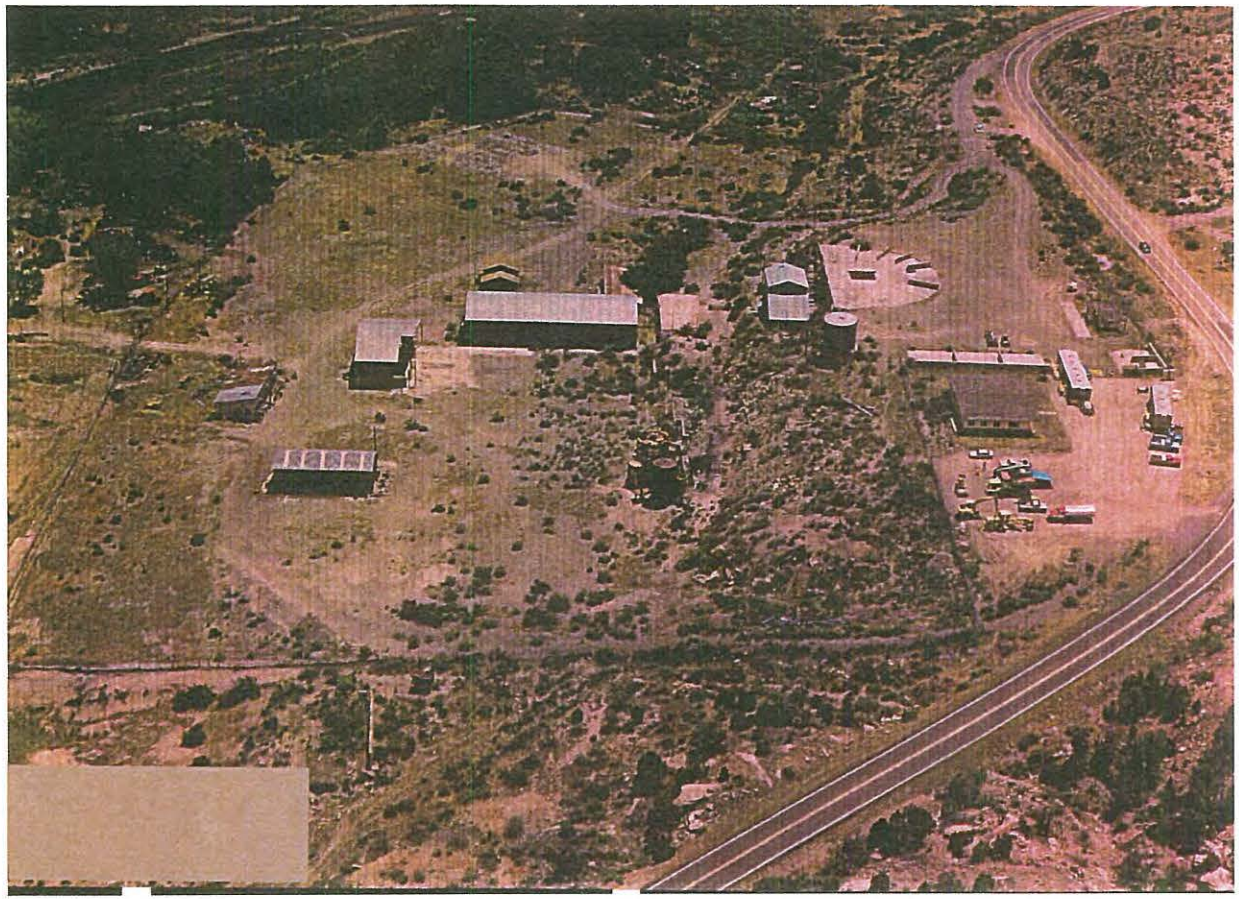
Figure 3-4. Overhead Aerial Photograph taken in 1986



110 0 110 Feet

Approximate Scale

N

macTec-ers	U.S. DEPARTMENT OF ENERGY GRAND JUNCTION OFFICE, COLORADO
1994 Aerial Photo Naturita, CO	
DATE PREPARED: September 24, 2001	FILENAME: U0138400-05

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Figure 3-5. Oblique Aerial Photograph taken in 1994

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230 0 230 Feet

Approximate Scale

N

U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION OFFICE, COLORADO

1996 Aerial Photo
Naturita, CO

DATE PREPARED: September 24, 2001

FILENAME: U0138400-06

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Figure 3-6. Oblique Aerial Photograph taken in 1996

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660 0 660 Feet

Approximate Scale

N

U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION OFFICE, COLORADO

1998 Aerial Photo
Naturita, CO

DATE PREPARED: September 24, 2001

FILENAME: U0138400-07

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Figure 3-7. Aerial Photograph taken in 1998

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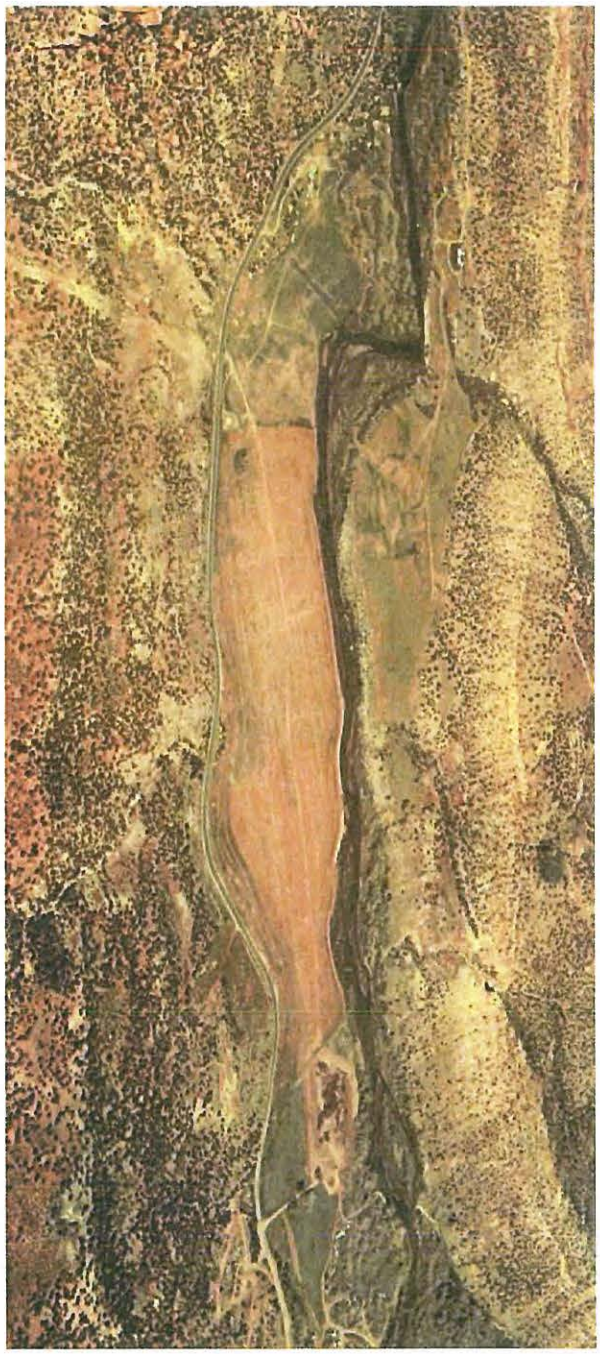

N

850 0 850 Feet

Approximate Scale

U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION OFFICE, COLORADO

2001 Aerial Photo
Naturita, CO

DATE PREPARED: September 24, 2001

FILENAME: U0138400-08

m:\ugw\511\0016\07\u01384\u0138400.apr smithw 9/24/2001, 21:32

Figure 3-8. Oblique Aerial Photograph taken in March 2001

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3.2.2.1 Supplemental Standards Areas

The Naturita site is unusual because of the large amount of supplemental standards areas left during the surface cleanup (DOE 1998a). Five areas of supplemental standards, totaling 11 acres (14 percent of the total site area), were left on the site and large areas of supplemental standards, also totaling 11 acres (36 percent of the total vicinity property area), were included in the vicinity property downgradient of the site (see Figure 8–3). Just over one acre on the millsite was left because the radium-226 standard was not met after excavating to 1 ft below the water table. Other supplemental standards areas on the millsite were left because removing the RRM would produce excessive environmental harm and increased risk to workers who would have to remove it compared to the low radiological hazard. These areas were along the steep slopes of U.S. Highway 141, near high-voltage power poles, and in wetland areas adjacent to the San Miguel River.

Contamination on approximately 5 of the 11 acres on the downgradient vicinity property was left on the floodplain near the San Miguel River because the property owner did not want the area disturbed, and the harm to the environment outweighed the benefit of removing it. The area is a riparian corridor with mature cottonwoods and other habitat suitable for indigenous species. The other 6 acres on the vicinity property, where RRM is probably windblown contamination, was left along State Highway 141 because of low radioactivity and potential danger to workers who would have to work along the steep banks.

3.2.3 Previous Investigations

Merritt (1971) provides detailed descriptions of the uranium concentration process, mill by-products, and process waste streams. Albrethsen and McGinley (1982) summarize the history of the domestic uranium procurement policies and practices under the AEC. McWilliams and Schoch-Roberts (1994) discuss the VCA mill as an important historical activity in the country's nuclear energy saga and provide detailed discussions about the processing and milling history.

Coffin (1921) discusses the early radium, uranium, and vanadium mines in southwestern Colorado. Fischer and Hilpert (1952) discuss the geology of the Uravan Mineral Belt. Chenoweth (1981) reviews uranium and vanadium deposits in the Uravan Mineral Belt. Weir and others (1984) discuss the regional hydrology.

Site-specific hydrogeologic and geochemical investigations and remedial actions are described in an engineering assessment (Ford, Bacon & Davis Utah 1981), an environmental assessment (DOE 1994), a BLRA (DOE 1995), a report by Groffman and Erskine (1996), a final RAP (DOE 1998a), a completion report (DOE 1998b), and a vicinity property completion report (DOE 1999a).

Table 3–1 is an update to Table 3.2 in the BLRA. This table shows the history of wells sampled at the site from 1998 to 2001. Only wells 0547 and 0548 remain from the surface program. Wells listed in Table 3–1 are currently being sampled.

Table 3–1. Current Monitor Well Information

Well ID	Location	Years Sampled	Times Sampled	Interval Screened (ft)
0548	Northwest of former tailings pile	1986, 1987, 1989, 1992, 1994, 1998–2001	20	16.0–21.0
0547	Southeast of former mill yard	1986, 1987, 1989, 1992, 1994, 1998–2001	20	10.0–20.0
MAU01	Maupin property, S border	1998–2001	9	9.2–14.2
MAU02	Maupin property, S border	1998–2001	9	15.8–16.8 triple completion
MAU03	Maupin property, NE	1998–2001	9	2.2–9.2 triple completion
MAU04	Maupin property, NE	1998–2001	9	3.2–10.2
MAU05	Maupin property, S border	1998–2001	9	8.2–8.7
MAU06	Maupin property, center eastern	1999–2001	8	3.5–8.5
MAU07	Maupin property, farthest N	1999–2001	8	2.9–7.9
MAU08	Maupin property, SW border	1999–2001	8	6.2–11.2
NAT01	N boundary former tailings pile	1998–2001	9	17.0–17.5 double completion
NAT02	Former tailings pile	1998–2001	8	6.4–11.4
NAT03	Former tailings pile	1998–2001	9	6.3–11.3
NAT04	Former tailings pile	1998–2001	9	12.0–12.5 triple completion
NAT05	Former tailings pile	1998–2001	9	8.7–13.7
NAT06	Former tailings pile	1998–2001	9	11.6–12.2 triple completion
NAT07	Former tailings pile	1998–2001	9	11.8–12.3 triple completion
NAT08	Former tailings pile	1998–2001	9	6.3–11.3
NAT09	Former taillings pile	1998–2001	9	5.7–10.7
NAT10	Former tailings pile	1998–2001	9	6.8–11.8
NAT11	Former tailings pile	1998–2001	9	8.7–13.7
NAT12	Former tailings pile	1998–2001	9	13.9–14.4 double completion
NAT13	Former tailings pile	1999–2001	8	11.8–12.3 triple completion
NAT14	Former tailings pile	1999–2001	8	11.0–11.5 triple completion
NAT15	Former tailings pile	1999–2001	8	13.8–14.3 triple completion
NAT16	Former tailings pile	1999–2001	8	11.7–12.2 triple completion
NAT17	Former mill yard	1999–2001	8	10.7–11.2 triple completion
NAT18	Former mill yard	1999–2001	8	10.7–11.2 triple completion
NAT19	Former mill yard	1999–2001	8	6.0–11.0
NAT20	S site boundary	1999–2001	8	5.2–10.2
NAT21	S site boundary	1999–2001	8	9.3–9.8 triple completion
NAT22	S site boundary	1999–2001	8	9.3–9.8 triple completion
NAT23	Northern site	1999–2001	8	4.7–9.7
NAT24	Northern site	1999–2001	8	4.7–9.2
NAT25	Northern site	1999–2001	8	10.2–15.2
NAT26	NW site	1999–2001	8	10.7–15.7
NAT27	Former tailings pile	1999–2001	8	6.7–7.2 triple completion
NAT28	Former tailings pile	1999–2001	8	6.7–7.2 triple completion
NAT29	Former tailings pile	1999–2001	8	1.4–6.4
NAT30	Southern site	1999–2001	8	7.8–8.3 triple completion
DM1	Background, gravel pit	1999–2001	8	2.7–7.7

3.3 Land and Water Uses

The population of Naturita is approximately 700. The town was a center for mining radium, vanadium, and uranium for 80 years and still supports coal mining and an associated power plant. A gravel pit operated by Southwest Redimix abuts the site on the south (upgradient) side. The pit intersects the water table and may influence migration of alluvial ground water across the site. Ranching and farming are the main occupations in the valley around the millsite.

One ranch residence is adjacent to the site on the downgradient side. The residents haul drinking water for domestic use and do not have a well.

The Blessing Ditch crosses the site from south to north on the west side. This irrigation ditch was last operational in 1972. The grade for a potential ditch was established on the site during remedial action.

Land including and surrounding the former millsite is zoned agricultural. The City of Naturita identifies the land within the former millsite as having possible uses as a western park or golf course. A portion of the site is currently deeded to the town, and the remainder belongs to Chemetall Foote. Plans to transfer the Chemetall Foote property to the City are under consideration.

Currently, there are no uses for ground water at the site. The ground water in the alluvial aquifer is of lesser quality than water from the San Miguel River flowing adjacent to the site. Livestock drink from the river. No domestic wells exist in the contaminated portion of the aquifer.

End of current text

4.0 1998 to 2001 Field Investigations

4.1 Introduction

The U.S. Geological Survey (USGS) has been conducting research sponsored by NRC at the Naturita site since 1997. NRC is interested in sorptive interactions between uranium and substrate, and more efficient and effective methods of measuring them. DOE teamed with the USGS to use their knowledge and sampling expertise to produce this SOWP. Therefore, most of the sampling from 1998 to 2001 was conducted by USGS and supplemented to a limited extent by DOE. Most surface and ground water analyses and soil/sediment analyses were also performed by USGS at their labs in Menlo Park, California, and Denver, Colorado. Other analyses were performed at the DOE Grand Junction Office.

4.2 Ground Water Monitoring Well Installations

The ground water monitor wells were installed by USGS with funding from NRC for a field demonstration of a uranium(VI) surface complexation model. Specifically, the wells were installed to (1) obtain an understanding of the direction and velocity of ground water flow; (2) characterize the ground water chemistry at the site, including the extent of uranium contamination; (3) investigate the role of U(VI) sorption in host sediments and rock; and (4) conduct small-scale tracer tests and aquifer tests to investigate U(VI) transport. Installation procedures, construction details, and locations for the wells are described in this section. Figure 4–1 shows monitoring well locations.

4.2.1 Wells Installed in 1998 and 1999

A total of 39 ground water monitoring wells were installed during October 1998 and June 1999. Two types of wells were installed: (1) 2-inch-diameter, single completion wells screened over a 5-ft interval at the bottom of the alluvial aquifer, and (2) 0.5-inch-diameter, multiple completion wells with two to three wells in the same borehole, each screened over a 6-inch vertical interval at different depths. All wells were drilled using the USGS drilling rig with hollow stem augers. Wells installed in June 1999 were drilled using a casing-advance method. Twenty wells were completed with 2-inch inside diameter (i.d.), flush joint, inside threaded, polyvinyl chloride (PVC) casing with size 20 slotted screen. One well was constructed with a 4-inch i.d. PVC casing for use in aquifer testing. Eighteen wells were constructed as multiple completion wells using 0.5-inch i.d. PVC casing. The multiple completion wells were constructed by setting the 0.5-inch casings at different levels in the filter pack. Each of the multiple completion wells in NAT04, NAT12, and MAU02 was separated by a 4-inch bentonite seal. For all other multiple completion wells, no seal was installed between the completion zones. All the 1998–1999 wells completed in the alluvial aquifer were less than 20 ft in depth. The screened interval for the 4-inch and 2-inch wells is 5 ft. Screened intervals for the 0.5-inch-diameter multiple completion wells is 6 inches. The filter pack was constructed with 10 to 20 sieve silica sand placed in the annular space from the bottom of the borehole to 1 to 3 ft above the top of the well screen. A 1- to 8-ft bentonite seal was placed above the sand pack. Bentonite grout was used to fill the annular space above the seal to the ground surface, and a cement pad was poured to anchor a locking steel protective cover. Examples of well completion diagrams for the 2-inch single completion and 0.5-inch multiple completion wells are shown in Figure 4–2 and Figure 4–3, respectively. Construction details for the wells are summarized in Table 4–1. Completion diagrams for all the wells are in Appendix A.

4.2.2 Wells Installed by DOE Before 1998

In addition to the wells installed in 1998 and 1999, DOE had previously installed two wells as part of an initial site characterization. These wells, designated 0547 and 0548, were installed in June 1986 with a direct rotary drill. Both wells have 2-inch i.d. PVC casings and are 23 ft deep. Well 0547 has a 10-ft screened interval and 0548 has a 5-ft screened interval. Both wells are capped with a locking steel cover. Drilling logs for these wells are included in Appendix A; construction details for DOE wells are summarized in Table 4–1.

4.2.3 Wells Installed by DOE After 1998

Several additional wells were installed during this current phase of characterization. Well 700 was installed in 2001 on the former millsite area to try in pinpoint the maximum concentrations of vanadium. Well 701 was installed in 2001 on the vicinity property to help complete data gaps in this area. Well 715 was drilled in 2002 to determine if contamination existed on the east side of the San Miguel River. And well 716 is currently planned in 2002 as a water well for the family living on the vicinity property.

4.2.4 Water Levels and Temperatures

Seasonal changes in water levels were measured 14 times in all the monitoring wells between October 1998 and June 2000. From November 2000 to March 2001, water levels were only measured in 28 wells. Depth to water was measured from the top of the PVC casing at each well at a set measuring point. Measuring point elevations above sea level are shown in Table 4–2 and were surveyed from a nearby benchmark during well installation to calculate the elevation of the water table. Water levels were monitored continuously with pressure transducers in up to six wells from November 1998 to March 2001. Water level data from the transducers were downloaded, and the instruments were recalibrated quarterly. Figure 4–4 shows the water table elevations and temperatures for wells NAT02, NAT08, and NAT29. Figure 4–5 shows the water table elevations in wells NAT11, NAT23, and NAT25.

Seasonal changes in water temperature was recorded along with water level in wells NAT02, NAT08 and NAT29 and is shown in Figure 4–4. Water temperature was also recorded in wells NAT02, NAT11, NAT19, NAT20, NAT23, NAT26, MAU03, MAU07, MAU08, and the San Miguel River.

4.3 Soil and Sediment Sampling

Soil and sediment samples for lithologic logging and chemical analysis were collected during installation of the ground water monitoring wells. Sediment and soil samples were collected for chemical analysis to determine distribution coefficients (K_d) and mobile fractions of site-related constituents to help characterize contaminant transport. Figure 4–6 shows the soil and sediment sampling locations. All samples were sent to the USGS Research Laboratories in Menlo Park, California, for K_d and batch leachate analysis using strict chain of custody procedures. Chemical analysis of the leachates was performed in Menlo Park and at the USGS National Water Quality Lab in Denver using the methods described in Section 4.7.2.

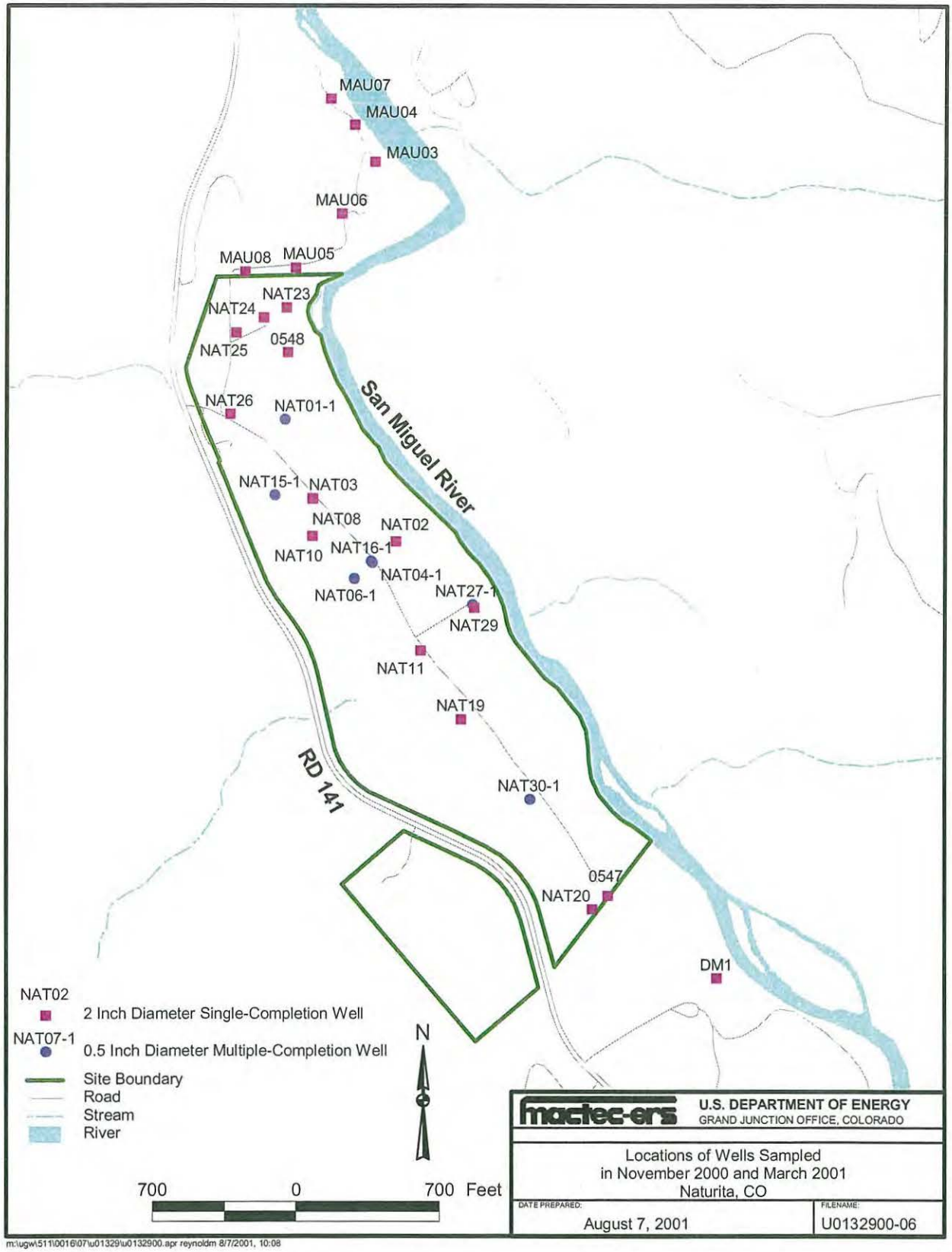

Figure 4–1. Locations of Naturita Wells Sampled in November 2000 and March 2001

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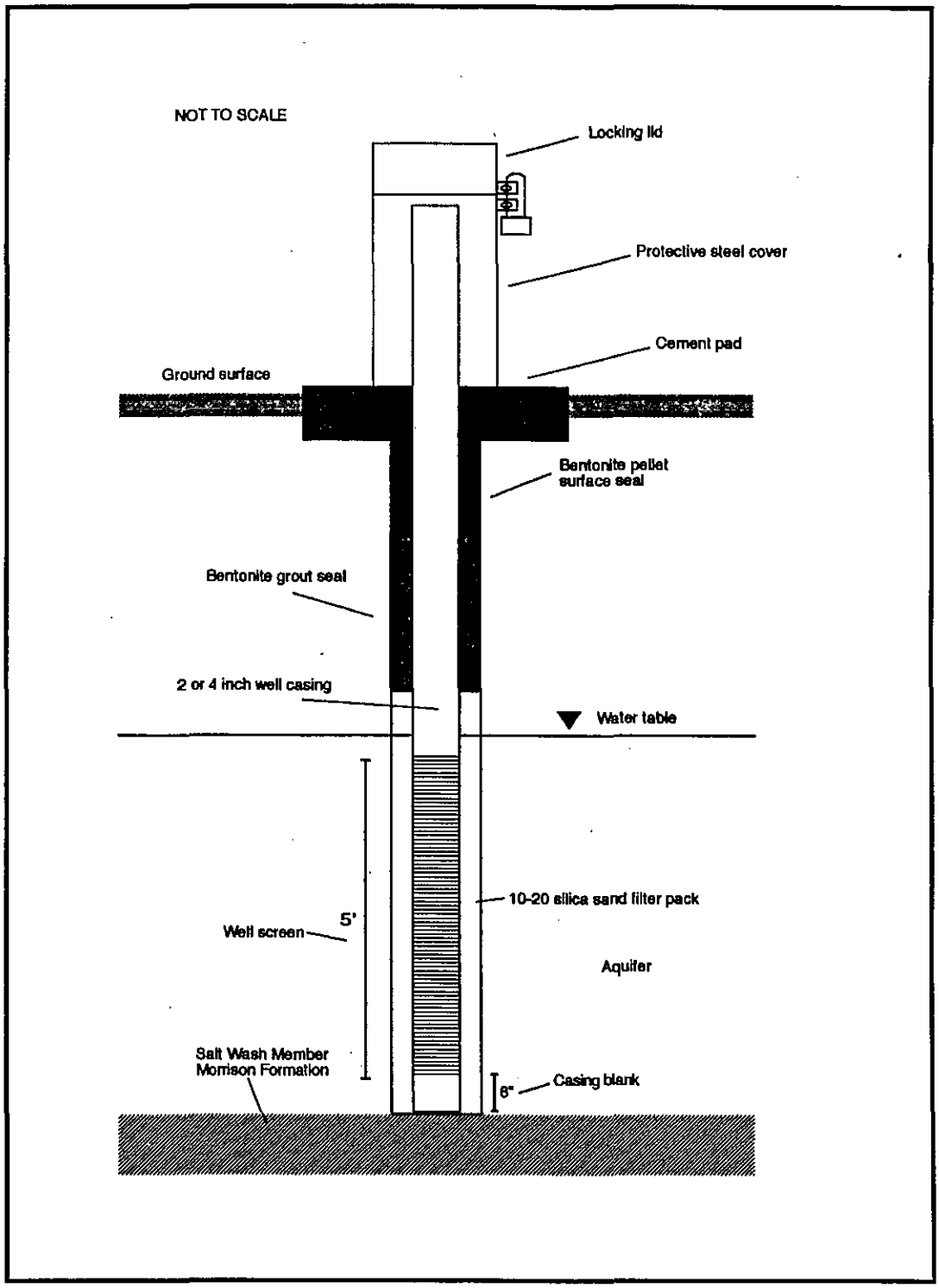


Figure 4–2. Construction Diagram for 2- and 4-inch-Diameter Monitoring Wells Installed at the Naturita Site

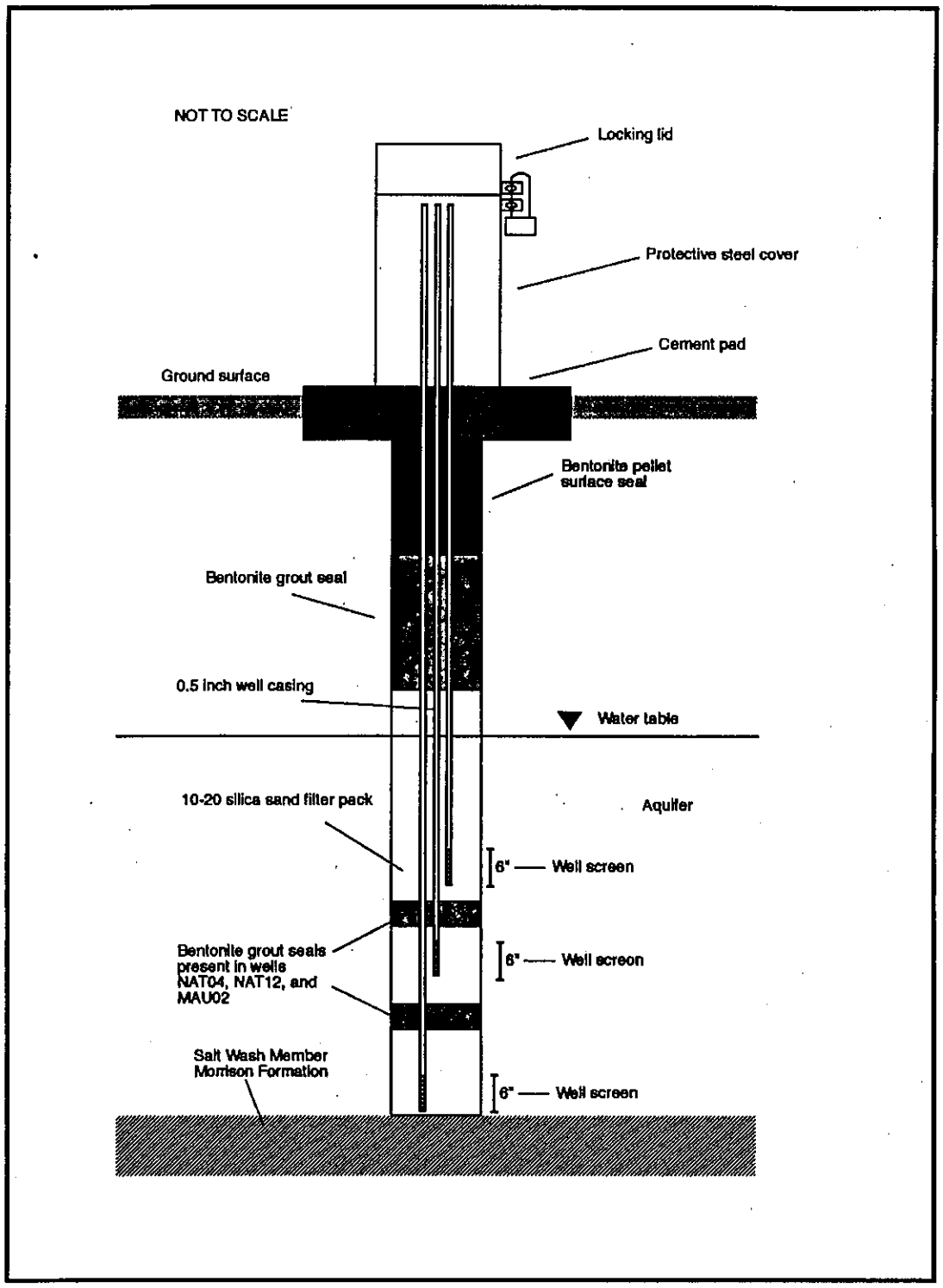


Figure 4–3. Construction Diagram for 0.5-inch-Diameter Multiple Completion Wells Installed at the Naturita Site

Table 4–1. Construction Details for Monitoring Wells Installed at the Naturita UMTRA Site

Location Code	North Coordinate, State Plane	East Coordinate, State Plane	Elevation of Land Surface, ft	Borehole Depth, ft	Borehole Diameter, inches	Elevation of Top of Casing, ft	Casing Length, ft	Casing Diameter, inches	Depth Below Land Surface, ft	Screen length, ft	Flow Code	Zone of Completion	Status
NAT01-1	588657	1106298	5288.11	18.0	14.0	5290.76	20.32	0.5	17.0	0.50	O	AI	Active
NAT01-2	588659	1106298	5288.11	18.0	14.0	5290.61	15.37	0.5	12.2	0.50	O	AI	Active
NAT02	588073	1106846	5287.37	11.5	9.0	5289.42	13.88	2.0	6.5	5.00	O	AI	Active
NAT03	588278	1106435	5286.57	11.6	9.0	5288.37	13.43	2.0	6.3	5.00	O	AI	Active
NAT04-1	587968	1106729	5288.42	12.5	9.0	5290.53	14.78	0.5	12.0	0.50	O	AI	Active
NAT04-2	587968	1106729	5288.42	10.7	9.0	5290.62	13.07	0.5	10.2	0.50	O	AI	Active
NAT04-3	587968	1106729	5288.42	8.7	9.0	5290.62	11.07	0.5	8.2	0.50	O	AI	Active
NAT05	588284	1106251	5287.63	14.0	9.0	5289.73	16.13	2.0	8.7	5.00	O	AI	Active
NAT06-1	587888	1106640	5288.88	12.3	9.0	5291.73	15.32	0.5	11.8	0.50	O	AI	Active
NAT06-2	587888	1106640	5288.88	9.9	9.0	5291.73	12.92	0.5	9.4	0.50	O	AI	Active
NAT06-3	587888	1106641	5288.88	6.1	9.0	5291.71	9.10	0.5	5.6	0.50	O	AI	Active
NAT07-1	588368	1106567	5285.73	12.5	9.0	5287.93	14.87	0.5	12.0	0.50	O	AI	Active
NAT07-2	588368	1106567	5285.73	10.8	9.0	5287.81	13.05	0.5	10.3	0.50	O	AI	Active
NAT07-3	588368	1106567	5285.73	8.7	9.0	5287.63	10.77	0.5	8.2	0.50	O	AI	Active
NAT08	588276	1106438	5286.30	12.0	12.0	5288.00	13.33	4.0	6.0	5.00	O	AI	Active
NAT09	588281	1106432	5286.52	11.0	9.0	5288.42	13.03	2.0	6.3	5.00	O	AI	Active
NAT10	588095	1106437	5287.28	12.0	9.0	5289.18	14.03	2.0	6.8	5.00	O	AI	Active
NAT11	587546	1106970	5291.23	14.0	10.0	5293.73	16.63	2.0	8.8	5.00	O	AI	Active
NAT12-1	588592	1106197	5289.84	14.6	9.0	5291.64	16.57	0.5	14.1	0.50	O	AI	Active
NAT12-2	588592	1106198	5289.84	10.3	9.0	5291.65	12.28	0.5	9.8	0.50	O	AI	Active
NAT13-1	587550	1106965	5291.50	12.5	4.0	5294.22	15.19	0.5	11.8	0.50	O	AI	Active
NAT13-2	587550	1106965	5291.50	10.5	4.0	5294.14	13.11	0.5	9.8	0.50	O	AI	Active
NAT13-3	587550	1106965	5291.50	8.5	4.0	5294.22	11.19	0.5	7.8	0.50	O	AI	Active
NAT14-1	587556	1106961	5291.34	11.7	4.0	5294.58	15.01	0.5	11.0	0.50	O	AI	Active
NAT14-2	587556	1106961	5291.34	10.4	4.0	5294.56	13.69	0.5	9.8	0.50	O	AI	Active
NAT14-3	587556	1106961	5291.34	8.4	4.0	5294.57	11.70	0.5	7.8	0.50	O	AI	Active
NAT15-1	588292	1106251	5287.96	14.5	4.0	5290.25	16.76	0.5	13.8	0.50	O	AI	Active
NAT15-2	588292	1106251	5287.96	12.5	4.0	5290.25	14.76	0.5	11.8	0.50	O	AI	Active
NAT15-3	588292	1106251	5287.96	10.5	4.0	5290.25	12.76	0.5	9.8	0.50	O	AI	Active
NAT16-1	587975	1106725	5288.43	12.3	4.0	5291.16	15.10	0.5	11.7	0.50	O	AI	Active
NAT16-2	587975	1106725	5288.43	10.5	4.0	5291.10	13.14	0.5	9.8	0.50	O	AI	Active
NAT16-3	587975	1106725	5288.43	8.5	4.0	5291.16	11.20	0.5	7.8	0.50	O	AI	Active
NAT17-1	587226	1107161	5293.65	11.3	4.0	5295.97	13.69	0.5	10.7	0.50	O	AI	Active
NAT17-2	587226	1107161	5293.65	9.3	4.0	5295.97	11.69	0.5	8.7	0.50	O	AI	Active
NAT17-3	587226	1107161	5293.65	7.3	4.0	5295.97	9.69	0.5	6.7	0.50	O	AI	Active
NAT18-1	587221	1107166	5293.66	11.3	4.0	5296.34	14.05	0.5	10.7	0.50	O	AI	Active
NAT18-2	587221	1107166	5293.66	9.3	4.0	5296.34	11.05	0.5	8.7	0.50	O	AI	Active
NAT18-3	587221	1107166	5293.66	7.3	4.0	5296.34	10.05	0.5	6.7	0.50	O	AI	Active
NAT19	587215	1107170	5293.82	11.3	4.0	5296.58	14.09	2.0	6.0	5.00	O	AI	Active
NAT20	586300	1107808	5301.43	10.5	4.0	5304.46	13.56	2.0	5.2	5.00	O	AI	Active
NAT21-1	586305	1107804	5301.47	10.0	4.0	5304.27	12.93	0.5	9.3	0.50	O	AI	Active
NAT21-2	586305	1107804	5301.47	8.0	4.0	5304.27	10.77	0.5	7.3	0.50	O	AI	Active
NAT21-3	586305	1107804	5301.47	6.0	4.0	5304.27	8.77	0.5	5.3	0.50	O	AI	Active
NAT22-1	586312	1107800	5301.47	10.0	4.0	5304.27	12.77	0.5	9.3	0.50	O	AI	Active
NAT22-2	586312	1107800	5301.47	8.0	4.0	5304.27	10.77	0.5	7.3	0.50	O	AI	Active
NAT22-3	586312	1107800	5301.47	6.0	4.0	5304.27	8.77	0.5	5.3	0.50	O	AI	Active

Table 4–1 (continued). Construction Details for Monitoring Wells Installed at the Naturita UMTRA Site

Location Code	North Coordinate, State Plane	East Coordinate, State Plane	Elevation of Land Surface, ft	Borehole Depth, ft	Borehole Diameter, inches	Elevation of Top of Casing, ft	Casing Length, ft	Casing Diameter, inches	Depth Below Land Surface, ft	Screen length, ft	Flow Code	Zone of Completion	Status
NAT23	589202	1106300	5283.07	10.0	4.0	5285.43	12.39	2.0	4.7	5.00	O	Al	Active
NAT24	589155	1106188	5285.11	9.5	4.0	5287.70	12.12	2.0	4.2	5.00	O	Al	Active
NAT25	589082	1106053	5289.39	15.5	4.0	5291.88	18.02	2.0	10.2	5.00	O	Al	Active
NAT26	588685	1106027	5293.23	16.0	4.0	5295.54	18.34	2.0	10.7	5.00	O	Al	Active
NAT27-1	587764	1107221	5289.81	7.3	4.0	5292.79	10.35	0.5	6.7	0.50	O	Al	Active
NAT27-2	587764	1107221	5289.81	5.3	4.0	5292.79	8.35	0.5	4.7	0.50	O	Al	Active
NAT27-3	587764	1107221	5289.81	3.3	4.0	5292.79	6.35	0.5	2.7	0.50	O	Al	Active
NAT28-1	587759	1107225	5289.88	7.3	4.0	5292.61	10.10	0.5	6.7	0.50	O	Al	Active
NAT28-2	587759	1107225	5289.88	5.3	4.0	5292.61	8.10	0.5	4.7	0.50	O	Al	Active
NAT28-3	587759	1107225	5289.88	3.3	4.0	5292.61	6.10	0.5	2.7	0.50	O	Al	Active
NAT29	587752	1107229	5290.08	6.8	4.0	5292.89	9.54	2.0	1.4	5.00	O	Al	Active
NAT30-1	586831	1107504	5297.04	8.5	4.0	5300.05	11.48	0.5	7.8	0.50	O	Al	Active
NAT30-2	586831	1107504	5297.04	6.5	4.0	5300.02	9.45	0.5	5.8	0.50	O	Al	Active
NAT30-3	586831	1107504	5297.04	4.5	4.0	5300.00	7.43	0.5	3.8	0.50	O	Al	Active
MAU01	589377	1106207	5283.19	14.5	9.0	5284.89	16.53	2.0	9.5	5.00	D	Al	Active
MAU02-1	589365	1106377	5282.44	16.5	9.0	5284.54	18.77	0.5	16.0	0.50	D	Al	Active
MAU02-2	589365	1106377	5282.46	11.2	9.0	5284.56	13.47	0.5	10.7	0.50	D	Al	Active
MAU02-3	589365	1106377	5282.46	9.6	9.0	5284.56	7.87	0.5	9.1	0.50	D	Al	Active
MAU03	589907	1106726	5275.29	9.5	10.0	5277.64	12.18	2.0	2.5	5.00	D	Al	Active
MAU04	590085	1106620	5274.10	10.5	9.0	5275.80	12.53	2.0	3.5	5.00	D	Al	Active
MAU05	589394	1106342	5282.13	9.0	9.0	5284.33	11.53	2.0	8.5	5.00	D	Al	Active
MAU06	589655	1106565	5279.43	8.8	4.0	5281.85	11.25	2.0	3.5	5.00	D	Al	Active
MAU07	590209	1106507	5273.16	8.3	4.0	5275.90	10.97	2.0	2.9	5.00	D	Al	Active
MAU08	589375	1106097	5283.51	11.5	4.0	5286.44	14.46	2.0	6.2	5.00	D	Al	Active
0502	586923	1106997	5348.90	249.0	6.0	5350.30	249.00	2.0	229.3	20.00	U	JS	Destroyed
0503	586588	1107630	5301.10	165.0	6.0	5302.50	165.00	2.0	140.0	25.00	U	JS	Destroyed
0505	587411	1107326	5297.90	24.0	6.0	5300.90	23.00	2.0	16.0	5.00	O	Al	Destroyed
0506	587257	1107057	5304.70	27.0	6.0	5306.30	27.00	2.0	22.5	5.00	O	Al	Destroyed
0546	586414	1107771	5302.10	23.0	6.0	5304.10	17.00	2.0	10.0	5.00	U	Al	Destroyed
0547	586276	1107988	5303.10	23.0	6.0	5304.80	22.00	2.0	10.0	10.00	U	Al	Active
0548	588903	1106435	5288.70	23.0	2.0	5290.40	14.60	2.0	16.0	5.00	O	Al	Active
0549	586184	1107902	5302.40	15.0	5.6	5304.50	17.00	2.0	11.5	5.00	U	Al	Destroyed
0616	587957	1106403	5288.50	7.6	ND	5290.90	10.00	3.0	2.5	2.50	O	Al	Destroyed
0619	588211	1106716	5288.90	8.0	ND	5291.10	10.00	3.0	7.5	2.50	O	Al	Destroyed
0630	588017	1107115	5289.80	7.5	ND	5292.50	10.00	3.0	7.5	2.50	O	Al	Destroyed
0632	587614	1106880	5289.00	8.0	ND	5291.70	10.00	3.0	7.5	2.50	O	Al	Destroyed
0637	587659	1107178	5288.50	5.5	ND	5291.30	8.00	3.0	5.5	2.50	O	Al	Destroyed
0656	588367	1106400	5287.90	9.0	ND	5288.90	10.00	3.0	7.5	2.50	O	Al	Destroyed
DM1	585970	1108417	5302.74	8.0	4.0	5305.95	11.24	2.0	2.7	5.00	U	Al	Active

Flow Codes
D downgradient
O on site
U upgradient
Zones of Completion
Al Alluvium
JS Jurassic Salt Wash Formation

Table 4–2. Measured Water Table Elevation in Wells at the Naturita Site from November 1998 to March 2001

Well ID	Date	Water Table Elevation (ft above sea level)
NAT01-1	11/18/98	5279.12
	12/18/98	5279.24
	01/27/99	5279.14
	02/24/99	5278.85
	03/22/99	5279.57
	05/13/99	5280.44
	06/07/99	5280.39
	09/02/99	5280.14
	09/20/99	5279.68
	11/10/99	5279.26
	02/28/00	5279.10
	06/13/00	5280.07
	11/29/00	5279.02
	02/27/01	5278.99
NAT01-2	11/18/98	5279.14
	12/18/98	5279.28
	01/27/99	5279.16
	02/24/99	5278.87
	03/22/99	5279.58
	05/13/99	5280.49
	06/07/99	5280.41
	09/02/99	5280.21
	09/20/99	5279.77
	11/10/99	5279.28
	02/28/00	5279.13
	06/13/00	5280.09
NAT02	11/17/98	5282.04
	12/18/98	5282.12
	01/27/99	5282.03
	02/24/99	5281.60
	03/22/99	5282.65
	05/13/99	5283.38
	06/07/99	5283.35
	09/02/99	5283.15
	09/20/99	5282.58
	11/10/99	5282.17
	02/28/00	5282.06
	06/13/00	5282.94
	11/29/00	5281.80
	02/29/01	5281.92
NAT03	11/18/98	5280.24
	12/18/98	5280.36
	01/27/99	5280.25
	02/24/99	5279.89
	03/22/99	5280.80
	05/13/99	5281.62
	06/07/99	5281.52
	09/02/99	5281.41
	09/20/99	5280.85
	11/09/99	5280.43
	02/28/00	5280.27
	06/13/00	5281.28
	11/29/00	5280.15
	02/27/01	5280.11
NAT04-1	11/17/98	5281.95
	12/18/98	5282.00
	01/27/99	5281.88
	02/24/99	5281.52
	03/22/99	5282.49
	05/13/99	5283.24
	06/07/99	5283.13
	09/02/99	5282.98
NAT04-1 (cont.)	09/20/99	5282.48
	11/09/99	5281.99
	02/28/00	5281.92
	06/13/00	5282.81
	11/28/00	5281.80
	02/28/01	5281.97
NAT04-2	11/17/98	5282.03
	12/18/98	5282.04
	01/27/99	5281.93
	02/24/99	5281.55
	03/22/99	5282.53
	05/13/99	5283.29
	06/07/99	5283.17
	09/02/99	5283.01
	09/20/99	5282.52
	11/09/99	5282.04
	02/28/00	5281.97
	06/13/00	5282.89
NAT04-3	11/17/98	5282.00
	12/18/98	5282.06
	01/27/99	5281.94
	02/24/99	5281.55
	03/22/99	5282.55
	05/13/99	5283.30
	06/07/99	5283.19
	09/02/99	5283.01
	09/20/99	5282.52
	11/09/99	5282.04
	02/28/00	5281.97
	06/13/00	5282.89
NAT05	11/18/98	5280.23
	12/18/98	5280.24
	01/27/99	5280.18
	02/24/99	5279.94
	03/22/99	5280.60
	05/13/99	5281.54
	06/07/99	5281.44
	09/02/99	5281.31
	09/20/99	5280.79
	11/09/99	5280.32
	02/28/00	5280.17
	06/13/00	5281.17
NAT06-1	11/17/98	5281.83
	12/18/98	5281.79
	01/27/99	5281.68
	02/24/99	5281.33
	03/22/99	5282.23
	05/13/99	5283.03
	06/07/99	5282.93
	09/02/99	5282.81
	09/20/99	5282.28
	11/09/99	5281.78
	02/28/00	5281.73
	06/13/00	5282.65
	11/29/00	5281.58
	02/28/01	5281.68
NAT06-2	11/17/98	5281.81
	12/18/98	5281.78
	01/27/99	5281.66
	02/24/99	5281.31
	03/22/99	5282.22
NAT06-2 (cont.)	05/13/99	5283.02
	06/07/99	5282.92
	09/02/99	5282.81
	09/20/99	5282.28
	11/09/99	5281.77
	02/28/00	5281.73
	06/13/00	5282.63
NAT06-3	11/17/98	DRY
	12/18/98	DRY
	01/27/99	DRY
	02/24/99	DRY
	03/22/99	DRY
	05/13/99	DRY
	06/07/99	5283.09
	09/02/99	5282.99
	09/20/99	5282.95
	11/09/99	DRY
	02/28/00	DRY
	06/11/00	DRY
NAT07-1	11/18/98	5280.25
	12/18/98	5280.43
	01/27/99	5280.31
	02/24/99	5279.91
	03/22/99	5280.89
	05/13/99	5281.63
	06/07/99	5281.51
	09/02/99	5281.43
	09/20/99	5280.88
	11/09/99	5280.48
	02/28/00	5280.32
	06/13/00	5281.25
NAT07-2	11/18/98	5280.22
	12/18/98	5280.40
	01/27/99	5280.27
	02/24/99	5279.89
	03/22/99	5280.86
	05/13/99	5281.60
	06/07/99	5281.50
	09/02/99	5281.41
	09/20/99	5280.86
	11/09/99	5280.43
	02/28/00	5280.29
	06/13/00	5281.22
NAT07-3	11/18/98	5280.23
	12/18/98	5280.43
	01/27/99	5280.30
	02/24/99	5279.92
	03/22/99	5280.89
	05/13/99	5281.63
	06/07/99	5281.49
	09/02/99	5281.43
	09/20/99	5280.87
	11/09/99	5280.44
	02/28/00	5280.30
	06/13/00	5281.23
NAT08	11/18/98	5280.27
	12/18/98	5280.38
	01/27/99	5280.26
	02/24/99	5279.89
	03/22/99	5280.74
	05/13/99	5281.57

Table 4–2 (continued). Measured Water Table Elevation in Wells at the Naturita Site from November 1998 to March 2001

Well ID	Date	Water Table Elevation (ft above sea level)
NAT08 (cont.)	06/07/99	5281.47
	09/02/99	5281.42
	09/20/99	5280.83
	11/09/99	5280.43
	02/28/00	5280.30
	06/13/00	5281.14
	11/29/00	5280.17
	02/27/01	5280.14
NAT09	11/18/98	5280.27
	12/18/98	5280.37
	01/27/99	5280.28
	02/24/99	5279.91
	03/22/99	5280.82
	05/13/99	5281.62
	06/07/99	5281.51
	09/02/99	5281.42
	09/20/99	5280.89
	11/09/99	5280.42
	02/28/00	5280.28
	06/13/00	5281.27
NAT10	11/18/98	5280.62
	12/18/98	5280.72
	01/27/99	5280.64
	02/24/99	5280.33
	03/22/99	5281.14
	05/13/99	5281.99
	06/07/99	5281.91
	09/02/99	5281.73
	09/20/99	5281.23
	11/09/99	5280.73
	02/28/00	5280.64
	06/13/00	5281.59
	11/29/00	5280.56
	02/27/01	5280.49
NAT11	11/17/98	5283.98
	12/18/98	5284.15
	01/27/99	5284.02
	02/24/99	5283.75
	03/22/99	5284.60
	05/13/99	5285.52
	06/07/99	5285.43
	09/02/99	5285.26
	09/20/99	5284.67
	11/09/99	5284.11
	02/28/00	5284.12
	06/13/00	5285.04
	11/28/00	5284.05
	02/28/01	5284.13
NAT12-1	11/18/98	5279.14
	12/18/98	5279.15
	01/27/99	5279.09
	02/24/99	5278.89
	03/22/99	5279.31
	05/13/99	5280.33
	06/07/99	5280.32
	09/02/99	5280.07
	09/20/99	5279.68
	11/10/99	5279.20
	02/28/00	5279.01
	06/13/00	5279.98
NAT12-2	11/18/98	5279.41
NAT12-2 (cont.)	12/18/98	5279.35
	01/27/99	5279.38
	02/24/99	DRY
	03/22/99	5279.33
	05/13/99	5280.39
	06/07/99	5280.33
	09/02/99	5280.13
	09/20/99	5279.69
	11/10/99	DRY
	02/28/00	DRY
	06/13/00	5280.00
NAT13-1	09/02/99	5285.25
	09/20/99	5284.67
	11/09/99	5284.12
	02/28/00	5284.12
	06/13/00	5285.08
NAT13-2	09/02/99	5285.23
	09/20/99	5284.66
	11/09/99	5284.10
	02/28/00	5284.08
	06/13/00	5285.07
NAT13-3	09/02/99	5285.25
	09/20/99	5284.67
	11/09/99	5284.12
	02/28/00	5284.11
	06/13/00	5285.09
NAT14-1	09/02/99	5285.24
	09/20/99	5284.69
	11/09/99	5284.11
	02/28/00	5284.11
	06/13/00	5285.08
NAT14-2	09/02/99	5285.22
	09/20/99	5284.67
	11/09/99	5284.11
	02/28/00	5284.10
	06/13/00	5285.07
NAT14-3	09/02/99	5285.23
	09/20/99	5284.68
	11/09/99	5284.12
	02/28/00	5284.11
	06/13/00	5285.09
NAT15-1	09/02/99	5281.35
	09/20/99	5280.82
	11/09/99	5280.37
	02/28/00	5280.21
	06/13/00	5281.20
	11/29/00	5280.15
	02/27/01	5280.08
NAT15-2	09/02/99	5281.32
	09/20/99	5280.80
	11/09/99	5280.33
	02/28/00	5280.19
	06/13/00	5281.16
NAT15-3	09/02/99	5281.33
	09/20/99	5280.79
	11/09/99	5280.33
	02/28/00	5280.20
NAT15-3 (cont.)	06/13/00	5281.15
NAT16-1	09/02/99	5282.95
	09/20/99	5282.45
	11/09/99	5281.98
	02/28/00	5281.93
	06/13/00	5282.82
	11/28/00	5281.73
	02/28/01	5281.96
NAT16-2	09/02/99	5282.94
	09/20/99	5282.46
	11/09/99	5281.99
	02/28/00	5281.92
	06/13/00	5282.81
NAT16-3	09/02/99	5283.00
	09/20/99	5282.51
	11/09/99	5282.03
	02/28/00	5281.98
	06/13/00	5282.85
NAT17-1	09/02/99	5289.57
	09/20/99	5288.94
	11/09/99	5288.29
	02/28/00	5288.16
	06/13/00	5289.23
NAT17-2	09/02/99	5289.57
	09/20/99	5288.93
	11/09/99	5288.29
	02/28/00	5288.15
	06/13/00	5289.22
NAT17-3	09/02/99	5289.57
	09/20/99	5288.93
	11/09/99	5288.30
	02/28/00	5288.15
	06/13/00	5289.22
NAT18-1	09/02/99	5289.56
	09/20/99	5288.89
	11/09/99	5288.28
	02/28/00	5288.14
	06/13/00	5289.20
NAT18-2	09/02/99	5289.55
	09/20/99	5288.88
	11/09/99	5288.26
	02/28/00	5288.12
	06/13/00	5289.19
NAT18-3	09/02/99	5289.55
	09/20/99	5288.85
	11/09/99	5288.24
	02/28/00	5288.11
	06/13/00	5289.18
NAT19	09/02/99	5289.58
	09/20/99	5288.90
	11/09/99	5288.24
	02/28/00	5288.13
	06/13/00	5289.22
	11/28/00	5287.94
	02/28/01	5287.99

Table 4–2 (continued). Measured Water Table Elevation in Wells at the Naturita Site from November 1998 to March 2001

Well ID	Date	Water Table Elevation (ft above sea level)
NAT20	09/02/99	5296.64
	09/20/99	5295.97
	11/08/99	5295.12
	02/28/00	5295.18
	06/13/00	5295.51
	11/28/00	5294.20
	02/28/01	5294.84
NAT21-1	09/02/99	5296.66
	09/20/99	5295.98
	11/08/99	5295.14
	02/28/00	5295.20
	06/13/00	5295.48
NAT21-2	09/02/99	5296.66
	09/20/99	5295.98
	11/08/99	5295.15
	02/28/00	5295.22
	06/13/00	5295.47
NAT21-3	09/02/99	5296.66
	09/20/99	5296.01
	11/08/99	DRY
	02/28/00	DRY
	06/09/00	DRY
NAT22-1	09/02/99	5296.63
	09/20/99	5295.97
	11/08/99	5295.11
	02/28/00	5295.19
	06/13/00	5295.45
NAT22-2	09/02/99	5296.63
	09/20/99	5295.97
	11/08/99	5295.12
	02/28/00	5295.19
	06/13/00	5295.46
NAT22-3	09/02/99	5296.63
	09/20/99	5295.95
	11/08/99	DRY
	02/28/00	DRY
	06/13/00	DRY
NAT23	09/02/99	5278.44
	09/20/99	5277.85
	11/09/99	5277.53
	02/28/00	5277.38
	06/13/00	5278.08
	11/30/00	5277.07
	02/27/01	5277.10
NAT24	09/02/99	5279.55
	09/20/99	5279.06
	11/09/99	5278.72
	02/28/00	5278.53
	06/13/00	5279.41
	11/30/00	5278.29
	03/01/01	5278.37
NAT25	09/02/99	5279.46
	09/20/99	5278.99
	11/10/99	5278.58
	02/28/00	5278.44
	06/13/00	5279.33
	11/30/00	5278.27
NAT25 (cont.)	03/01/01	5278.31
NAT26	09/02/99	5279.89
	09/20/99	5279.44
	11/10/99	5278.97
	02/28/00	5278.79
	06/13/00	5279.74
	11/29/00	5278.59
	03/01/01	5278.60
NAT27-1	09/02/99	5286.04
	09/20/99	5285.40
	11/09/99	5284.87
	02/28/00	5284.84
	06/13/00	5285.77
	11/28/00	5284.70
	02/28/01	5284.80
NAT27-2	09/02/99	5286.07
	09/20/99	5285.43
	11/09/99	5284.92
	02/28/00	5284.87
	06/13/00	5285.78
NAT27-3	09/02/99	DRY
	09/20/99	DRY
	11/09/99	DRY
	02/28/00	DRY
	06/10/00	DRY
NAT28-1	09/02/99	5286.06
	09/20/99	5285.44
	11/09/99	5284.92
	02/28/00	5284.87
	06/13/00	5285.80
NAT28-2	09/02/99	5286.06
	09/20/99	5285.43
	11/09/99	5284.91
	02/28/00	5284.87
	06/13/00	5285.80
NAT28-3	09/02/99	DRY
	09/20/99	DRY
	11/09/99	DRY
	02/28/00	DRY
	06/10/00	DRY
NAT29	09/02/99	5285.91
	09/20/99	5285.36
	11/09/99	5284.87
	02/28/00	5285.00
	06/13/00	5285.75
	11/28/00	5284.94
	02/28/01	5284.75
NAT30-1	09/02/99	5292.88
	09/20/99	5292.28
	11/09/99	5291.66
	02/28/00	5291.64
	06/13/00	5292.39
	11/28/00	5291.02
	02/28/01	5291.28
NAT30-2	09/02/99	5292.93
	09/20/99	5292.35
NAT30-2 (cont.)	11/09/99	5291.71
	02/28/00	5291.70
	06/13/00	5292.44
NAT30-3	09/02/99	DRY
	09/20/99	DRY
	11/09/99	DRY
	02/28/00	DRY
	06/09/00	DRY
MAU01	11/19/98	5274.52
	12/18/98	5274.61
	01/27/99	5274.60
	02/24/99	5274.51
	03/22/99	5274.79
	05/13/99	5275.78
	06/07/99	5275.51
	09/02/99	5275.31
	09/20/99	5274.72
	11/09/99	5274.63
	02/28/00	5274.59
	06/13/00	5274.73
MAU02-1	11/19/98	5274.43
	12/18/98	5274.50
	01/27/99	5274.49
	02/24/99	5274.38
	03/22/99	5274.72
	05/13/99	5275.75
	06/07/99	5275.45
	09/02/99	5275.26
	09/20/99	5274.66
	11/09/99	5274.55
	02/28/00	5274.50
	06/13/00	5274.61
MAU02-2	11/19/98	5274.48
	12/18/98	5274.57
	01/27/99	5274.56
	02/24/99	5274.40
	03/22/99	5274.77
	05/13/99	5275.78
	06/07/99	5275.47
	09/02/99	5275.30
	09/20/99	5274.69
	11/09/99	5274.58
	02/28/00	5274.52
	06/13/00	5274.71
MAU02-3	11/19/98	5274.47
	12/18/98	5274.57
	01/27/99	5274.56
	02/24/99	5274.43
	03/22/99	5274.78
	05/13/99	5275.78
	06/07/99	5275.47
	09/02/99	5275.30
	09/20/99	5274.70
	11/09/99	5274.58
	02/28/00	5274.52
	06/13/00	5274.71
MAU03	11/19/98	5271.71
	12/18/98	5271.81
	01/27/99	5271.80
	02/24/99	5271.60

Table 4–2 (continued). Measured Water Table Elevation in Wells at the Naturita Site from November 1998 to March 2001

Well ID	Date	Water Table Elevation (ft above sea level)
MAU03 (cont.)	03/22/99	5272.05
	05/13/99	5272.56
	06/07/99	5272.20
	09/02/99	5272.34
	09/20/99	5271.80
	11/09/99	5271.84
	02/28/00	5271.82
	06/13/00	5271.50
	11/30/00	5271.75
	03/01/01	5271.85
MAU04	11/19/98	5269.58
	12/18/98	5269.63
	01/27/99	5269.67
	02/24/99	5269.56
	03/22/99	5269.75
	05/13/99	5269.97
	06/07/99	5269.75
	09/02/99	5269.91
	09/20/99	5269.66
	11/09/99	5269.75
	03/01/01	5269.75
	02/28/00	5269.77
	06/13/00	5269.35
	11/30/00	5269.55
MAU05	11/19/98	5274.37
	12/18/98	5274.46
	01/27/99	5274.46
	02/24/99	5274.33
	03/22/99	5274.65
	05/13/99	5275.63
	06/07/99	5275.34
	09/02/99	5275.16
	09/20/99	5274.57
	11/09/99	5274.47
	02/28/00	5274.47
	06/13/00	5274.56
	11/30/00	5274.18
	03/01/01	5274.38
MAU06	09/02/99	5274.22
	09/20/99	5273.57
	11/09/99	5273.61
	02/28/00	5273.60
	06/13/00	5273.27
	11/30/00	5273.36
	03/01/01	5273.56
MAU07	09/02/99	5269.61
	09/20/99	5269.22
	11/09/99	5269.38
	02/28/00	5269.37
	06/13/00	5268.82
	12/01/00	5269.08
	03/01/01	5269.47
MAU08	09/02/99	5276.28
	09/20/99	5275.76
	11/09/99	5275.62
	02/28/00	5275.56
	06/13/00	5275.89
	11/30/00	5275.34
	03/01/01	5275.55
0547	06/16/86	5295.51
0547 (cont.)	02/24/99	5295.06
	03/22/99	5295.15
	05/13/99	5296.14
	06/07/99	5296.22
	09/02/99	5296.63
	09/20/99	5295.93
	11/09/99	5295.05
	02/28/00	5295.12
	06/13/00	5295.41
	11/28/00	5294.25
	02/25/01	5294.84
0548	06/17/86	5281.95
	02/24/99	5278.41
	03/22/99	5279.19
	05/13/99	5279.85
	06/07/99	5281.70
	09/02/99	5279.62
	09/20/99	5279.15
	11/10/99	5278.72
	02/28/00	5278.58
	06/13/00	5279.50
	11/29/00	5278.48
	02/27/01	5278.35
DM1	09/02/99	5298.32
	09/20/99	5297.77
	11/10/99	5297.67
	02/28/00	5297.83
	06/13/00	5297.29
	12/01/00	5297.48
	03/02/01	5297.90

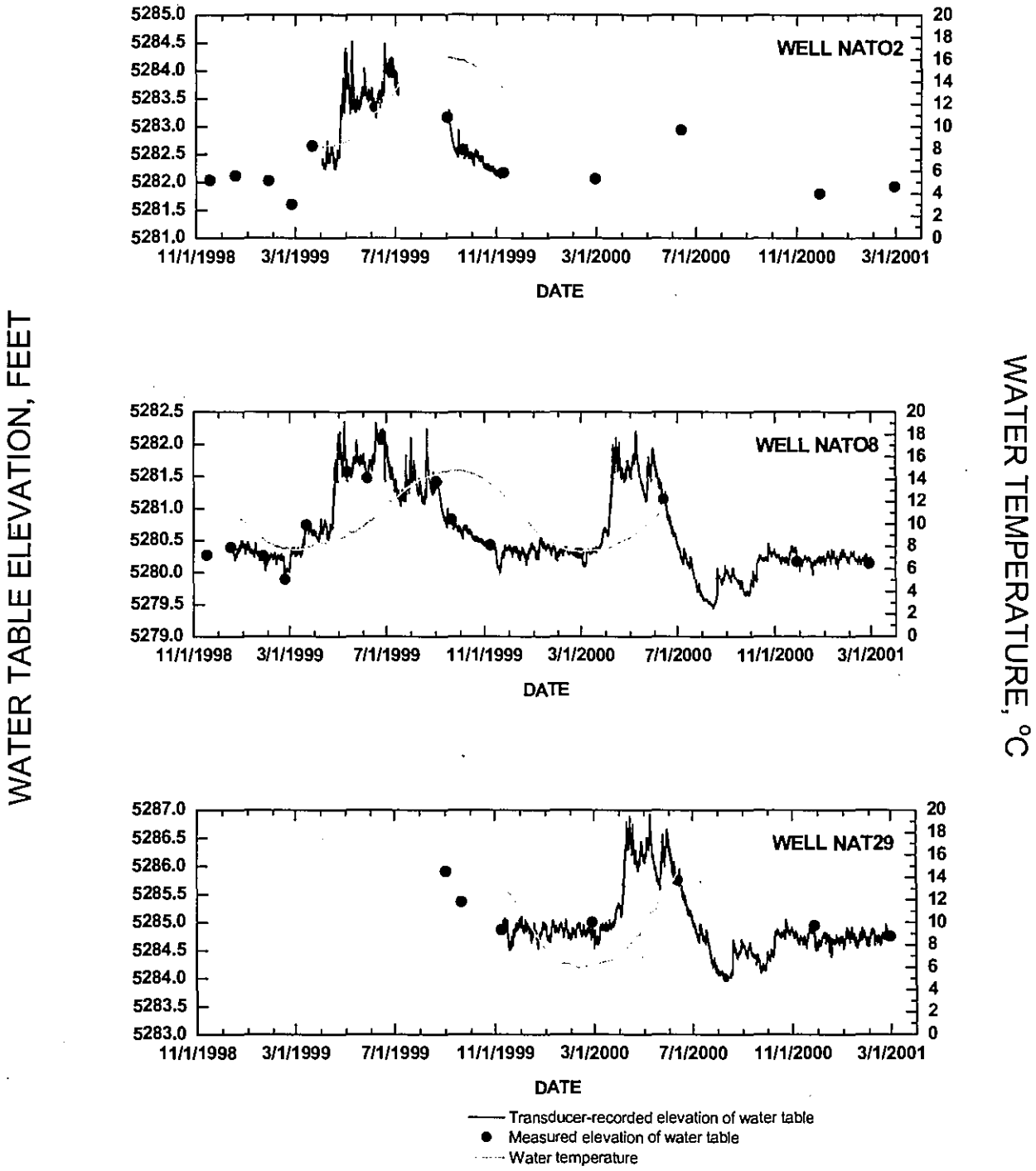


Figure 4–4. Water Level and Water Temperature Recorded in Wells NAT02, NAT08, and NAT29 at the Naturita Site

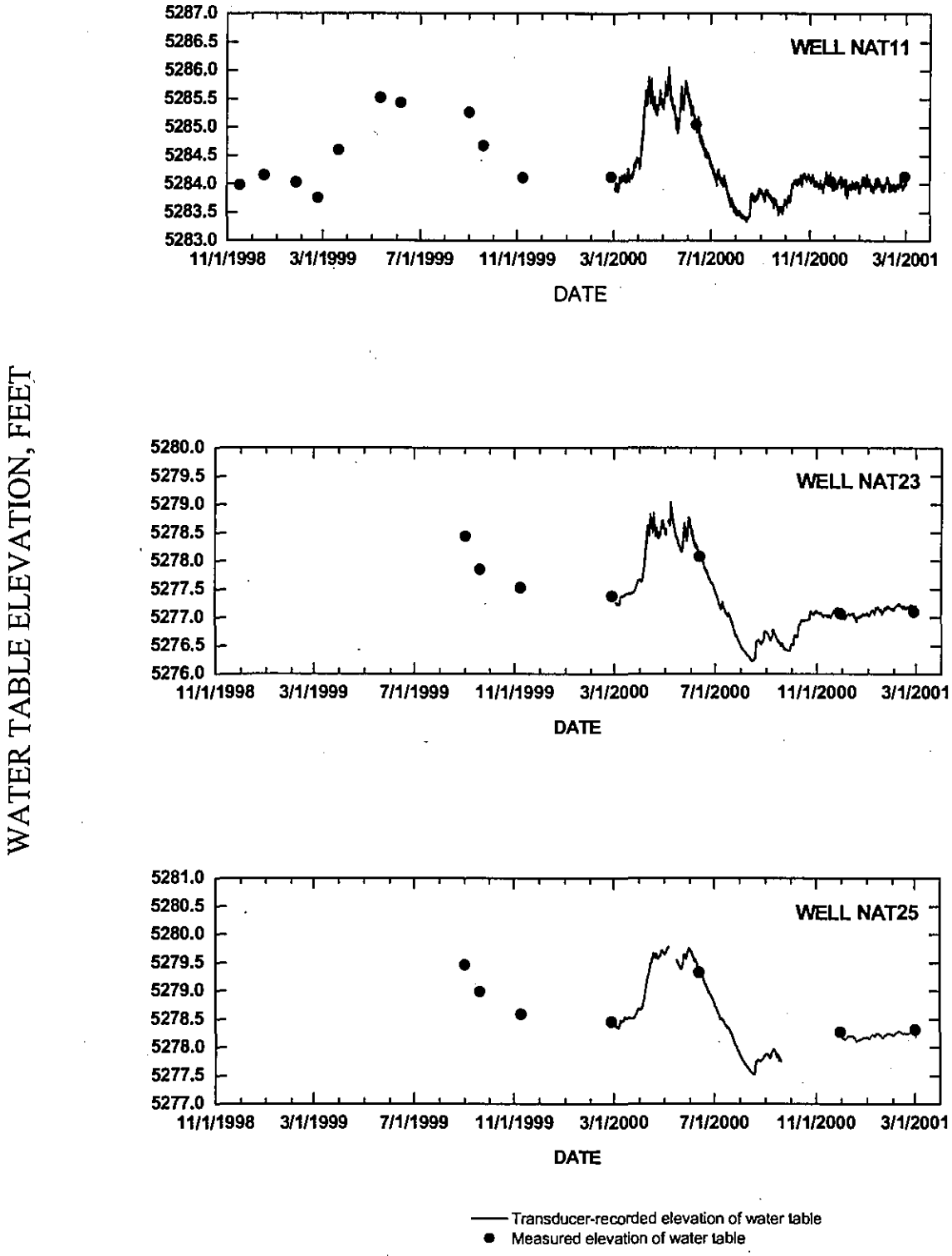


Figure 4–5. Water Table Elevation for Wells NAT11, NAT23, and NAT25

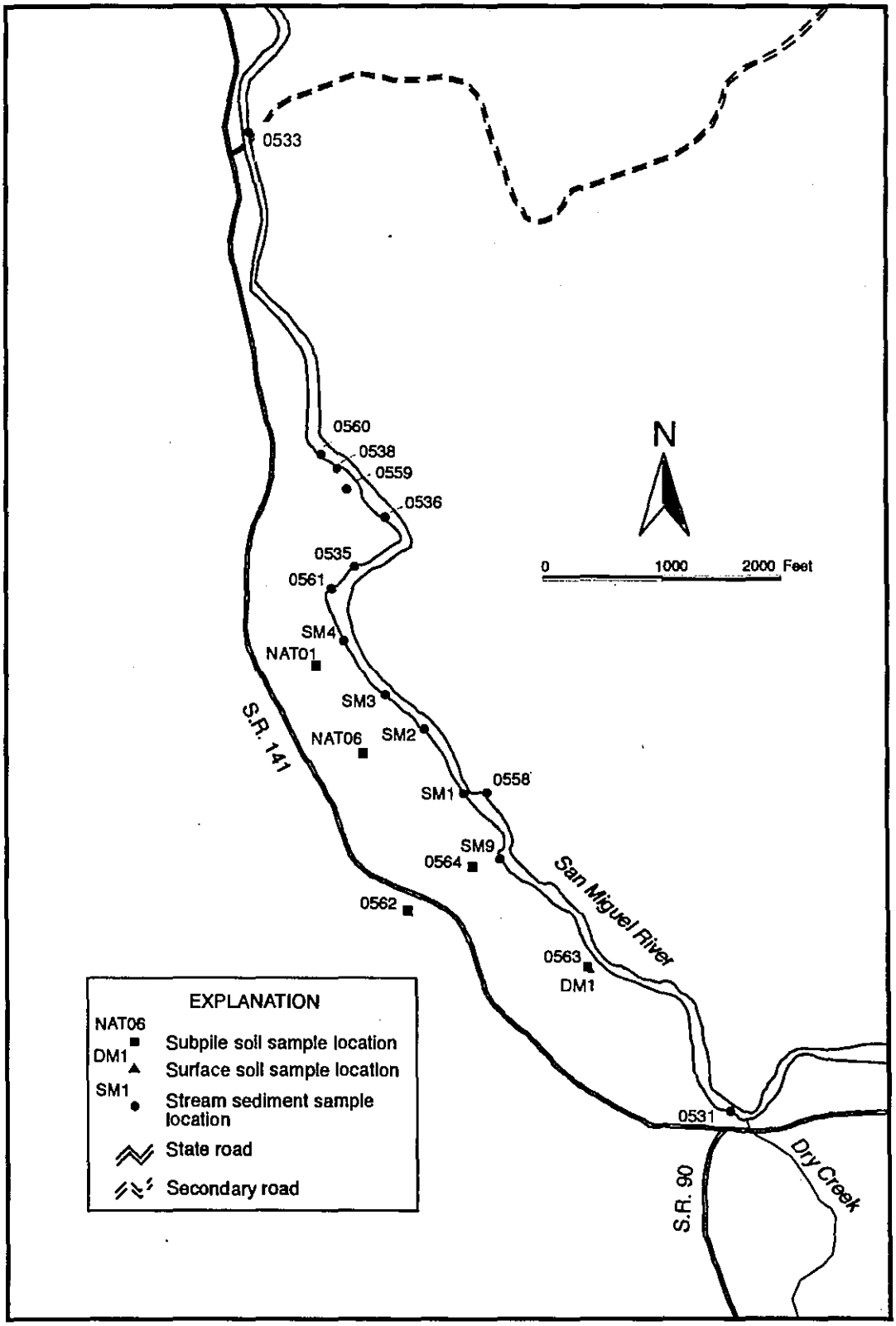


Figure 4–6. Soil and Sediment Sampling Locations

On July 16 and 17, 1998, a background sediment sample was collected from saturated alluvium about half way between well 0547 and well DM1 (Figure 4–6). The sample was screened in the field to remove cobbles larger than about 65 millimeter (mm), and it was estimated visually that about 30 to 50 percent of the material scooped by the backhoe did not pass the 65 mm screen.

Uranium-contaminated material from the saturated zone of the alluvial aquifer was collected from auger flights during installation of monitoring wells in October 1998. The subsurface material was air dried and sieved through 3-mm sieves.

DOE collected additional soil samples in March 2001 with a backhoe. Samples from locations 0564 and 0563 were collected at the water table, which was at a depth of 6 and 5 ft below land surface, respectively. At location 0562, which is southwest of the site and above the alluvial aquifer, the sample was collected from below the fill material at a depth of 2 ft below land surface. This location is a former ore storage area that was remediated under the surface program. Samples were collected from the backhoe bucket and placed in a sealed plastic bag. During excavation, the clean fill that had been emplaced during reclamation was placed in one pile and the native subsurface material in another. When the hole was refilled, the native material was replaced first and clean fill was used to cover it.

Surface composite and stream bottom sediment samples were collected during December 2000 and January 2001. Surface and stream sediment samples were collected with a clean shovel and placed in a sealed plastic bag. Samples were composited from a 10-ft radius at each sample location. Approximately 2.5 pounds of sample were collected at each site.

4.4 Lithologic Logging

Lithologic descriptions of the alluvial material were recorded from drill cuttings during installation of monitoring wells NAT13 through NAT30, DM1, MAU07, and MAU08 in June 1999. No attempt was made at split barrel sampling due to the difficulty in retrieving unconsolidated silt, sand, and gravel. No attempt was made at lithologically logging the underlying Salt Wash Member of the Morrison Formation. Appendix A presents the lithologic well logs recorded by the site geologist.

4.5 Distribution Coefficient (K_d) Analysis

The K_d is a bulk parameter that has been used with some success to describe the retardation of contaminant movement in an aquifer system. Laboratory measurements to estimate the K_d for selected analytes were performed on alluvial material to support computer-modeling efforts in characterizing subsurface contaminant transport at the Naturita site. The analysis presented here was performed by the Grand Junction Office (GJO) Environmental Sciences Laboratory according to standard procedures used at UMTRA Ground Water Project sites (DOE 1999b). Analyses using a somewhat different methodology were also performed by the USGS; these are presented in Appendix E.

4.5.1 Method of Solution

Laboratory analyses were performed according to procedure MAC 3017 (DOE 1999b), which is slightly modified from American Society for Testing and Materials (ASTM) procedure D 4646–87 (ASTM 1993), for two site-related contaminants of potential concern (COPCs): uranium and vanadium. This procedure is a 24-hour test and obtains a parameter that is an estimate of the

K_d—the distribution ratio (R_d). K_d and R_d are defined identically, though K_ds are considered to be equilibrium values and R_ds may or may not represent equilibrium. R_d is one of the most commonly used estimates for the K_d.

The procedure involves placing a sample representative of a location (e.g., soil, sediments, cuttings, core) into a solution representative of contaminated ground water with which the material is likely to come in contact. The ground water solution is agitated for 24 hours and then centrifuged. The supernatant solution is analyzed and compared to the contaminant concentrations of the original solution. The difference between the two is assumed to be adsorbed to the sample. The linear adsorption isotherm distribution coefficient is generally defined as

$$C_{soil} = K_d \times C_{water}, \text{ which can be rearranged to } K_d = C_{soil}/C_{water},$$

or the ratio of the concentration of the contaminant in soil (or other material of interest) to the concentration of the contaminant in water at equilibrium. Therefore, the higher the K_d, the greater the retardation of contaminant movement in ground water.

The procedure requires analysis of only the solutions (and no actual soil samples) used in the experiments. Site samples collected from background areas or uncontaminated site samples are generally used, and all contaminant loss in the final solution is attributed to sample adsorption.

4.5.1.1 Sample Selection

A sample of background alluvial material (>5 kilograms [kg]) was collected above the water table approximately 30 ft west of background well DM1 (Figure 4–6) on August 22, 2001. The sample was considered uncontaminated because concentrations of dissolved uranium in water samples from well DM1 (and decommissioned DOE wells nearby) were always near the background uranium concentrations in the San Miguel River. The background sample of alluvium was screened in the field to remove cobbles larger than about 65 mm, and it was visually estimated that about 50 percent of the material scooped by the backhoe did not pass the 65-mm screen.

4.5.1.2 Sample Preparation and Processing

The sample was air dried at room temperature. The greater than 6.6-mm fraction was removed based on visual examination. The remainder of the sample was sieved to separate the <2 mm fraction. Of the sample submitted for laboratory analysis, approximately 51 percent of the grain size was <2 mm, 15 percent was between 6.6 mm and 2 mm, and the remaining 34 percent was >6.6 mm.

A 2.5 liter (L) sample of San Miguel River water was collected for use in the K_d determinations. Because the San Miguel River is the primary source of recharge for the alluvial aquifer, it is assumed that river water upgradient of the site is representative of uncontaminated alluvial aquifer water. The water sample was filtered through a 0.45 micrometer (μm) filter and refrigerated until ready for use. An aliquot of the San Miguel River sample was spiked with vanadium and uranium to produce a 1 mg/L concentration of each. Three spiked water samples were retained as control samples—one sample was simply refrigerated before analysis; the other two were processed in the same manner as the samples for K_d determinations but without inclusion of soil.

To prepare samples for K_d analysis, 8 samples of soil ranging from 0.5 g to 30 gram (g) were each placed in 125-milliliter (mL) Nalgene bottles; 100 mL of spiked water was added to each sample. These samples, along with the two spiked water samples without soil, were placed on a rotating stir bar (8 revolutions per minute [rpm]) for 24 hours. Samples were then removed from the stir bar, centrifuged, filtered through a 0.45 µm filter, and acidified before submission to the Analytical Chemistry Laboratory for uranium and vanadium analysis. Unprocessed water samples were also analyzed as control samples.

4.5.1.3 Sample Results

Analytical results are presented in Tables 4–3 and 4–4. Table 4–3 contains results of the control sample analysis. Results indicate that only minor amounts of uranium and vanadium occur in San Miguel River water. Little difference exists between processed and unprocessed spiked samples; concentrations of uranium and vanadium in sample NAT-DM1-B1 were determined to be suitable for use as initial concentrations for purposes of performing K_d calculations.

Table 4–3. Laboratory Analytical Results for Control Water Samples

Sample ID	Sample Description	Solution Volume (mL)	Target Concentration (mg/L)		Analyzed Concentration (mg/L)	
			U	V	U	V
NAT-DM1-R	Unprocessed San Miguel River (SMR) water—no spikes	100	na	na	0.0024	0.0061
NAT-DM1-P	Unprocessed SMR with spikes	100	1.0	1.0	0.913	0.971
NAT-DM1-B1*	Processed spiked SMR water	100	na	na	0.91	0.98
NAT-BM1-B2	Processed spiked SMR water	100	na	na	0.925	0.982

*Used for initial concentrations
na = not applicable
Note: initial pH of spiked SMR sample was 6.94; alkalinity was 110 mg/L $CaCO_3$

Table 4–4 presents the analyses of final solutions contacted with differing masses of site soils. Based on the volume and concentration of water samples used, the mass of sorbed uranium and vanadium was calculated for each sample.

Table 4–4. Analytical Results for Soil-Contacted Solutions

Sample ID	Solution Volume (mL)	Sample Mass (g)	Final Solution Concentration (mg/L)		Mass Sorbed (mg)	
			U	V	U	V
NAT-DM1-0.5	100	0.5	0.89	0.9	0.002	0.008
NAT-DM1-1.0	100	1.0	0.885	0.781	0.0025	0.0199
NAT-DM1-2.5	100	2.5	0.861	0.568	0.0049	0.0412
NAT-DM1-5	100	5.0	0.808	0.327	0.0102	0.0653
NAT-DM1-10	100	10.0	0.746	0.149	0.0164	0.0831
NAT-DM1-20	100	20.0	0.66	0.0627	0.025	0.09173
NAT-DM1-25	100	25.0	0.643	0.0496	0.0267	0.09304
NAT-DM1-30	100	30.0	0.616	0.038	0.0294	0.0942

4.5.1.4 R_d Calculation

R_ds are calculated using the analytical data summarized in Table 4–4 and the equation:

$$R_d = \frac{(A - B)V}{(M_s)B}$$

where
A = total initial concentration (mg/L) of the COPCs in the test solution,
B = final concentration of the COPCs in the solution after 24 hours in contact with the soil sample (mg/L),
V = volume of solution (mL),
M_s = mass of soil sample (grams), and
R_d = distribution ratio (milliliters per gram [mL/g]).

Results of the calculations are presented in Table 4–5.

Table 4–5. Results of R_d Calculations

Sample ID	SampleMmass (g)	R_d—Uranium mL/g	R_d—Vanadium mL/g
NAT-DM1-0.5	0.5	4.49	17.78
NAT-DM1-1.0	1.0	2.82	25.48
NAT-DM1-2.5	2.5	2.28	29.01
NAT-DM1-5	5.0	2.52	39.94
NAT-DM1-10	10.0	2.20	55.77
NAT-DM1-20	20.0	1.89	73.15
NAT-DM1-25	25.0	1.66	75.03
NAT-DM1-30	30.0	1.59	82.63

Results of the R_d calculations show considerable variation, particularly for vanadium. The variation appears to be, in part, correlated with mass of soil used in the procedure. Higher R_d values were obtained with smaller soil masses for uranium; the opposite relationship is noted for vanadium. Results are generally consistent with those obtained at other UMTRA Ground Water Project sites. Uranium typically has a higher mobility than vanadium and is found over a greater areal extent; vanadium plumes are normally more confined. At the Naturita site, the uranium plume extends off site for a considerable distance downgradient; elevated concentration of vanadium are restricted to the site itself (see Section 5.3.3.2 for further discussion).

Because the procedure for estimating K_d values uses only the <2 mm fraction, it is likely that the K_ds overestimate adsorptive properties of the entire aquifer system (Kaplan and others 2000; EPA 1999b). A common way of modifying the values to account for this is to assume that the >2 mm fraction has a K_d of 0 and to adjust the values proportionally. For the Naturita site, it was noted that approximately 50 percent of the alluvial material collected for analysis was greater than 2 mm in size; therefore, a more realistic estimate of K_ds for the site may be considerably less than the calculated R_d values. The major quantitative use for the K_d estimates is in the ground water fate and transport modeling. To account for uncertainty in K_d estimates, a stochastic model was used that incorporates a range of K_d values.

4.6 Soil and Sediment Analysis

All radioactive tailings were removed from the Naturita site during 1977 to 1979. Contaminated soils and surface materials were removed from the site in 1997, and the excavated areas were backfilled with clean, clay-sized material. At that point, no radioactive materials were left. However, it is possible that contaminants have leached into the soils below the depth of remediation. These soils could contaminate infiltrating ground water and prolong the cleanup effort.

4.6.1 Subpile Soil Sample Selection

Samples were collected from two boreholes drilled in October 1998 and from three DOE excavations in March 2001. Section 4.3 describes the sample collection methods. Uranium-contaminated borehole samples from wells NAT01 and NAT06 were collected in the area of the former tailings pile. Location 0562 is in an old ore storage location; 0563 represents an upgradient background site; and 0564 is in the former mill yard area. Figure 4–6 shows these sampling locations.

4.6.2 Surface Soil and Sediment Sample Selection

Surface soil samples were collected from two locations to verify complete removal of contaminated material from the site. The samples were collected from a former ore storage area at location 0562 and from an off-site location within a 10-ft radius of well DM1 to represent background (location 0563). Because the alluvial aquifer at the site discharges to the San Miguel River, it is important to characterize any potential for contamination to the river. Therefore, stream sediment samples were collected near the riverbank at locations 0531, SM9, 0558, SM1, SM2, SM3, SM4, 0561, 0535, 0536, 0560, and 0533. Sediment samples were also collected from a ground water seep in an abandoned river channel near the San Miguel River at sites 0538 and 0559 (Figure 4–6).

4.6.3 Sediment and Soil Sample Preparation and Extraction

Chemical extractions were used to evaluate the potential leachable amount of contaminants present. Each sample was extracted using a 5 percent nitric acid solution. The acid solution is used to remove most amorphous oxides that most likely contain adsorbed contaminants. The solution will not remove contaminants locked in recalcitrant minerals such as apatites or other heavy mineral grains. The acid treatment also dissolves carbonate minerals and releases any adsorbed cations.

The following extraction procedure was used at the USGS lab in Menlo Park:

1. Air dry the sample (no oven heat).
2. If desired, sieve the sample. Samples are usually sieved to less than 2 mm because sieved samples are easier to work with; also, because the contamination is more concentrated in the finer fractions, the sieved samples provide a more sensitive indicator of the contamination.
3. Place 2 g ± 10 mg of soil in a centrifuge tube (or divide evenly between two 50-mL centrifuge tubes; use a riffle splitter so that both splits are equivalent).

4. Place 100 mL (or 50 mL in each of the 50-mL tubes) of the test solution (e.g., 5 percent nitric acid) in the centrifuge tube.
5. Agitate end over end for 4 hours ± 20 minutes.
6. Remove the tubes from the shaker and centrifuge for sufficient time to settle most of the 2 µm particles (about 30 minutes at 3,000 rpm).
7. Decant into a 200-mL volumetric flask.
8. Add a second 100-mL portion of test solution to the residue.
9. Agitate end over end for 30 ± 5 minutes.
10. Remove the tubes from the shaker and centrifuge for sufficient time to settle most of the 2 µm particles (about 30 minutes at 3,000 rpm).
11. Decant into the same 200-mL volumetric flask (step 7).
12. Fill to volume with test solution.
13. Filter the 200-mL decantate through a 0.45 µm filter.
14. Measure pH and oxidation-reduction potential.
15. Preserve as needed and submit for chemical analysis.
16. Calculate the soil concentration in milligrams per kilogram (mg/kg) from the concentration in the decantate:

$$\frac{200\text{ mL solution}}{2\text{ g soil}} \times \frac{\mu\text{g decantate}}{\text{L}} \times \frac{\text{L}}{1{,}000\text{ mL}} \times \frac{\text{mg}}{1{,}000\ \mu\text{g}} \times \frac{1{,}000\text{ g}}{\text{kg}} = \text{mg}/\text{kg}$$

4.6.4 Stream and Seep Sediment Concentration Results

Table 4–6 shows a summary of contaminant concentrations from stream sediment and ground water seep sediment samples collected at the Naturita site in November and December 2000. Figure 4–7 through Figure 4–12 show concentrations of arsenic, cadmium, molybdenum, selenium, uranium, and vanadium, respectively, in these sediments. Appendix D presents analytical results of the constituents measured in the samples and in one blank extraction.

4.6.4.1 Arsenic in Sediments

Concentrations of arsenic shown in Figure 4–7 are at or near background concentrations measured at location 0531. Concentrations from all samples are below the common range of soil concentrations cited by Rose, Hawkes, and Webb (1979). This suggests that there has been no transport of arsenic surficially or by ground water to the stream sediments.

4.6.4.2 Cadmium in Sediments

Figure 4–8 shows that concentrations of cadmium in the stream sediment samples were generally elevated over the background level measured at location 0531. Concentrations at the sample locations were also higher than the range commonly found in soils (Rose, Hawkes, and Webb 1979). Sediments and samples collected from the ground water seep area have concentrations that are in the normal range and near background for stream sediment. Surface soil collected at background location 0563 had the highest concentration of cadmium measured, and the concentration in the subpile soil was very close to the detection limit. No cadmium was detected at any subpile soil sampling location. The elevated cadmium concentrations in the stream sediment samples may be due to windborne transport or surface runoff from the former tailings pile.

Table 4–6. Mass of Contaminant Extractable by 5 percent Nitric Acid Solution per Mass of Sediment

Sample Site	Sample type	Location	As (mg/kg)	Cd (mg/kg)	Fe (mg/kg)	Mo (mg/kg)	Mn (mg/kg)	Se (mg/kg)	U (mg/kg)	V (mg/kg)
		Upgradient Samples								
0531	stream sediment	San Miguel River	1.83	0.56	2,307	<0.40	367	0.18	0.53	6.56
		On-Site Samples								
0538	stream sediment	ground water seep	2.60	0.62	1,921	1.51	721	0.14	8.90	9.54
0559	stream sediment	ground water seep	2.83	0.53	1,532	2.19	278	0.14	12.50	7.94
0535	stream sediment	San Miguel River	1.80	0.62	2,104	0.78	413	0.19	0.67	5.96
0536	stream sediment	San Miguel River	1.91	0.65	3,004	0.74	389	0.24	0.80	5.20
0558	stream sediment	San Miguel River	1.87	0.47	2,699	0.76	278	0.23	1.27	6.11
0560	stream sediment	San Miguel River (main channel)	1.94	0.60	3,519	0.62	479	0.26	2.27	5.97
0561	stream sediment	San Miguel River	2.01	0.60	2,514	0.70	428	0.21	1.45	7.06
SM1	stream sediment	San Miguel River	1.27	0.75	2,541	0.47	291	0.26	0.76	1.22
SM2	stream sediment	San Miguel River	1.66	0.88	3,256	0.55	341	0.27	1.78	1.70
SM3	stream sediment	San Miguel River	2.15	1.13	2,608	0.50	372	0.23	0.77	1.74
SM4	stream sediment	San Miguel River	1.60	0.85	2,899	0.45	357	0.25	0.80	0.77
SM9	stream sediment	San Miguel River	1.98	1.07	3,186	0.60	427	0.26	0.82	0.44
		Downgradient Samples								
0533	stream sediment	San Miguel River	2.14	0.70	3,148	0.54	498	0.24	1.00	5.26

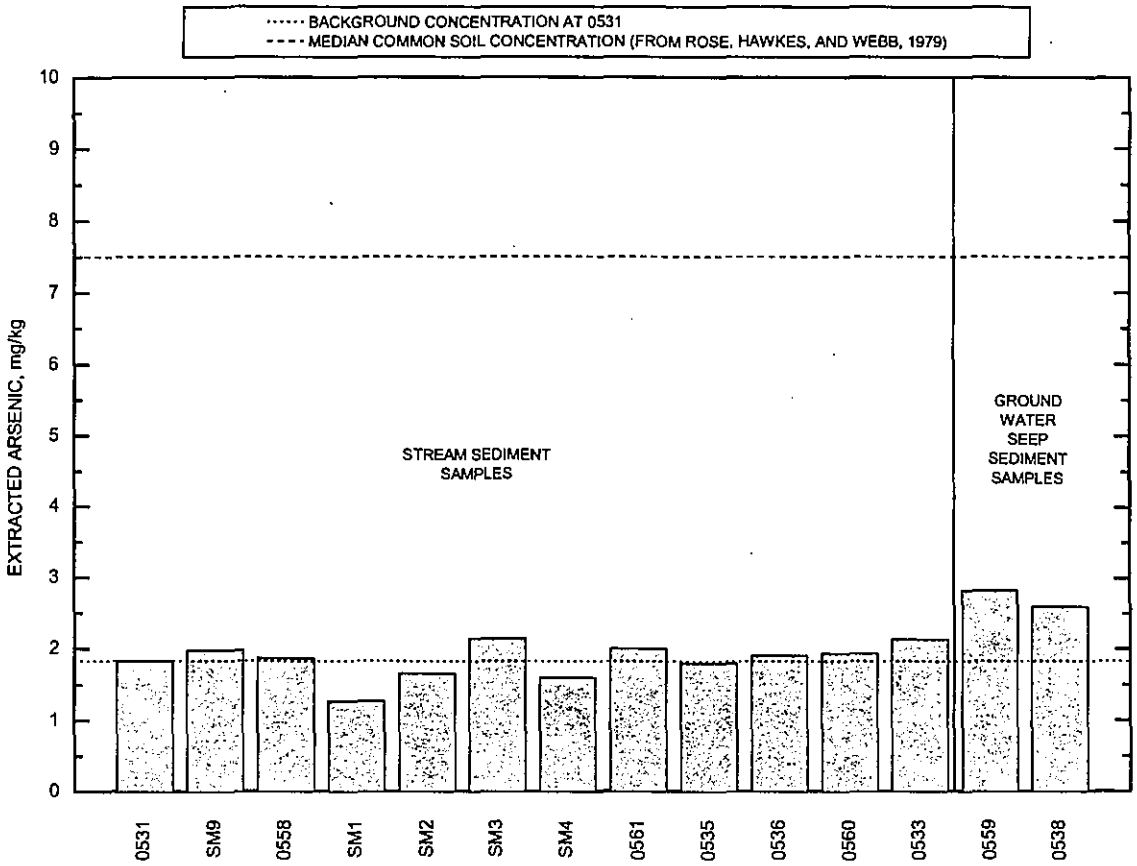


Figure 4–7. Arsenic Concentrations in Sediment

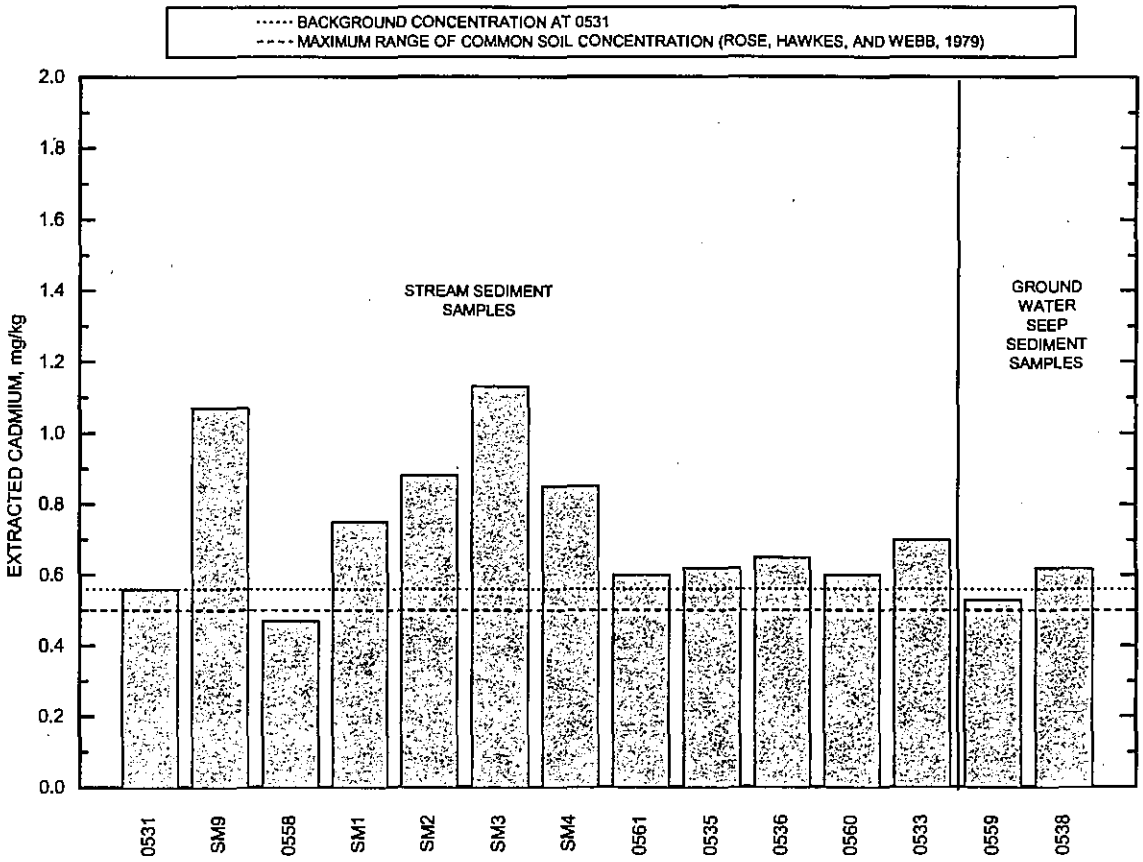


Figure 4–8. Cadmium Concentrations in Sediment

4.6.4.3 Molybdenum in Sediments

Concentrations of molybdenum (Figure 4–9) were all above the background value measured at location 0531 (concentration was below detection limit at 0531). However, concentrations were all lower than those in typical soils (Rose, Hawkes, and Webb 1979). The highest concentrations were in samples from the ground water seep sediments. This suggests a small amount of molybdenum may be transported by the alluvial aquifer, but very little is being retained by the sediments, making them an insignificant source of contamination.

4.6.4.4 Selenium in Sediments

As shown in Figure 4–10, selenium concentrations in all stream sediment samples were slightly elevated above the background concentration measured at location 0531. Concentrations in sediment from the ground water seep area were below background concentrations, and concentrations at all locations were lower than those in typical soils (Rose, Hawkes, and Webb 1979). This suggests that no site-related selenium is in the stream sediments.

4.6.4.5 Uranium in Sediments

Uranium concentrations in all samples of stream sediment and ground water seep sediment were elevated over those measured at background location 0531 (Figure 4–11). Samples from locations 0558, SM2, 0561, and 0560 all had uranium concentrations greater than typical soil concentrations (Rose, Hawkes, and Webb 1979). The highest concentrations were in the ground water seep sediments. Concentrations in the seep sediment samples were approximately 17 to 24 times greater than those measured in the upgradient stream sediment background sample. Because this is a low-lying area of the river floodplain, the potential exists for these contaminated sediments to be transported downstream during flooding.

4.6.4.6 Vanadium in Sediments

Concentrations of vanadium shown in Figure 4–12 are all near or below the background value measured at location 0531. Concentrations are also much lower than those in typical soils (Rose, Hawkes, and Webb 1979). This suggests that there is no site-related contamination from vanadium in stream sediments or surface soils. .

4.6.5 Surface and Subpile Soil Concentration Results

Table 4–7 shows a summary of contaminant concentrations from surface and subpile soil samples collected at the Naturita site. Figure 4–13 through Figure 4–16 show concentrations of arsenic, selenium, uranium, and vanadium, respectively, in these soils. Appendix D presents a complete listing of the constituents measured in the samples and in one blank extraction.

4.6.5.1 Arsenic in Surface and Subpile Soils

With the exception of samples NAT01 and NAT06, which were collected in the area of the former tailings pile, all arsenic concentrations in soil were below the background value measured at location 0563 (Figure 4–13). No surficial arsenic contamination appears to be present at background location 0563 or in the former ore storage area at location 0562. Arsenic concentration in a sample from location 0564, which is in the former mill yard area, was lower than the background level. Concentrations in samples from NAT01 and NAT06 were only

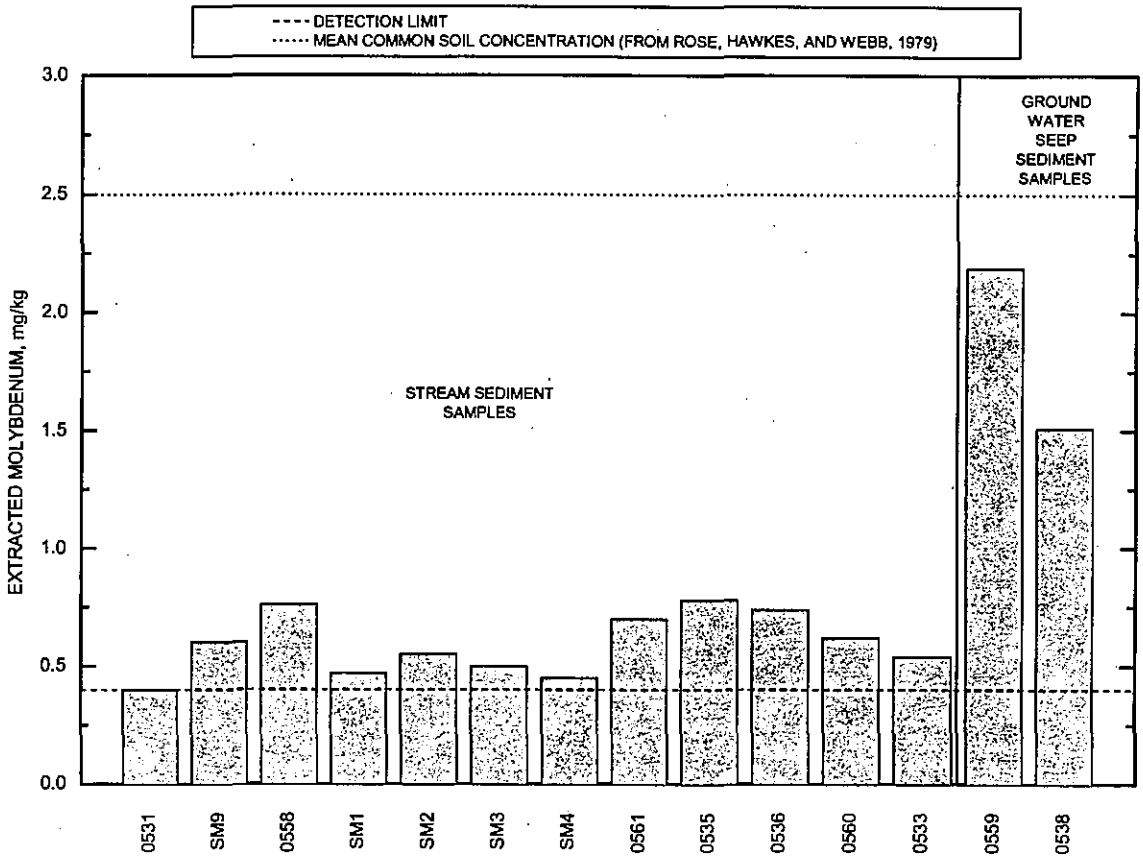


Figure 4–9. Molybdenum Concentrations in Sediment

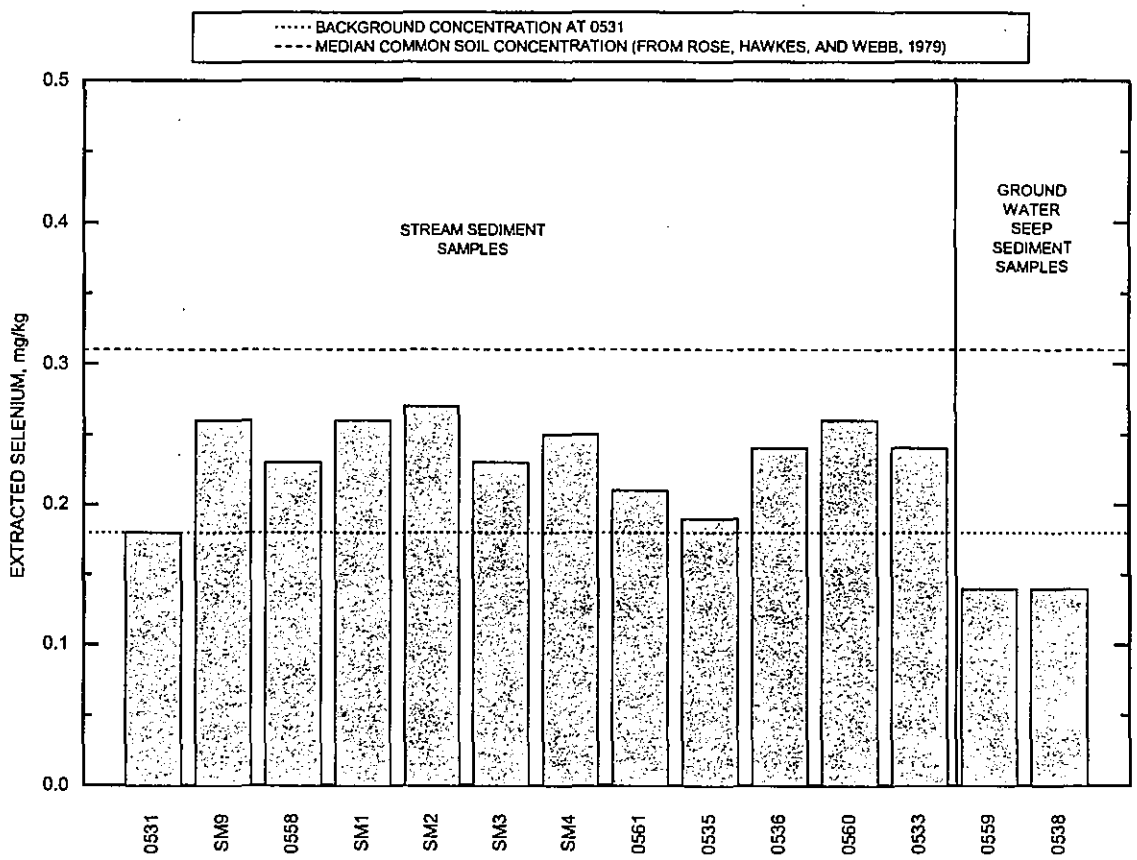


Figure 4–10. Selenium Concentrations in Sediment

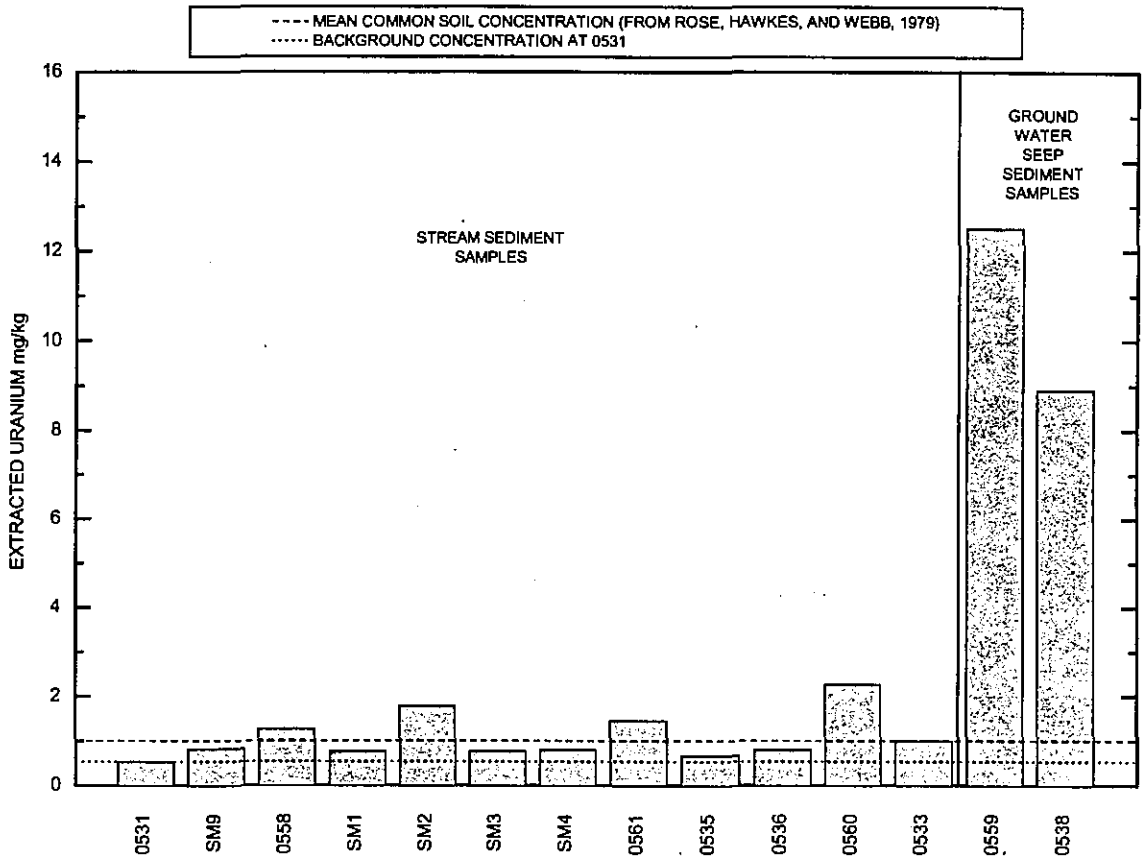


Figure 4–11. Uranium Concentrations in Sediment

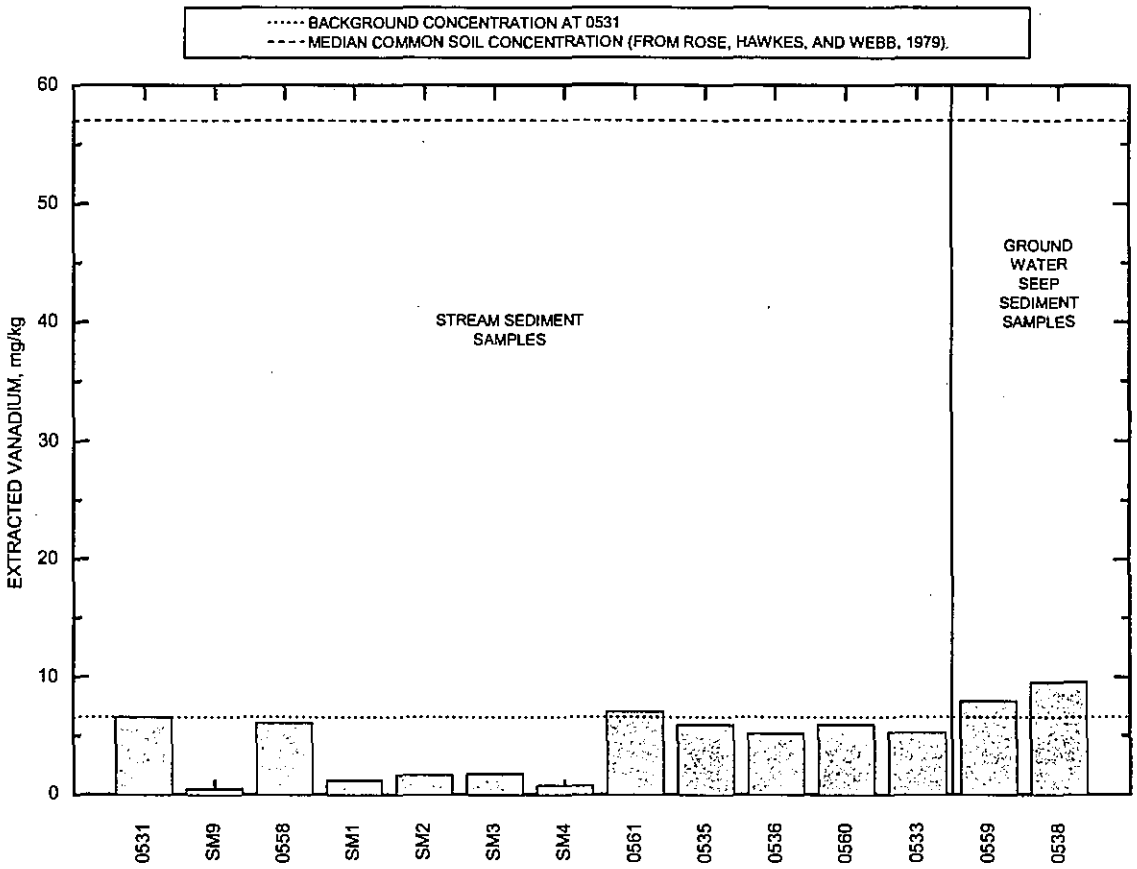


Figure 4–12. Vanadium Concentrations in Sediment

Table 4–7. Mass of Contamination Extraction by 5 Percent Nitric Acid Solution per Mass of Soil

Sample Site	Sample type	Location	As (mg/kg)	Cd (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Mo (mg/kg)	Se (mg/kg)	U (mg/kg)	V (mg/kg)
		Upgradient Samples								
DM1	surface soil	background soil	3.19	1.66	1,535	427	0.49	0.21	3.23	9.28
0563	subpile soil	background soil near DM1	18.9	0.44	1,415	195	<0.4	1.40	1.00	6.05
		On-Site Samples								
0562	surface soil	former ore storage area	0.52	<.40	410	224	1.21	0.20	3.30	9.74
0562	subpile soil	former ore storage area	4.50	<0.40	310	285	<0.4	5.80	0.34	1.76
0564	subpile soil	former mill yard area	8.70	<0.40	1,198	361	<0.4	1.30	1.28	8.37
NAT01	subpile soil	former tailings area	20.9	<0.40	1,874	259	<0.4	1.80	6.02	5.35
NAT06	subpile soil	former tailings area	24.0	<0.40	2,071	117	<0.4	5.70	6.50	412

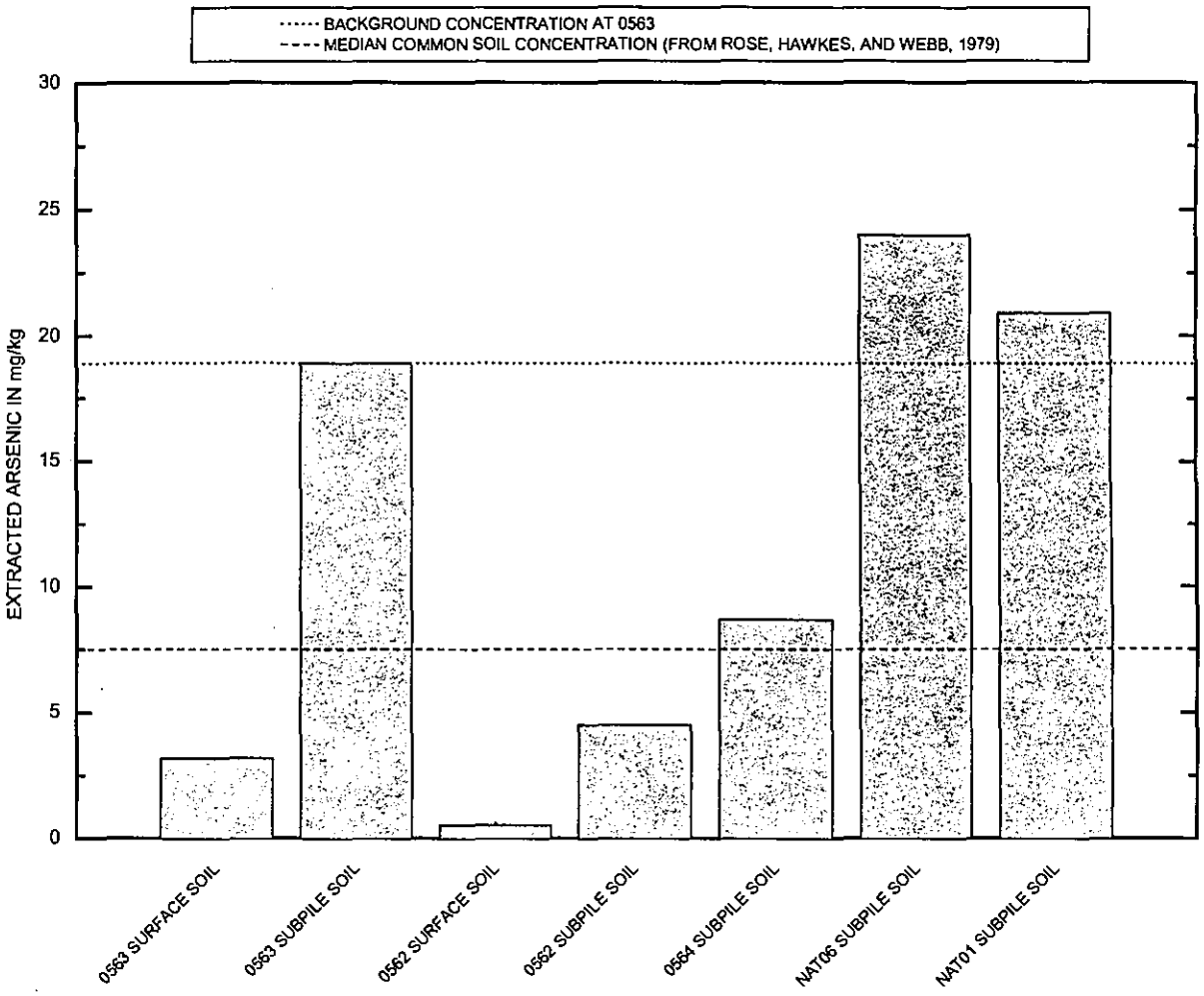


Figure 4–13. Arsenic Concentrations in Surface and Subpile Soil Samples

slightly higher than background values, and any future contamination from those sources would be difficult to distinguish from the natural background concentration.

4.6.5.2 Cadmium in Surface and Subpile Soils

Measurable cadmium was only detected in soil samples from locations DM1 and 0563 (Table 4–7). The subpile concentration was very close to the detection limit, but the surface concentration was almost four times greater. Although no cadmium was measured in any other soil sample, it was detected in most stream sediment samples (Section 4.6.4.2). This suggests that cadmium was transported to the river and location 0563 by wind or surface runoff.

4.6.5.3 Molybdenum in Surface and Subpile Soils

No molybdenum was detected in any of the subpile soil samples collected at the Naturita site (Table 4–7). The two surface soil samples at locations 0562 and DM1 had concentrations of 0.49 and 1.21 mg/kg molybdenum, respectively. These concentrations are in the range of average soil abundance cited by Rose, Hawkes, and Webb (1979).

4.6.5.4 Selenium in Surface and Subpile Soils

Selenium concentrations in all subpile soil samples depicted in Figure 4–14 are 4 to 18 times greater than the median typical soil concentration (Rose, Hawkes, and Webb 1979). Concentrations at locations 0562, NAT01, and NAT06 are all elevated over the background concentrations measured at location 0563. Location 0562 is not connected to the alluvial aquifer, and contaminants in soil at that location do not pose a significant future threat to ground water. Samples from location NAT01 had selenium levels that were only slightly elevated over the background concentration. Location NAT06 is in the area of the former tailings pile and has the highest concentration of selenium of any of the alluvial aquifer subpile soils. However, due to the reducing conditions of the ground water at this location, it is believed that most of the selenium will remain adsorbed to the sediments. Increased flushing of the alluvial aquifer could change the oxidation-reduction potential of the ground water and potentially desorb selenium from sediments near well NAT06.

4.6.5.5 Uranium in Surface and Subpile Soils

Concentrations of uranium in surface soil at background location 0563 and the former ore storage area at 0562 are approximately the same and are elevated over the background level at location 0563 (Figure 4–15). The fact that both values are elevated over those of their respective subpile soil analyses suggests some degree of windborne contamination. Location 0564, which is in the area of the former mill yard (Table 4–7), has only slightly higher concentrations of uranium than that measured in the background sample. Samples taken at NAT01 and NAT06 in the area of the former tailings pile have the highest concentrations of uranium. This indicates that significant leachable uranium is still present in subpile soils and could represent a future source of uranium contamination.

4.6.5.6 Vanadium in Surface and Subpile Soils

The subpile soil sample collected at well NAT06 had a significantly higher concentration of vanadium than any other sampled location at the Naturita site (Figure 4–16). Samples from all locations except NAT06 had vanadium concentrations that were at or near the background

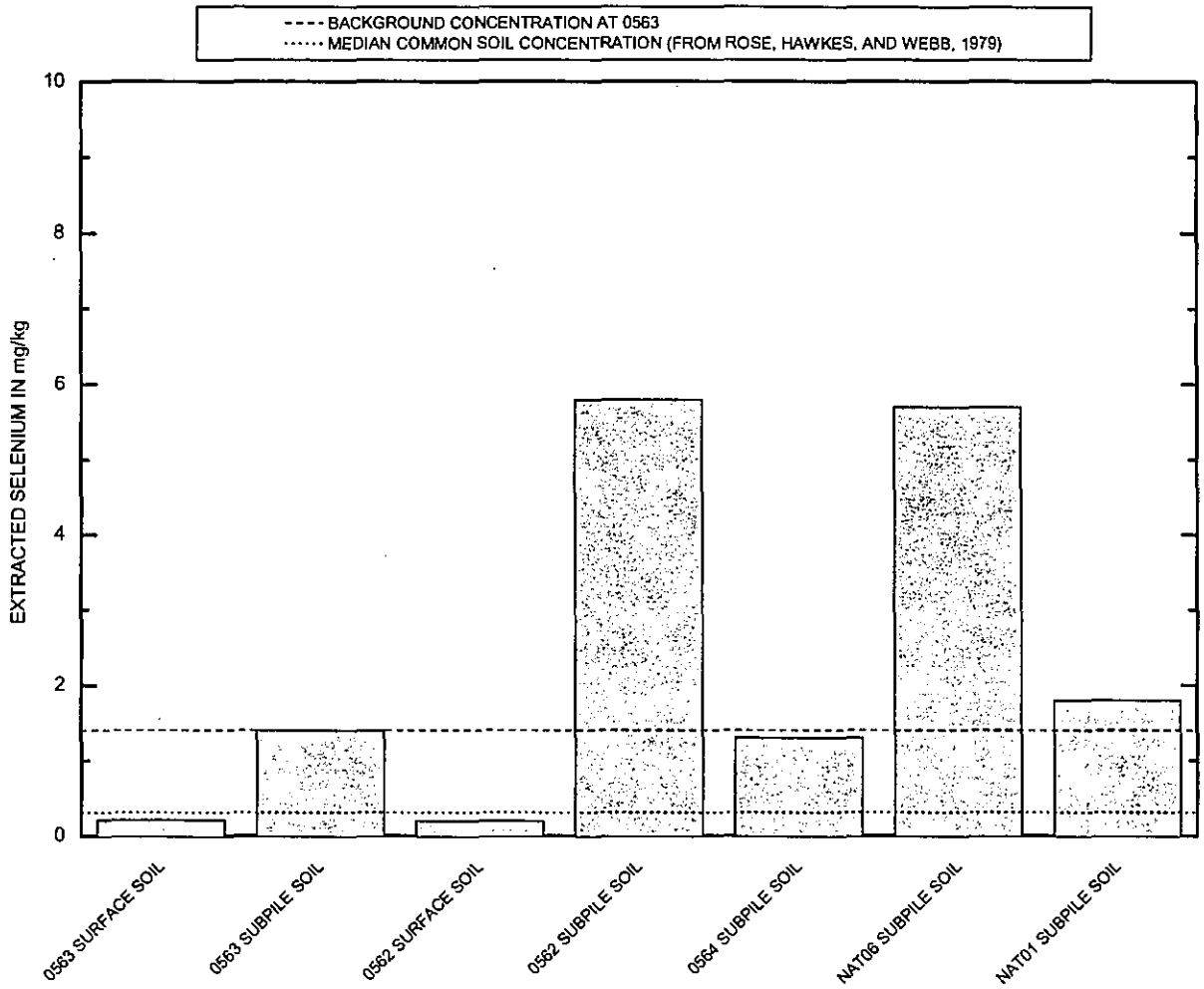


Figure 4–14. Selenium Concentrations in Surface and Subpile Soil Samples

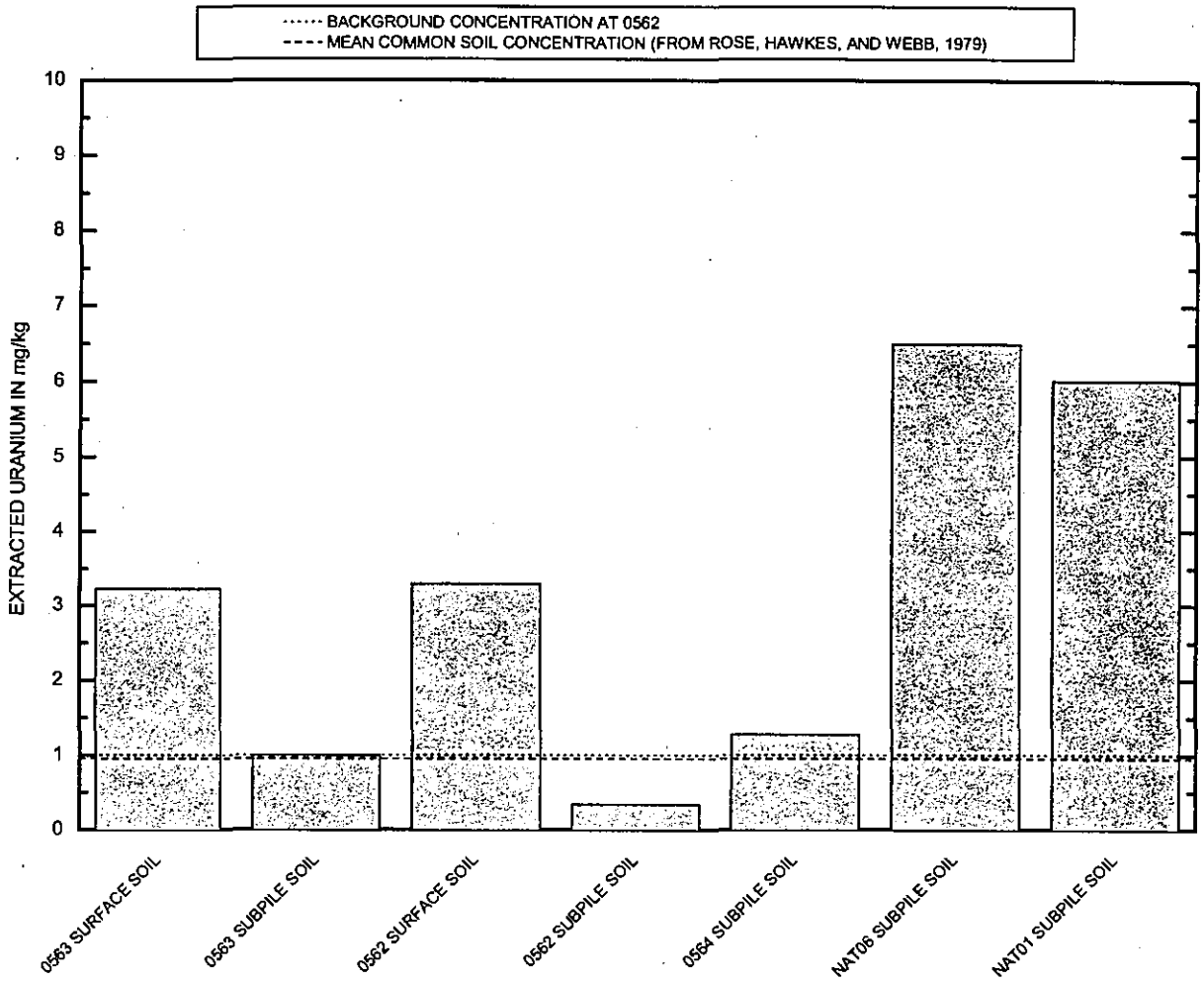


Figure 4–15. Uranium Concentrations in Surface and Subpile Soil Samples

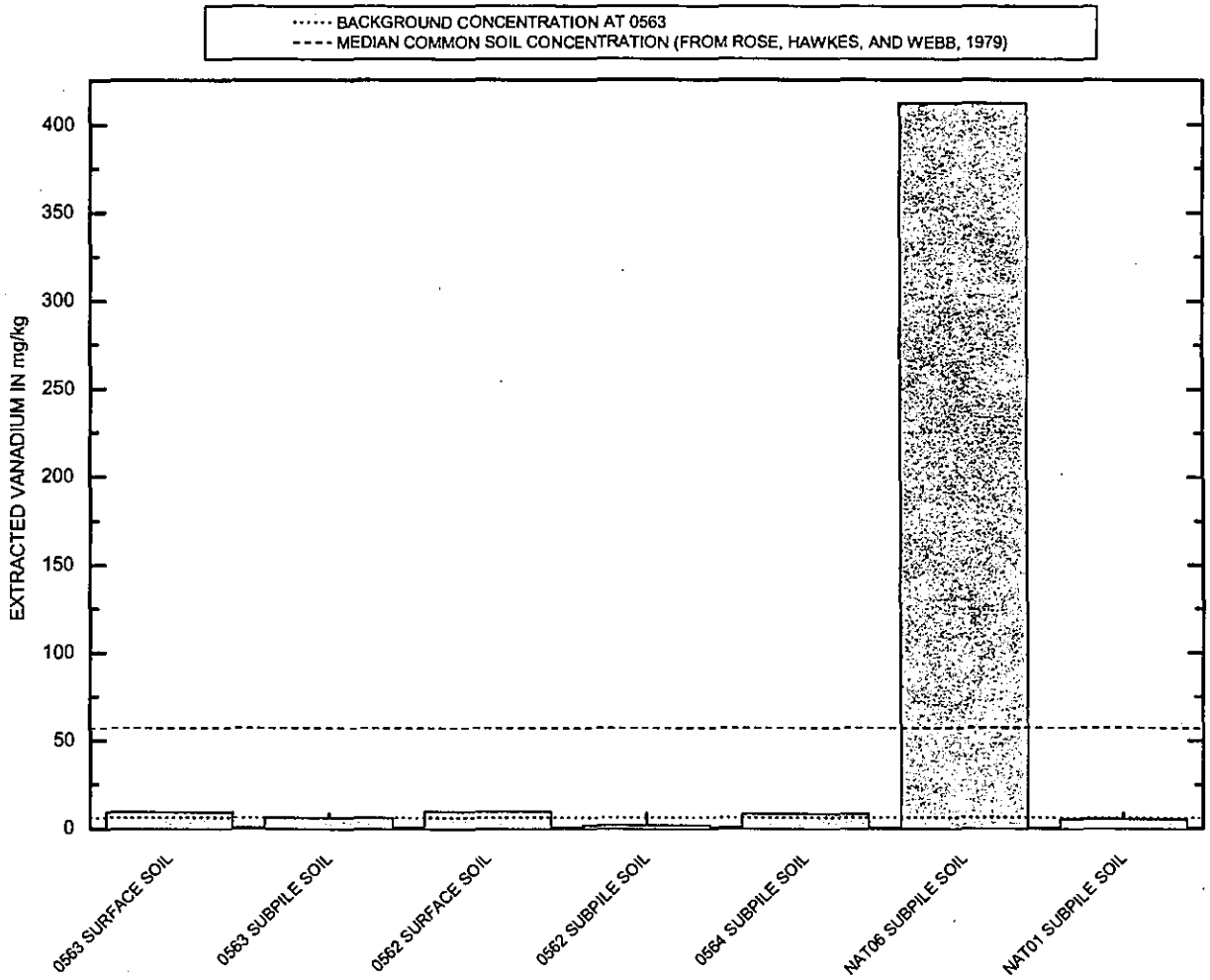


Figure 4–16. Vanadium Concentrations in Surface and Subpile Soil Samples

concentration. Drill cuttings from well NAT06 had a vanadium concentration an order of magnitude greater than background levels. Due to its low mobility, the vanadium contamination in the subpile soils is probably limited to the extent of the former tailings pile area and will most likely remain there for a considerable length of time.

4.7 Water Sampling and Analysis

From August 1998 through June 2000, ground water at the Naturita site was sampled to support research by the USGS for the NRC on surface complexation modeling. During November 2000 and March 2001 and continuing into June and September 2001, samples were collected to monitor the nature and extent of ground water contamination at the site for the DOE UMTRA Ground Water Project. Because the two projects have different goals, different sets of wells were sampled. Also, at times, different sampling and analytical procedures were used. All sampling during the NRC sampling period was performed in accordance with the *U.S. Geological Survey National Field Manual for the Collection of Water-Quality Data* (USGS 1998). All sampling during the DOE UMTRA Ground Water Project monitoring phase was performed in accordance with the *Sampling and Analysis Plan for the UMTRA Ground Water Project* (DOE 1999c).

Monitoring wells and surface water sites were sampled quarterly. Sampling for the surface complexation modeling study was conducted from August 1998 through June 1999. Samples from wells 0547 and 0548 were collected in August 1998. Samples were collected from 22 wells and one surface water location during November 1998. Six wells were dry and could not be sampled. Twenty-four ground water samples and one surface water sample were collected in March 1999. Four wells were dry and could not be sampled. During June 1999, 26 wells and one surface water location were sampled. Two wells did not contain water and could not be sampled. In late June and early July 1999, additional monitor wells were installed at the site. In September 1999 and March 2000, 60 ground water wells and one surface water site were sampled. During that time, 12 wells were dry and were not sampled. Well DM1 also was not sampled at that time. Seventy-four ground water wells, including DM1 and one surface water location, were sampled in June 2000. The wells that were dry were always the shallowest of a nested set of wells. Alluvial water was present at all locations during each sampling round.

DOE funded and the USGS conducted monitoring during November 2000 and February 2001. For that monitoring phase, 28 ground water and 14 surface water samples were collected. None of the wells selected by DOE for monitoring were dry during the November 2000 and February 2001 sampling. Additional sampling is planned for June and September 2001.

4.7.1 Ground Water Sampling Procedures

Before samples were collected, about three casing volumes of water were purged from each well with a peristaltic pump. Two-inch-diameter wells were purged and sampled through dedicated 0.5-inch-diameter PVC tubes with a 6-inch screen on the bottom. These tubes were set in the casing to sample 2.5 ft from the bottom of the well where possible. This depth is set at the middle of the screened interval. Half-inch-diameter wells were connected directly to the pump tubing. Samples from these wells were collected from the 6-inch screened interval at the bottom of the well casing. All purging and sampling was done through a peristaltic pump using low-diffusion Norprene tubing. All field measurements except turbidity (pH, specific conductance, oxidation-reduction potential, water temperature, and dissolved oxygen) were monitored continuously during purging with a flow-through chamber attached to a Hydrolab Mini-Sonde Water Quality Multi-probe. Turbidity was measured with a Hach portable turbidity monitor

every half gallon in 0.5-inch-diameter wells, and every gallon in 2-inch-diameter wells. Turbidity was only monitored during the DOE UMTRA monitoring phase of the project. After purging was completed, water samples for anion analysis were filtered on site using a 0.45-µm capsule filter and collected in field-rinsed, 4-ounce polyethylene bottles. Samples for cation analysis were also filtered on site and collected in 4-ounce, acid-rinsed bottles. After collection, these samples were preserved with ultra-pure concentrated nitric acid. During the DOE monitoring phase, an additional nutrient sample was filtered and collected in an amber polyethylene bottle that was kept on ice until analysis. Ferrous iron (Fe^{2+}) was measured colormetrically in the field using a Chemetrics photometer. This was done by first filling a small vial with unfiltered sample water, then immediately breaking a small ampoule containing a reactive solution in the vial. The ampoule is under a negative pressure and therefore draws sample water into the ampoule where it mixes with the reactive solution. After a one minute reaction time, the vial is placed in the photometer, which measures the ionic concentration of the constituent. Alkalinity as $CaCO_3$ in filtered (0.45 µm) water samples was generally measured on site with a Hach digital titrator and 1.6 normal sulfuric acid. During the February 2001 sampling, alkalinity was measured in the lab using an auto-titrator due to malfunction of equipment in the field.

4.7.2 Analytical Laboratory Sample Analysis

Water analyses were conducted at the USGS Research Laboratories in Menlo Park, California, and at the USGS National Water Quality Lab (NWQL) in Denver. Dissolved uranium was measured by kinetic phosphorescence analysis (KPA) at the Menlo Park laboratory aluminum, arsenic, boron, barium, bromine, calcium, cadmium, cobalt, chromium, copper, iron, lithium, magnesium, manganese, molybdenum, sodium, nickel, phosphorus, lead, selenium, silicon, strontium, vanadium, and zinc concentrations were measured by inductively coupled plasma optical emission spectrometry (Standard Methods 1992). The potassium concentration was measured by direct air-acetylene flame atomic absorption spectrometry. Chloride, nitrate, and sulfate concentrations were measured by ion chromotography (Standard Methods 1992). For comparison during the DOE UMTRA monitoring phase, 10 samples were sent to the NWQL for uranium analysis by inductively coupled plasma–mass spectrometry (ICP–MS). All samples collected for DOE UMTRA monitoring were analyzed for arsenic and selenium at the NWQL using ICP–MS. Table 4–8 presents a summary of the methods used for water analysis at the two labs. Results from all surface and ground water analyses are listed in Appendices C and B, respectively.

4.7.3 Quality Assurance and Quality Control Samples

One process blank sample and one field replicate were collected for each sampling trip during the NRC sampling period. During the DOE UMTRA monitoring, a process blank and field replicate were collected for every 20 samples. Field replicates were collected immediately after collection of a regular sample using the same filter and equipment. Process blanks were collected from a bottle of USGS-prepared inorganic blank standard by pumping through the Norprene tubing and 0.45 µm filter with the peristaltic pump.

Table 4–8. Summary of Methods Used for Water Analysis

Analyte	Detection Limit	Analytical Instrument	Lab	Sample phase
Al	0.14 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
As	0.18 µg/L	ICP-MS	USGS-NWQL	DOE UMTRA
As	0.14 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
B	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Ba	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Br	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Ca	0.065 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Cd	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Co	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Cr	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Cu	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Fe	0.015 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Li	0.014 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Mg	0.08 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Mn	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Mo	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Na	0.06 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Ni	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
P	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Pb	0.10 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Se	0.36 µg/L	ICP-MS	USGS-NWQL	DOE UMTRA
Se	0.14 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Si	0.01 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Sr	0.14 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
U	0.018 µg/L	ICP-MS	USGS-NWQL	DOE UMTRA
U	0.50 µg/L	KPA	USGS-Menlo	NRC, DOE UMTRA
V	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
Zn	0.02 mg/L	ICP-OES	USGS-Menlo	NRC, DOE UMTRA
K	0.01 mg/L	AA	USGS-Menlo	NRC, DOE UMTRA
Cl	0.005 mg/L	IC	USGS-Menlo	NRC, DOE UMTRA
NO_3	0.01 mg/L	IC	USGS-Menlo	NRC, DOE UMTRA
SO_4	0.005 mg/L	IC	USGS-Menlo	NRC, DOE UMTRA

USGS-Menlo USGS Menlo Park Research Lab
USGS-NWQL USGS National Water Quality Lab
KPA Kinetic phosphorescence analysis
ICP-MS Inductively coupled plasma–mass spectrometry
ICP-OES Inductively coupled plasma–optical emission spectrometry
AA Atomic absorption spectrometry
IC Ion chromatography
mg/L milligrams per liter
µg/L micrograms per liter

4.8 Alluvial Aquifer Tests

Estimates of the alluvial aquifer properties are necessary to develop a better understanding of the site hydrogeologic characteristics that could influence contaminant migration in ground water and to develop input parameters in a ground water flow and solute transport model. Both hydraulic and bromide tracer tests were conducted at the Naturita site to determine aquifer properties.

4.8.1 Aquifer Test Procedure

Slug tests were performed on wells at the Naturita site during November 9 through 11, 1999, and during May 17 through 19, 2000. Three to four slug test replicates were done on each well. To perform the tests, a pressure transducer was suspended in the well. A slug with a known displacement volume attached to a thin rope was lowered into the well and the water level was allowed to stabilize. The displacement volume of the slug used in each well was dependent on the height of the water column in the well. The slug was then rapidly removed from the well, and water level recovery and elapsed time were recorded with a pressure transducer. Replicate slug tests were performed after water levels recovered to their pre-test equilibrium values.

Actual displacement of each slug was usually smaller than the measured displacement in the well for the first 0.5 to 0.75 second. After 0.75 to 0.9 second, disturbance of the water surface ceased, and measured displacement was more in line with the actual displacement. The effective casing radius for most tests seemed to be the actual casing radius. Elapsed time and normalized displacement data for each slug test were then analyzed with AQTESOLV software. The Bouwer-Rice solution (Bouwer and Rice 1976) for unconfined aquifers was used to determine all hydraulic conductivity values.

4.8.2 Aquifer Test Analysis

The Bouwer-Rice slug test solution was used in AQTESOLV to compute hydraulic conductivity. A "double straight line" effect can be seen in displacement-time graphs for wells NAT03 (tests 1 and 2), NAT19, and NAT24. In this situation, it is believed that the water levels dropped sufficiently below the top of the screened intervals to allow direct drainage from the sand packs into the well casings (Bouwer 1989). The initial straight line is the result of sand pack drainage. The second straight line in the graphs was controlled by the hydraulic conductivity of the aquifer, and hydraulic conductivity values were derived from the slopes of these lines.

4.8.3 Aquifer Test Results

Table 4–9 summarizes hydraulic conductivity values computed for each slug test along with the mean, standard deviation, and standard error of the tests performed. No attempt was made to compute hydraulic conductivity values for wells NAT20 and NAT23 due to suspect data. Conductivity values for wells MAU03 (May 2000) and MAU04 should be regarded as estimates due to the shapes of the displacement-time graphs, which made analysis problematic. Hydraulic conductivity averages for wells analyzed at the Naturita site ranges from 18.9 ft/day in well MAU04 to 333 ft/day in well NAT09. The average hydraulic conductivity measured during the November 1999 tests is 83 ft/day. The average hydraulic conductivity measured during the May 2000 test is 106 ft/day. This range of values is typical for an alluvial aquifer characterized by mixed sand and gravel. Domenico and Schwartz (1990) report a range of hydraulic conductivities from 0.24 to 137 ft/day for medium sand and from 82 to 8,200 ft/day for gravel.

Table 4–9. Summary of Hydraulic Conductivity Values Determined from Slug Tests

Well	Date	Slug Test 1, ft/day	Slug Test 2, ft/day	Slug Test 3, ft/day	Slug Test 4, ft/day	Average Hydraulic Conductivity, ft/day	Standard Deviation, ft/day	Standard Error %
MAU03	May-00	17	38	22	nd	26	11	42.7
MAU03	Nov-99	85	70	104	nd	86	17	19.6
MAU04	May-00	27	18	12	nd	19	7	38.3
MAU07	Nov-99	16	27	26	nd	23	6	26.2
NAT02	Nov-99	nd	29	41	nd	35	8	24.1
NAT03	May-00	104	90	nd	nd	97	10	10.0
NAT03	Nov-99	96	85	nd	nd	91	8	9.0
NAT05	May-00	66	84	60	nd	70	13	18.1
NAT05	Nov-99	76	67	nd	nd	72	6	8.7
NAT09	May-00	288	325	386	nd	333	50	14.9
NAT10	Nov-99	38	30	27	nd	32	6	18.3
NAT11	May-00	108	115	105	nd	109	5	4.7
NAT11	Nov-99	93	81	90	95	90	6	6.8
NAT19	May-00	153	107	128	nd	129	23	17.8
NAT23	Nov-99	246	313	295	nd	285	35	12.2
NAT24	May-00	23	66	67	nd	52	25	48.8
NAT25	May-00	113	126	116	nd	118	7	5.8
NAT-25	Nov-99	24	44	32	nd	33	10	29.9

nd No data

4.8.4 Bromide Tracer Tests

In addition to the hydraulic conductivity values measured directly with slug tests, bromide tracer tests were conducted in June and July 1999 to estimate the hydraulic conductivity of the aquifer. The tracer tests were performed by first pumping 60 gallons of water from a well, then adding a measured amount of potassium bromide to the water, then injecting the water back into the well. Samples were collected from the injection well at regular intervals to monitor the disappearance of bromide from the well. In some tests, downgradient wells were also sampled to monitor bromide migration.

The estimated hydraulic conductivity values obtained from the bromide disappearance tests were calculated by first developing an empirical correlation between hydraulic conductivity and bromide disappearance half-life. The correlation shown in Figure 4–17 was developed from eight wells where both slug tests and bromide tracer tests were performed. Additional hydraulic conductivity values were then estimated using the equation shown in Figure 4–17 at wells NAT06–1, NAT07–1, NAT09, NAT11, NAT12–1, NAT20, NAT26, and NAT30–1 where bromide disappearance tests had been conducted. Table 4–10 shows the half-life for bromide disappearance for each well tested and the estimated hydraulic conductivity.

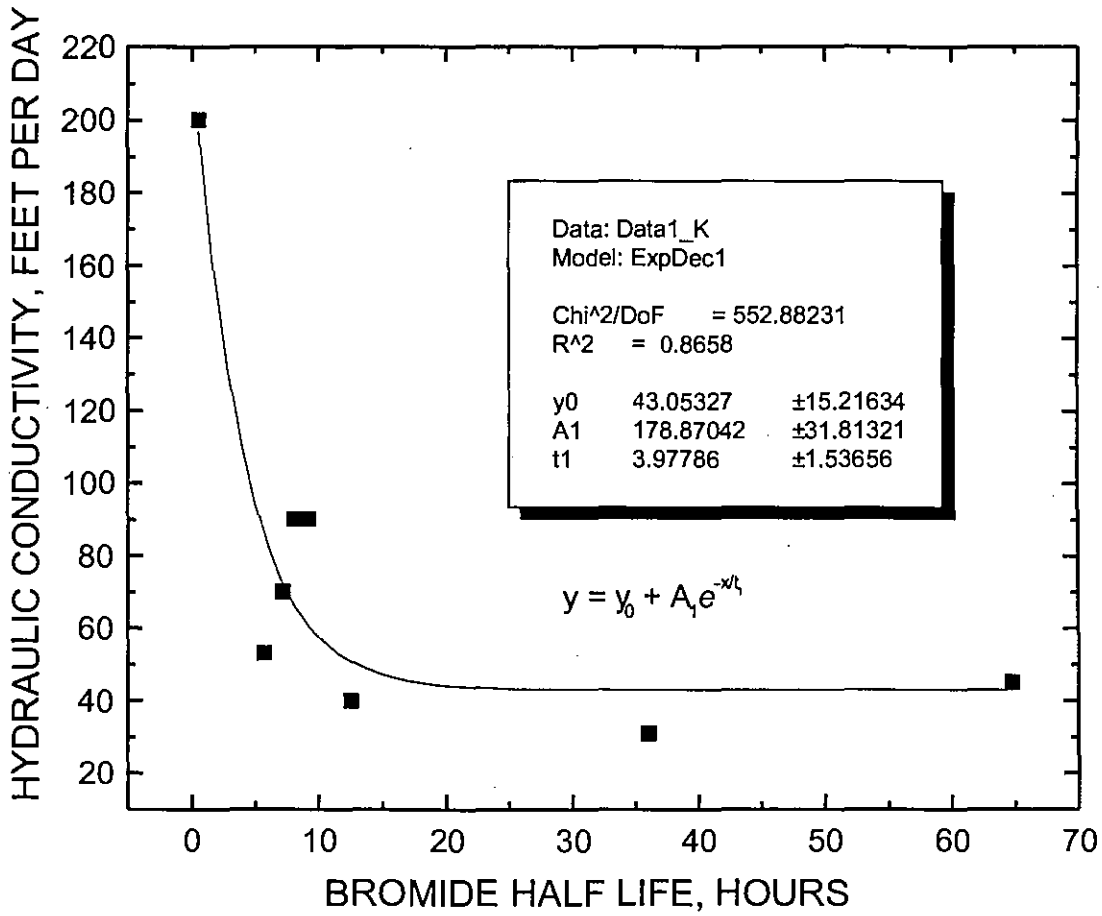


Figure 4–17. Plot Showing Relationship Between Hydraulic Conductivity and Bromide Injection Half-life

Table 4–10. Summary of Hydraulic Conductivity Values Estimated from Bromide Tracer Tests

Well	Bromide Half-Life, hours	Estimated hydraulic conductivity, ft/day
NAT06-1	5.5	88
NAT07-1	14.9	47
NAT12-1	22.1	44
NAT20	0.2	215
NAT26	46.5	43
NAT30-1	0.9	184

4.8.5 Hydraulic Conductivity Estimated from Tritium-Helium Results

In June 2000 a subset of the wells at the Naturita site was sampled for the purpose of determining the age of the ground water. Twelve wells were sampled for age dating by the tritium-helium method (see Section 5.3.4 for a detailed description of the tritium-helium age dating technique). Table 4–11 shows the tritium-helium ages for eight wells. The age of ground water is defined as the time since water was isolated from the atmosphere (Freeze and Cheery 1979). Table 4–11 also shows flow path lengths calculated with MODPATH. Although flow modeling suggests long path lines for wells MAU04 and MAU07, the geochemical signature of the ground water in these wells suggests a significant inflow of fresh water from the San Miguel River (see Section 5.3.3.2). Therefore, the path lines from wells MAU04 and MAU07 may actually originate near NAT25. Average velocities listed in Table 4–11 were calculated using the recharge age and the MODPATH calculated flow path lengths. The estimated velocities range from 0.21 ft/day at MAU07 (along the short flow path) to approximately 2.4 ft/day at DM1 and at MAU04 (along the long flow path). The hydraulic conductivity values calculated from Darcy's law, a porosity of 0.25, and an average sitewide gradient of 0.0044 ft/ft are also listed in Table 4–11. The values range from 12 to 139 ft/day with a mean of 61 ft/day.

Table 4–11. Velocities and Hydraulic Conductivities Estimated from the Tritium-Helium Age Dating Results

Location	Tritium/ Helium Age	Length of Recharge Path(ft)	Average Velocity (ft/day)	Hydraulic Conductivity (ft/day)	Comments
DM1	0.2	174	2.38	135	
MAU04	5.6	4,991	2.44	139	
		840[a]	0.41	23	Assumes recharge from bend in river
MAU07	12.4	5,466	1.21	69	
		944[a]	0.21	12	Assumes recharge from bend in river
NAT19	9.2	2,955	0.88	50	
NAT23	13.5	5,520	1.12	64	
NAT24	33.9	5,465	0.44	25	
NAT25	28.2	5,440	0.53	30	
NAT29	5.8	2,202	1.04	59	

[a]Values are based on the assumed shorter flow path to MAU04 and MAU07.

4.8.6 Hydraulic Conductivity Summary

Figure 4–18 shows a map of hydraulic conductivity values from slug tests, bromide tracer tests, and tritium-helium age dating that were measured and estimated at the Naturita site. When plotted spatially, the hydraulic conductivity at the Naturita site is roughly distributed into two zones, a "high K zone" located at the southern end of the site with values greater than 100 ft/day, and a "low K zone" at the northern end with values less than 100 ft/day. The boundary between the two zones falls roughly at the extent of the former tailings area.

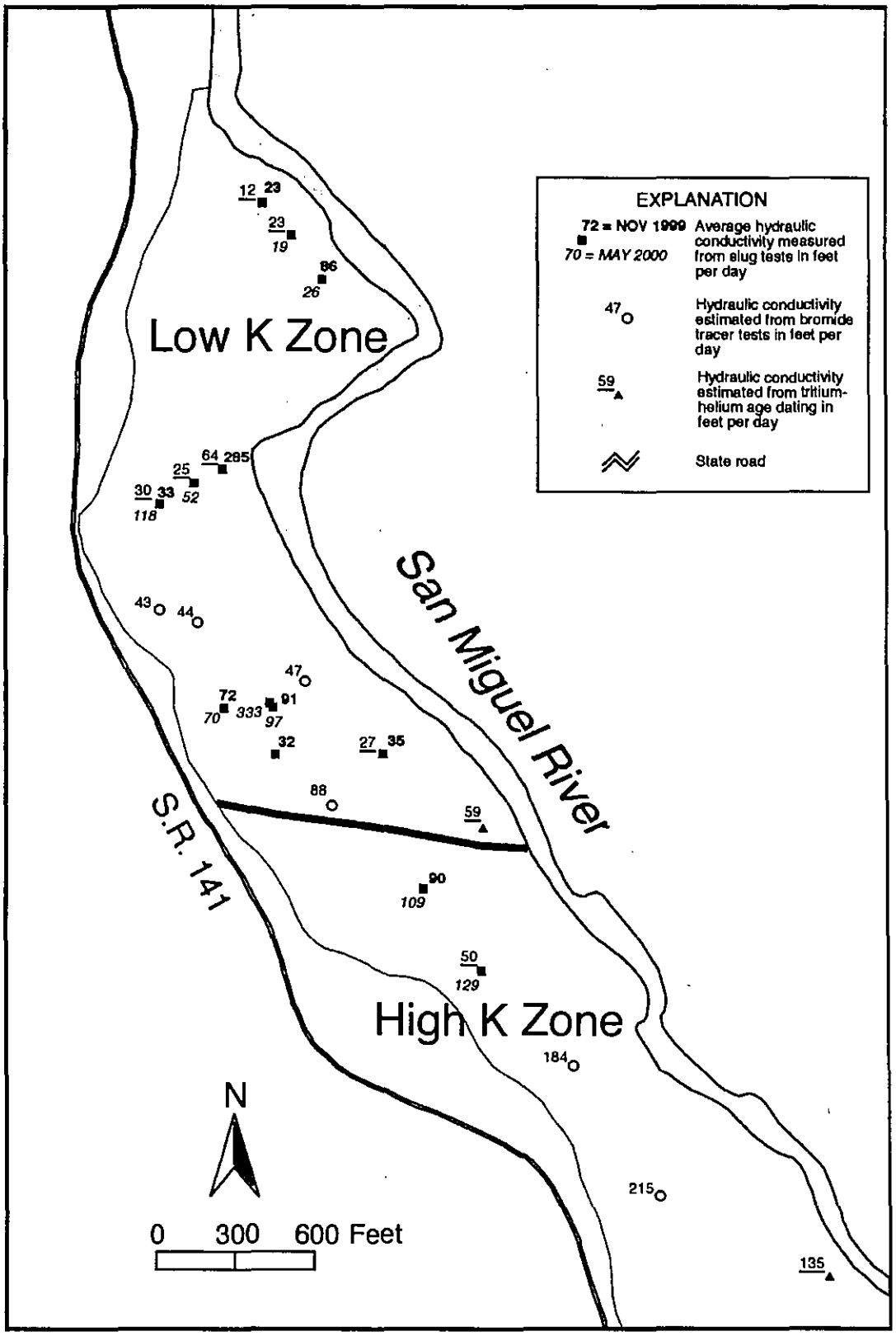


Figure 4–18. Hydraulic Conductivity Values Calculated from Slug Tests and Estimated from Bromide Tracer Tests and Tritium-Helium Age Dating

4.9 Surface Flow Measurements

The Naturita site is bordered on the east by the San Miguel River. It is believed that ground water in the alluvial aquifer is recharged mainly by inflow from the river upstream of the UMTRA site. The aquifer also discharges back to the river downstream of the site. The San Miguel River drains an area of approximately 1,500 square miles, beginning in the San Juan Mountains and discharging into the Dolores River, about 25 miles downstream from the Naturita site. Surface flow of the San Miguel River has been historically recorded at two USGS gaging stations: Brooks Bridge, located 4.5 miles upstream of the Naturita site, and at Uravan, located 15 miles downstream from the site. In addition, stream elevations were surveyed at nine sites along the San Miguel River at the Naturita site. These measuring points are shown in Figure 4–19.

River stage was also recorded at location Stage 1 (Figure 4–19) near well NAT29 for comparison to changes in ground water levels. The stage was recorded during the period November 1999 to March 2001 using an Omnidata Data Logger pressure transducer. No attempt was made to quantify flow of surface water. The paired stage–water table data were collected to quantify the effects and lag times of river stage on the alluivial aquifer. Figure 4–19 shows two ephemeral streams that cross the site from the slope on the western side of the site. These streams have been observed to flow during large storm events and are believed to be a source of intermittent areal recharge. Also, after heavy rainfall, the soil in these areas often remain saturated for several days.

4.9.1 San Miguel River at Brooks Bridge near Nucla, Colorado

USGS maintains a gaging station on the San Miguel River at the Brooks Bridge near Nucla. The gage is located approximately 4.5 miles upstream from the Naturita site. Figure 4–20 shows a hydrograph for the period March 31, 1995, to September 30, 1999. Stream discharge ranges from a base flow of approximately 3 cubic ft per second (cfs) to 100 cfs. Peak flows range from 1,000 to 2,500 cfs. However, these ranges are only based on 4 years of data, recorded from 1996 to 1999. The peak flows result from snow melt in the San Juan mountains at the head of the watershed and generally start in the first week of April and continue until early summer. Low-flow conditions are generally constant and occur between roughly the first week of August to the end of March, although rainfall can cause short-term increases in stream flow.

4.9.2 San Miguel River at Uravan, Colorado

USGS maintains another gaging station on the San Miguel River at Uravan. The gage is located approximately 15 miles downstream from the Naturita site. Figure 4–20 shows a hydrograph for the period August 30, 1996, to September 30, 1999. Base flow ranges from 20 to 100 cfs, and peak flows typically range from 2,000 cfs to a historical high of 8,910 cfs on September 6, 1970 (not shown on hydrograph). These ranges are based on records dating back to 1954. As shown in Figure 4–20, the San Miguel River exhibits the same pattern of flow at Uravan as at Brooks Bridge, with peaks and base flows occurring at the same time of year. Dry Creek is a perennial stream that enters the San Miguel River about a mile upsteam from the site. This stream and numerous ephemeral streams are the main sources of discharge to the river between the Brooks Bridge and Uravan gaging stations.

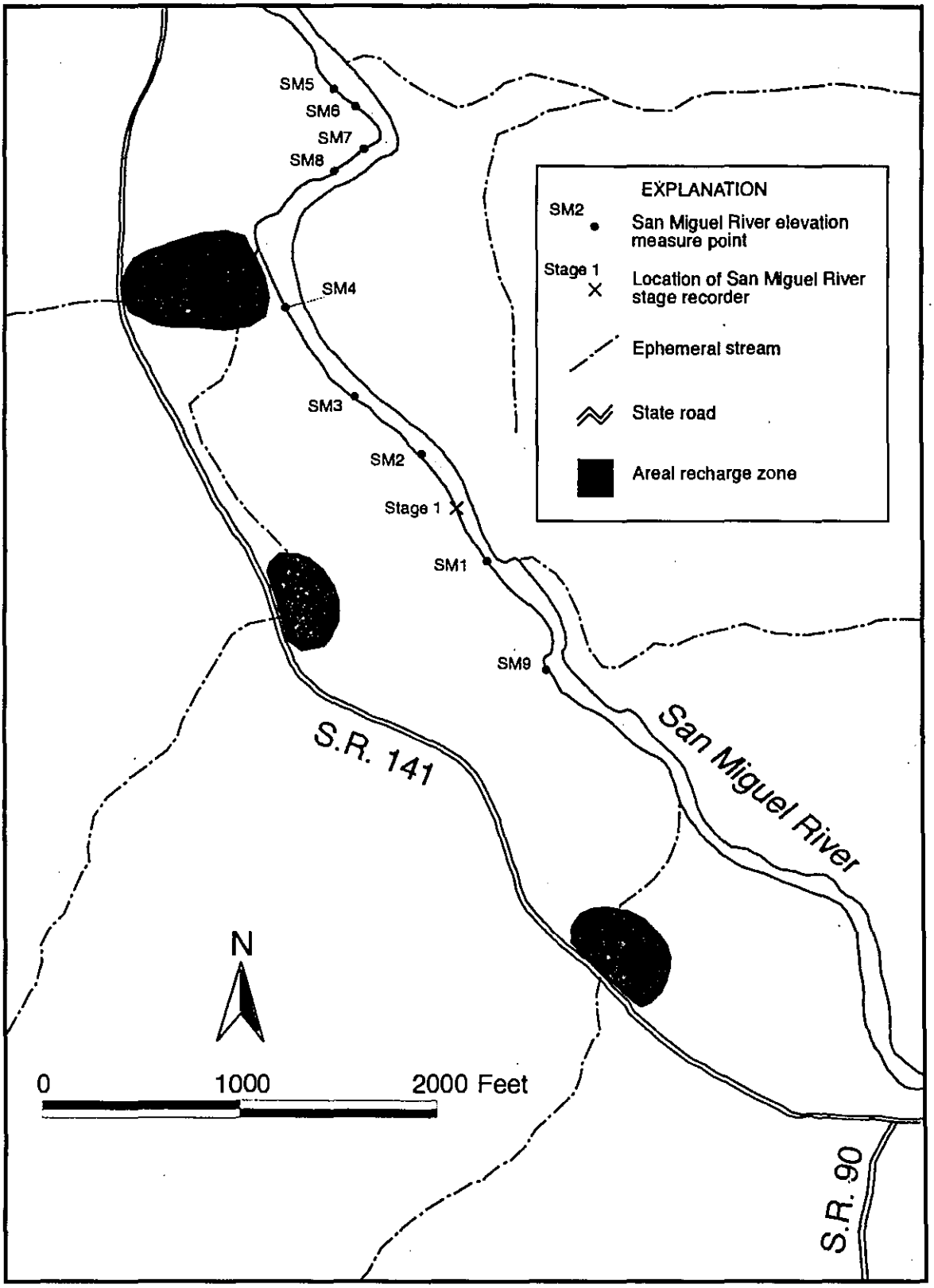


Figure 4–19. Locations of San Miguel River Elevation Measuring Points, Stage Recorder, and Zones of Areal Recharge at the Naturita UMTRA Site

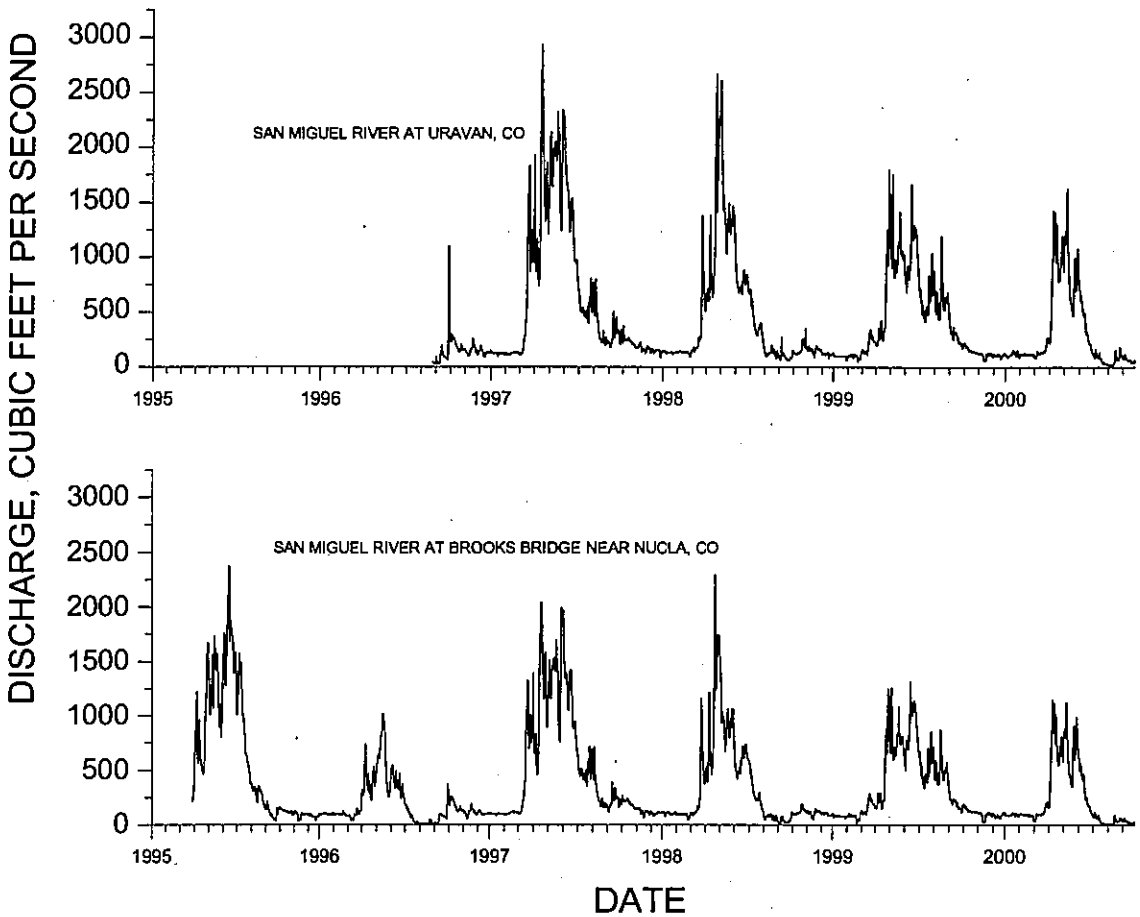
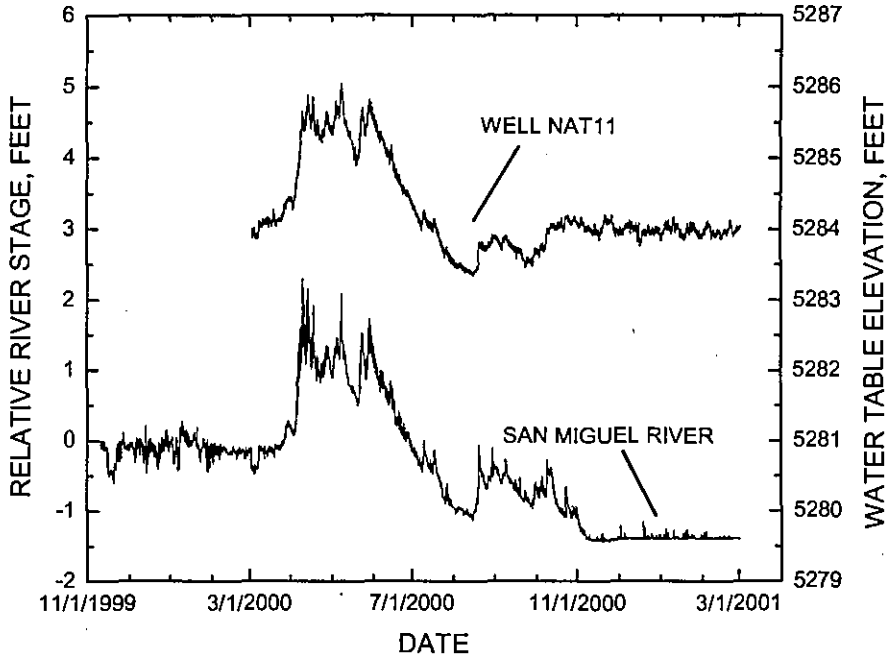


Figure 4–20. Hydrographs from USGS Gaging Stations on the San Miguel River near the Naturita UMTRA Site

4.9.3 Stage Recorder and Surface Water Elevation Measurements

Flow from the San Miguel River is believed to be the most important source of recharge to the alluvial aquifer. This is supported by the close coupling between the stage in the San Miguel River and the observed heads in several of the wells in the aquifer. Figure 4–19 shows the location of the stage recorder. No gauge was installed at the site to relate stream stage changes to a set datum. Figure 4–21 shows the changes seen in the river stage in well NAT29, which is 138 ft from the river, and in well NAT11, which is 445 ft from the river. Figure 4–22 illustrates the correlation between temporal variations in the river stage and the head in NAT08 (380 ft from the river). Figure 4–23 shows the same correlation in wells NAT25 (380 ft from the river) and NAT23 (100 ft from the river). The head changes more slowly at NAT23 and NAT25 relative to NAT29, NAT11, and NAT08. This is probably because NAT23 and NAT25 are located farther down the ground water flow path and are more hydraulically removed from the river than the other wells. This effect would tend to dampen out small changes seen in the river stage.



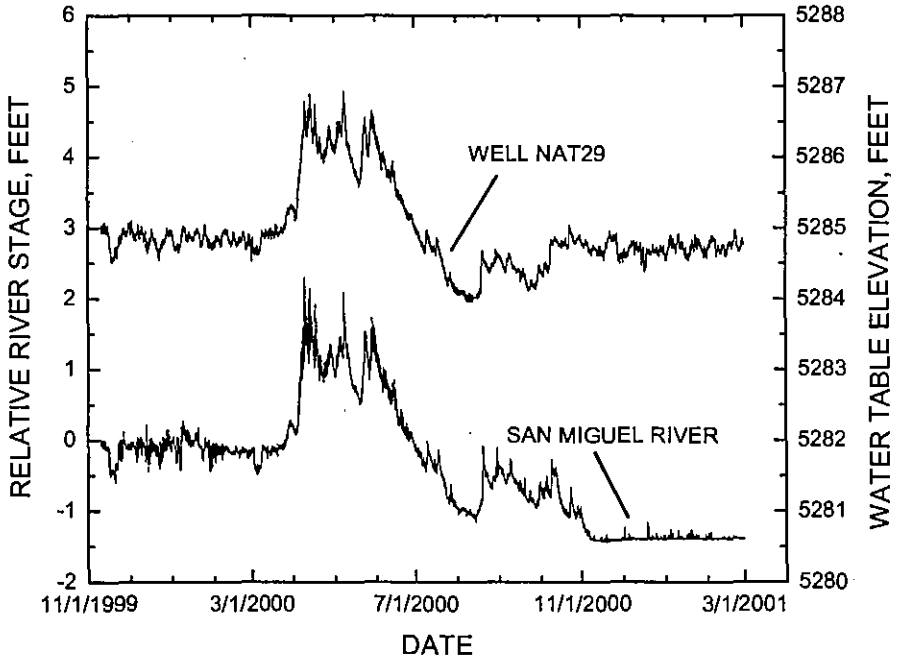


Figure 4–21. Correlation Between Water Table Elevation in Wells NAT11 and NAT29 and Relative Stage of the San Miguel River Measured at Location Stage 1

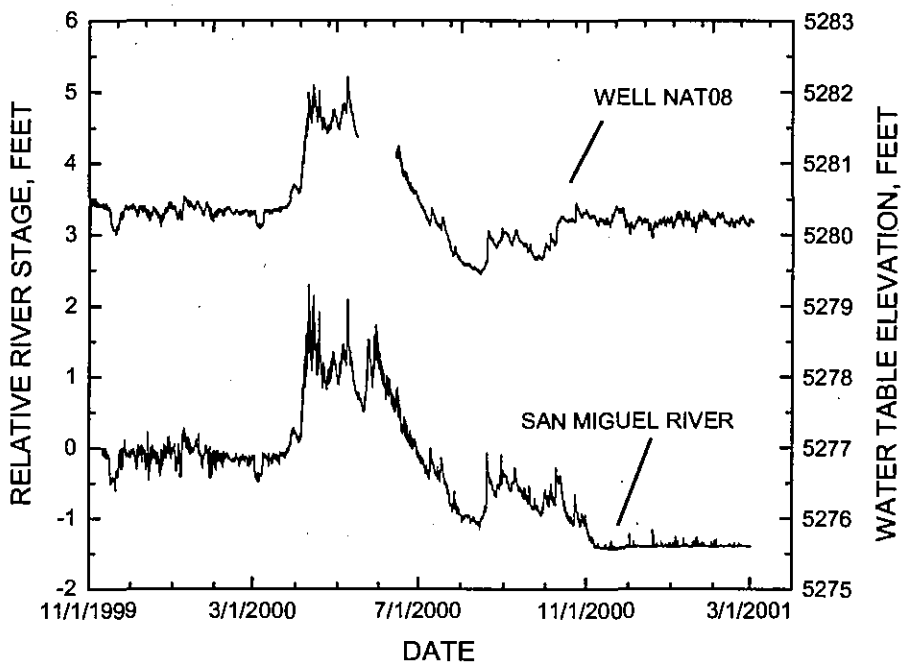
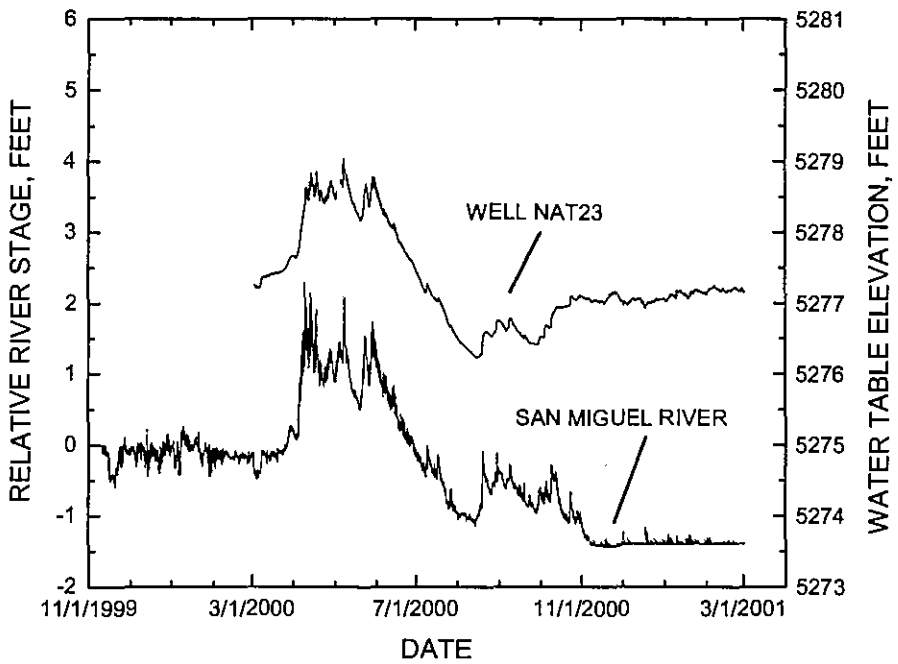


Figure 4–22. Correlation Between Water Table Elevation in Well NAT08 and Relative Stage of the San Miguel River Measured at Location Stage 1

Reference elevation points were installed and surveyed at nine points along the San Miguel River adjacent to the Naturita site. The points are shown as SM1 through SM9 in Figure 4–19. Table 4–12 shows the elevations measured for each reference point.

Figure 4–24 shows a hydrograph comparing the relative change in river stage as recorded by the river pressure transducer to the elevation of the San Miguel River measured at location SM1.



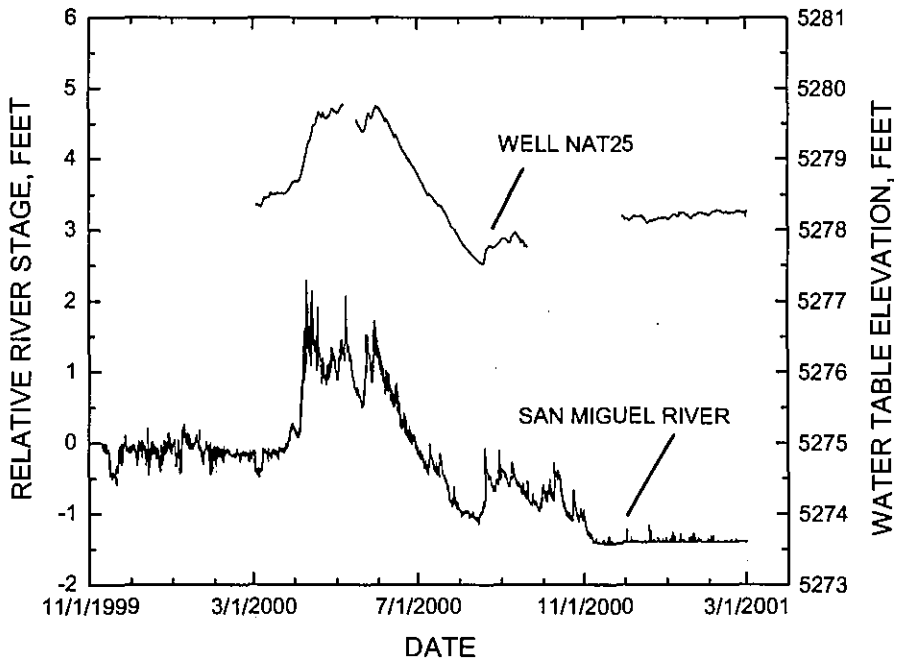


Figure 4–23. Correlation Between Water Table Elevation in Wells NAT23 and NAT25 and Relative Stage of the San Miguel River Measured at Location Stage 1

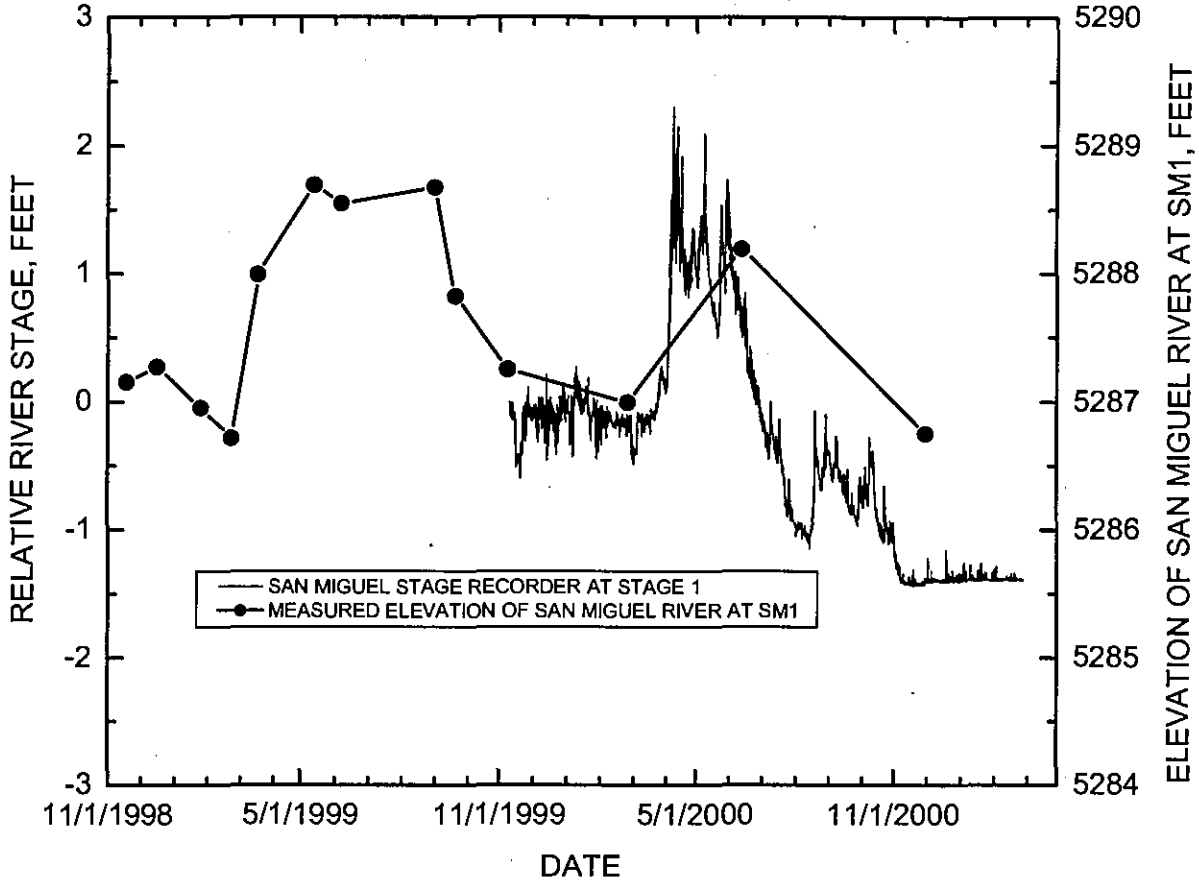


Figure 4–24. Relative Stage of the San Miguel River Recorded at Location Stage 1 and Measured Elevation of the San Miguel River at Location SM1

Table 4–12. Elevation of the San Miguel River at Locations SM1 through SM9

Date	SM1	SM2	SM3	SM4	SM5	SM6	SM7	SM8	SM9
11/18/98	5287.15	5284.25	5281.86	5278.93	5271.16	nd	nd	nd	nd
12/17/98	5287.27	5284.45	5281.88	5279.11	5271.19	nd	nd	nd	nd
01/27/99	5286.95	5284.17	5281.75	5278.92	5271.05	5271.36	5273.73	5273.97	5291.34
02/25/99	5286.72	5283.98	5281.65	5278.67	5270.89	5271.12	5273.60	5273.83	5291.00
03/22/99	5287.99	5284.82	5282.36	5279.64	5271.61	5272.06	5274.31	5274.76	5292.17
05/13/99	5288.69	5286.67	5284.40	5281.32	nd	5272.78	5274.89	5275.41	5292.72
06/07/99	5288.55	5285.39	5282.95	5280.24	5272.13	5272.62	5274.75	5275.33	5292.60
09/02/99	5288.67	5285.46	5283.00	5280.31	5272.14	5272.70	nd	5275.41	5292.82
09/21/99	5287.82	5284.83	5282.29	5279.50	5271.56	5271.99	5274.33	5274.79	5292.06
11/09/99	5287.25	5284.25	5281.93	5279.16	5271.31	5271.55	5273.87	5274.39	5292.54
02/28/00	5286.99	5284.21	5281.83	5279.00	5271.11	5271.40	5273.87	5274.23	5291.32
06/13/00	5288.19	5285.19	nd	5281.58	5271.94	5272.44	5274.79	5275.25	5292.36
12/01/00	5286.75	nd	5281.75	5279.02	5270.95	5271.34	5273.87	5274.17	5291.18
02/26/01	5286.66	nd	5281.72	5278.85	5270.95	5271.33	5273.62	5274.03	5291.04

nd = no data

4.10 Ecological Field Investigations

In general, the goal of ecological field investigations under the UMTRA Project is to acquire data to determine if site-related contamination may adversely affect ecological receptors (flora and fauna). The ecology of the former millsite and surrounding areas has been characterized to support the assessment of potential ecological risks associated with site-related contaminated ground water and to update the *Baseline Risk Assessment of Ground Water Contamination at the Uranium Mill Tailings Site Near Naturita, Colorado* (BLRA, DOE 1995). Data needed to evaluate potential risks include faunal and floral species composition, ecological interactions, contaminated media, contaminant concentrations within specific media, and exposure pathways. This section summarizes the data collected and identifies any additional data needs. Section 6.2 of this SOWP evaluates the data and draws conclusions as to the level of risk presented by site-related contamination to ecological receptors.

Because UMTRCA does not specify an ecological risk assessment protocol, the UMTRA Ground Water Project adopted EPA's 1992 risk assessment guidance (EPA 1992) as a best management practice. The BLRA preceded EPA's 1998 risk assessment guidelines (EPA 1998). The data and subsequent evaluation (Section 6.2) have been developed to support a risk-based compliance strategy that is protective of the environment. It includes a discussion of the ecological contaminants of potential concern (E-COPC), potential receptors, and potential adverse effects. A defensible ecological risk assessment (ERA) will provide a sound basis for development of a risk-based compliance strategy. The following sections provide descriptions of ecological field activities conducted to date.

4.10.1 Site Ecological Setting

The Naturita site lies in the Canyonlands section of the Colorado Plateau physiographic province and borders the San Miguel River to the northeast. The USGS reports that average low flow of the San Miguel River is about 60 cfs. The San Miguel River joins the Dolores River approximately 20 miles downstream from the site. Site-related ground water contamination moves in a generally northeast direction toward the river. Ground water flow from the site terminates in the San Miguel River along a stretch approximately 500 ft long. Seeps are evident along the northeastern boundary of the site, directly adjacent to the river. The most prominent seep at sampling location 0538 forms a small pond within the river channel during low flow, which empties into the river. This area presents the greatest potential for receptors to access contaminated media.

4.10.1.1 Site Flora and Fauna

The flora and fauna of the Naturita millsite and surrounding areas were investigated between 1986 and 1994. Section 7.2 of the BLRA describes the potential ecological receptors in detail. Additional information is provided in the *Environmental Assessment of Remedial Action at the Naturita Uranium Processing Site Near Naturita, Colorado* (DOE 1994), which documents the results of the investigations and lists the potential ecological receptors, including threatened or endangered species. Ecological characterization and surveys targeted terrestrial ecological receptors, with an emphasis on riparian plant communities and associated wildlife along the San Miguel River.

The BLRA also identifies and discusses six federally listed threatened or endangered species, one federally proposed species, and nine federal candidate species that may occur in the vicinity of the site. Of the species listed, the area may provide suitable habitat for only the southwestern willow flycatcher (*Empidonax traillii extimus*).

Plant Ecology Characterization

The San Miguel River valley includes the riparian community along the river surrounded by moderate to steep hillsides. Surrounding areas include two other major community types: piñon-juniper woodland and sagebrush-grass communities. Figure 7.1 of the BLRA shows the plant communities in the vicinity of the site at the time of remediation. In October 2000, vegetation of the former millsite was assessed using a semiquantitative relevé technique. With this method, representative stands of each vegetation type are subjectively chosen and traversed. The vegetation types are differentiated on the basis of the two dominant species present in each one. A list of all the plant species in the stand is made, and the percent cover of each species is estimated. A value for one of six cover class percentages is assigned to each species, and the percent cover is not measured precisely.

The goal of the investigation was to identify potential exposure pathways and ecological receptors. Field characterization activities focused on the identification of phreatophytic species that may be rooted into areas of site-contaminated ground water, in both riparian and upland communities.

Results

The Naturita site is dominated by upland plants that are mostly grasses and annual weeds. However, several areas have phreatophytes, or plants that can root into ground water. Phreatophytic species include willows (*Salix* spp.), cottonwoods (*Populus* spp.), tamarisk (*Tamarix* spp.), and greasewood (*Sarcobatus vermiculatus*). A strip of riparian and wetland vegetation growing along the San Miguel River includes willows and cottonwoods. Tamarisk and willows grow along a ditch through the site at the north end. An island of shrubby vegetation around a group of power poles in the field includes greasewood. Altogether, there are four riparian/wetland vegetation types and three upland vegetation types, as shown in Figure 4–25.

A willow-dominated riparian area is at the north end of the site along the river. Sandbar willow (*Salix exigua*) up to 8 ft tall is the main species; the understory is smooth brome (*Bromus inermis*), thistle (*Cirsium* sp.), common reed (*Phragmites australis*), Woods rose (*Rosa woodsii*), and aster species.

The south end of the riparian area has two distinct vegetation types. One has an abundance of mature lanceleaf cottonwoods (*Populus accuminata*), with an herbaceous understory of scratchgrass muhly (*Muhlenbergia asperifolia*) and sweet clover (*Melilotus officinalis*). The other is a mixture of willows and cottonwoods, both juvenile and mature, with a variety of grasses and forbs underneath.

The final wetland vegetation type is a 10-ft-wide strip along a ditch toward the north end of the site. The vegetation is mostly 6–8-ft-tall sandbar willow (*Salix exigua*) with some Canada thistle (*Cirsium arvense*), tamarisk, and common reed (*Phragmites australis*).

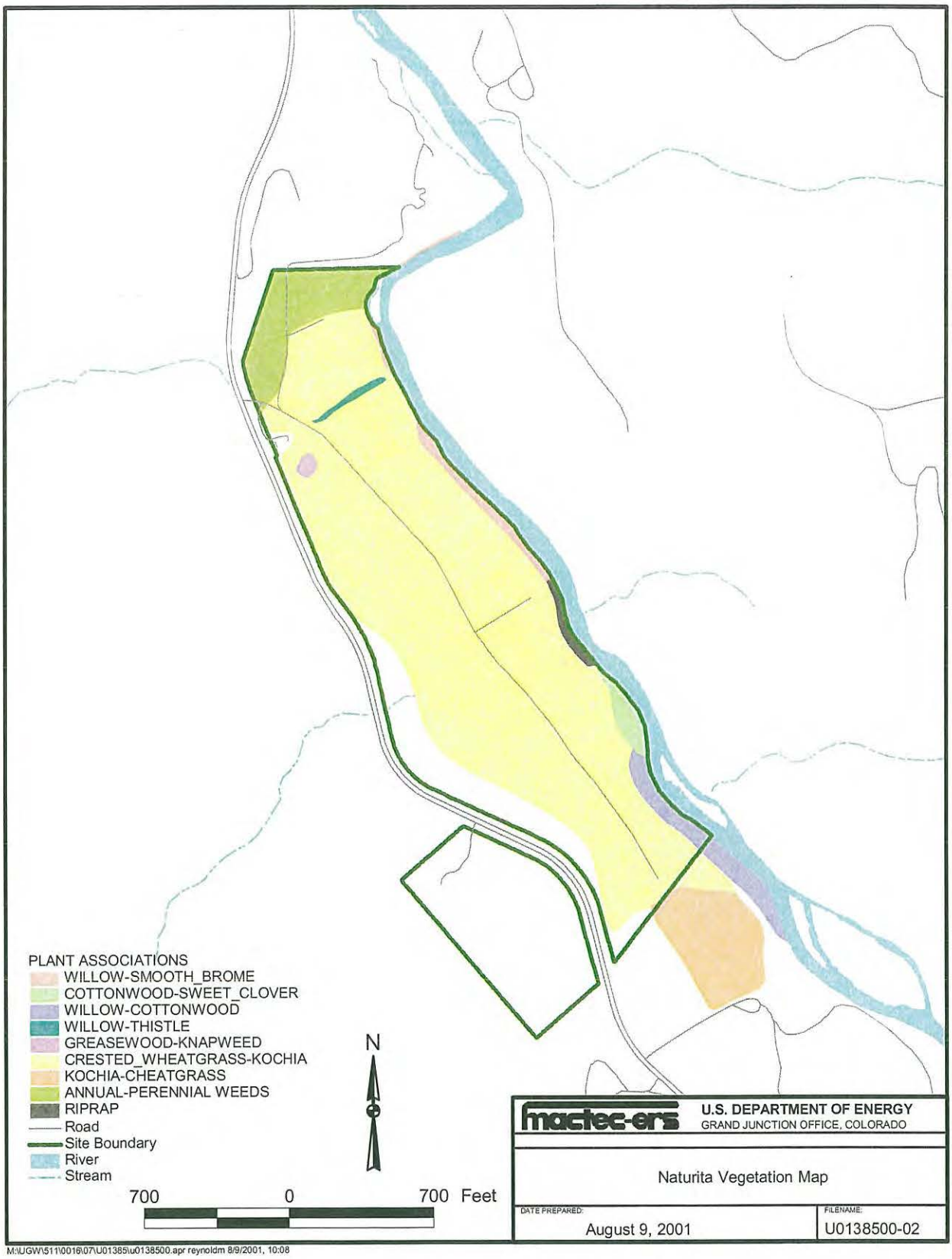


Figure 4–25. Vegetation Map of the Naturita Millsite

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The major upland type is the reseeded portion of the field. It is approximately 50 percent bare, and the main vegetation consists of crested wheatgrass (*Agropyron cristatum*) and kochia (*Kochia scoparia*), both under 6 inches tall. The far north end of the field is dominated by annual and perennial weeds, including Russian thistle (*Salsola iberica*), Russian knapweed (*Centaurea repens*), and cheatgrass (*Anisantha tectorum)*. The knapweed will be treated and this portion of the site will be reseeded in September 2001. Small islands around the power poles in the field contain mostly greasewood and Russian knapweed. The south end of the upland area is a weedy field with kochia and cheatgrass. Grazing restrictions will be implemented by installing fencing to improve the condition of the upland vegetation at the site.

4.10.2 Sampling and Analysis

4.10.2.1 BLRA Results

Ground water was sampled and analyzed to determine if concentrations of site-related contaminants exceeded background or maximum concentration limits established in 40 CFR 192. If ground water concentrations exceeded background, the contaminant was evaluated for potential ecological risks. Table 3.1 of the BLRA summarizes the ground water characterization results for key contaminants. Section 3.4 and Table 3.3 of the BLRA identified 27 E-COPCs that, based on the median concentrations, exceeded background ground water concentrations. Table 4–13 lists the 23 inorganic and 4 radionuclides identified in the BLRA as E-COPCs. No explanation is provided as to why three constituents (tin, zinc, and radium-226), which had concentrations that exceeded background in Table 3.1 of the BLRA, were not identified as exceeding background. It is assumed that tin and zinc were excluded because they only slightly exceeded background. It is assumed that radium-226 was excluded because the median concentration (4.9 pCi/L) within the contaminated area is just under the maximum concentration limit of 5 pCi/L (40 CFR 192). However, Table 3.3 of the BLRA, which lists E-COPCs, included radium-226 but excluded thorium-230. Tin and zinc were also excluded as E-COPCs in Table 3.3.

Because soil was remediated to standards in 40 CFR 192 under the surface remediation program, both soil and air are eliminated as media of concern for ecological receptors. However, ground water presents a possible secondary source and exposure medium. The primary concern is the possibility that contaminated ground water may be hydrologically connected to surface water, thereby creating the potential to contaminate the adjacent river or ponds. Because the San Miguel River is close to the ground water contamination, it is included for evaluation. Therefore, ground water, surface water, and associated sediments are the media of interest for ecological risk assessment. These media were selected because both direct and indirect pathways to ecological receptors are possible.

4.10.2.2 Abiotic Sampling and Analysis

Ground water data were used to determine E-COPCs for terrestrial receptors. Surface water and sediment sampling was conducted to determine E-COPCs for both terrestrial and aquatic receptors, but primarily for aquatic receptors. This section summarizes the data reported in Sections 3.0 and 7.0 of the 1995 BLRA.

Table 4–13. E-COPCs that Exceeded Background Ground Water Concentrations

Inorganics	Radionuclides
Aluminum	Lead-210
Ammonium	Polonium-210
Antimony	Radium-226
Arsenic	Radium-228
Barium	
Boron	
Calcium	
Chloride	
Fluoride	
Magnesium	
Manganese	
Molybdenum	
Nitrate	
Phosphate	
Potassium	
Selenium	
Silica	
Silver	
Sodium	
Strontium	
Sulfate	
Uranium	
Vanadium	

Ground Water

Ground water sampling at the site was conducted between 1986 and 2001. However, BLRA data and interpretation addressed only the period from 1986 through 1994. Data gathered after 1995 are addressed in Section 6.2, the BLRA update. Table 4–14 lists the ground water sampling locations that were sampled from 1986 through 1994. Ground water locations 0547 and 0548 are the only locations of the 12 historical sampling locations that continue to be monitored.

Table 4–14. Ground Water Sampling Locations from 1986 through 1994

Location Number	Description	Dates Sampled	References/Comments
0505	Mill Yard/On site	1986–94	BLRA Table 3.2
0506	Tailings Pile/On site	1986–94	BLRA Table 3.2
0546[a]	Upgradient/Off site	1986–92	BLRA Table 3.2
0547[a]	Upgradient/Off site	1986–94	BLRA Table 3.2
0548	Downgradient/Off site	1986–94	BLRA Table 3.2
0549[a]	Upgradient/Off site	1987–92	BLRA Table 3.2
0616	Tailings Pile/On site	1989–92	BLRA Table 3.2
0619	Tailings Pile/On site	1989–92	BLRA Table 3.2
0630	Tailings Pile/On site	1989–92	BLRA Table 3.2
0632	Tailings Pile/On site	1989–92	BLRA Table 3.2
0637	Tailings Pile/On site	1989–92	BLRA Table 3.2
0656	Tailings Pile/On site	1990–92	BLRA Table 3.2

[a]Background Location
BLRA = Baseline Risk Assessment

Surface Water

On the basis of the E-COPCs, surface water sampling locations 0531, 0532, and 0533 were initially established in the San Miguel River channel to determine if ground water was affecting the quality of surface water. Both filtered and unfiltered samples were collected. Location 0531 was used to establish background concentrations. Four additional locations 0534, 0535, 0536, and 0538 were added in 1994 (Table 4–15). Location 0538, which is referred to as a spring in the BLRA, is actually a seep that feeds into a small pond in the river floodplain. The pond eventually discharges to the river approximately 200 ft downstream. Because the seep was believed to be ground water discharging to the surface, location 0538 was discussed in the ground water section of the BLRA. The BLRA also refers to other ponds that no longer exist due to fluctuations and changes in the river's channel. All four 1994 locations were only sampled once.

Table 4–15. Surface Water Locations from 1986 to 1994.

Location Number	Description	Dates Sampled	References/Comments
0531	S.M. River/upstream	1986–94	BLRA Fig. 3.5/Table 3.5
0532	S.M. River/middle of site	1986–94	BLRA Fig. 3.5/Table 3.5
0533	S.M. River/downstream	1986–94	BLRA Fig. 3.5/Table 3.5
0534	S.M. River/south end of site	1994	BLRA Fig. 3.5/Table 3.5
0535	S.M. River/north end of site	1994	BLRA Fig. 3.5/Table 3.5
0536	S.M. River/north end of site	1994	BLRA Fig. 3.5/Table 3.5
0538	Floodplain/north end of site	1994	BLRA Fig. 3.5/Table 3.1

BLRA = Baseline Risk Assessment

Although data showed the potential for a slight increase over background for three site-related constituents (sodium, sulfate, and uranium), initial sampling and statistical evaluations indicated that the San Miguel River was not being affected. Therefore, no E-COPCs were identified for surface water at that time. However, additional sampling and analysis was recommended. Section 3.6 of the BLRA details the results of sampling.

Sediments

Sediment samples were collected at all seven surface water locations (Table 4–16) in one round of sampling in 1994. Sediment benchmarks were found for nine of the E-COPCs. The benchmarks are updated in the current ecological risk assessment in Section 6.2 of this SOWP. A qualitative assessment showed that concentrations of uranium, sulfate, and zinc appeared to be higher in downstream sediments than in upstream. Zinc was the only constituent that showed a noticeable increase over background at location 0538. The BLRA recommended that additional data be collected to confirm the results. However, it was also noted that it may not be possible to distinguish between the site-related contribution of elevated concentrations (e.g., uranium) and naturally occurring contributions.

Table 4–16. Sediment Samples Collected in 1994

Location Number	Description	Dates Sampled	References/Comments
0531[a]	S.M. River/upstream	1994	BLRA Fig. 3.5/Table 3.6
0532	S.M. River/middle of site	1994	BLRA Fig. 3.5/Table 3.6
0533	S.M. River/downstream	1994	BLRA Fig. 3.5/Table 3.6
0534[a]	S.M. River/south end of site	1994	BLRA Fig. 3.5/Table 3.6
0535	S.M. River/north end of site	1994	BLRA Fig. 3.5/Table 3.6
0536	S.M. River/north end of site	1994	BLRA Fig. 3.5/Table 3.6
0538	Floodplain/north end of site	1994	BLRA Fig. 3.5/Table 3.6

[a]Background location
BLRA = Baseline Risk Assessment

4.10.2.3 Biotic Sampling

With the exception of wetland plants, no sampling of benthic, terrestrial, or aquatic organisms was conducted at the site before 1995. Therefore, there is no information in the BLRA or site documents addressing the analysis of these organisms.

Wetland plants were sampled once at six locations (0531–0536) in 1994. Samples were collected in areas influenced by the site-related contaminated ground water, the millsite floodplain, and in reference areas. Reference areas, or background areas, resemble the site ecologically—landform, soil, and vegetation are similar—but lack the influence of millsite-related ground water contamination. Reference areas were used for baseline chemical data for the ERA and to help project possible successional pathways. The reference areas used to evaluate risk for the millsite vegetation were locations 0531 and 0534. Spikerusk (*Eleocharis* spp.) was sampled in saturated substrate at each location. On the basis of the limited data, no consistent difference between background reference sites and site sample concentrations was noted. Table 7.2 of the BLRA lists the results for 10 selected constituents. No explanation is provided as to why these constituents were selected. It is assumed that they were selected due to the higher concentrations in on-site ground water. In addition, ground water concentrations in the alluvial aquifer were compared to screening benchmarks for terrestrial plants (BLRA, Table 7.5). Additional sampling was recommended.

4.10.3 Update

No sampling of any media was conducted between 1995 and 1997. In 1998, sampling and analysis resumed. Several additional locations were added and some of the historical locations were no longer used. Changes in sampling locations and target analytes were made on the basis of pre-1995 sampling. Details of the changes are provided in the following sections.

4.10.3.1 Abiotic Sampling and Analysis

Ground Water

Thirty-nine sampling locations were added between 1998 and 2000. Only two locations, 0547 and 0548, were retained from the original 12 (Figure 4–1), bringing the total number of ground water locations to 41. The 2001 Statement of Work reduced the list of wells to be monitored to 28. Table 4–17 summarizes monitor well locations retained for monitoring.

Table 4–17. Monitor Well Locations Retained for Monitoring

Location Number	Description	Dates Sampled	References/Comments
0547[a]	Upgradient/off site	1986–94, 1999–2001	BLRA Table 3.2/USGS data
0548	Downgradient/off site	1986–94, 1999–2001	BLRA Table 3.2/USGS data
DM1[a]	Upgradient/off site	2000–01	USGS Data
MAU03	Downgradient/off site	1998–01	USGS Data
MAU04	Downgradient/off site	1998–01	USGS Data
MAU05	Downgradient/off site	1998–01	USGS Data
MAU06	Downgradient/off site	1999–01	USGS Data
MAU07	Downgradient/off site	1999–01	USGS Data
MAU08	Downgradient/off site	1999–01	USGS Data
NAT01	Off site/downgradient	1998–01	USGS Data
NAT02	On site	1998–01	USGS Data
NAT03	On site	1998–01	USGS Data
NAT04	On site	1998–01	USGS Data
NAT06	On site	1998–01	USGS Data
NAT08	On site	1999–01	USGS Data
NAT10	On site	1998–01	USGS Data
NAT11	On site	1998–01	USGS Data
NAT15	On site	1999–01	USGS Data
NAT16	On site	1999–01	USGS Data
NAT19	On site	1999–01	USGS Data
NAT20	Upgradient/off site	1999–01	USGS Data
NAT23	Downgradient/off site	1999–01	USGS Data
NAT24	Downgradient/off site	1999–01	USGS Data
NAT25	Downgradient/off site	1999–01	USGS Data
NAT26	Downgradient/off site	1999–01	USGS Data
NAT27	On site	1999–01	USGS Data
NAT29	On site	1999–01	USGS Data
NAT30	On site	1999–01	USGS Data

[a]Background Location

On the basis of the BLRA and subsequent evaluation, DOE determined that only 19 of the original 27 E-COPCs would be sampled for during the 1998 through 2000 sampling events (Table 4–18). Ammonium, antimony, fluoride, and silver were the nonradionuclides excluded. No explanation is provided in previous documentation as to why these and the four radionuclides identified in the BLRA were not retained for further sampling. Iron and zinc were added to the list for risk assessment purposes, bringing the total number of constituents to 21 (Table 4–18). For the eight constituents excluded from current sampling, the analysis of ecological risk is completed on the basis of historical (pre-1998) data.

Table 4–18. E-COPCs Selected for Analysis in the 1998–2000 Ground Water Samples

Inorganics	Radionuclides
Aluminum	None
Arsenic	
Barium	
Boron	
Calcium	
Chloride	
Iron	
Magnesium	
Manganese	
Molybdenum	
Nitrate	
Phosphate	
Potassium	
Selenium	
Silica	
Sodium	
Strontium	
Sulfate	
Uranium	
Vanadium	
Zinc	

In the *Statement of Work for Ground Water Characterization at the Naturita, Colorado UMTRA Site* (DOE 2001) for work conducted by USGS for DOE, 11 constituents were identified for future sampling (Table 4–19). Those denoted with an asterisk in the table were sampled for ecological risk assessment.

Table 4–19. Summary of 11 E-COPCs Retained for Sampling in the 2001 Statement of Work

E-COPCs Retained	E-COPCs Not Retained
Arsenic	Aluminum
Barium*	Ammonium
Boron*	Antimony
Manganese	Calcium
Molybdenum	Chloride
Nitrate	Fluoride
Selenium	Iron
Sulfate	Lead-210
Uranium	Magnesium
Vanadium	Phosphate
Zinc	Polonium-210
	Radium-226 and 228
	Silica
	Silver
	Sodium
	Strontium
	Thorium-230

The 17 E-COPCs excluded are evaluated for risk in Section 6.2 on the basis of historical data. Those retained will be evaluated based on data collected from 2000 through 2001.

Surface Water

Nine sampling locations (0558–0561, SM1–SM4, and SM9) were added from 1998 through 2001 (Figure 4–6). Four locations (0531, 0533, 0536, 0538) of the original seven were also retained, bringing the total number of surface water sampling locations to 13 through 2001. Table 4–20 summarizes surface water locations from 1998 through 2001. The 11 analytes listed in Table 4–19 for ground water were also identified for surface water analysis. Therefore, the evaluation of potential ecological risks associated with surface water for these constituents is based on 1998–2001 sampling data. E-COPCs that are not currently being analyzed are evaluated in Section 6.2 based on historical data.

Table 4–20. Surface Water Locations Sampled Between 1998 and 2001

Location Number	Description	DOE	USGS	Dates Sampled	References/ Comments
0531	S.M. River/upstream	X		1986–94, 2000–2001	BLRA Fig. 3.5/Table 3.5
0533	S.M. River/downstream	X		1986–94, 2001	BLRA Fig. 3.5/Table 3.5
0535	S.M. River/north end of site	X		1994, 2001	BLRA Fig. 3.5/Table 3.5
0536	S.M. River/north end of site	X		1994, 2001	BLRA Fig. 3.5/Table 3.5
0538	Floodplain/north end of site	X		1994, 2000–2001	BLRA Fig. 3.5/Table 3.1
0558	S.M. River/middle of site	X		2000–2001	2001 SOW
0559	S.M. River/north end of site	X		2000–2001	2001 SOW
0560	S.M. River/north end of site	X		2000–2001	2001 SOW
0561	S.M. River/middle of site	X		2000–2001	2001 SOW
SM1	S.M. River/middle of site		X	1998–2001	2001 SOW
SM2	S.M. River/middle of site		X	2000–2001	2001 SOW
SM3	S.M. River/middle of site		X	2000–2001	2001 SOW
SM4	S.M. River/middle of site		X	2000–2001	2001 SOW
SM9	S.M. River/middle of site		X	2000–2001	2001 SOW

BLRA = Baseline Risk Assessment
SOW = Statement of Work
S.M. = San Miguel

Filtered surface water samples were collected. The filtered sample represents the soluble component for aquatic receptors. Each sample bottle was first rinsed with the surface water; the rinse water was then discarded prior to sample collection. A sample was collected by immersing the bottle just below the water surface and filling to just below the mouth of the bottle. Samples were then filtered using a 0.45-µm filter and acidified for preservation.

Sample labels showing the date, time, location, laboratory bar code, sampler, analyses requested, preservatives, and comments were applied to each container and secured with clear plastic tape. All sample containers were placed in coolers containing ice for transport to the GJO Analytical Chemistry Laboratory. All samples were maintained under strict chain of custody.

Sediments

Nine sediment sampling locations (0558–0561, SM1–SM4, and SM9) were co-located with surface-water samples from 1998 through 2001 (Figure 4–6). Four locations (0531, 0533, 0536, and 0538) of the original seven were also retained, bringing the total number of sediment locations sampled through 2001 to 13.

The area for sample collection was typically a circle with a radius less than 5 ft. Excess organic matter and larger rocks and pebbles were removed from the sample prior to compositing. The contents of one stainless-steel auger (i.e., one subsample) were collected at each composite location and placed in a large stainless steel mixing pan. The material in the mixing pan was mixed thoroughly with a stainless steel spoon, and about 4 ounces (114 g) of material was removed for metals analysis.

Sample labels were applied to each container and secured with clear plastic tape. All sample containers were placed in coolers containing ice for transport to the GJO Analytical Chemistry Laboratory. All samples were maintained under strict chain of custody. The preparation method for the sediment samples included a complete acid digestion rather than an acid leach as was used for some previous sediment analyses.

4.10.3.2 Biotic Sampling and Analysis

No biotic sampling was conducted between 1998 and 2001, no further sampling of vegetation or other biota is currently planned. If future ecological risks are suspected, DOE will consider further sampling at that time.

5.0 Site Conceptual Model

The site conceptual model discusses the important processes that influence the distribution, present levels, and estimated future conditions of contamination at the Naturita site. Results of information gathered during the past year and a review of previous information were used to construct the model. The compliance strategies will be based on information in the site conceptual model.

5.1 Geology

5.1.1 Regional Geologic Setting

The Naturita site is in the Canyonlands physiographic region, along the northeastern side of the Colorado Plateau. This area is characterized by canyons deeply incised into red sandstones of Mesozoic age with isolated mesas. The plateau was uplifted about 10 million years ago, causing rivers to entrench as the uplift proceeded, and may still be experiencing some uplift (Cater 1970). The Uncompahgre Plateau is the dominant structure along the eastern side of the site that was reactivated during the Pliocene and possibly later (Cater 1970). It is a broad northwest-trending upwarp bounded on the west by the north-flowing San Miguel and Dolores Rivers. To the west is the Paradox Basin, a large Pennsylvanian basin that formed concurrently with the ancestral uplift along the Uncompahgre Plateau (Barrs and Stevenson 1981). The basin is characterized by numerous folds and faults produced by compressional forces during the Laramide orogeny. This event allowed lower salt beds to mobilize into elongated upward-piercing diapirs that produced anticlines. Later, the compressional forces were relaxed, allowing tension and the structural failure of the anticlines. Subsequent uplift of the entire region caused erosion and exposed the failed salt anticlines that weathered and produced further collapse and formation of the modern salt valleys. *The Remedial Action Plan for the Inactive Uranium Processing Site at Naturita, Colorado* (DOE 1998a) presents a more detailed description of the geologic setting.

5.1.2 Local Geology and Stratigraphy

Locally, the San Miguel River valley follows part of the Nucla Syncline, a broad gentle downwarp off the eastern flank of the Salt Valley Anticline (a collapsed salt anticline) located to the west. Bedrock dips in the area of the site are subtle, 1 to 2 degrees to the northeast (DOE 1995).

The stratigraphy at the site is simple. Figure 5–1 shows a generalized geologic cross section trending from the south center of the site to the northwest and across Highway 141. The cross section was constructed from wells used during surface remediation; and NAT–30 and DM–1 constructed during this phase of characterization. Unconsolidated alluvium deposited by the San Miguel River fills the valley floor. This material consists of clayey gravel to sandy cobbles, interbedded with layers of silty to sandy clay that pinch off against the bedrock highs on the west and attain a thickness of 23 ft at well 0548. Toward the west side of the site, red to chocolate-colored clayey to sandy colluvium from weathering of Brushy Basin and stratigraphically higher sediments fill drainages entering from the west. Figure 5–2 shows the approximate bedrock surface below the site. Figure 5–3 (alluvium thickness) shows a thicker area of alluvium along the south side of the site where a gravel pit is currently operating. Another thick area of alluvium occurs farther north near the bend of the river. This contouring is based on one well log, well 0548, which recorded the top of the Brushy Basin at 23 ft, much deeper than in surrounding wells.

Bedrock underlying the alluvium consists of the Brushy Basin and Salt Wash Members of the Jurassic Morrison Formation that range up to 820 ft in thickness in the Naturita area. This is the same formation that yielded most of the uranium and vanadium ore from the Uravan district and is unusually thick in this area. The upper Brushy Basin Member contains numerous sequences of variegated bentonitic fluvial to lacustrine mudstones, siltstones, claystones, and some sandstones that range in color from brown to red, green, and gray. It has been partly eroded away below the site but is still 120 to 150 ft thick and can be twice to three times this thickness (Williams 1964). Below the Brushy Basin is the Salt Wash Member, consisting of fluvial sandstones with some siltstone and conglomerate lenses. It sometimes contains carbonaceous plant fragments, which can act as a reducing agent that causes the precipitation and concentration of uranium and vanadium. This member contains several prominent sands and can be up to 300 ft thick (Williams 1964).

Above the Brushy Basin sediments are the sandstones and conglomerates of the Lower Cretaceous Burro Canyon Formation and above them the sandstones of the late Cretaceous Dakota Sandstone. The remnant of a coal mine high on the hillside on the east side of the San Miguel River near the site is in the Dakota Sandstone. These formations have little influence on the millsite.

5.2 Hydrologic System

5.2.1 Surface Water Hydrology

The San Miguel River is the dominant source of surface water at the site. It is a perennial stream that originates in the San Juan` Mountains near Telluride and joins the Dolores River about 20 miles downstream from Naturita. A USGS gauging station at Naturita records an average maximum flow of 2,000 cfs and an average minimum of 60 cfs (DOE 1994). Maximum flows occur during the spring runoff usually in June and during summer storm events. The only current use of river water near the former millsite is for irrigation and livestock watering.

Several arroyos on the west side of Highway 141 drain Sawtooth Ridge and periodically contribute water and sediment to the site. A culvert near the middle of the site drains one of these valleys to the west. Water from summer storms in 2000 eroded the culvert, and it was repaired in 2001. Figure 3–1, an aerial photograph from 1954, shows a prominent delta deposit on the floodplain produced by another drainage located farther north.

Dry Creek enters the San Miguel River about 0.5 mile upgradient of the site and drains Mancos Shale and Dakota Sandstone in Dry Valley. It flows during the spring and intermittently during other parts of the year. Water from Dry Creek is usually turbid and increases the suspended sediment load in the San Miguel River near the site.

A distributary cutoff on the Maupin property is the source of several small ponds fed by springs. Surface location 0538 is recorded as a spring in the BLRA and is part this system. Figure 3–3 from 1974 shows the main course of the San Miguel River was located farther south and occupied the present seep/pond area of 0538. By 1986 (Figure 3–4) the current course of the river had shifted to the north, and by 1998 (Figure 3–7) the present course of the river had left the former channel as a low scarp along an expanding riparian willow-sapling zone.

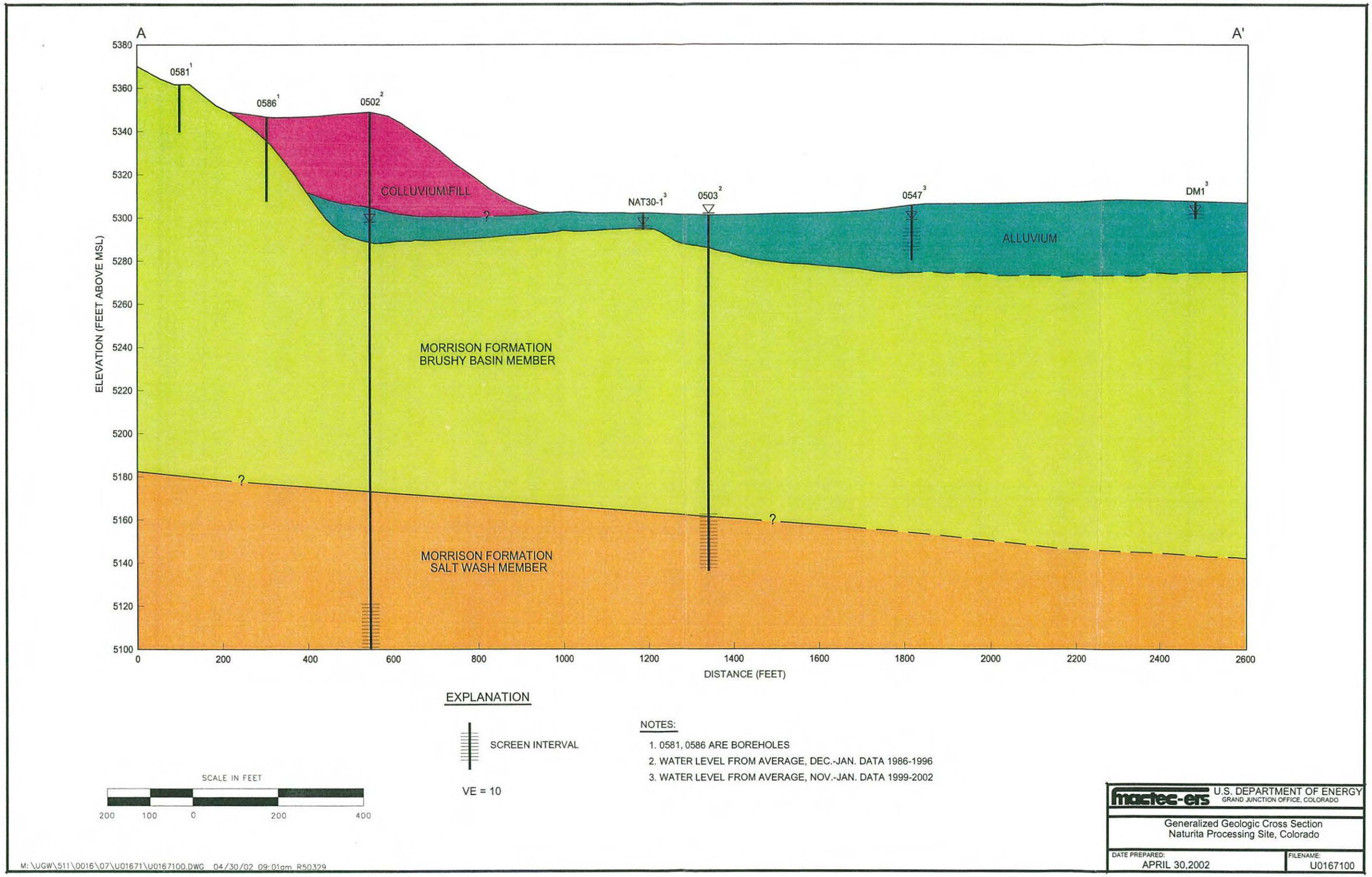

Figure 5–1. Generalized Geologic Cross Section of the Naturita Site

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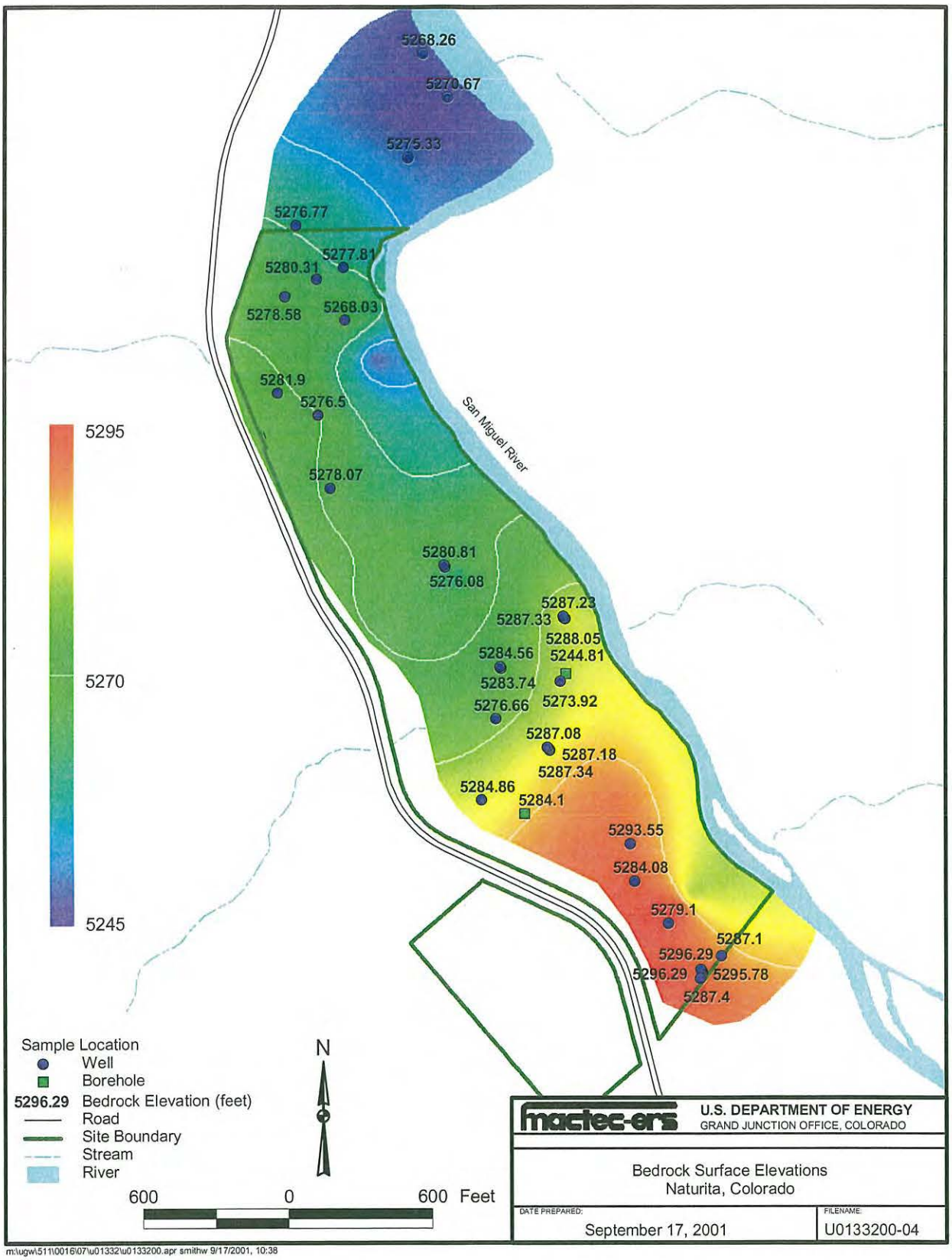

Figure 5–2. Bedrock Surface Elevations at the Naturita Site

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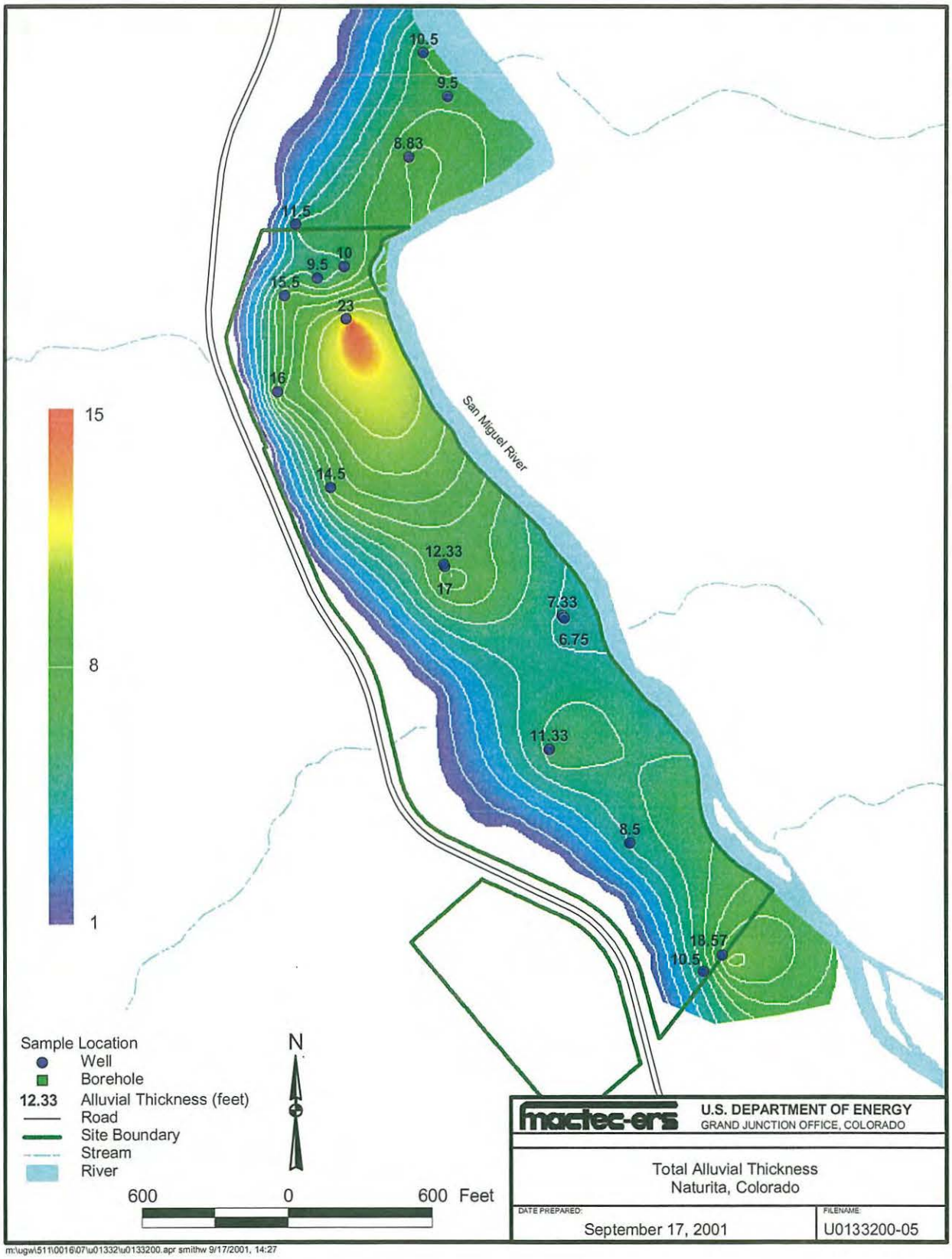

Figure 5–3. Thickness of the Alluvium at the Naturita Site

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5.2.2 Alluvial Aquifer

The alluvial aquifer is the uppermost aquifer at the Naturita site and consists of the saturated portion of the river-lain alluvium. It is the only aquifer of concern for ground water contamination because the underlying Brushy Basin Member of the Morrison Formation has an upward hydraulic gradient. The alluvial aquifer is a wedge of sediment that varies in thickness from zero as it pinches out along the western bedrock to about 23 ft along the San Miguel River near the northern portion of the site (Figure 5–3 and Figure 5–4). However it generally ranges from only about 5 to 10 ft in thickness over most of the site. The section of interest underlying the site is approximately 4,000 ft long and 700 ft wide. Recharge and discharge occur along the length of the San Miguel River depending on the river level. However, the primary recharge zone is thought to be a 600-ft strip from the San Miguel River about 2,400 ft south of the site near the confluence of Dry Creek, where the river makes a sharp bend. From there, water migrates slowly northwest through the aquifer until it finally exits back into the San Miguel River north of the site along a 500-ft zone where the river intersects bedrock on the Maupin property. The aquifer pinches off against the San Miguel River at that point. Another source of water entering the alluvial aquifer is from arroyos draining from the west. Their significance is probably greater locally where water from these drainages could contribute to flushing contaminants in the aquifer near the western edge of the site. The last source of recharge is infiltration of rainfall. The Hopkins-Montrose airport in Nucla 2.5 miles east of the site receives approximately 11 inches of rain per year. The surficial aquifer below the site contains approximately 30,000,000 gallons (4 million cubic feet) of water at any one time.

Hydraulic characteristics of the alluvial aquifer were determined by water age determinations, stable isotope and chloride measurements, falling head slug tests, and bromide tracer tests. Ground water age determination studies using tritium-helium and chlorofluorocarbon methods generally indicate increases in the age of water near the western side of the site. Flow paths are generally parallel to the San Miguel River (Figure 5–42), and older ages suggest slower flow rates along the western side of the site. This agrees well with ground water surface contour map shown in Figure 5–5. Lines of equal elevations are generally perpendicular to the San Miguel River and flow directions perpendicular to the elevation contours. Discussion of the methods for determining ground water age and comparison of results of ground water ages are in Section 5.3.4. The results of the age determinations agree with modeling results that show the "dog-leg" portion of the aquifer in the northwestern part of the site has slower ground water flow rates than areas along the eastern side of the site. The open gravel pit at the southern end of the site intersects ground water. Chloride and stable isotope studies suggest that this dewatering of the upgradient head of the aquifer will have an important, although negative, effect on potential natural flushing or pumping of contaminated water at the site. Section 5.4.6 discusses this in greater detail.

Falling head slug tests were performed for 13 wells in November 1999 and May 2000. The hydraulic conductivity ranged from 19 ft/day (MAU04) to 333 ft/day (NAT09) and averaged 95 ft/day. Bromide tracer tests were performed on six wells. These results indicated hydraulic conductivities that ranged from 43 ft/day to 215 ft/day. No recognized pumping tests were performed for the site.

5.2.3 Bedrock Aquifer

Two wells, 0502 and 0603, were drilled through the Brushy Basin Member and penetrated the Salt Wash Member of the Morrison Formation during the surface program. Falling head slug tests were conducted in the wells to estimate hydraulic conductivities in the Salt Wash and alluvial aquifers. Results indicated a low hydraulic conductivity in the Brushy Basin Member and a vertical hydraulic gradient from the Salt Wash Member into the Brushy Basin Member. This combination prevents any downward migration of contaminated water into the Salt Wash aquifer and demonstrates that the Brushy Basin acts as an effective aquitard. Appendix B of the Remedial Action Plan for the Naturita site (DOE 1998a) provides details of the bedrock aquifer.

5.3 Geochemistry

5.3.1 Source Areas and Contaminants

The sources of contamination at the Naturita site were ores hauled from the surrounding area, mostly within a 50-mile radius, from 1939 to 1958 and processed at the mill. These ores typically contained, in addition to uranium and vanadium, elevated concentrations of arsenic, molybdenum, selenium, and sulfate. During the period from 1947 to 1963, 704,000 tons of ore were processed at the site. Sulfuric acid, bases, and other chemicals were used to process the ores. Estimated volumes of production water and wastewater were not found in a search of the literature, but millions of gallons of contaminated water may have seeped into the ground.

Tailings at the Naturita site were hauled away for further processing in the late 1970s, and the site underwent surface remedial action to remove approximately 771,000 cubic yards of RRM from 1993 to 1998. A number of areas containing contaminated soils were left in place under the application of supplemental standards. The most contaminated ground water on the site is below the former tailings pile area. There, vanadium concentrations still reflect the footprint of the former surface contamination.

5.3.2 Surface Water Quality

The only permanent surface water features at the Naturita site are the San Miguel River and a ground water seep that discharges near location 0559 and flows to the San Miguel River near location 0538. Contaminated alluvial ground water from the site has the potential to discharge to these two areas, both of which are downgradient of the former tailings area. Impacts to these surface water locations are evaluated by comparison to water quality measurements at locations that are unaffected by site-related contamination.

5.3.2.1 Background Surface Water Quality

Background surface water quality samples were collected from the San Miguel River at location 0531 during November 2000 and March 2001. Location 0531 is upstream and upgradient from the site (Figure 5–6). Table 5–1 summarizes the analytical results of these background samples.

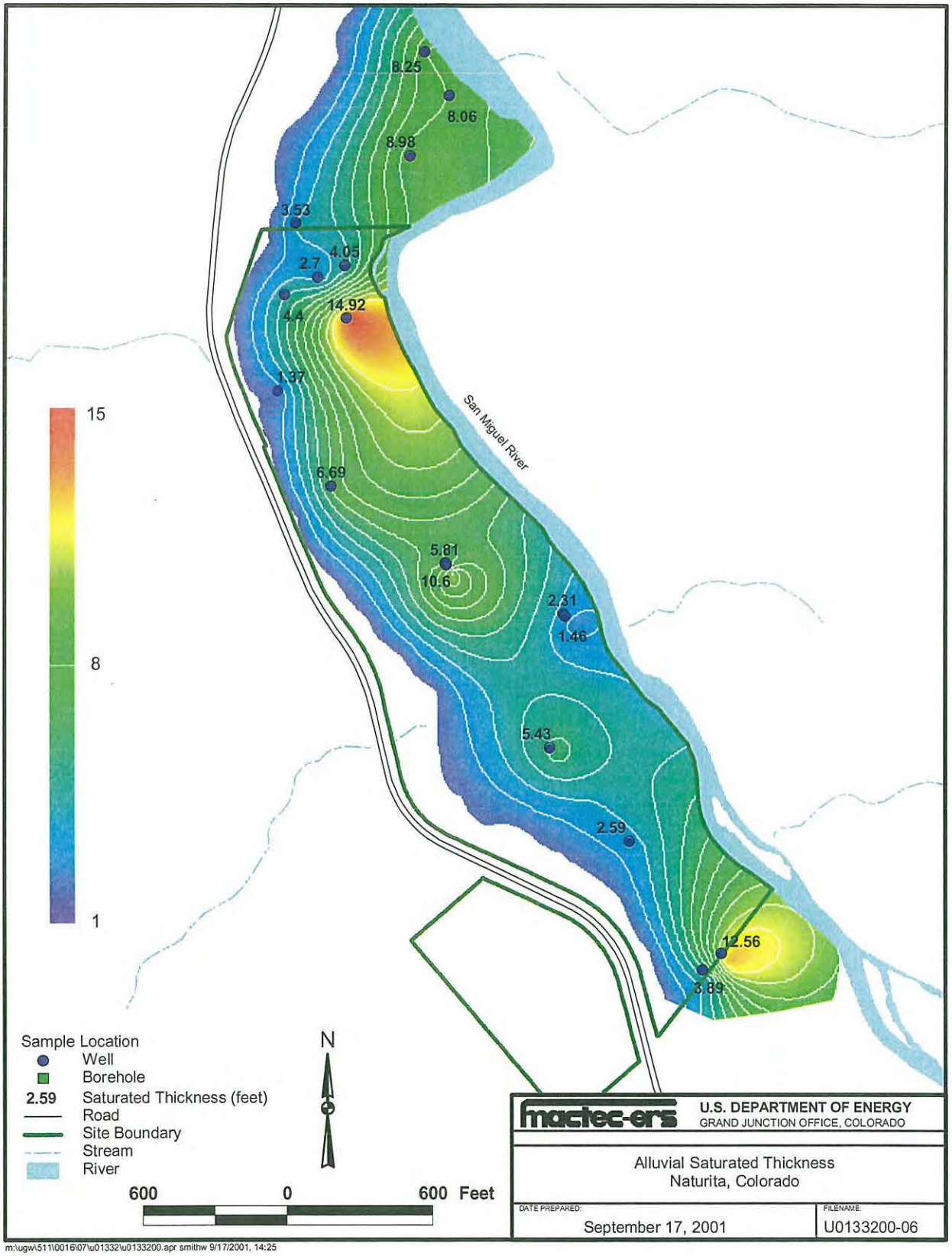

Figure 5–4. Thickness of Saturated Alluvium at the Naturita Site

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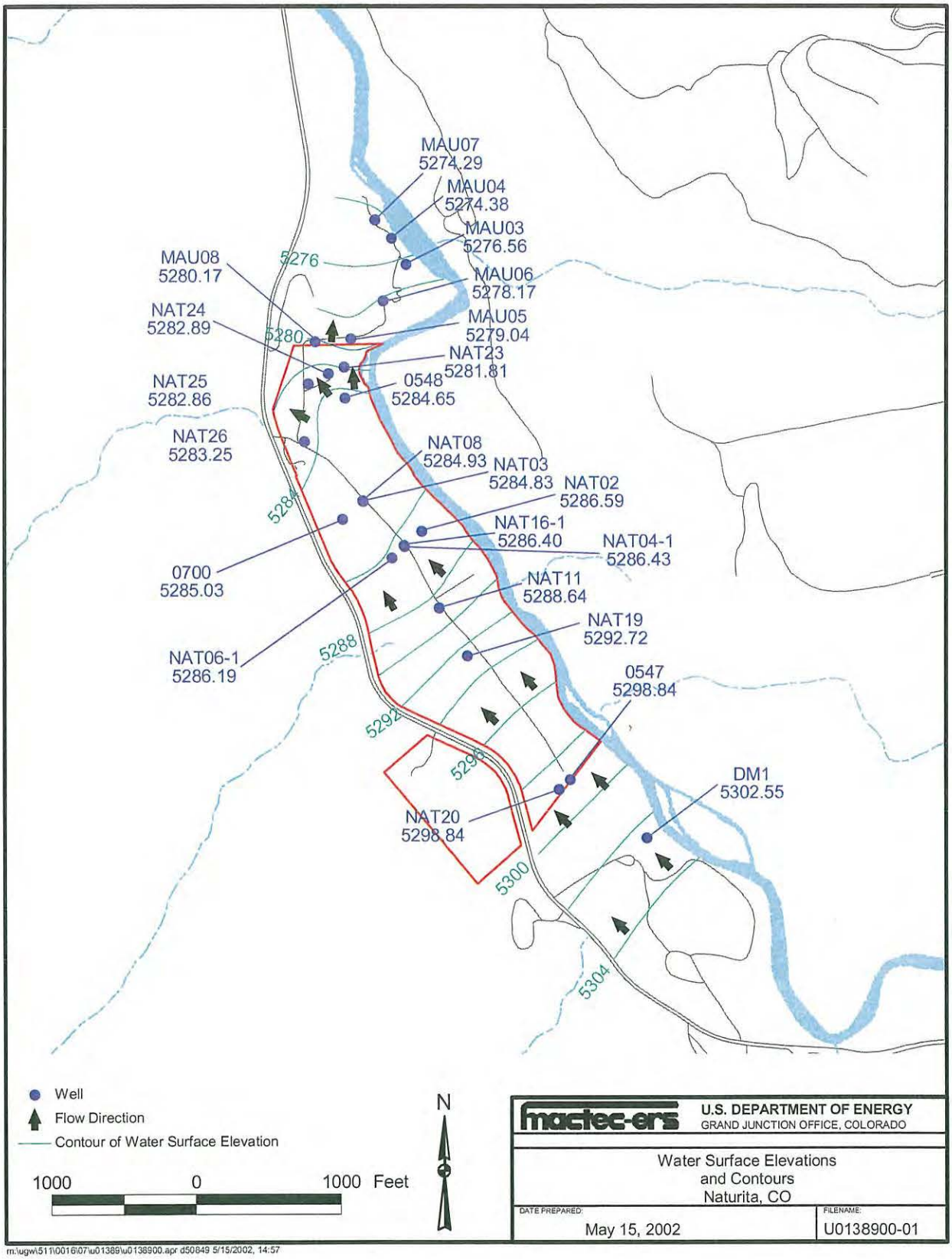

Figure 5–5. Water Surface Elevations and Contours

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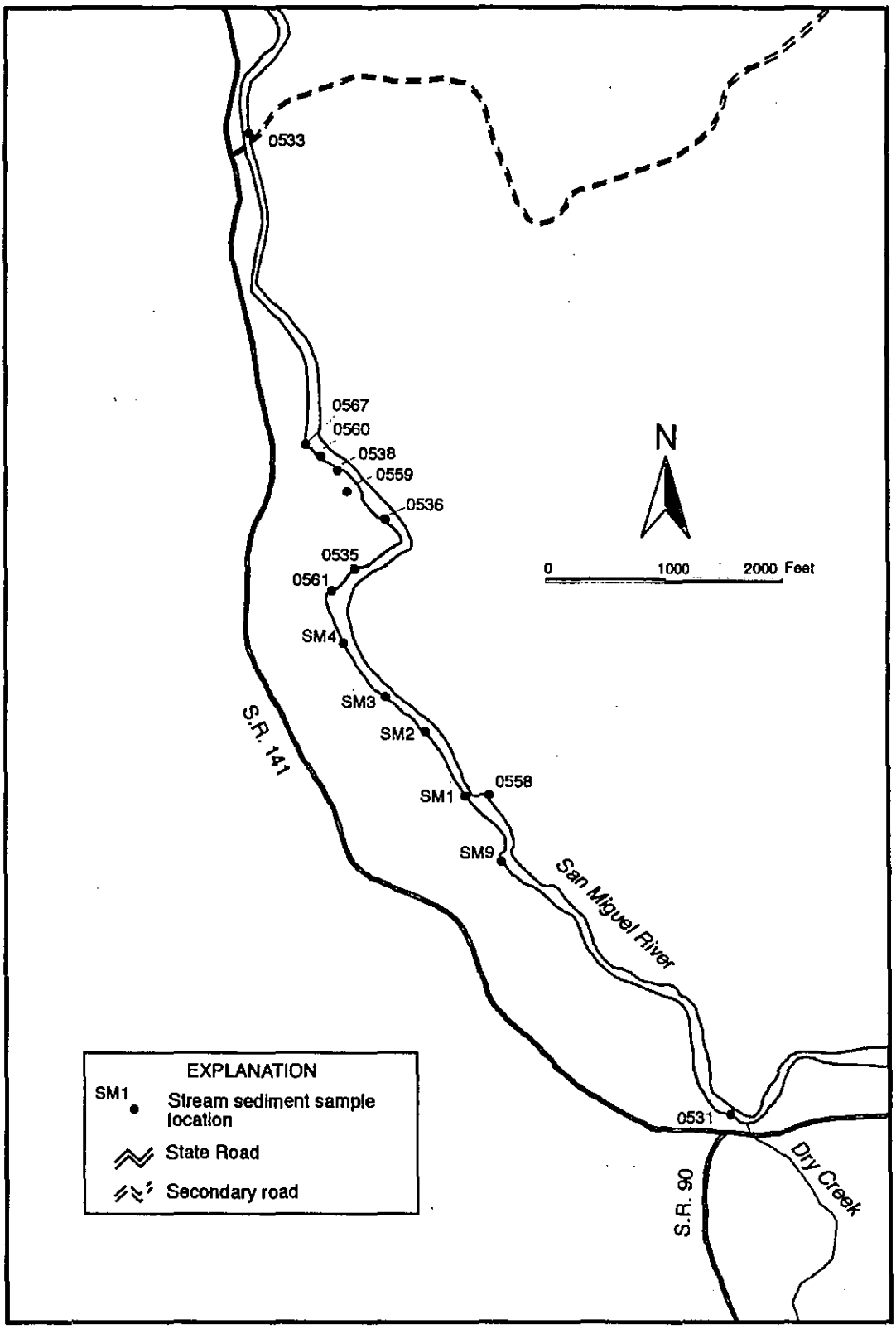

Figure 5–6. Locations of Surface Water and Sediment Samples at the Naturita Site

Table 5–1.Background Surface Water Quality at Location 0531

		Concentration		
Analyte	**Units**	**November 2000**	**Feb/Mar 2001**	**Average**
Major Ions				
Calcium	mg/L	54	82	68
Chloride	mg/L	0.40	8.4	4.40
Magnesium	mg/L	29	27	28.2
Nitrate	mg/L	0.05	<0.02	
Potassium	mg/L	1.7	1.8	1.74
Sodium	mg/L	23	28	25.4
Sulfate	mg/L	236	239	238
Metals				
Aluminum	mg/L	<0.28	<0.28	
Arsenic	mg/L	0.0007	0.0007	0.0007
Cadmium	mg/L	<0.04	<0.04	
Chromium	mg/L	<0.04	<0.04	
Cobalt	mg/L	<0.04	<0.04	
Copper	mg/L	<0.04	<0.04	
Iron	mg/L	<0.03	<0.03	
Lead	mg/L	<0.20	<0.20	
Manganese	mg/L	<0.04	<0.04	
Molybdenum	mg/L	<0.04	<0.04	
Nickel	mg/L	<0.04	<0.04	
Selenium	mg/L	0. 0008	0.001	0.0009
Uranium	mg/L	0.0029	0.0023	0.0026
Vanadium	mg/L	<0.04	<0.04	
Zinc	mg/L	<0.04	<0.04	
Other				
Barium	mg/L	0.08	0.05	0.06
Boron	mg/L	<0.04	0.09	
Bromide	mg/L	6.6	0.05	3.33
Lithium	mg/L	<0.03	<0.03	
Phosphorus	mg/L	<0.04	<0.04	
Silicon	mg/L	3.4	2.4	2.90
Strontium	mg/L	1.2	1.1	1.15
Field Measurements				
Alkalinity as $CaCO_3$	mg/L	134	108	121
Dissolved oxygen	mg/L	10.8	13.6	12.2
Oxidation-Reduction Potential	mV	290	361	325
pH	standard units	8.43	8.48	8.46
Specific Conductance	µS/cm	730	816	773
Temperature	°C	1.57	3.82	2.70

Notes:

The mean was not calculated if at least one result was below detection limit.
Specific conductance, oxidation-reduction potential, and pH were measured on unfiltered samples; samples for all other measurements were filtered through a 0.45 µm filter.

µS/cm = microsiemens per centimeter
mV = millivolts

5.3.2.2 Site Impacts on Surface Water

Samples were collected adjacent to the millsite at locations SM9, SM1, 0558, SM2, SM3, SM4, 0561, 0535, 0536, 0560 and downgradient of the site at location 0533 to evaluate the effects of ground water contaminants on the San Miguel River. Samples were also collected from a ground water seep at locations 0559 and 0538. Ponded water at location 0567 was collected in March 2001.

A comparison of San Miguel River sampling results from on-site, upgradient, and downgradient locations generally indicates that water quality is unaffected by discharge from the contaminated alluvial aquifer.

Figure 5–7 through Figure 5–11 show concentrations of arsenic, chloride, selenium, sulfate, and uranium, respectively, at surface water locations along the San Miguel River. Vanadium, molybdenum, and nitrate concentrations were at or below detection limits at all locations and are not shown. Most arsenic (Figure 5–7), selenium (Figure 5–9), and uranium (Figure 5–11) concentrations at locations adjacent to and downstream of the former tailings area are all near the background concentration measured at location 0531. However, samples collected during March 2001 at locations 0567 and 0561 have elevated concentrations of most constituents, including uranium, which exceeded the maximum concentration limit established for the UMTRA Project. These samples were collected during low-flow conditions in pools close to the bank of the river. These values most likely represent concentrations of discharging ground water before it is diluted with river water. Some further concentration of contaminants may have occurred through evaporation. At low river stage, flow from these pools to the river is minimal. When the river rises in the spring and summer, this contaminated water should be diluted and flushed out of the stagnant pool areas.

Figure 5–12 through Figure 5–17 compare arsenic, chloride, selenium, and sulfate concentrations, sulfate/chloride ratio, and uranium concentrations, respectively, in samples from the ground water seep locations. Because the chemistry of water discharging from the seep more closely resembles that of ground water than surface water, the concentrations shown in Figure 5–12 through Figure 5–16 are compared to background ground water concentrations measured at well DM1. The water is similar in chemistry to that of nearby wells MAU03, MAU04, and MAU07, which are also shown for comparison. Water quality results from the ground water seep at locations 0559 and 0538 show that concentrations of most constituents exceed the background concentrations measured at location 0531 and well DM1. Vanadium, molybdenum, and nitrate concentrations were at or below detection limits at all locations and are not shown.

Concentrations of arsenic, chloride, and selenium in the ground water seeps shown in Figure 5–12 through Figure 5–14, respectively, are at or near background concentrations measured at location 0531 and well DM1. These values are also well below the UMTRA Project maximum concentration limits. Water in well MAU07 is thought to reflect millsite contamination due to concentrations of chloride, sulfate, and uranium above background values. This may be from deposits of tailings washed in by the San Miguel River many decades ago and deposited in an old channel of the river.

Figure 5–15 shows sulfate concentrations in samples from the ground water seep locations. Almost all concentrations exceed background values measured at location 0531 and DM1 and exceed the Colorado secondary drinking water standard. An exception is the sample collected in

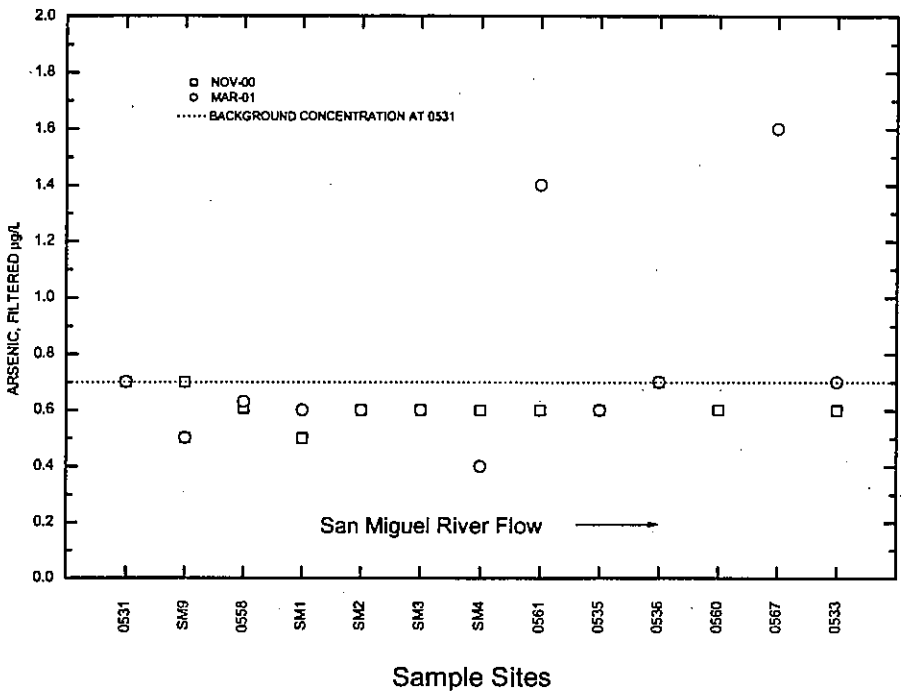

Figure 5–7. Arsenic Concentrations at Surface Water Sampling Locations Along the San Miguel River

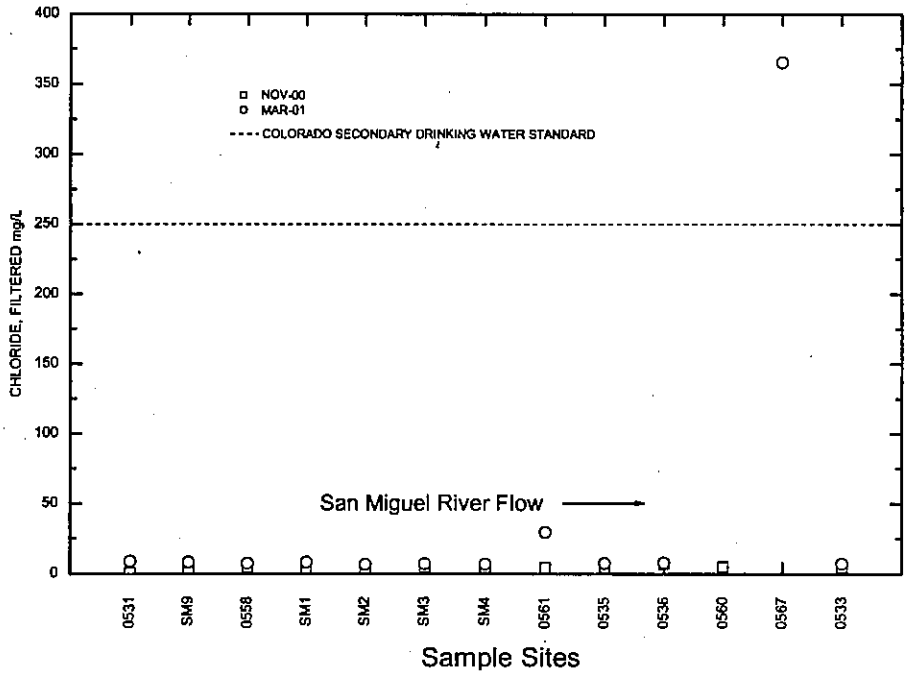

Figure 5–8. Chloride Concentrations at Surface Water Sampling Locations Along the San Miguel River

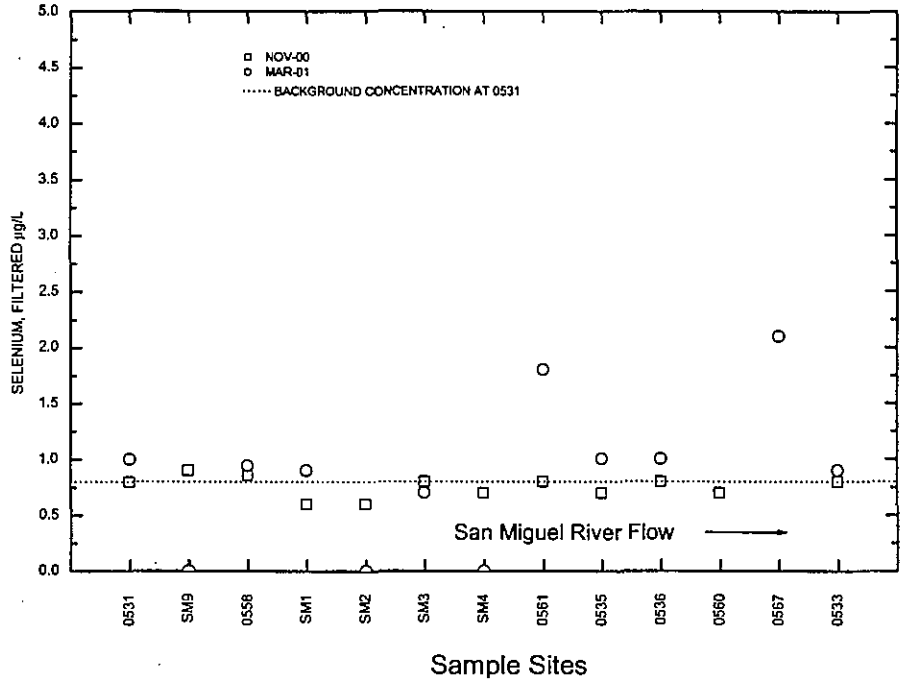

Figure 5–9. Selenium Concentrations at Surface Water Sampling Locations Along the San Miguel River

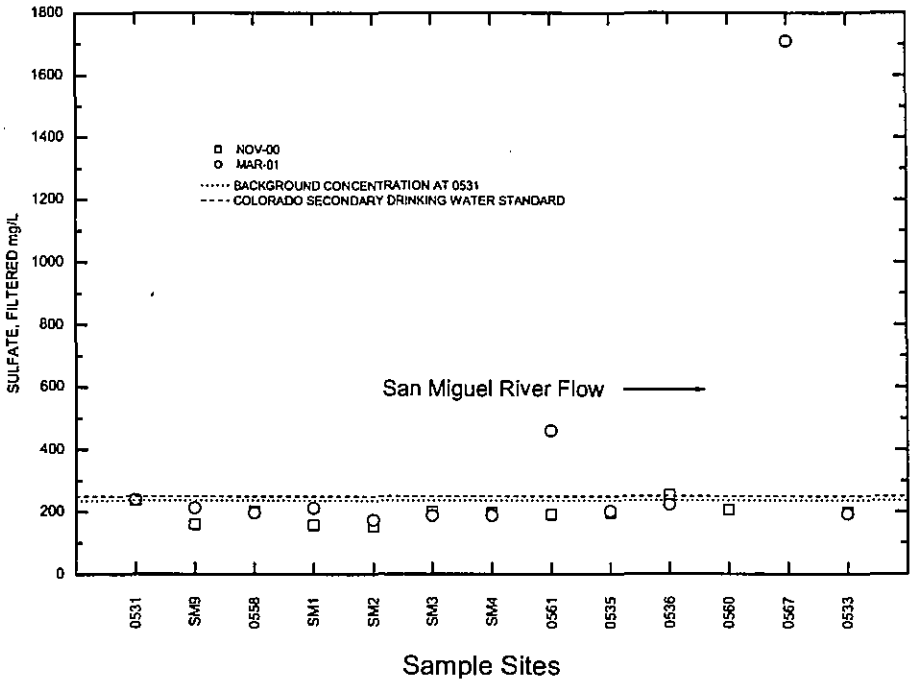

Figure 5–10. Sulfate Concentrations at Surface Water Sampling Locations Along the San Miguel River

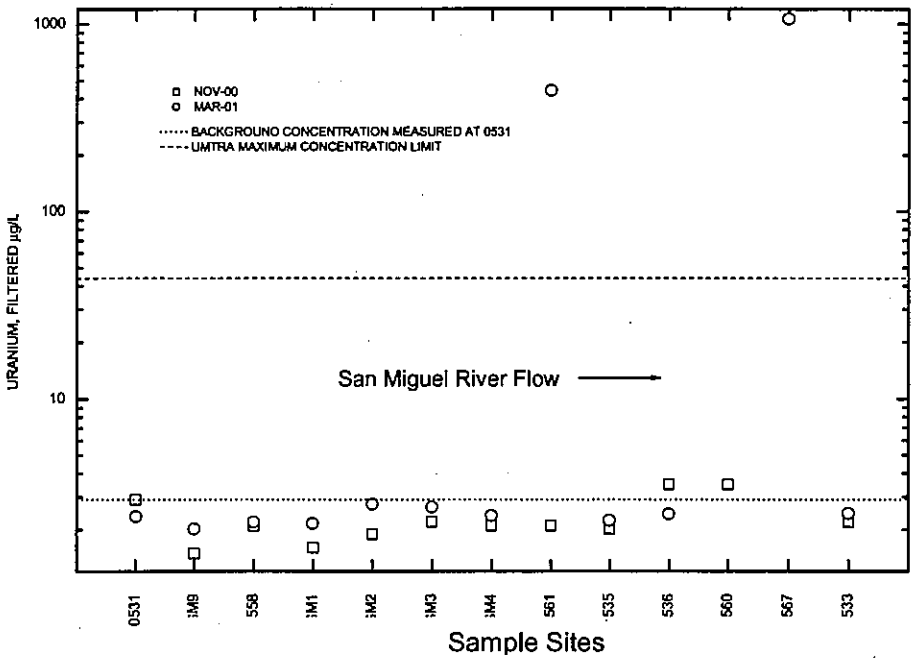

Figure 5–11. Uranium Concentrations at Surface Water Sampling Locations Along the San Miguel River

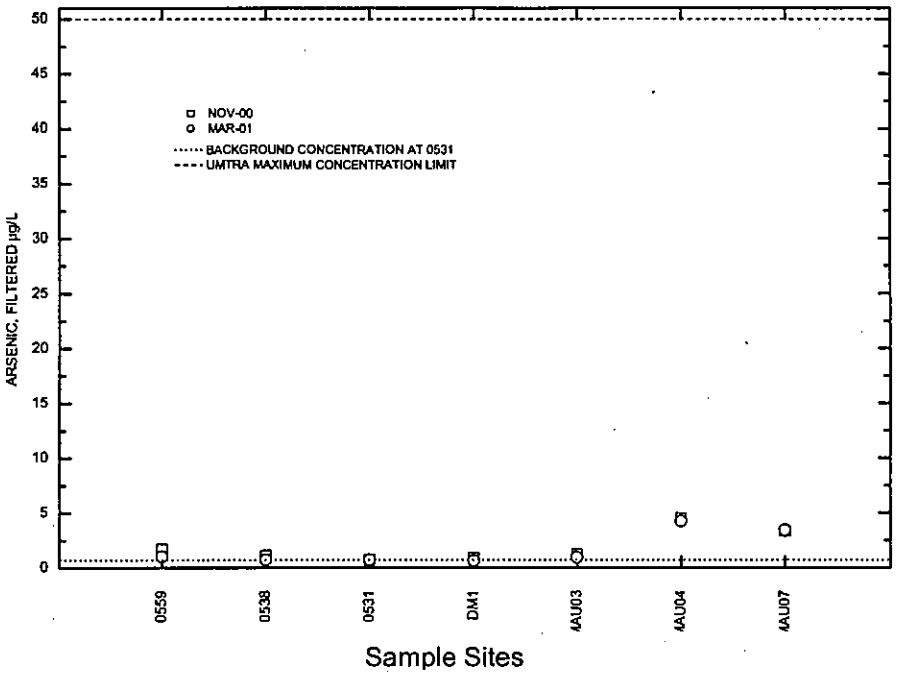

Figure 5–12. Arsenic Concentrations at the Ground Water Seep Locations

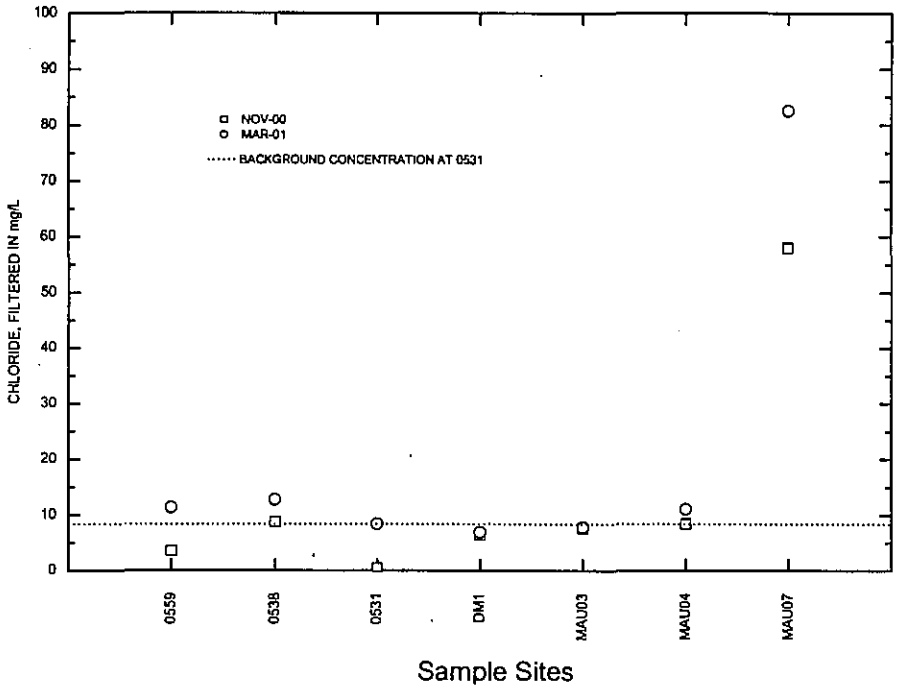

Figure 5–13. Chloride Concentrations at the Ground Water Seep Locations

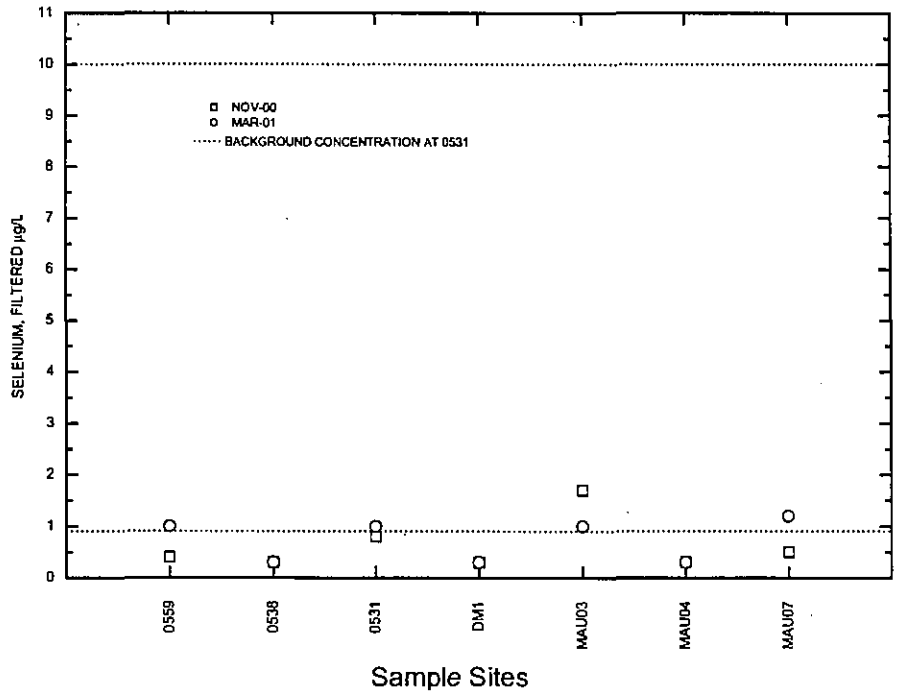

Figure 5–14. Selenium *Concentrations at the Ground Water Seep Locations*

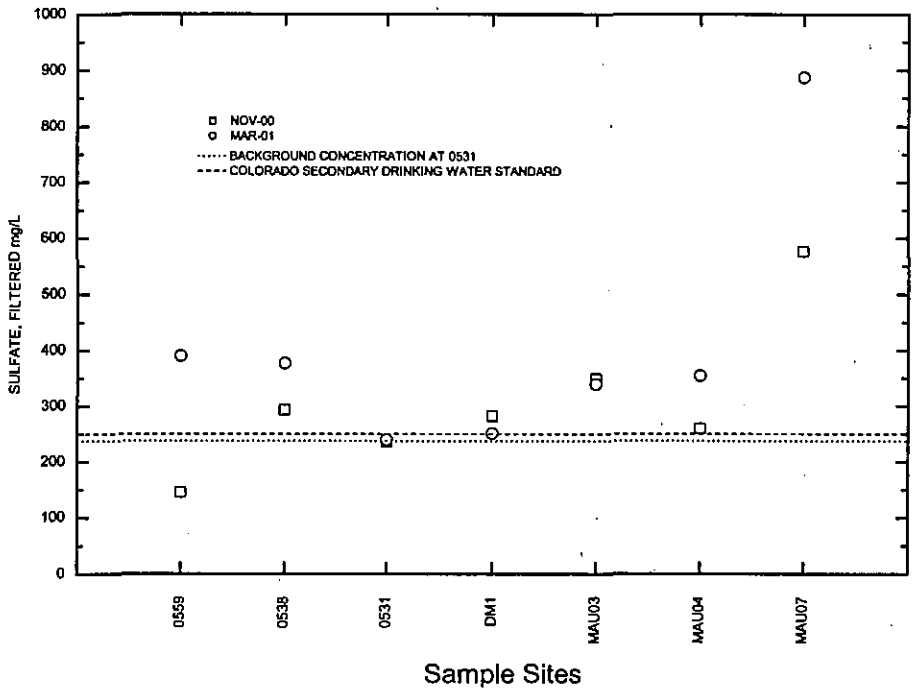

Figure 5–15. Sulfate Concentrations at the Ground Water Seep Locations

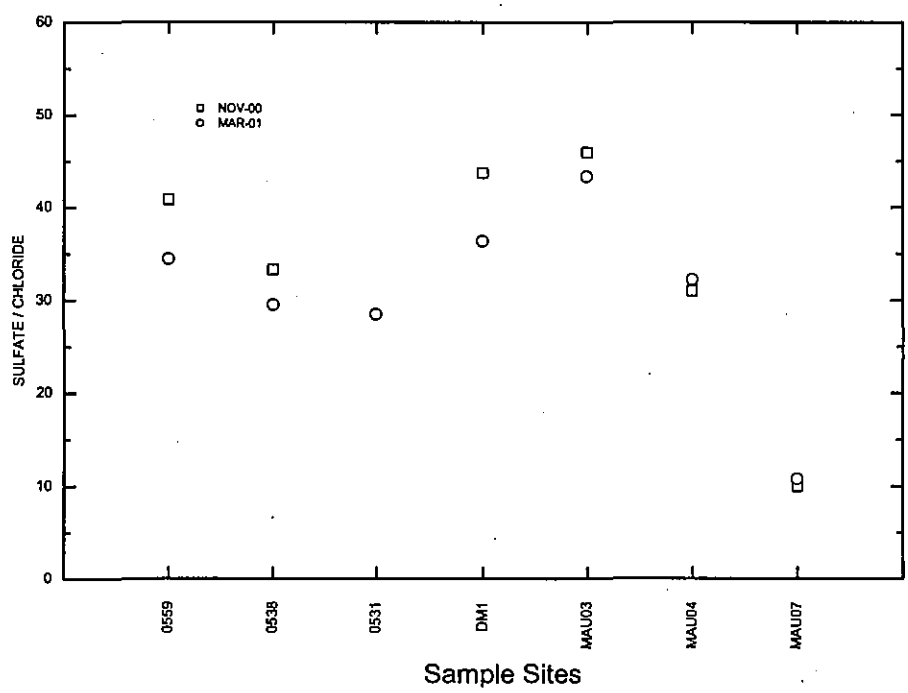

Figure 5–16. Sulfate/Chloride Ratio at the Ground Water Seep Locations

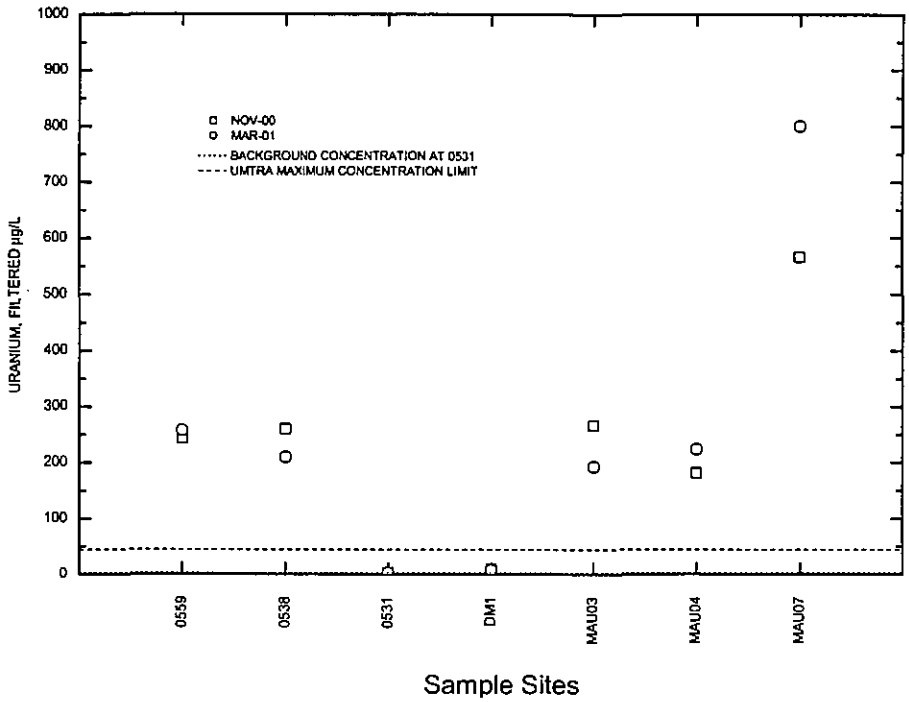

Figure 5–17. Uranium Concentrations at the Ground Water Seep Locations

November 2000, which has less sulfate than that measured in 0538 and in the background samples. During March 2001, sulfate concentrations were above background levels and were similar to those measured at location 0538. A similar pattern can also be seen in chloride concentrations shown in Figure 5–13. Figure 5–16 shows the sulfate/chloride ratio in the ground water seeps. The ratio for the two sites is similar to that calculated for the San Miguel River and nearby wells MAU03 and MAU04. Well MAU07 has a lower sulfate/chloride ratio than the ground water seeps and is more typical of the ratio found in the contaminated area of the alluvial aquifer away from the San Miguel River (see Section 5.3.3.2). This suggests that ground water in the area of the seeps, MAU03, and MAU04 has a greater influence from surface water than that located at MAU07.

As seen in Figure 5–17, uranium concentrations exceed background concentrations and exceed the UMTRA Project maximum concentration limit. Concentrations in the seeps are similar to those in nearby wells MAU03 and MAU04. Uranium concentration in well MAU07 is much higher than in the ground water seeps. The sulfate/chloride ratio indicates that ground water in the area of MAU03, MAU04, and the ground water seeps has a significant component of surface water from the San Miguel River that has been contaminated by buried uranium tailings near surface water location 0535 (Figure 5–6). Because samples were collected from the ground water seep locations only in November 2000 and March 2001, no historical trend in uranium concentration can be inferred. However, USGS has collected data at nearby wells MAU03 and MAU04 since November 1998 and at MAU07 since September 1999. As shown in Figure 5–18, Figure 5–19, and Figure 5–20, respectively, uranium concentrations in wells MAU03, MAU04, and MAU07 have not decreased with time, but rather appear to be controlled by the water table, which is controlled by river stage. Uranium concentrations at location 0559 show a trend similar to that observed in the wells, that is, concentration was greater in March 2001 than in November 2000; location 0538 shows the opposite trend in comparison to the wells (uranium

concentration was greater in November 2000 than in March 2001). Additional data are needed to determine if the uranium concentration in the ground water seeps varies directly with river stage and with uranium concentrations in nearby wells.

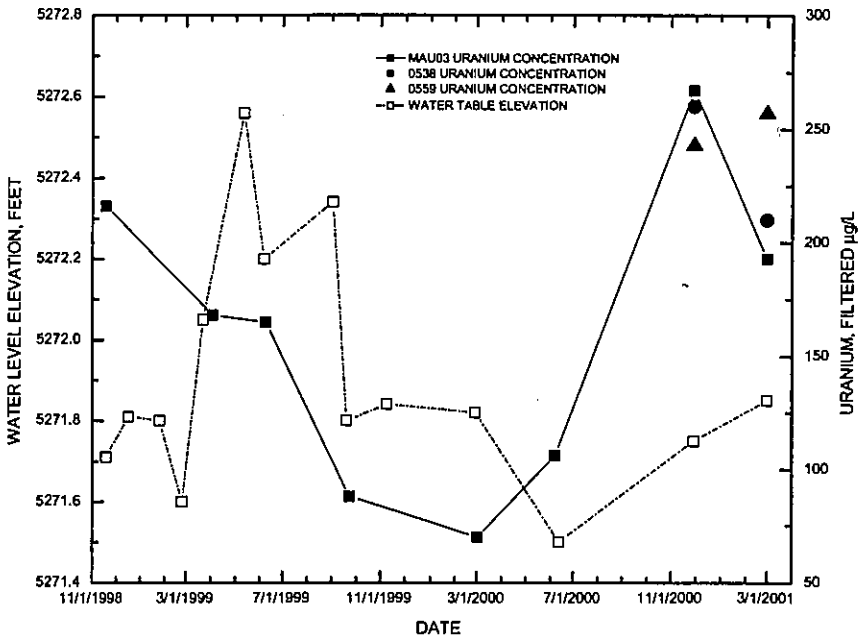

Figure 5–18. Uranium Concentrations and Water Table Elevation in Well MAU03

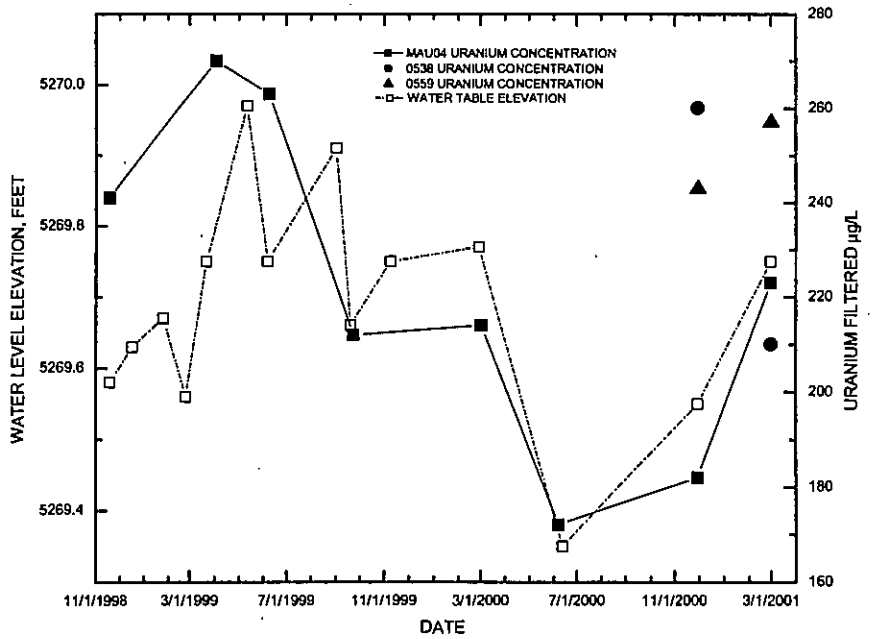

Figure 5–19. Uranium Concentrations and Water Table Elevation in Well MAU04

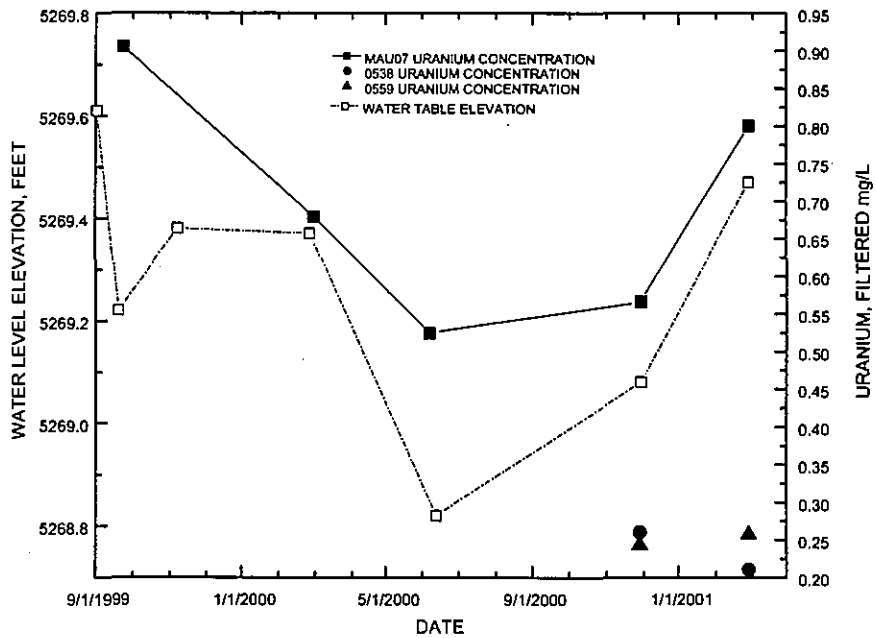

Figure 5–20. Uranium Concentrations and Water Table Elevation in Well MAU07

5.3.3 Alluvial Aquifer Water Quality

USGS has collected ground water quality data at the Naturita site since November 1998 as part of a uranium transport study. The most recent samples were collected in November and December 2000 and in February and March 2001 to support DOE's monitoring of ground water quality.

5.3.3.1 Background Alluvial Ground Water Quality

Background ground water quality is characterized by samples from a site located in the same aquifer upgradient from the former millsite (Figure 5–21). Data from these samples are summarized in Table 5–2; Appendix B is a complete list of ground water monitoring results.

Background ground water quality at the Naturita site is generally good, with slightly high levels of sulfate and manganese. Sulfate concentration at background location DM1 exceeded the Colorado secondary drinking water standard of 250 mg/L during November 2000 and March 2001. Mean background concentrations are lower than the UMTRA Project maximum concentration limits for arsenic (0.05 mg/L), cadmium (0.01 mg/L), molybdenum (0.1 mg/L), nitrate (44 mg/L as NO_3), selenium (0.01 mg/L), and uranium (0.044 mg/L). Vanadium concentrations were below detection. Concentrations of all the trace elements and nitrate were at or near detection limits. Chloride and iron concentrations are also below the limits set by the Colorado secondary drinking water standard of 250 mg/L and 0.3 mg/L, respectively.

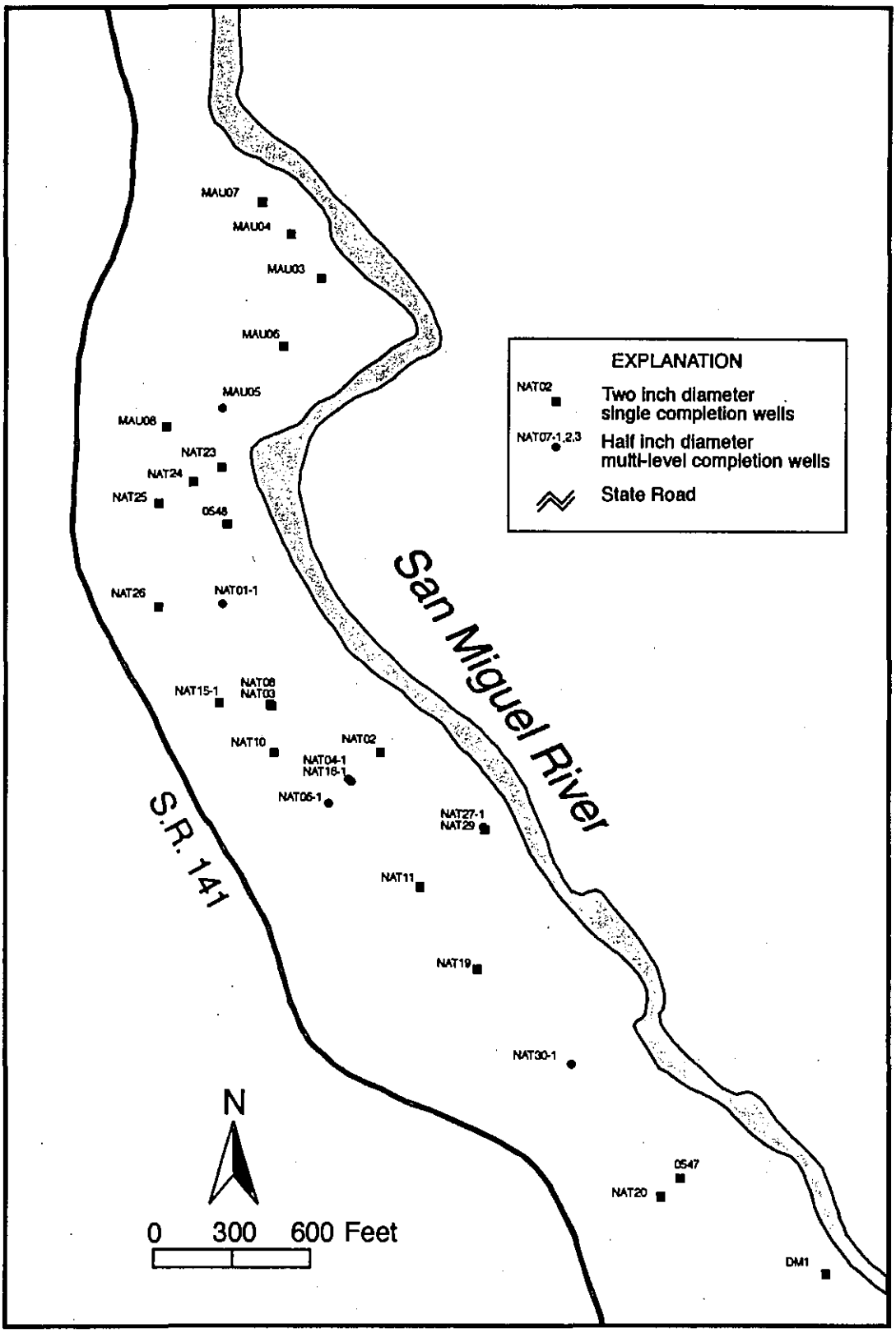

Figure 5–21. Locations of Naturita Wells Sampled in November 2000 and March 2001 During the DOE UMTRA Phase

Table 5–2. Background Concentrations in Well DM1

Analyte[a]	Units	June 2000	November 2000	March 2001	DM1 Mean[b]
Major					
Calcium	mg/L	54.1	111	109	91.4
Chloride	mg/L	4.70	6.45	6.90	6.02
Magnesium	mg/L	20.3	28.9	27.2	25.5
Nitrate	mg/L	NA[c]	0.05	0.05	0.05
Potassium	mg/L	1.85	1.76	1.44	1.68
Sodium	mg/L	18.2	25.1	25.1	22.8
Sulfate	mg/L	131	282	251	221
Metals					
Aluminum	mg/L	<0.29	0.18	0.34	0.22
Arsenic	mg/L	ND[d]	0.0009	0.0006	0.00075
Cadmium	mg/L	<0.04	<0.02	<0.04	
Iron	mg/L	0.29	0.08	0.09	0.15
Lead	mg/L	<0.21	<0.10	<0.20	
Manganese	mg/L	0.32	0.29	0.19	0.27
Molybdenum	mg/L	<0.04	<0.02	<0.04	
Selenium	mg/L	ND[d]	<0.0003	<0.0003	
Uranium	mg/L	0.00432	0.0087	0.00707	0.0067
Vanadium	mg/L	<0.04	<0.02	<0.04	
Other					
Silicon	mg/L	4.64	4.05	4.07	4.25
Strontium	mg/L	0.83	1.28	1.10	1.07
Field Measurements					
Alkalinity	mg/L $CaCO_3$	227	156	159	180
Dissolved oxygen	mg/L	0.35	0.16	0.25	0.25
Oxidation-Reduction Potential	mV	138	210	214	187
pH	standard units	7.12	7.13	7.33	7.19
Specific Conductance	µS/cm	589	851	852	764

Detection limits may vary due to sample dilution during analysis
[a]Specific conductance, pH, and oxidation-reduction potential were measured on unfiltered samples; all other analysis were performed on samples that were filtered through a 0.45µm filter.
[b]For results less than the detection limit, one-half the detection limit was used to calculate the mean of the three sampling rounds. If at least two of the three values were below the detection limit, the mean was not calculated.
[c]NA = not analyzed.
[d]ND = Not detected. Method detection limit was too high to be used. Subsequent samples were analyzed using a different method to achieve a lower detection limit.

In general, background anions are dominated by sulfate, and the cations are composed of a calcium-sodium-magnesium mixture in which calcium is the most abundant. Background alkalinity as calcium carbonate ranges from 156 to 227 mg/L. Sulfate concentrations range from 131 to 282 mg/L. Calcium concentrations range from 54 to 111 mg/L. Sodium concentrations range from 18 to 25 mg/L. Magnesium concentrations range from 20 to 29 mg/L. The pH ranges from 7.1 to 7.3 with a mean value of 7.2. Oxidation-reduction potential referenced to the standard hydrogen electrode ranges from 138 to 214 mV and averages 187 mV, which is slightly oxidizing.

5.3.3.2 Nature and Extent of Alluvial Ground Water Contamination

From August 1998 through June 2000, USGS sampled ground water at the Naturita site to provide data for the surface complexation modeling being performed for the NRC. During November 2000 and March 2001, sampling was done to monitor the nature and extent of ground water contamination at the site to support this Site Observational Work Plan. Results from all the sampling activities are listed in Appendix B and are summarized in Table 5–3. Locations of the monitoring wells are shown in Figure 5–21.

All the constituents listed in Table 5–3 except nitrate, aluminum, cadmium, lead, and molybdenum are fairly prevalent in the aquifer, as shown by the high frequency (greater than 50 percent) of constituents with concentrations that exceeded the upper limit of the background concentration range. Constituents that exceeded background concentration in less than 50 percent of the wells (nitrate, aluminum, cadmium, lead, and molybdenum) were most often present in quantities below detection limit.

Uranium, chloride, and vanadium exceed background concentrations by the greatest amount. The maximum uranium concentration of 2.51 mg/L detected in well NAT26 is 289 times greater than the background concentration measured in well DM1. The maximum vanadium concentration of 7.55 mg/L detected in well NAT08 is 189 times greater than background. The maximum chloride concentration of 632 mg/L was also detected in well NAT26 and is 92 times greater than background. The remaining constituents show less contrast; arsenic exceeds the background concentration by a factor of 71, sodium exceeds by a factor of 47, selenium exceeds by a factor of 46, potassium exceeds by a factor of 22, manganese exceeds by a factor of 20, and iron exceeds by a factor of 19.

Concentrations of arsenic, molybdenum, selenium, and uranium all exceed their UMTRA maximum concentration limits (Table 2–1). Chloride and sulfate concentrations both exceed the Colorado secondary drinking water standard of 250 mg/L, although the background range of sulfate also slightly exceeds this value. Vanadium concentrations are elevated above risk-based levels for drinking water (see Section 6.1). These constituents have been selected for the remainder of this discussion.

Several wells were added during 2001 and 2002 for various reasons. These wells are shown on Plate 1. Well 700 was placed in an area that was thought to be the center of the vanadium plume. Concentrations were not higher than those found in nearby wells. Well 701 was established to determine the level of ground water contamination in an area of supplemental standards on the vicinity property. Contaminant concentrations were not higher at well 701 than in other wells on the vicinity property farther downgradient. Other boreholes in this area (702, 703, 704, and 705) were not completed as wells.

Well 715 was drilled in March 2002 to determine if contamination had traveled under the San Miguel River and into the alluvial aquifer on the east side of the river. Analyses of water from the well demonstrated that uranium concentrations range up to 0.080 mg/L, or about twice the UMTRA standard. A map in Section 3 of the Naturita Remedial Action Plan (DOE 1998a) labeled "Final Contaminated Material Excavation Plan" shows areas containing millsite related contamination on the east side of the San Miguel River and downgradient of the millsite on this vicinity property. A part of this area underwent remedial action and other portions of this property received supplemental standards. This figure shows that millsite contamination and

potentially associated ground water contamination could extend as far downgradient as the Calamity Bridge, about 3,750 feet downgradient of the millsite. Another possibility is that the plume found on the west side (the millsite side) of the San Miguel River has traveled below the river and has contaminated the alluvial aquifer on the east side at well 715. The entire area designated for potential supplement standards application was included in the institutional control boundary.

Well 716 is a water well that will be drilled approximately 600 feet into the Entrada Sandstone aquifer to supply potable water to the family living on the vicinity property. The well will be drilled through about 480 feet of Morrison Formation mudstones, shales, siltstones, and sandstones that contain poor quality water and could contain concentrations of uranium above the UMTRA standard. To guard against possible cross contamination of the potable water below, the first portion of the well will be drilled through the Morrison Formation into the underlying shales of the Summerville Formation, which will act as an aquitard. This section of the well will be sealed off to the surface using steel casing. The well will be drilled another 100 feet and completed in the Entrada Sandstone below Summerville Formation.

Arsenic

Figure 5–22 shows the concentrations of arsenic measured during the November 2000 and March 2001 sampling. Arsenic concentrations at most wells were near the detection limit of 0.00018 mg/L, and concentrations in the March 2001 samples exceeded the UMTRA maximum concentration limit of 0.05 mg/L in only three wells (NAT03, NAT08, and NAT11). The maximum concentration was detected in well NAT08, which is near the center of the former tailings area. These three samples all show an increase in arsenic concentration from the November 2000 sampling. This pattern is also seen in well NAT16–1. However, concentrations in samples from wells NAT04–1, NAT06–1, NAT10, and NAT08 all decreased slightly. As shown in Figure 5–23, the highest concentrations of arsenic have not migrated beyond the area of the former tailings pile. This is most likely due to the low mobility of arsenic under the reducing conditions found in this area. Under these conditions, arsenic is readily adsorbed onto iron hydroxides that may coat sediments.

Molybdenum

Most measurements of molybdenum were near the detection limit (Figure 5–24). Concentrations in samples from wells NAT15–1, NAT01–1, NAT26, and in one sample from well MAU05 were over the UMTRA maximum concentration limit of 0.1 mg/L. The maximum concentration of 0.18 mg/L was detected in well NAT26. All these wells except MAU05 are located in the area of the former tailings pile. Figure 5–25 shows the distribution of molybdenum concentrations.

Selenium

As Figure 5–26 shows only well NAT26 had selenium concentrations that were greater than the UMTRA maximum concentration limit of 0.01 mg/L. Most wells located near the former tailings area had concentrations of selenium that were in the range found in upgradient wells 0547 and NAT20 (Figure 5–27). As with arsenic, selenium is also less mobile under reducing conditions, and any selenium contamination that came from the former tailings area should still be present at the site.

Table 5–3. Ground Water Quality at the Naturita Site, August 1998 to March 2001

Analyte[a]	Units	Mean[b]	Range	Max Well	Number of Samples	Percent of Samples Over Background	Background Range
Major Ions							
Calcium	mg/L	202	60.2–492	NAT01–2	315	94	54.1–111
Chloride	mg/L	74	0.05–632	NAT26	315	98	4.70–6.90
Magnesium	mg/L	59.1	16.2–145	NAT01–2	315	96	20.3–28.9
Nitrate	mg/L		<0.02–3.56	NAT26	54	9	0.05
Potassium	mg/L	10.5	1.41–40.2	MAU08	315	99	1.44–1.85
Sodium	mg/L	211	20.8–1,170	NAT26	315	99	18.2–25.1
Sulfate	mg/L	735	120–1,930	NAT01–2	315	95	131–282
Metals							
Aluminum	mg/L		0.15–0.74	MAU08	315	30	0.18–0.29
Arsenic	mg/L	0.0136	0.0005–0.064	NAT08	54	74	0.0006–0.0009
Cadmium	mg/L		<0.04		315		<0.04
Iron	mg/L	0.41	<0.02–5.54	NAT01–2	315	76	0.08–0.29
Lead	mg/L		<0.1–<0.65		315		<0.04
Manganese	mg/L	1.30	<0.04–6.46	MAU05	315	87	0.19–0.32
Molybdenum	mg/L		<0.02–0.18	NAT26	121	30	<0.04
Selenium	mg/L	0.00182	<0.0003–0.014	NAT26	54	94	<0.0003
Uranium	mg/L	0.727	0.003–2.510	NAT26	315	98	0.00432–0.0087
Vanadium	mg/L	1.48	<0.02–7.55	NAT08	315	56	<0.04
Other							
Silicon	mg/L	7.98	3.43–12.4	MAU01	315	99	4.05–4.64
Strontium	mg/L	2.44	0.64–6.35	NAT01–2	315	88	0.83–1.28
Field Measurements							
Alkalinity	mg/L CaCO3	343	124–596	MAU01	306	93	156–227
Dissolved oxygen	mg/L	0.31	<0.1–1.73	NAT09	296	27	0.16–0.35
Oxidation-Reduction Potential	mV	198	-12–426	MAU01	282	43	138–214
pH	standard units	7.10	6.54–7.53	MAU06	307	8	7.12–7.33
Specific Conductance	µS/cm	2,060	615–5,730	NAT26	307	92	589–852

Detection limits may vary due to sample dilution during analysis

[a]All measurements were performed on filtered samples except specific conductance, pH, and oxidation-reduction potential.

[b]One-half the detection limit was used to calculate the mean; mean was not calculated if concentrations in more than half the samples were below detection limit.

Uranium

Figure 5–28 shows uranium concentrations in selected wells at the Naturita site. There is a large range in concentration, from 0.003 mg/L in well 0547, which is upgradient from the former tailings area, to 2.510 mg/L in well NAT26. As shown in Figure 5–29, concentrations in all wells located downgradient from well NAT30 exceed the UMTRA maximum concentration limit for uranium (0.044 mg/L). This is the approximate extent of the former mill yard area. Uranium concentration continues to increase as ground water moves downgradient into the former tailings area. Concentrations decrease slightly near the bend in the San Miguel River at the northern end of the site. Chloride and sulfate concentrations along with ground water age and flow modeling suggest that ground water in wells MAU06, MAU03, and MAU04 comes mainly from recent recharge by the San Miguel River, and well MAU07 is a mixture of fresh river water and contaminated water from the alluvial aquifer. However, wells MAU06, MAU03, and MAU04 have uranium concentrations that are orders of magnitude greater than that of the San Miguel River. This contamination is most likely due to buried tailings located near well 0700.

As discussed in Section 5.3.2.2, uranium concentrations in wells MAU03, MAU04, and MAU07 have not been observed to decrease with time, but rather appear to be influenced by the water table and river stage. Wells in the alluvial aquifer can be divided into four groups based on the response of uranium concentration to water level. Figure 5–30 shows the locations of these zones. Zone A wells are located away from the San Miguel River in the central portion of the aquifer and include wells NAT01–1, NAT05, NAT15–1, NAT25, NAT26, and MAU08. Figure 5–31 shows a time-concentration plot and water level at well NAT25 from this group. These wells typically have the highest concentrations of uranium. Zone B wells are also located in the central region of the study area but closer to the river than wells in Zone A. These wells show a fluctuation in uranium that lags behind fluctuations in water level. In this case, water level peaks are followed by high uranium concentrations a few months later. This trend is apparent in well 0548, shown in Figure 5–32. Zone C wells are located closest to the San Miguel River in the central portion of the study area. Small spikes in uranium concentration can be seen following water level peaks similar to the wells in Zone B; however, these spikes are much less pronounced than those in Zone B wells. Zone C wells also show a general decrease in uranium over time. Figure 5–33 illustrates this trend, which is observed in well NAT02. Zone D wells are located near the bend in the river at the northern end of the site. Uranium concentrations appear to fluctuate more quickly in this region in response to changes in water level. This is best seen in well MAU04 (Figure 5–19).

From these trends it appears that wells in Zone C receive the greatest inflow of fresh water from the San Miguel River and should be the first to be decontaminated by natural flushing. Wells in Groups B and D are also undergoing natural flushing; however, they are still receiving an intermittent inflow of ground water uranium that is coupled with water level. On the timescale of the measurements made, wells in Zone A show no signs of natural flushing. There is no evidence in this area that changes in water level will affect uranium concentrations.

Two mechanisms have been proposed to explain the changes in uranium concentration with water level. The first involves desorption of uranium from sediments as the water table rises. This desorbed uranium is then transported to downgradient wells where it is measured a few months later. If this is the dominant process, then attempts to induce a greater degree of natural flushing may result in short-term increases in the mass of uranium being desorbed from sediments in the vadose zone. This effect should be much more pronounced in Zones B and D than in Zone C. Zone A wells should not show a significant change.

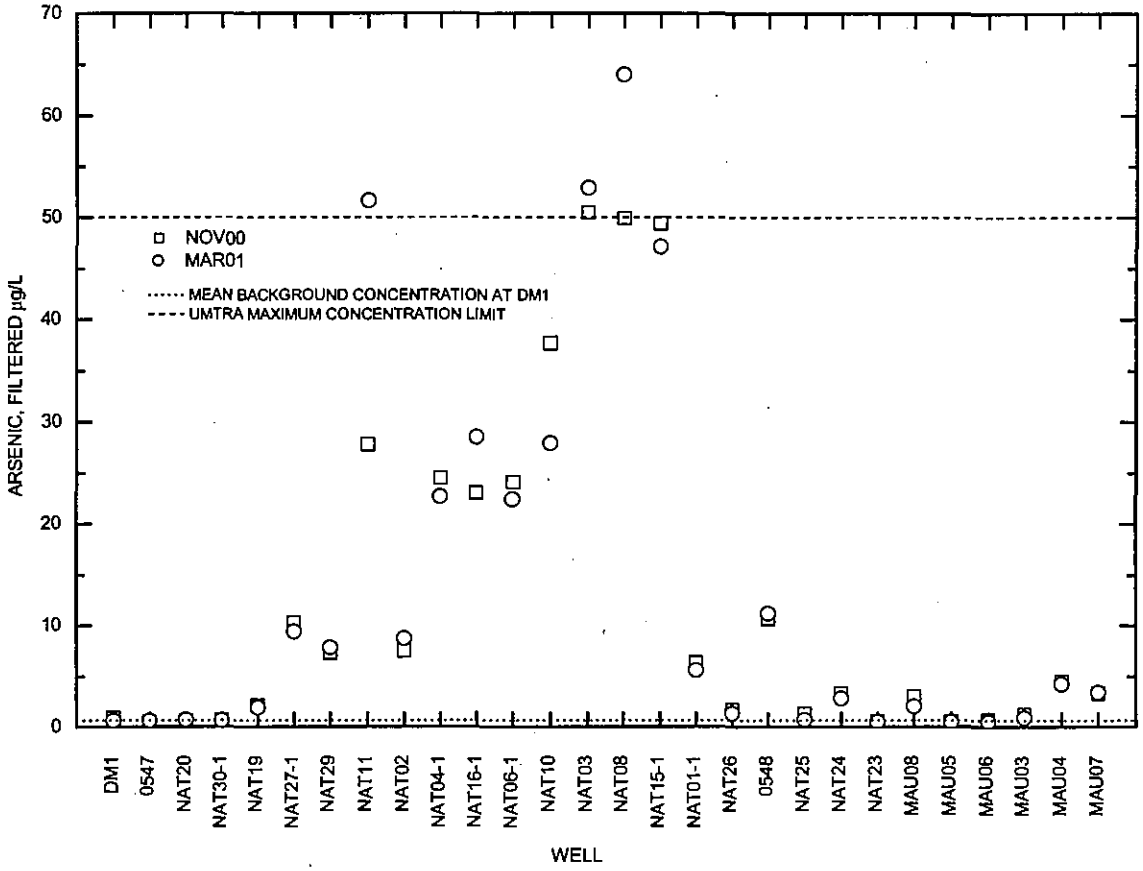

Figure 5–22. Arsenic Concentrations in Selected Wells at the Naturita Site Measured During November 2000 and March 2001

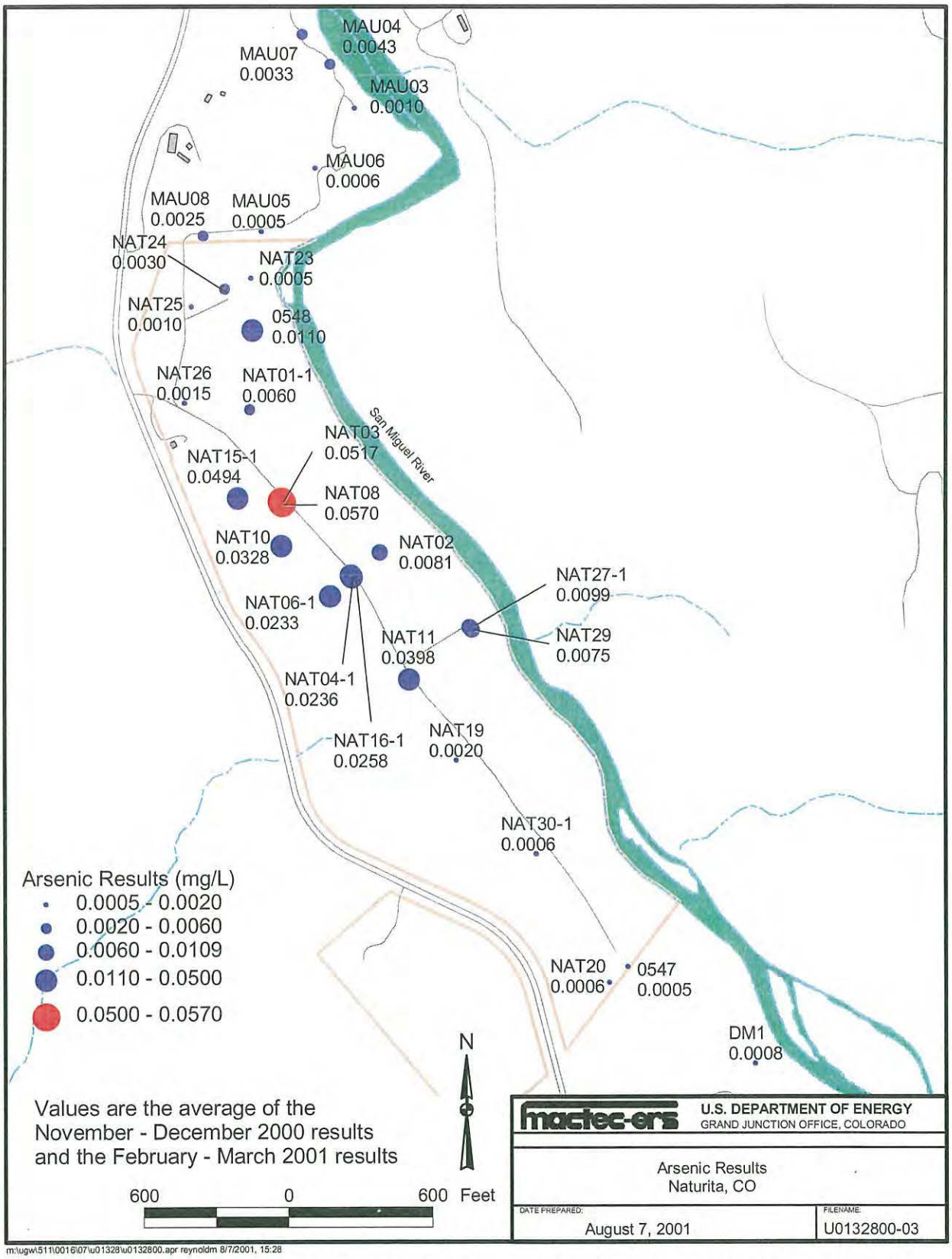

Figure 5–23. Average Arsenic Concentrations Measured in November and December 2000 and February and March 2001

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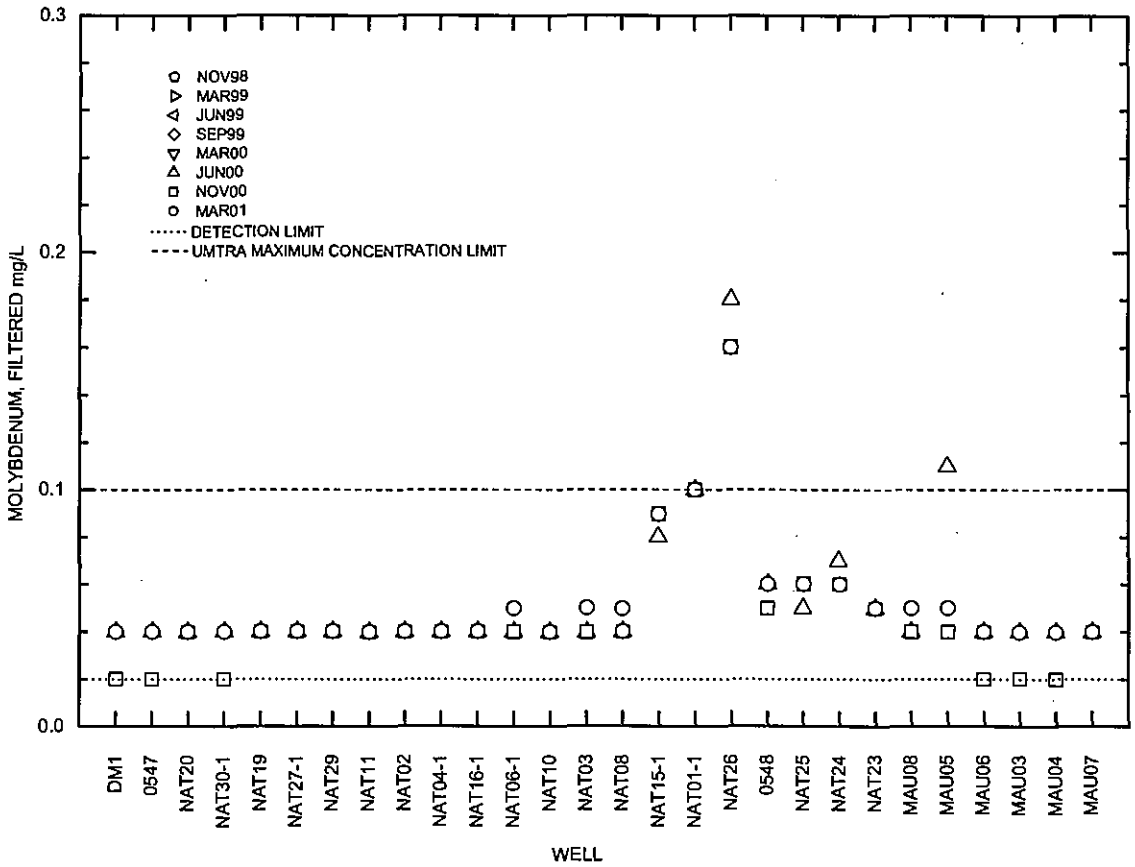

Figure 5–24. Molybdenum Concentrations in Selected Wells at the Naturita Site Measured from November 1998 to March 2001

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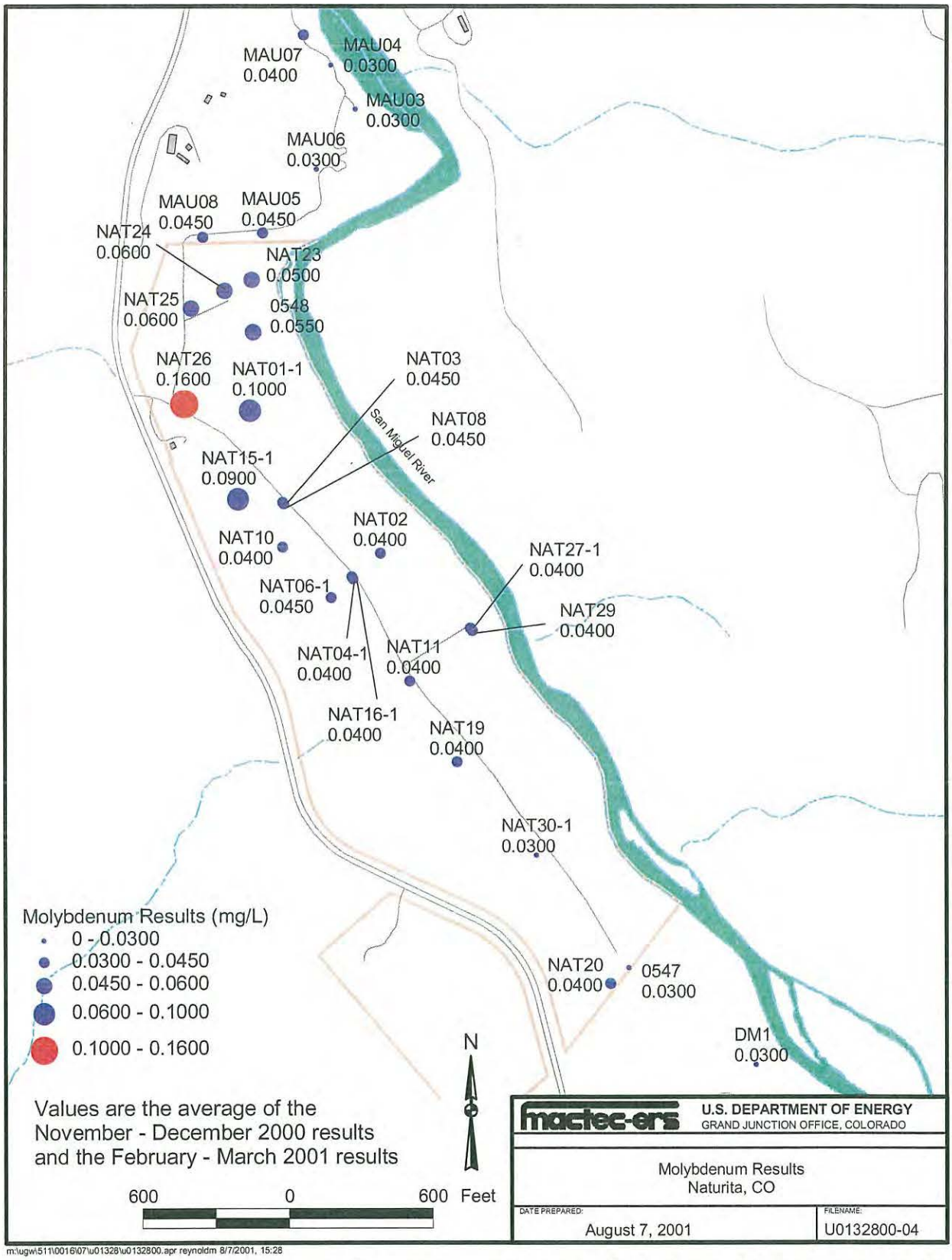

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Figure 5–25. Average Molybdenum Concentrations Measured in November and December 2000 and February and March 2001

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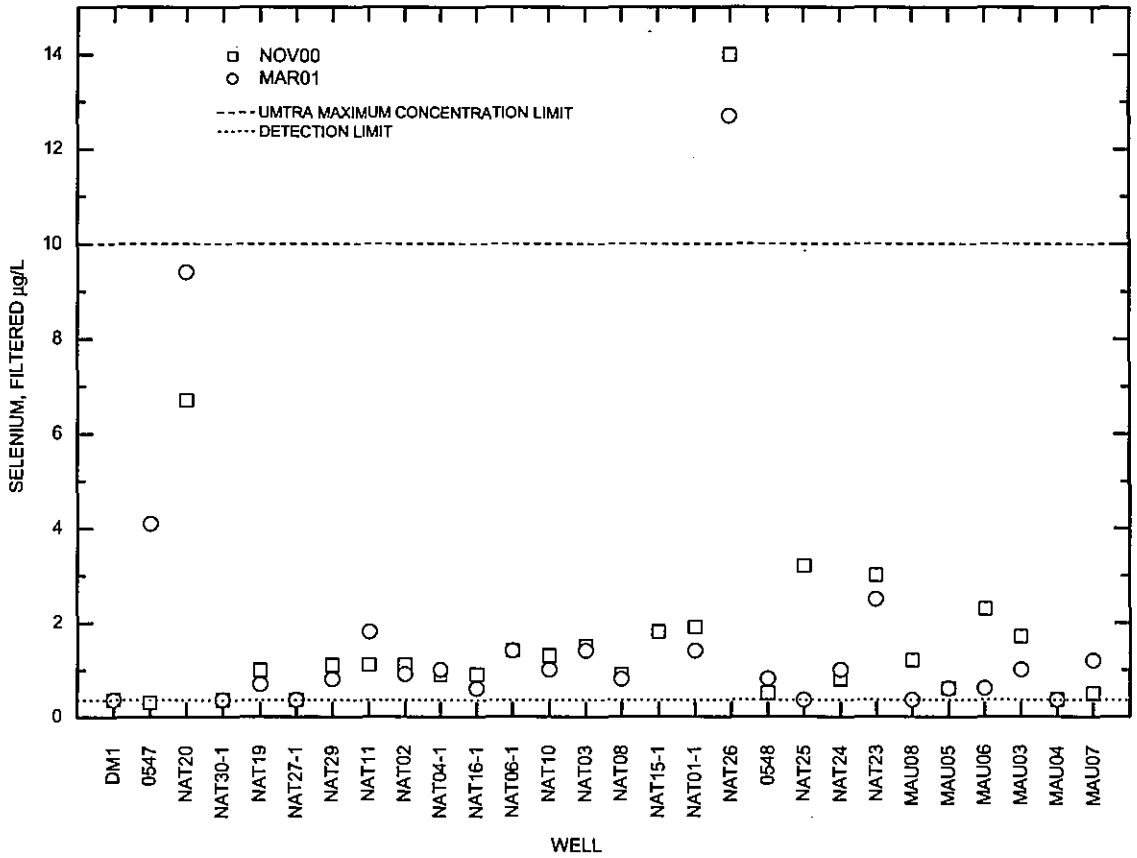

Figure 5–26. Selenium Concentrations in Selected Wells at the Naturita Site Measured During November 2000 and March 2001

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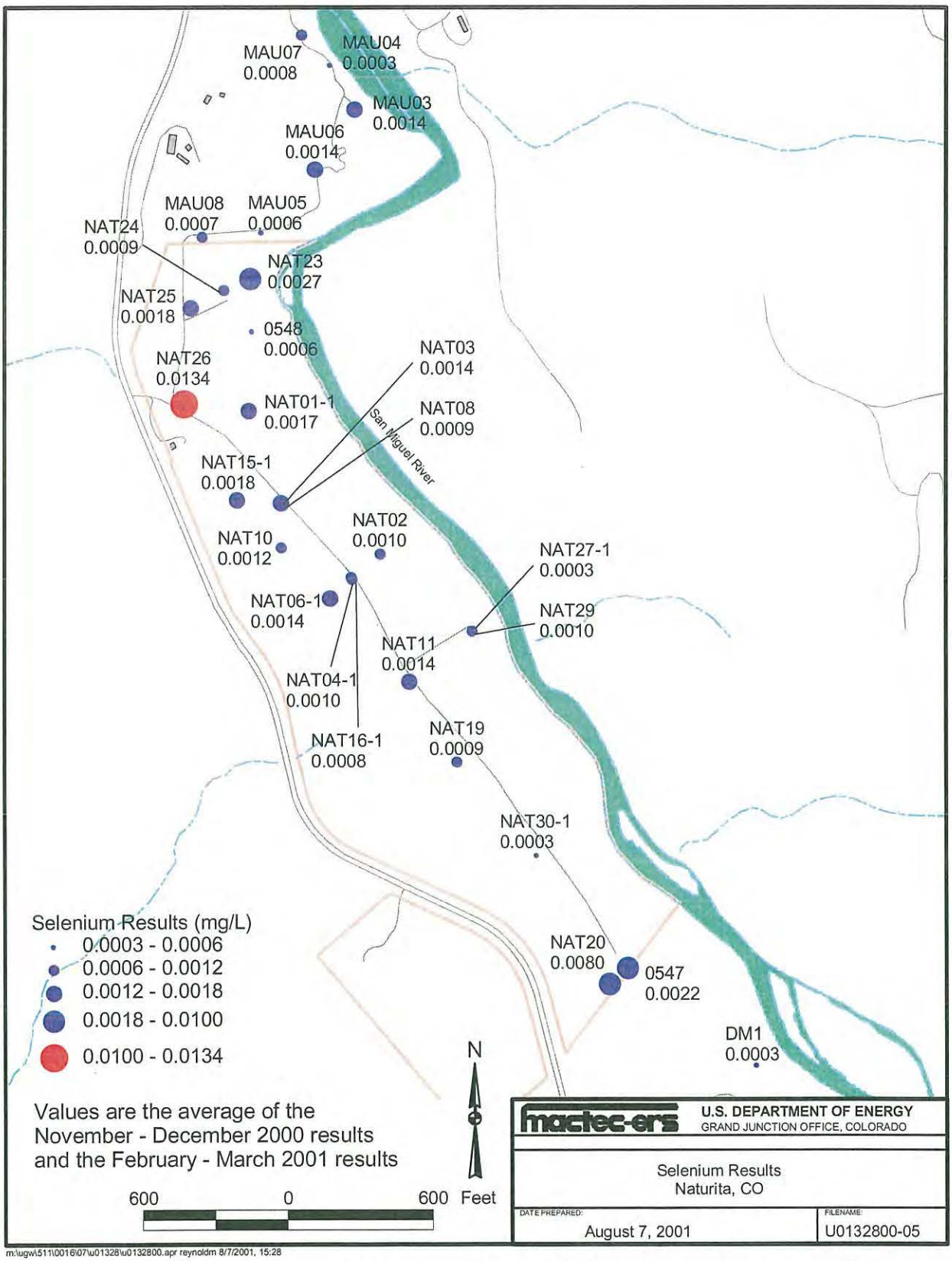

Figure 5–27. Average Selenium Concentrations Measured in November and December 2000 and February and March 2001

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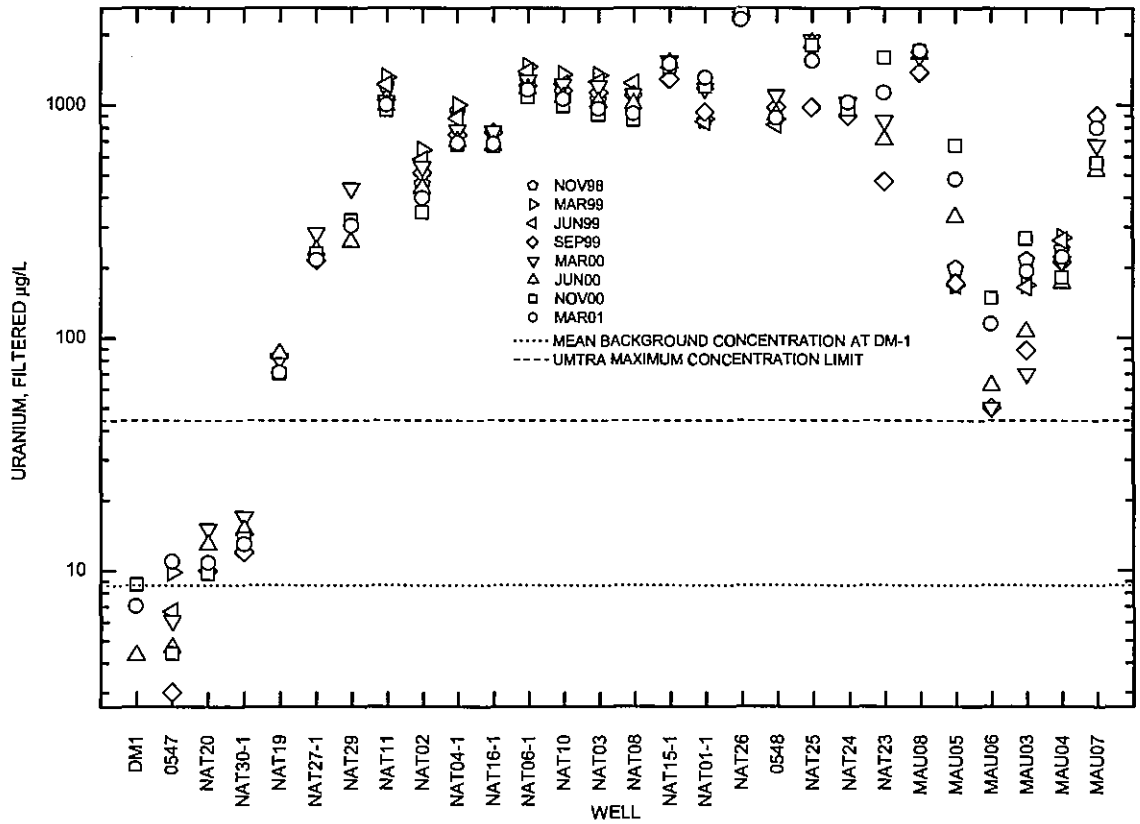

Figure 5–28. Uranium Concentrations in Selected Wells at the Naturita Site Measured from November 1998 to March 2001

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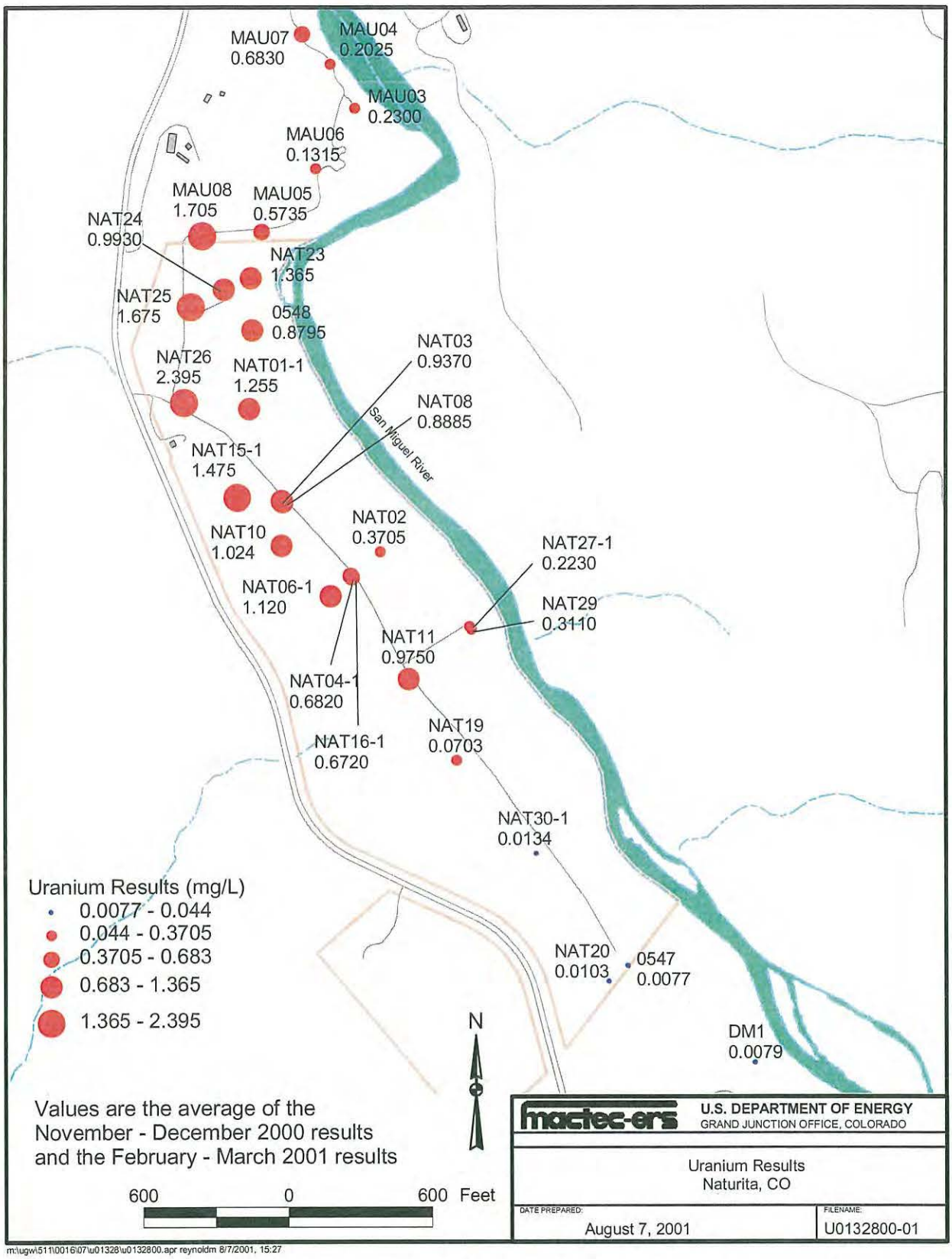

Figure 5–29. Average Uranium Concentrations Measured in November and December 2000 and February and March 2001

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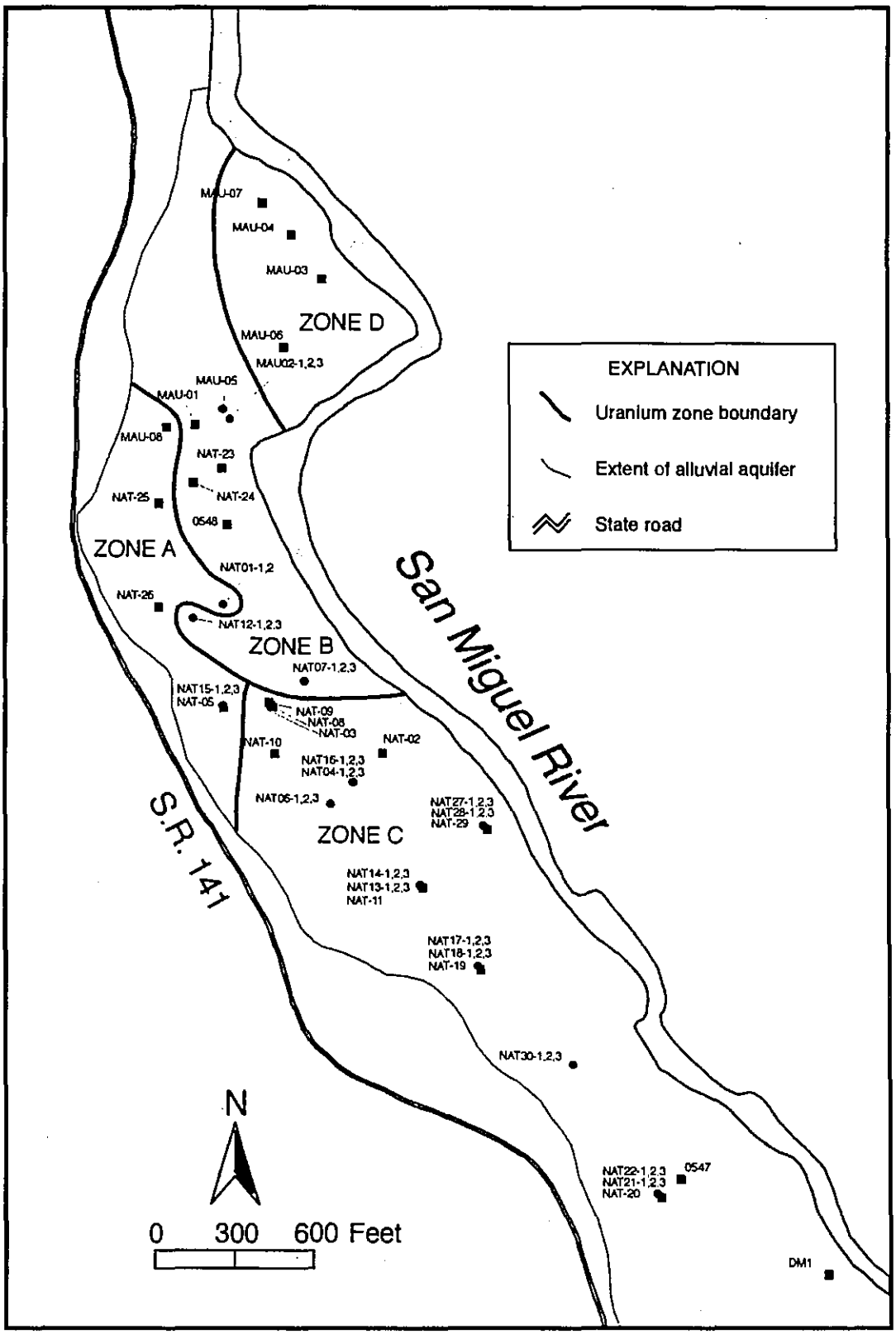

Figure 5–30. Alluvial Aquifer Zones Based on the Response of Uranium Concentration to Changes in Water Level

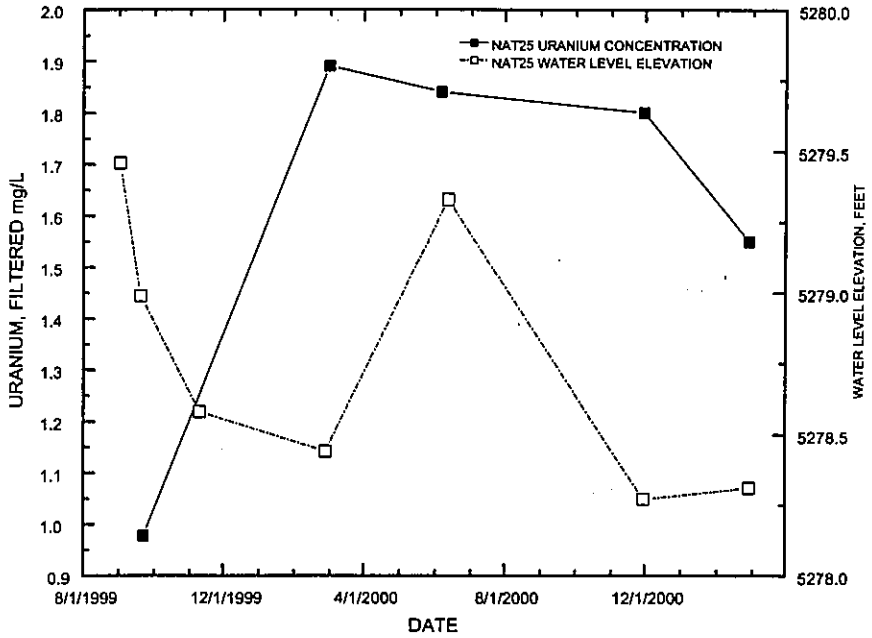

Figure 5–31. Time-Concentration Plot for Uranium and Water Level at Well NAT25

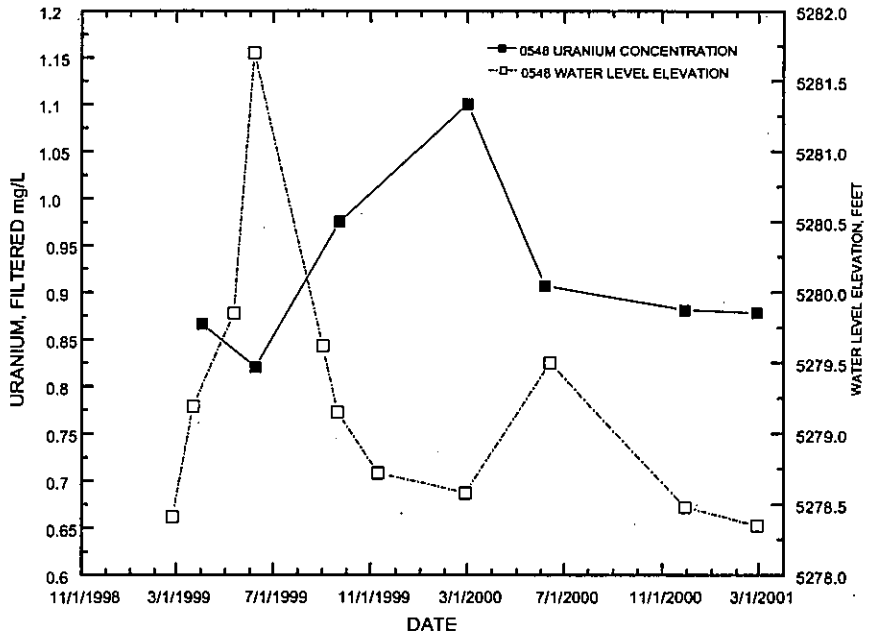

Figure 5–32. Time-Concentration Plot for Uranium and Water Level at Well 0548

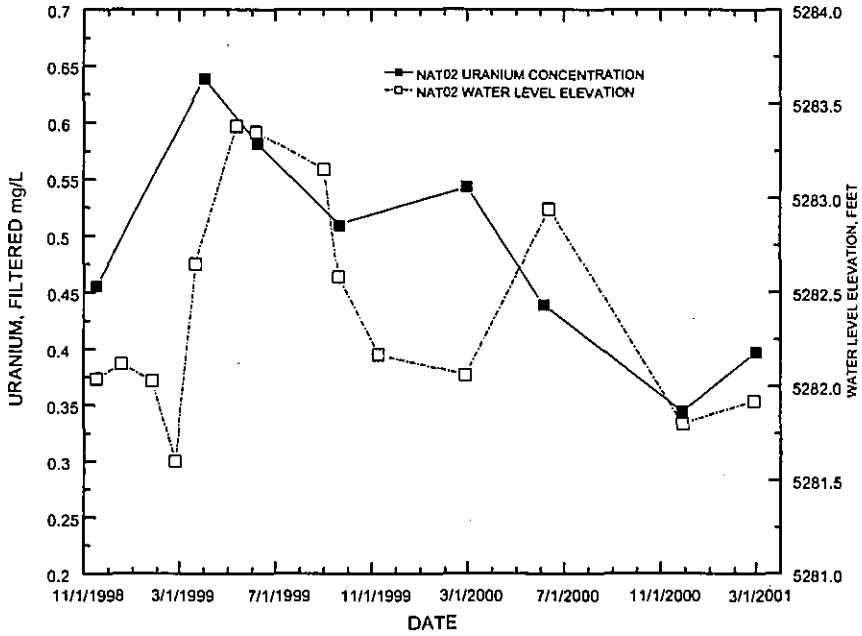

Figure 5–33. Time-Concentration Plot for Uranium and Water Level at Well NAT02

The second proposed mechanism involves lateral fluctuations of the uranium-contaminated zone due to increased inflow from the San Miguel River. When the water level is high, more fresh water flows to the Zone B wells, effectively diluting uranium concentration. This fresh water does not reach the Zone A wells, and they are therefore unaffected. When the water level is low, there is a greater degree of flow from the highly contaminated area to the Zone B wells, increasing the uranium concentration. A small amount of this ground water with high uranium levels may reach the Zone C wells. This is shown by small increases in uranium concentrations as water level decreases. If natural flushing were to be augmented in this case by increasing irrigation and raising the water table, changes in uranium concentration may depend strongly on where the irrigation is applied. For instance, if the water table is raised in Zone A, this may increase uranium concentrations in wells in Zones B and C. If water is applied to Zone C, however, wells in Zone B should continue to show decreasing uranium concentrations. It is unclear whether water applied in this area would clean up wells,in Zone A.

If the first mechanism is the dominant process, uranium and other sorbed ions should be the only species to increase in concentration following an increase in water level. Conservative ions like chloride should have been removed from the sediments at an early stage. However, Figure 5–34 shows an increase in chloride concentration with uranium, which suggests that changes in uranium concentration in Zone B wells is most likely due to a greater influx of contaminated water from Zone A. In addition to the close correlation of uranium and chloride, there is also a good correlation between uranium and specific conductance (Figure 5–35). Because of this strong correlation, specific conductance can be used as a proxy to monitor uranium concentrations at the site. This could be done continuously over extended periods using a data recorder with a specific conductance meter.

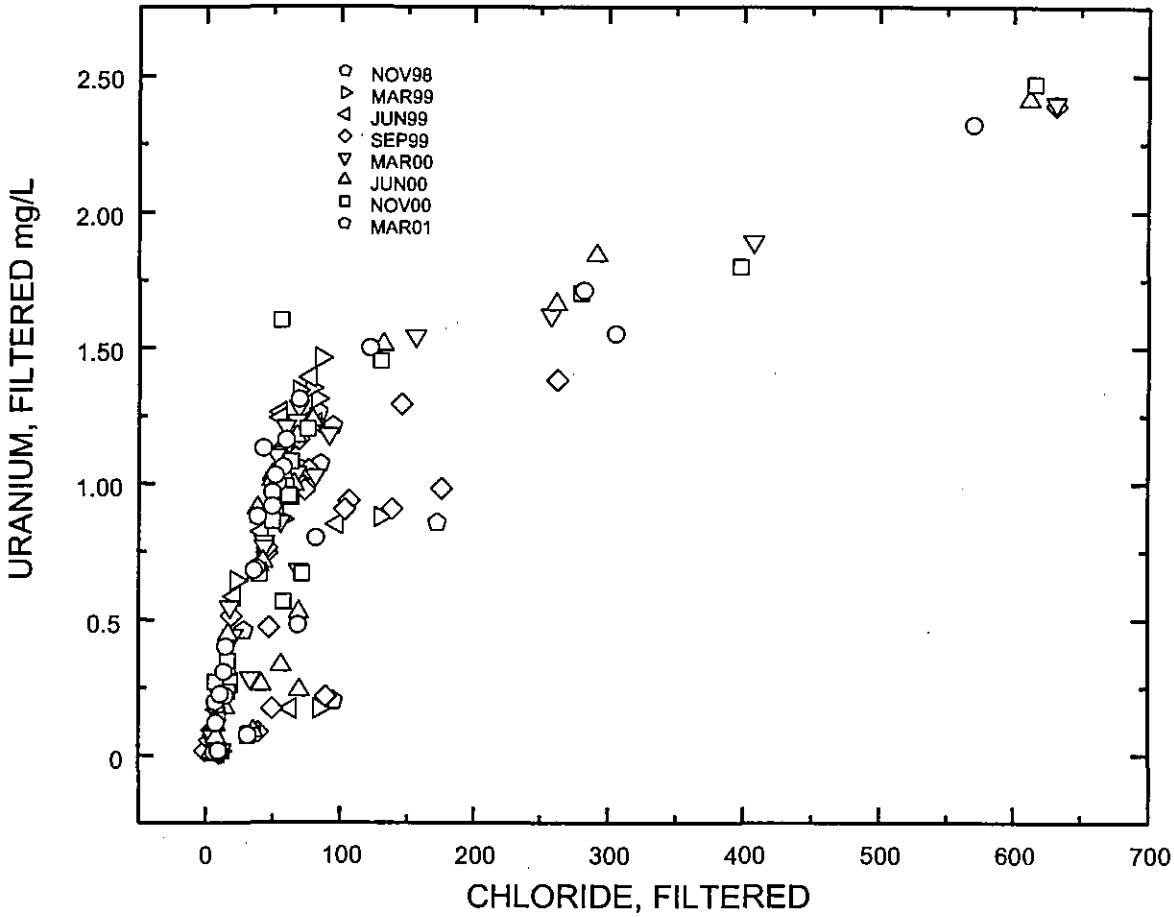

Figure 5–34. Uranium Versus Chloride Concentration in Ground Water

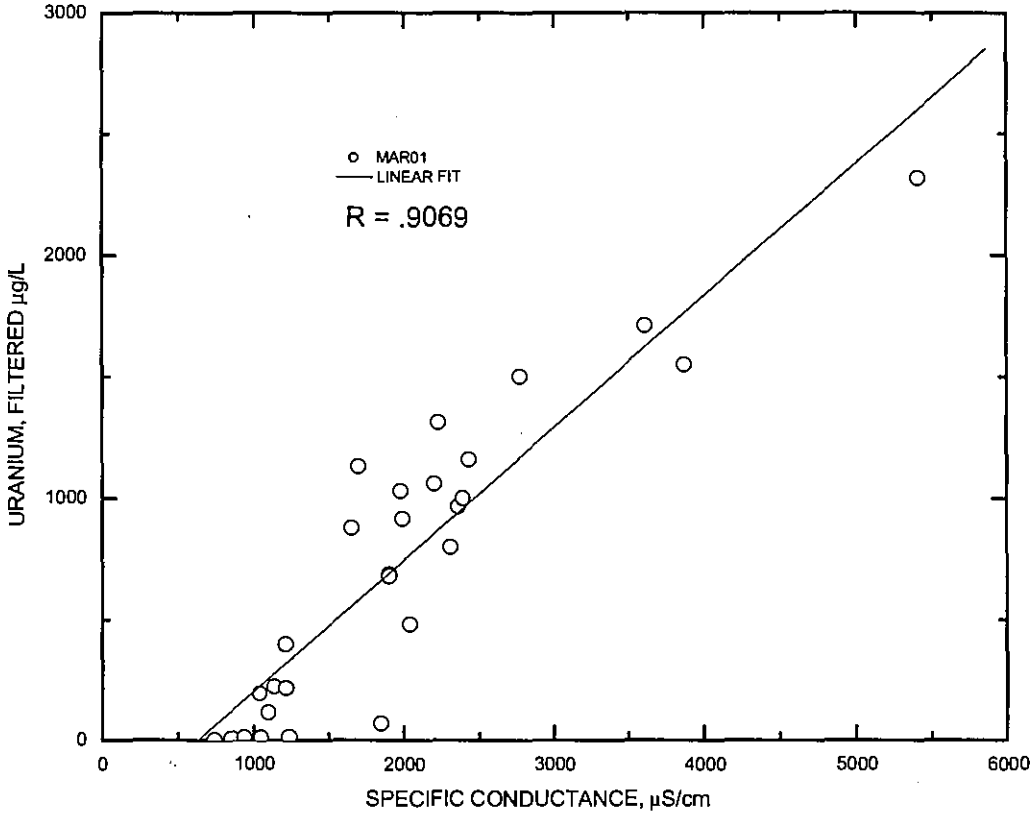

Figure 5–35. Uranium Concentration Versus Specific Conductance in Ground Water. R = Correlation Coefficient

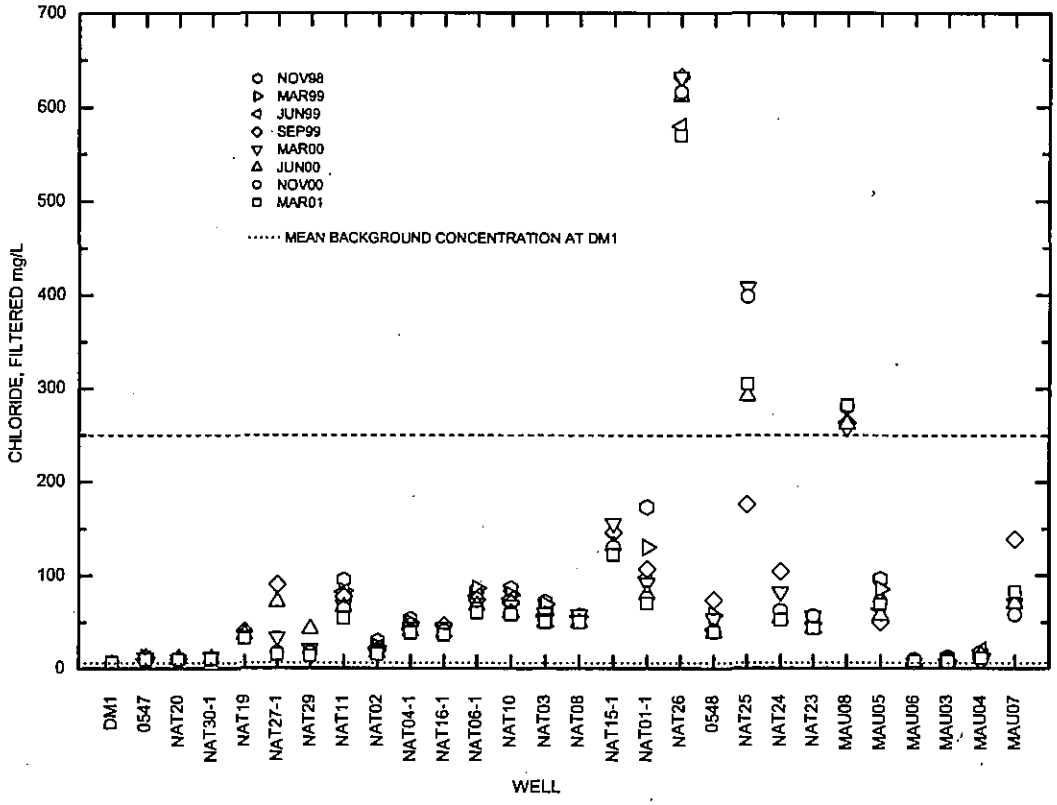

Figure 5–36. Chloride Concentrations in Selected Wells at the Naturita Site Measured from November 1998 to March 2001

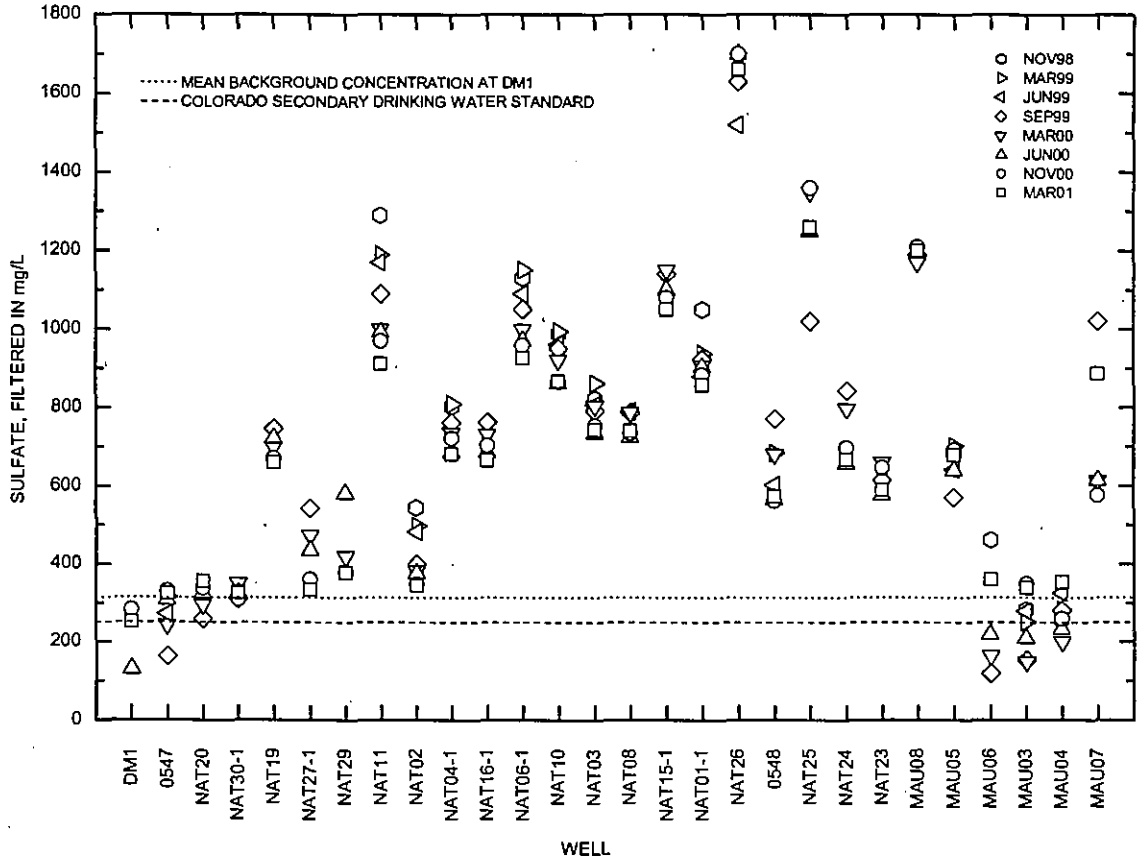

Figure 5–37. Sulfate Concentrations in Selected Wells at the Naturita Site Measured from November 1998 to March 2001

Chloride

When sampled in March 2001, wells NAT25, NAT26, and MAU08 were the only wells with chloride concentrations that exceeded the Colorado secondary drinking water standard of 250 mg/L. However, almost all the wells downgradient of well NAT30–1 had significantly more chloride than the concentration measured in background well DM1 (Figure 5–36). The increase in chloride concentration from inflow of San Miguel River water ranges from 1.72 to 11.3 mg/L; therefore, concentrations greater than this range indicate another source of chloride. The main source of additional chloride comes from the sodium chloride used during processing of the uranium ore (DOE 1995). Because chloride is considered a conservative species and is largely unaffected by adsorption, it is a good indicator of the degree of natural flushing taking place in the aquifer. The wells with the highest chloride concentrations are located in the western portion of the alluvial aquifer. This area corresponds to Zone A (Figure 5–30). Wells closer to the San Miguel River on the eastern portion of the site have lower concentrations of chloride (less than 100 mg/L). This distribution is the result of two factors. The first that more alkaline tailings were deposited on the western half of the site, and acidic tailings were deposited on the eastern portion closest to the river (DOE 1995). The second factor is that the eastern zone receives a greater degree of fresh water inflow from the San Miguel River and undergoes a greater degree of natural flushing. Wells MAU03, MAU04, and MAU06 have chloride concentrations ranging

from 3.8 to 19.8 mg/L, indicating they receive most of their inflow directly from the nearby river. Concentrations in well MAU07, which is just downgradient from well MAU04, range from 58 to 139 mg/L. The higher chloride concentration in MAU07 suggests that this well receives some component of ground water from the contaminated alluvial aquifer. A simple mixing calculation using chloride concentrations can be made by assuming a binary mixture of water from the contaminated alluvial aquifer near well MAU08 and from the San Miguel River. During June 2000 the concentration of chloride in well MAU08 was 262 mg/L, and the concentration in the river was 1.72 mg/L. The concentration in well MAU07 was 70 mg/L. This indicates that 26 percent of the water in well MAU07 came from the contaminated alluvial aquifer, and 74 percent came from the river. This ratio should be considered a maximum inflow from the river, because these values were recorded during high river stage. The values measured during March 2001, which corresponds to a period of low flow, indicate that 27 percent of the flow came from ground water and 73 percent came from surface water. This is a small percentage change over a large difference in flow.

Sulfate

Between August 1998 and March 2001, sulfate concentrations exceeded background levels in 95 percent of the samples collected at the site (Table 5–3) and exceeded the Colorado secondary drinking water standard of 250 mg/L in 97 percent of the samples. As shown in Figure 5–37, concentrations range from 120 mg/L to 1,930 mg/L. Figure 5–38 shows that the distribution of sulfate concentrations is similar to that of chloride and uranium; the highest levels are in the west-central portion of the alluvial aquifer. Wells in the northern section near the bend in the river show a mixing trend similar to that of the chloride concentrations.

As Figure 5–39 shows the sulfate/chloride ratio is also a good indicator of the influence of surface water from the river. Wells near the river or upgradient from the contaminated zone have larger sulfate/chloride ratios and show a broader range of ratios. With the exception of well MAU07, this group corresponds to Zones C and D (Figure 5–30). Wells located in the contaminated area (Zones A and B) have a much narrower range of sulfate/chloride ratios, and the ratios are generally lower than those in Zones C and D. Although located near the San Miguel River, water in well MAU07 has a sulfate/chloride ratio that is more typical of the ratio in ground water from the contaminated area of the alluvial aquifer. As discussed in the chloride section, it is believed that this well receives a significant inflow of water from the contaminated portion of the alluvial aquifer, which gives it a different sulfate/chloride ratio than that of other wells in the area.

Vanadium

Vanadium concentrations range from below the detection limit (0.02 mg/L) to 7.55 mg/L and are shown in Figure 5–40. The highest value was measured in September 1999 in well NAT08, the same well in which the maximum level of arsenic was detected. Figure 5–41 shows the distribution of vanadium concentrations. Due to its lower mobility, the vanadium has not been transported as far downgradient as other constituents such as uranium (Figure 5–29), and the higher concentrations are generally confined to the area of the former tailings pile. This distribution is similar to that of arsenic (Figure 5–23).

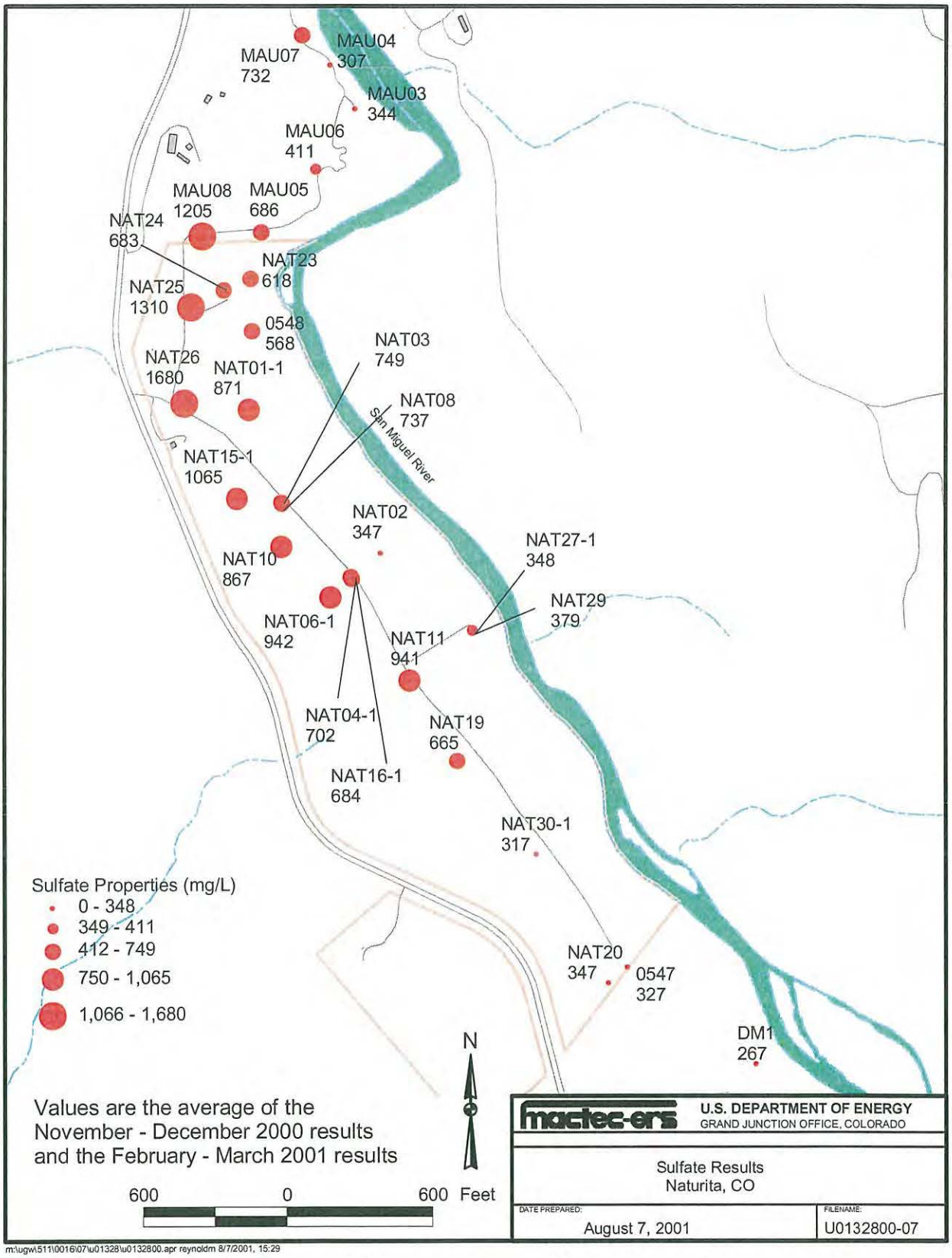

Figure 5–38. Average Sulfate Concentrations Measured November and December 2000 and February and March 2001

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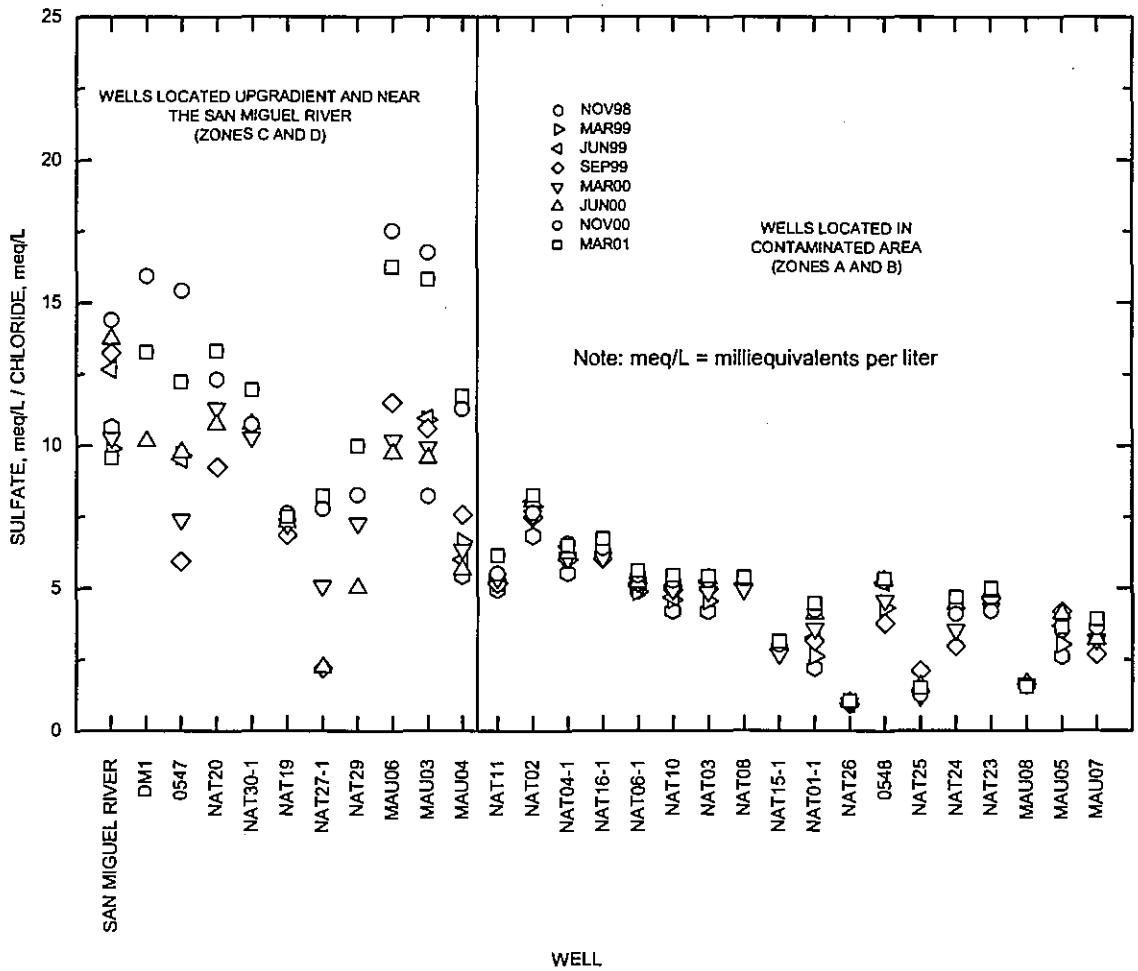

Figure 5–39. Sulfate/Chloride Concentration Ratio in Selected Wells at the Naturita Site Measured from November 1998 to March 2001

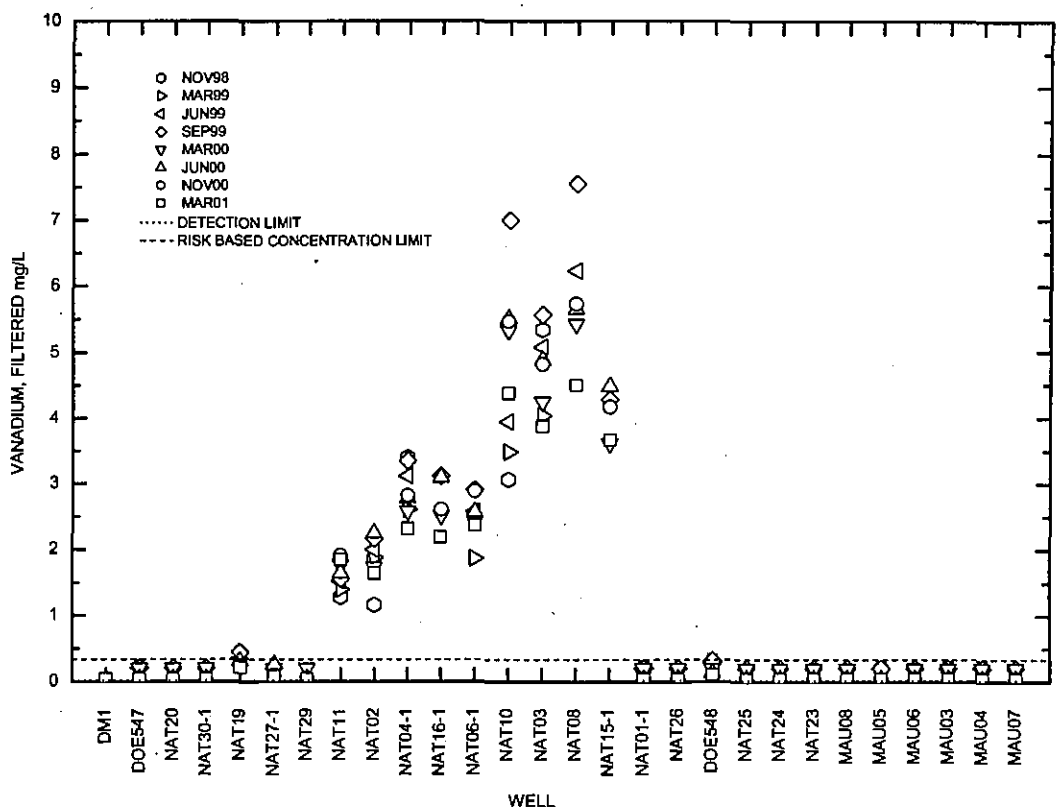

Figure 5–40. Vanadium Concentrations in Selected Wells at the Naturita Site Measured from November 1998 to March 2001

5.3.4 Age Dating Alluvial Ground Water

To better understand flow paths and travel times of alluvial ground water at the Naturita site, samples were collected in June 2000 to age date ground water. The age of ground water is defined as the time since water was isolated from the atmosphere (Freeze and Cherry 1979). Two techniques were used to determine the age of ground water at Naturita. The first involves measuring the ground water concentration of chlorofluorocarbons (CFCs). Because the solubility of CFCs is known, and the air concentration of CFCs for the past 50 years is also known (or reconstructed), ground water age can be measured based on the concentration of dissolved CFCs. The second method measures the ratio of hydrogen-bomb-produced tritium (^3H) to its decay product helium-3 (^3He) in ground water. Both methods have been used successfully at a number of sites to date relatively young ground water (less than 60 years old) (Plummer and Busenberg 2000; Solomon and Cook 2000).

All the wells at Naturita with 2-inch-diameter casings and one site along the San Miguel River were sampled for CFCs; samples were analyzed by the USGS at the Reston Chlorofluorocarbon Laboratory. Twelve of these wells were also sampled for $^3H/^3He$ analysis. These samples were analyzed at the Lamont-Doherty Earth Observatory at Columbia University. In addition to the 2-inch-diameter wells, 6 CFC samples were collected from 0.5-inch-diameter wells and were analyzed at the University of Utah Department of Geology and Geophysics. Table 5–4 presents a complete list of the samples collected at each well.

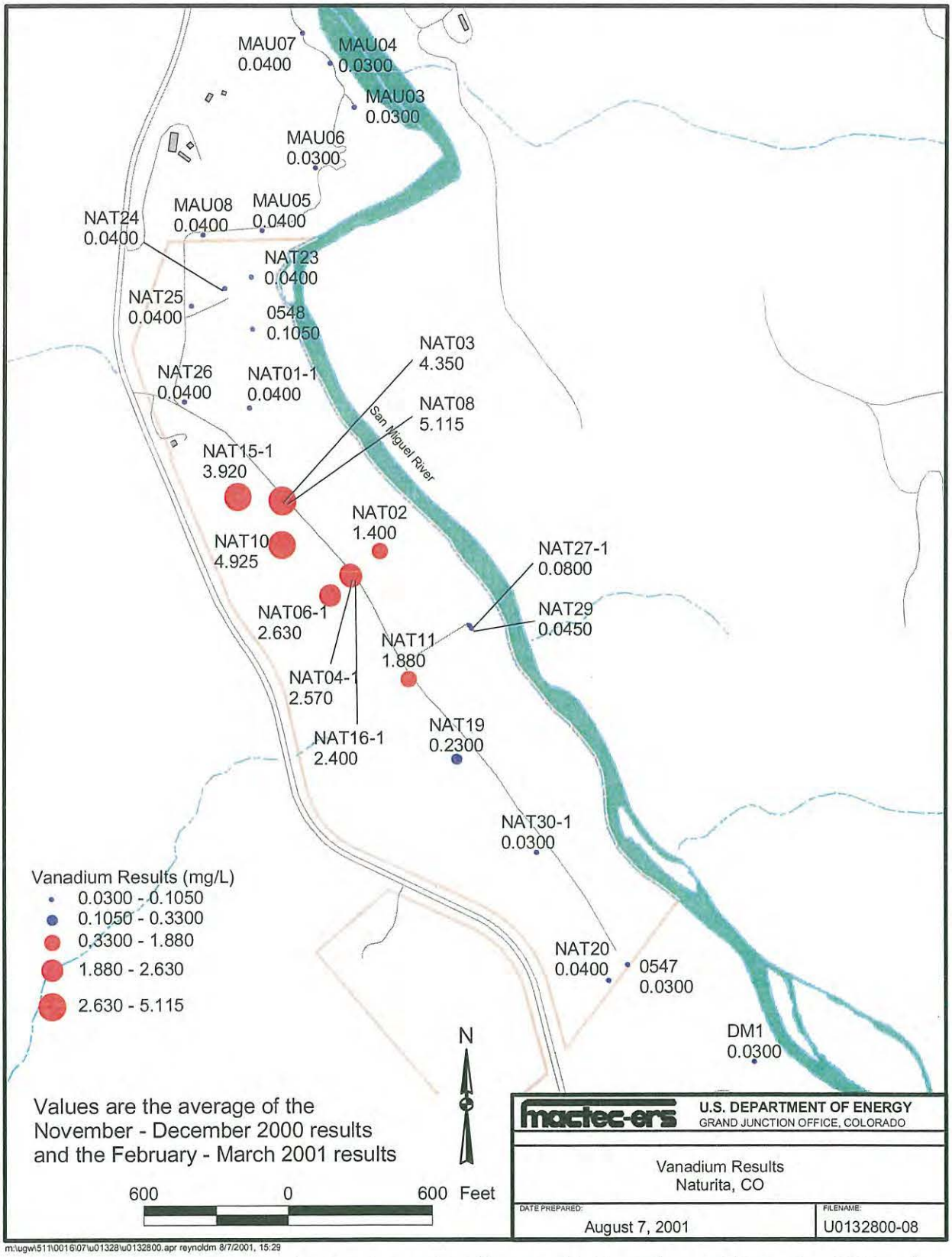

Figure 5–41. Average Vanadium Concentrations Measured in November and December 2000 and February and March 2001

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Table 5–4. Samples Collected During June 2000 for Age Dating of Ground Water at the Naturita Site

Location	Sample Date	USGS Analyzed Samples	University of Utah Analyzed Samples	Tritium-Helium-3 Samples
DM1	6-7-2000	x		x
0547	6-7-2000	x		
0548	6-7-2000	x		
MAU01	6-8-2000	x		
MAU02–2	6-12-2000		x	
MAU03	6-8-2000	x		
MAU04	6-8-2000	x		x
MAU06	6-8-2000	x		
MAU07	6-8-2000	x		x
MAU08	6-8-2000	x		x
NAT02	6-6-2000	x		x
NAT03	6-7-2000	x		
NAT05	6-6-2000	x		x
NAT06–1	6-11-2000		x	
NAT08	6-7-2000	x		
NAT09	6-7-2000	x		
NAT10	6-7-2000	x		
NAT11	6-7-2000	x		
NAT15–1	6-12-2000		x	
NAT15–2	6-12-2000		x	
NAT15–3	6-12-2000		x	
NAT19	6-6-2000	x		x
NAT20	6-10-2000	x		
NAT23	6-8-2000	x		x
NAT24	6-8-2000	x		x
NAT25	6-7-2000	x		x
NAT26	6-6-2000	x		x
NAT29	6-6-2000	x		x
NAT30–1	6-9-2000		x	
San Miguel River	6-8-2000	x		

5.3.4.1 Tritium-Helium Data

Tritium-Helium Sampling

Twelve ground water samples were collected for $^3H/^3He$ age dating from the alluvial aquifer at Naturita (Table 5–4). The samples were collected from 2-inch-diameter wells using a Bennett gas-piston pump driven by compressed nitrogen. Three well casings were purged before samples were collected. Collecting water samples for $^3H/^3He$ determination requires filling a special copper sample tube that is sealed with pinch-off clamps. The copper tube sample is used for dissolved helium and neon analysis, determination of the $^3H/^3He$ isotope ratio, and tritium concentration. If the tritium concentration is low, a more accurate determination can be made using the helium-ingrowth method. In case this analysis was needed, a duplicate sample was collected in a 500-mL bottle with a polyseal lid. The samples were analyzed at the Lamont-Doherty Earth Observatory at Columbia University.

Tritium-Helium Results

Table 5–5 shows the calculated age and recharge year for nine samples collected for $^3H/^3He$ analysis; analytical results were not yet available for samples MAU08, NAT05, and NAT26. Ages range from 0.2 years to 33.9 years. As Figure 5–42 shows ground water generally increases in age as it moves downgradient. This is consistent with ground water flow modeling results that indicate water recharges the aquifer from the San Miguel River and flows downgradient parallel to the river. Ground water age decreases downgradient from well NAT24 and in wells NAT23, MAU04, and MAU07. These younger ages are most likely the result of influx of young water from the San Miguel River in that area. Figure 5–42 also shows inferred flow paths based on ground water ages and chloride concentrations. These flow paths indicate that water is entering the alluvial aquifer all along the San Miguel River. This figure is really a snapshot of the ground water ages and concentrations during June 2000. Beyerle et al. (1999) have shown that the amount and area of infiltration of river water to a shallow aquifer, and thus the ground water ages, can fluctuate seasonally. This fluctuation is seen mainly in the area nearest to the river. Parts of the aquifer that are deeper and farther removed from the river typically show less of an influence from young recharge (Beyerle et al. 1999)

Helium-4 (^4He) is produced in the aquifer by radioactive decay of uranium and thorium. As minerals and dissolved uranium release ^4He to ground water, the ^4He concentration in the water increases. If the ^4He release rate to the aquifer can be quantified, and other sources of ^4He are accounted for, the ^4He concentration should be proportional to the ground water travel time (Solomon and Cook 2000). As seen in Figure 5–43, a strong correlation can be made between ^4He- and $^3H/^3He$-based ground water ages at the Naturita site. Because high concentrations of uranium are dissolved in the ground water or sorbed onto the surfaces of mineral grains, this curve represents the release rate of ^4He directly to the ground water. Therefore, ground water at the Naturita site can be dated directly by measuring the ^4He concentration. Sampling and measuring ^4He is cheaper and easier than other common age-dating methods such as CFCs and $^3H/^3He$, so this may be an important tool to further quantify ground water travel times at Naturita.

As suggested by the chloride and sulfate concentrations, well MAU07 is most likely a mixture of older ground water from the contaminated portion of the aquifer and fresh, younger water from the San Miguel River (Section 5.3.3.2). If it is assumed that the water at MAU07 is a binary mixture of older water from the alluvial aquifer and younger water (age 0 to 5 years) from the river, the mixing ratios can be calculated using ^4He as a tracer. Assuming the input concentration of ^4He from the aquifer is equal to that in well NAT25 (70.27×10^{-8} cm^3 (standard temperature and pressure) g^{-1}), and the younger concentration is similar to that measured in well MAU04 (14.14×10^{-8} cm^3 (STP) g^{-1}), well MAU07 receives approximately 22 percent of its water from the alluvial aquifer. This roughly agrees with the mixing ratio calculated using chloride (26 percent alluvial, 74 percent river).

Table 5–5. Tritium-Helium Age-Dating Results.

Location	Tritium/Helium Age (years)	Tritium/Helium Recharge Year	Tritium in Tritium Units	^4He 10^{-8} cm^3 (STP) /g
DM1	0.2	2000	10.58	5.42
NAT02	15.1	1985	10.9	30.97
NAT05	nd	nd	10.18	nd
NAT19	9.2	1991	10.33	17.12
NAT23	13.5	1987	10.54	25.8
NAT24	33.9	1966	10.68	79.42
NAT25	28.2	1972	10.36	70.27
NAT26	nd	nd	11.01	nd
NAT29	5.8	1994	10.61	5.2
MAU04	5.6	1994	10.61	14.14
MAU07	12.4	1988	10.39	26.4
MAU08	nd	nd	10.27	nd

All samples were collected June 6 through 8, 2000.
nd = No data.

As shown in Figure 5–44, a strong correlation can also be made with ground water age and uranium concentration (R = .81531). This is not surprising, because uranium concentration generally increases along the ground water flow path. However, this would suggest that uranium concentration could be used as an estimation of ground water age (higher uranium concentration equals greater age). Comparing ground water ages with uranium concentration can give an idea of the extent of natural attenuation at the site. If natural flushing of uranium is occurring, there should be relatively old ground water present with low uranium concentrations. Figure 5–44 shows increasing uranium with age, suggesting natural flushing at these wells has not yet begun. More detailed age dating of the aquifer could possibly show areas where natural flushing is occurring.

5.3.4.2 Chlorofluorocarbon Data

CFC Sampling

CFC samples were collected from each of the 2-inch-diameter wells using a Bennett gas-piston pump driven by compressed nitrogen. Three well casings were purged before five replicate samples were collected. To isolate samples from the modern atmosphere, the samplers collected them in sealed borosilicate glass ampoules that were flushed with ultra-high-purity nitrogen. The samples were analyzed at the USGS Reston Chlorofluorocarbon Laboratory by purge-and-trap gas chromatography using an electron capture detector. Busenberg and Plummer (1992) provide a more detailed description of the sampling procedure. CFC samples from the 0.5-inch-diameter wells were collected in copper tubes sealed with pinch-off clamps. During sampling, a peristaltic pump was attached to a 3/8-inch-diameter copper pipe that was inserted into the well. The well was purged of at least 3 gallons before sampling. A 3/8-inch copper sample tube similar to those used in tritium-helium sampling (see Section 5.3.4.1) was connected to the sample pipe and to the intake side of the pump head. Once flushed with ground water to remove any trapped air, the copper sample tube was sealed with pinch off-clamps. Three replicate samples were collected at each well. These samples were analyzed at the University of Utah Department of Geology and Geophysics by purge-and-trap gas chromatography using an electron capture detector. Wilkowske (1998) presents a more detailed description of the copper tube sampling technique.

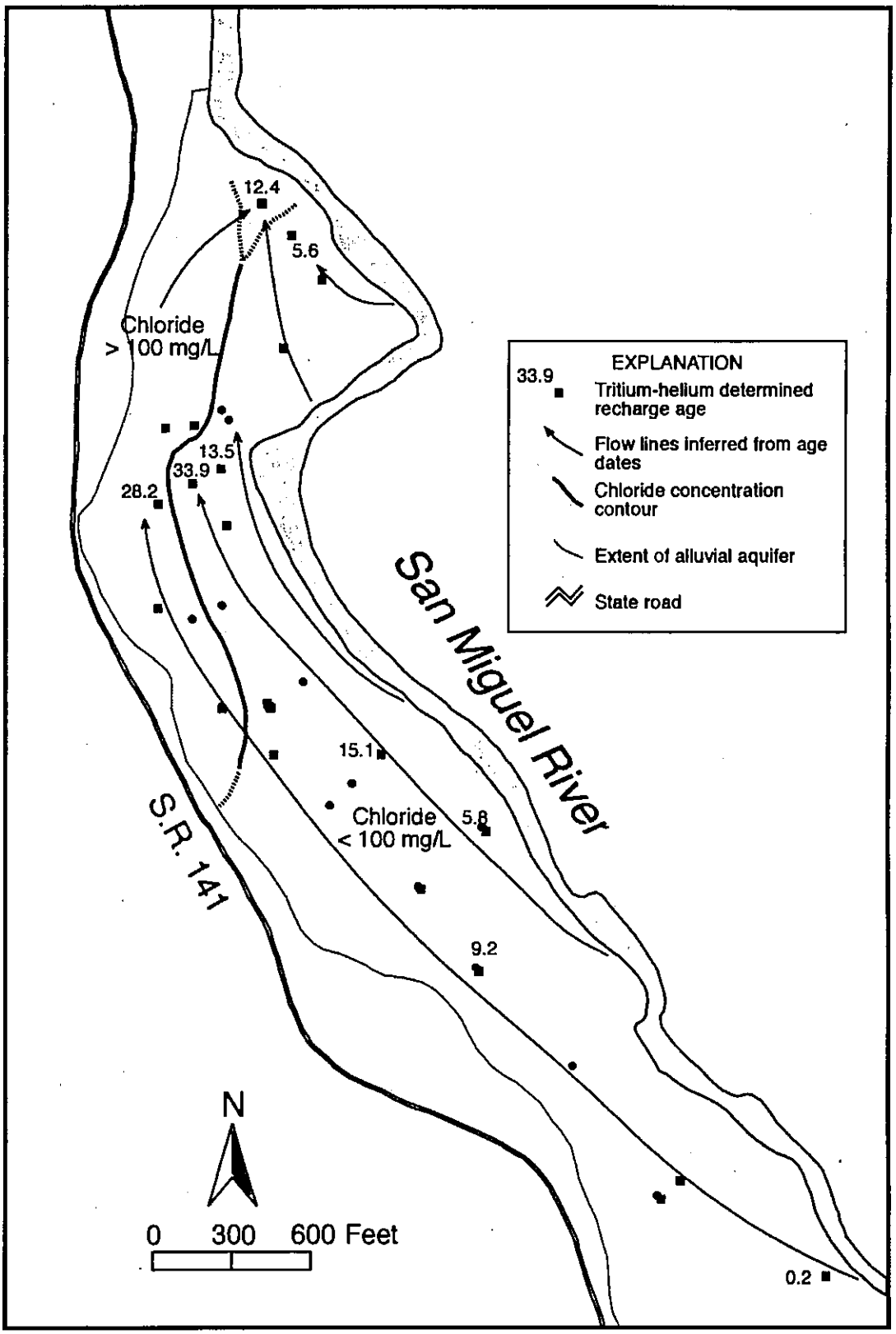

Figure 5–42. Tritium-Helium-Determined Recharge Ages and Inferred Flow Paths at the Naturita Site

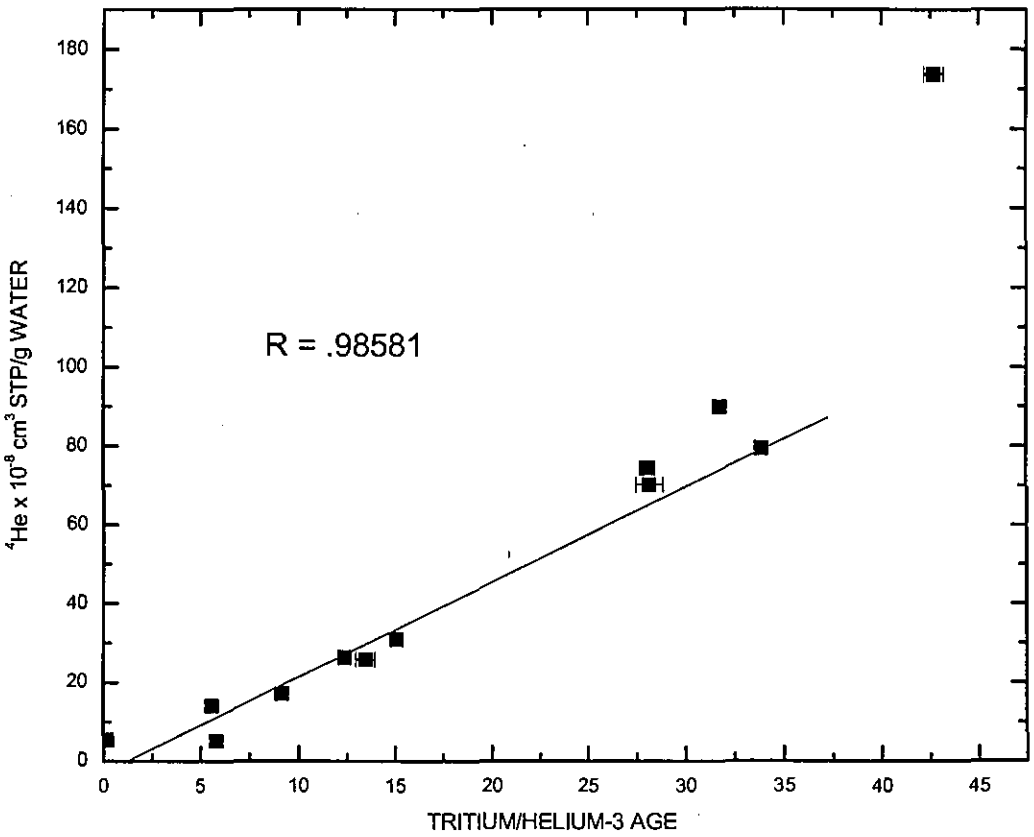

Figure 5–43. ^{4}He Concentration versus Ground Water Age as Determined by ^{3}H/^{3}He Dating

Calculation of Recharge Temperature

The calculated equivalent air concentration of CFCs is based on the solubility of CFCs in water and is therefore temperature dependent. It is important to get a good estimate of the temperature of the water at the time it recharged the aquifer. To measure the recharge temperature, samples were collected from well MAU06 for dissolved gas analysis at the USGS Reston Chlorofluorocarbon Laboratory. The analyses included dissolved nitrogen, argon, methane, carbon dioxide, and oxygen. The concentration, as well as the ratios of concentrations of these gases, can be used to calculate the recharge temperature of a ground water sample. Based on the N_2/Ar ratio, the calculated recharge temperature for the Naturita aquifer is 16 °C. This is similar to the value of 13 °C, which was the average temperature of the San Miguel River during peak flow in May and June 2000.

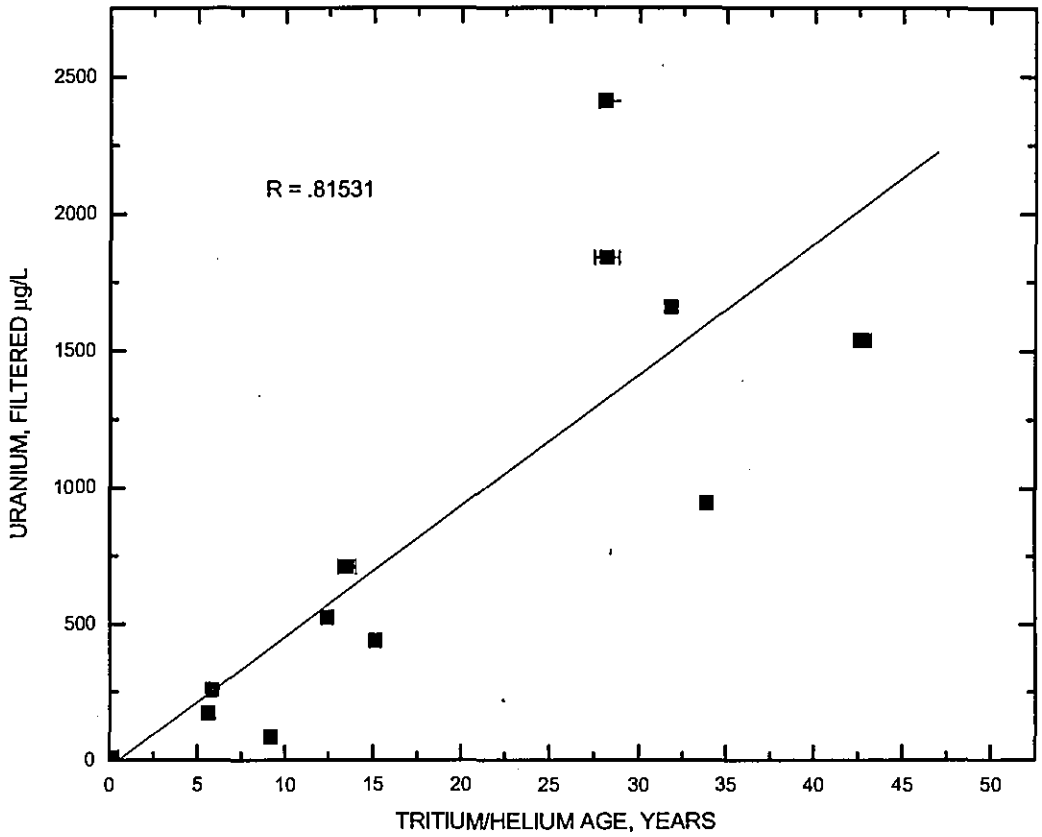

Figure 5–44. Uranium Concentration versus Age as Determined by $^3H/^3He$ Dating

CFC Age Dating Results

CFC samples were analyzed for three compounds: CFC-11 (trichlorofluoromethane, $CFCl_3$), CFC-12 (dichlorodifluoromethane, CF_2Cl_2), and CFC-113 (trichlorotrifluoroethane, $C_2F_3Cl_3$). Figure 5–45shows the average CFC concentration for each of the three species and their modeled recharge age. Because tritium-helium age dating is unaffected by factors such as biodegradation, sorption, and urban contamination, these dates are considered to more accurately model the recharge age of ground water. Figure 5–45 shows that recharge ages modeled from CFC-11 and CFC-12 values are too young in comparison to $^3H/^3He$ ages. This suggests either biodegradation of both CFC species or mixing of old CFC-free water that is presumably upwelling through the underlying consolidated rock. This mixing would effectively dilute the CFC concentration and give an apparent older recharge age. Degradation of CFC-11 and CFC-12 under anaerobic conditions is well documented (Plummer and Busenberg 2000). Degradation of CFC-11 is typically more pronounced than that of CFC-12, which is the case with the samples from the aquifer at Naturita (Figure 5–45). In a water sample with no biodegradation that is a mixture of old CFC-free water and young water containing CFCs, the CFC-11 and CFC-12 ages should match. Therefore, it is apparent that CFC-11 has been significantly degraded and cannot be used for age determination.

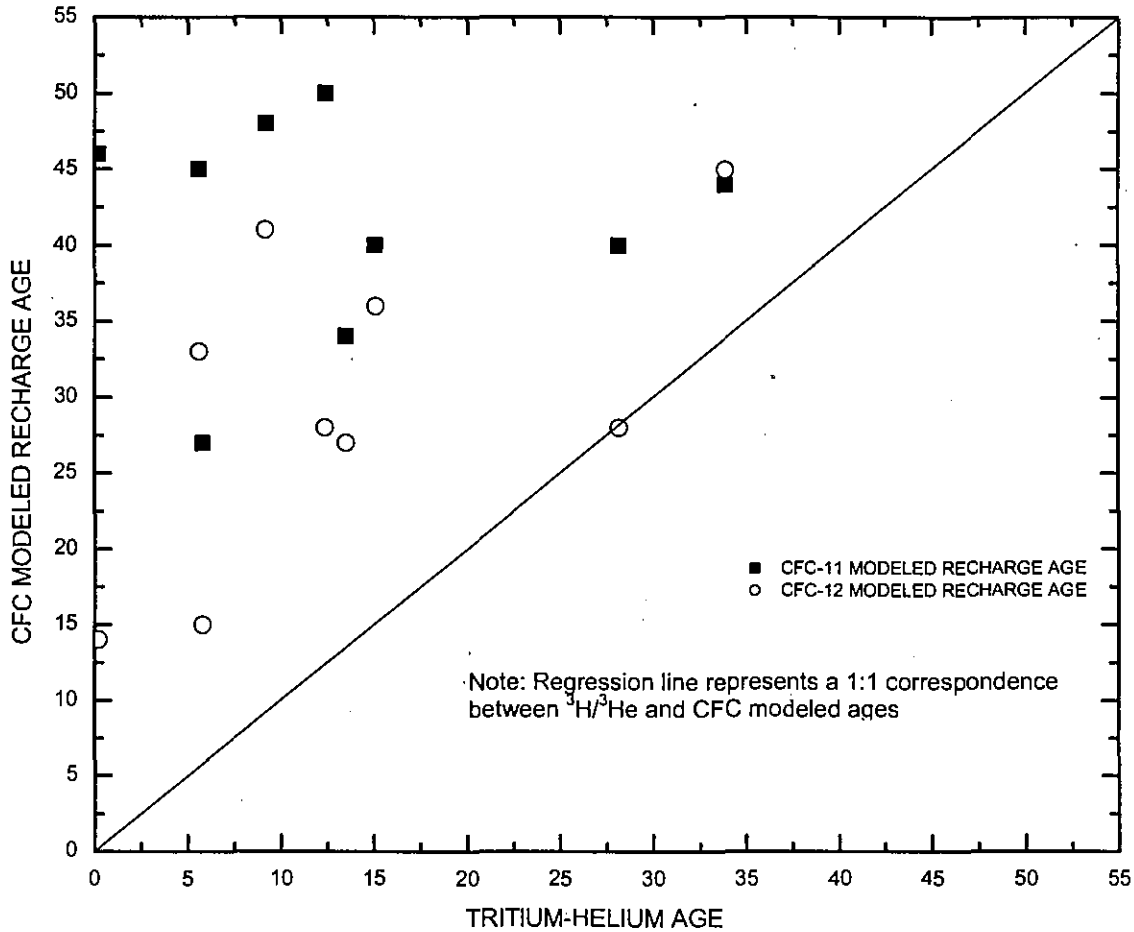

Figure 5–45. Recharge Age Modeled from CFC-11 and CFC-12 Data Compared to $^3H/^3He$ Age

The deep ground water from the Morrison Formation has high chloride concentrations, and the head gradient between the deep and alluvial aquifer is upward. Simple mixing calculations can be made to evaluate the percentage of water in the alluvial aquifer that could have originated from the deep, and presumably old, ground water. These calculations assume that (1) chloride is conservative, (2) the end member waters are the San Miguel River and the deep ground water, and (3) there are no other chloride sources. Table 5–6 summarizes these mixing calculations. These calculations suggest that upgradient of the former mill yard, less than 2 percent of the water is from the deep aquifer. In the contaminated area, the calculations are approximate because of contamination from sodium chloride used in processing the ore (Section 5.3.3.2). This is evident from the high chloride concentrations observed in historical data from abandoned well 0656. Well NAT03 is located close to the former location of well 0656. If the assumption is made that the 6 years from 1992 to 1998 and the surface soil remediation were sufficient to flush the mill-related chloride from the NAT03 area, then the deep ground water could have accounted for 7.6 percent of the total water. Because much of the chloride in this area could very likely be left from contamination, this value should be considered as a maximum amount of mixing. The results at NAT04, which is several hundred meters upgradient of NAT03, are similar to the results at NAT03.

Table 5–6. Chloride Concentrations and Mixing Ratios in Different Waters at the Naturita Site

Location	Measurement Period	Concentration mg/L	Percentage of Water from the Deep Aquifer
River			
SM1	1998–2001	5.2	0
Deep Aquifer			
0502	1986–1995	699	100
Upgradient Wells			
0547	1986–1997	9.0	0.5
0547	1998–2001	11	0.8
NAT20–22	1999–2001	10	0.7
Contaminated Wells			
0656	1990–1992	155	21.6
NAT03	1998–2001	58	7.6
NAT04	1998–2001	44	5.6

The $^3H/^3He$ age-dating technique only dates the young, tritium-containing fraction of ground water, because the isotope ratio is nearly independent of dilution with old tritium-free water (Plummer et al. 1998b). Therefore, these ages should be comparable to the CFC dates of the young water fraction. This fraction can be calculated using the mixing ratios from the chloride concentrations. Assuming that the water at well NAT02 is mixed with 7.6 percent old CFC-free water, the remaining young fraction should have a CFC-12 apparent age of 1986. The tritium-helium recharge age at this well is 1994. At well NAT29, assuming a mixing ratio of 7.6 percent old water, the young fraction should have an apparent CFC-12 recharge age of 1965. The $^3H/^3He$ recharge age at well NAT29 is 1985. In order to match the $^3H/^3He$ recharge ages at well NAT02 to the CFC-modeled ages, San Miguel River water would have to be mixed with about 85 percent old CFC-free water. Well NAT29 would need to be mixed with about 25 percent old water. Because the maximum amount of older water based on chloride concentrations is about 7.6 percent, it would appear that the CFC-12 ages are affected by some other process, such as biodegradation, and also cannot be used for age determination.

CFC-113 also proved unacceptable for ground water age dating. All samples except those from NAT09, NAT11, NAT24, and the San Miguel River were contaminated with CFC-113. CFC-113 contamination is defined by a sample concentration that is greater than would be present if the sample were equilibrated with modern air.

5.3.5 Contaminant Fate and Transport

5.3.5.1 Ground Water Flow and Transport Modeling

A ground water flow and transport model was developed to evaluate if natural processes will reduce concentrations of site-related COPCs to regulatory levels in the alluvial aquifer within 100 years. Two versions of the model were developed and employed to address conditions at the site. A steady state deterministic flow and transport model was used as the basis for the steady state stochastic flow and transport model. The steady state stochastic flow and transport model was used to quantify the uncertainty in flow and transport parameters. Modeling results indicate that natural flushing is not an acceptable compliance strategy to reduce ground water concentrations of uranium and vanadium to acceptable levels within 100 years.

The USGS was contracted to develop a steady state deterministic flow model for the Naturita site. The existing ground water flow pattern at the site was modeled using the MODFLOW software (McDonald and Harbaugh 1988), a multilayered, three-dimensional hydrologic flow model published by USGS. USGS uses the Argus Open Numerical Environments family of products for the pre- and post-processing for MODFLOW. The calibrated MODFLOW files created by the Argus ONE products were then converted to a format compatible with the version of MODFLOW in GWVistas.

The gravel mining operation upgradient of the former site has recently expanded and it is likely that there will be future expansions. This operation was not considered in the USGS flow model and subsequently not considered in the transport model. The recent and future expansion of this operation could significantly impact the ground water flow and the transport of contaminants. Without modeling the impacts from the gravel mining operation, the predicted concentrations of the COPCs in this report are most likely underestimated.

The calibrated steady state deterministic flow model of the USGS was used as a basis for a steady state stochastic flow model developed using GWVistas. The steady state deterministic and stochastic transport models were developed using GWVistas.

Output from the flow model was used as input to MT3DMS (Zheng and Wang 1999), a version of a modular three-dimensional transport model to simulate advection, dispersion, and chemical reactions of contaminants in the ground water system. A steady state deterministic transport model was developed to predict future concentrations of COPCs. Sensitivity analysis of the flow and transport parameters, within the deterministic models, determined that hydraulic conductivity and recharge are sensitive and affect the transport simulation results. These two flow parameters and the transport parameters of porosity, longitudinal dispersivity, and the K_d were treated as uncertain for stochastic simulation.

Section 4.5.1.4 briefly discusses the determination of K_d values from R_d values. The K_d values of 0.6078 and 12.46 mL/g for uranium and vanadium, respectively, that are used for the deterministic modeling are 25 percent of the average R_d value. For the stochastic modeling the estimated range of values is 25 percent of the minimum and maximum R_d values. For uranium the estimated range of values is from 0.3975 to 1.1225 milliliters per gram (mL/g). For vanadium the estimated range of values is from 4.445 to 20.6575 mL/g.

Details of the model construction, steady state calibration, and steady state stochastic parameters are presented in Appendix F. The codes used are fully described in the references cited and have been verified, benchmarked, and approved for use by most government and regulatory agencies. The following sections present a summary of the modeling results.

Steady State Deterministic Model

Predicted uranium concentrations in ground water after 100 years are presented in Figure 5–46. The simulation predicts that the maximum concentration will decrease to 0.23654 mg/L, which is above the UMTRA Project MCL of 0.044 mg/L. Vanadium simulations show similar results. Vanadium concentrations in ground water after 100 years are presented in Figure 5–47. The simulation predicts the maximum concentration will decrease to 4.3286 mg/L, which is well above the risk-based concentration of 0.33 mg/L. Simulation results show that at 10 years the maximum remaining arsenic concentration is 0.045 mg/L, which is below the UMTRA Project MCL of 0.05 mg/L.

Steady State Stochastic Model

The steady state stochastic modeling predicts similar results. Only uranium was modeled using the stochastic models. Figure 5–48 presents the results for uranium after 100 years. Maximum average concentrations are above the standard at 0.12087 mg/L. The stochastic simulations predict that after 100 years there is a 49 percent probability that the maximum concentration will be greater than the proposed standard over a significant area of the alluvial aquifer, as shown in Figure 5–49.

5.4 Pattern Recognition Modeling of Natural Attenuation Processes

The first step in documenting the natural removal of contaminants in ground water systems is to identify the "footprint" of the natural attenuation process (National Research Council 2000). The mechanisms that destroy or sequester the constituents cannot be observed directly; however, the removal process can leave a number of footprints that are directly related to the loss of the contaminant (National Research Council 2000). Multiple chemical and physical footprints of a specific natural attenuation process are usually required to provide a defensible link between cause and effect. Some footprints can be obscured by reactions that produce or use the footprint materials. For example, dissolution of calcareous materials along a ground water flowpath could mask the footprints of biodegradation reactions that change the total inorganic carbon concentration in the ground water (National Research Council 2000). These same principles are applicable to documenting the geochemical and hydrologic footprints of the natural attenuation of selected contaminants at the Naturita site.

Statistical techniques collectively referred to as pattern recognition modeling are useful in extracting chemical information from large, multivariate databases that may otherwise be difficult or impossible to interpret (Meglan 1988). Pattern recognition modeling uses statistical and graphical techniques to chemically fingerprint groups of multivariate data that have undergone similar geochemical and hydrologic processes. These techniques can be used to efficiently identify the footprints related to natural attenuation processes at the Naturita site.

The objectives of this section are to (1) describe how pattern recognition modeling techniques were used to model multivariate data from the Naturita site, and (2) interpret the results of pattern recognition modeling with respect to the geochemical and hydrologic footprints controlling uranium removal at the site.

5.4.1 Methodology

Pattern recognition modeling techniques were applied to the multivariate data matrix collected from the Naturita site during June 2000 (Table 5–7 and Appendix G). The data set consists of 66 locations (Figure 5–50) and 23 chemical, physical, and isotopic constituents. The constituents in the data set are aluminum, alkalinity as calcium carbonate, boron, bromide, calcium, chlorine, dissolved oxygen (DO), iron, potassium, magnesium, manganese, sodium, oxidation-reduction potential, pH, silicon, sulfate, specific conductance, strontium, temperature, uranium, vanadium, delta oxygen-18 ($\delta^{18}O$), and delta deuterium (δD). The pattern recognition modeling of the database consisted of (1) hierarchical cluster analysis (HCA) and (2) principal component analysis (PCA) combined with data visualization techniques using the software package PIROUETTE 3.01 (Infometrix 2000).

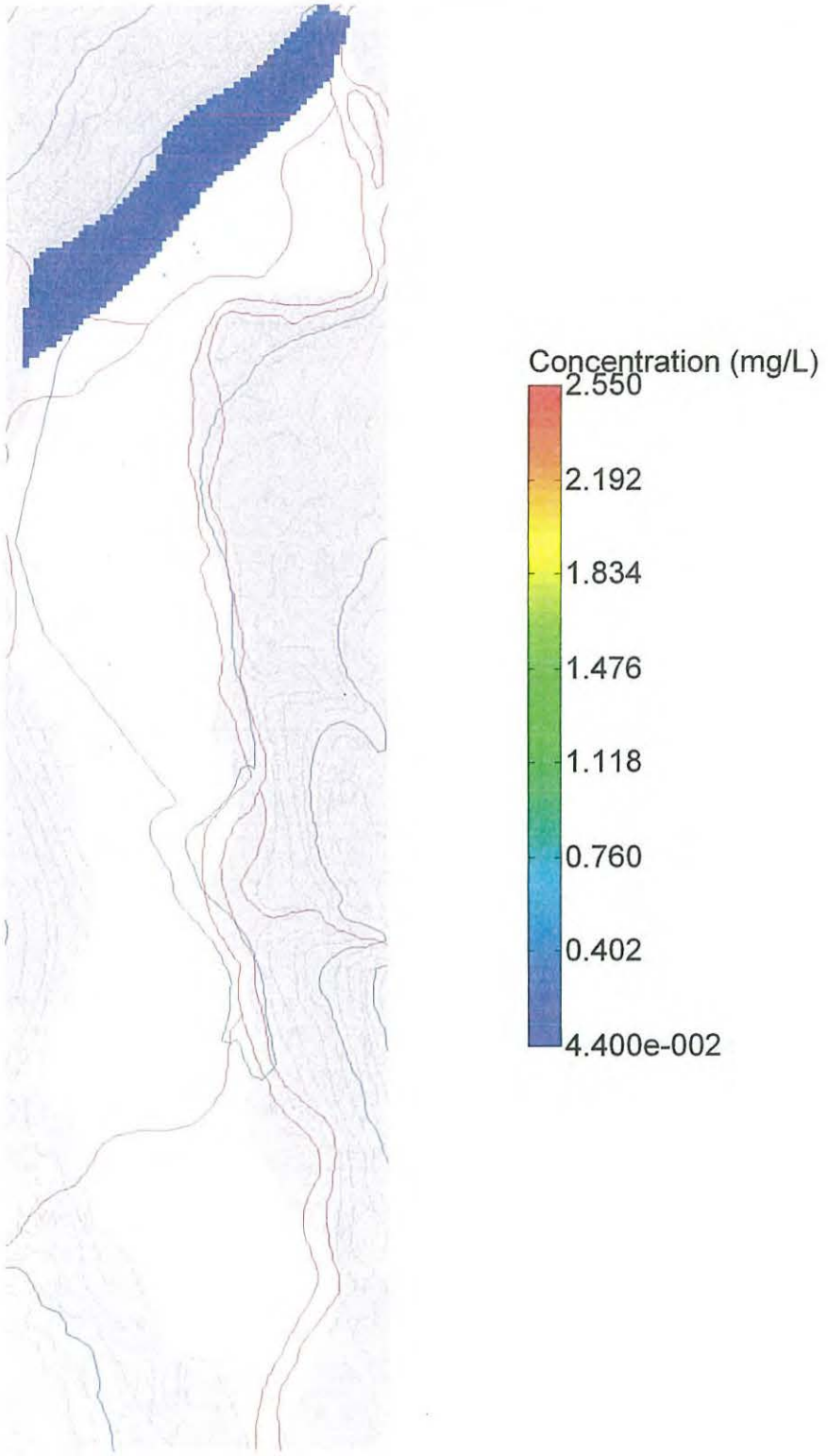

Figure 5–46. Predicted Uranium Concentrations in Ground Water After 100 Years (steady state deterministic model)

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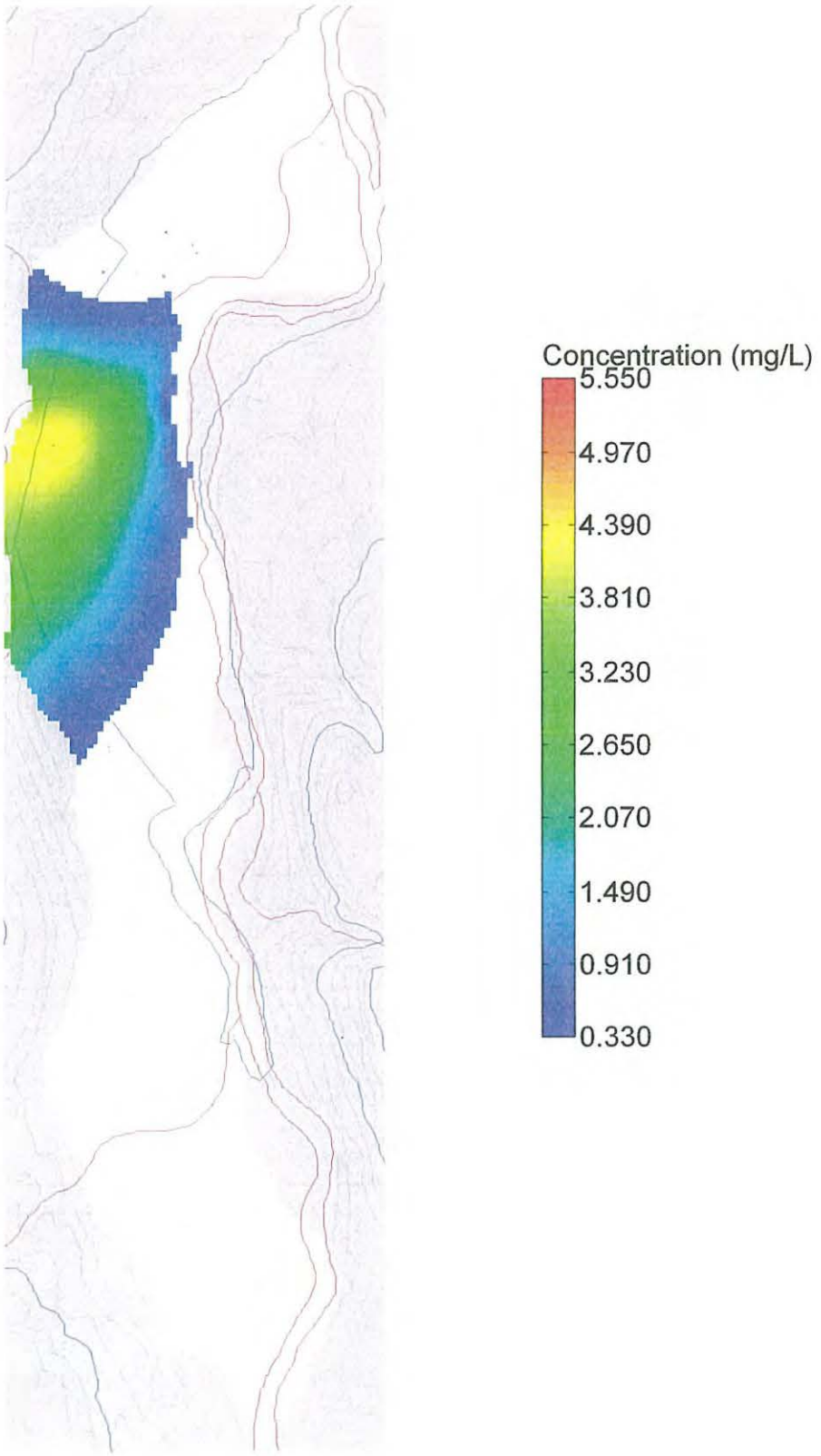

Figure 5–47. Predicted Vanadium Concentrations in Ground Water After 100 Years (steady state deterministic model)

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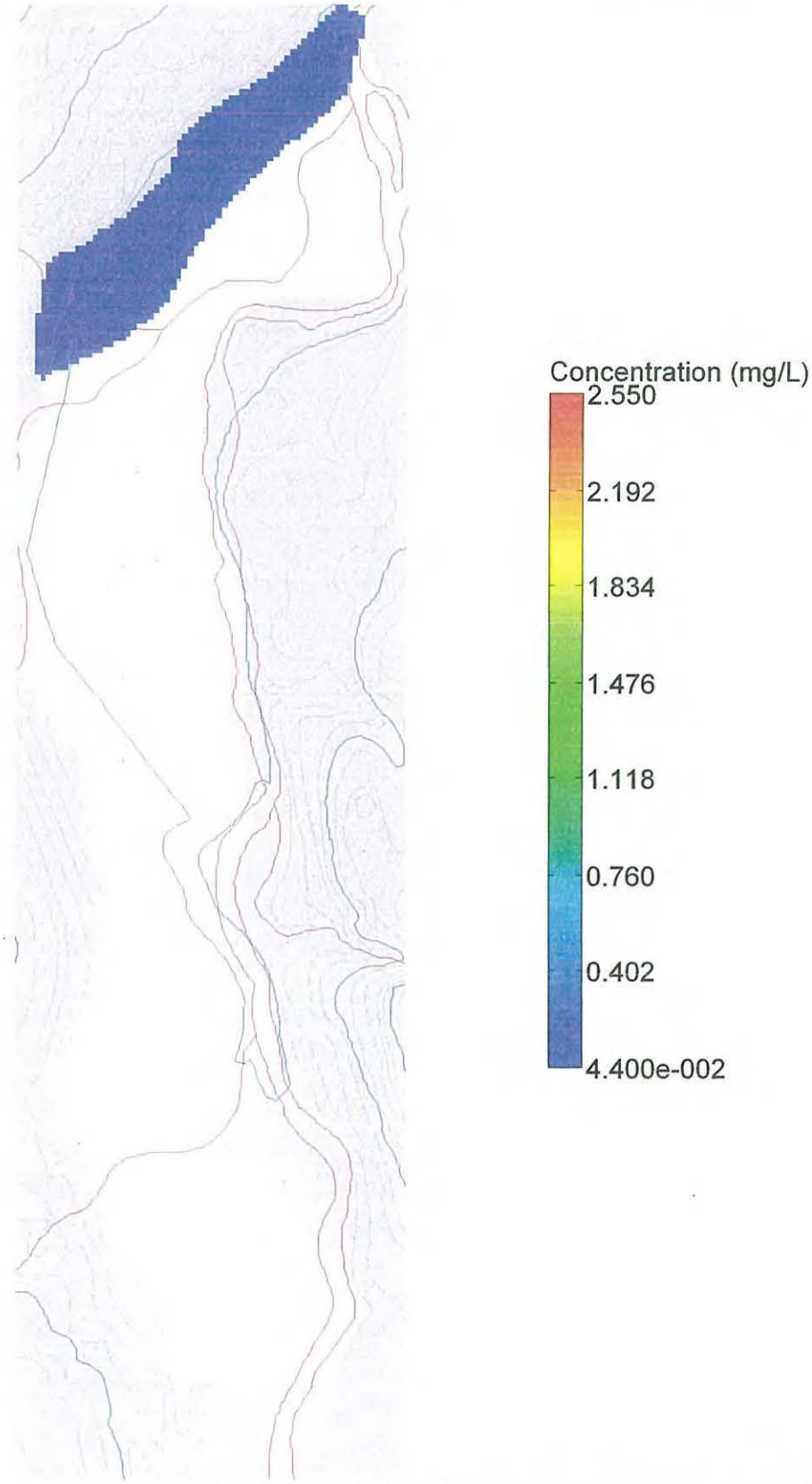

Figure 5–48. Predicted Uranium Concentrations in Ground Water After 100 Years (steady state stochastic model)

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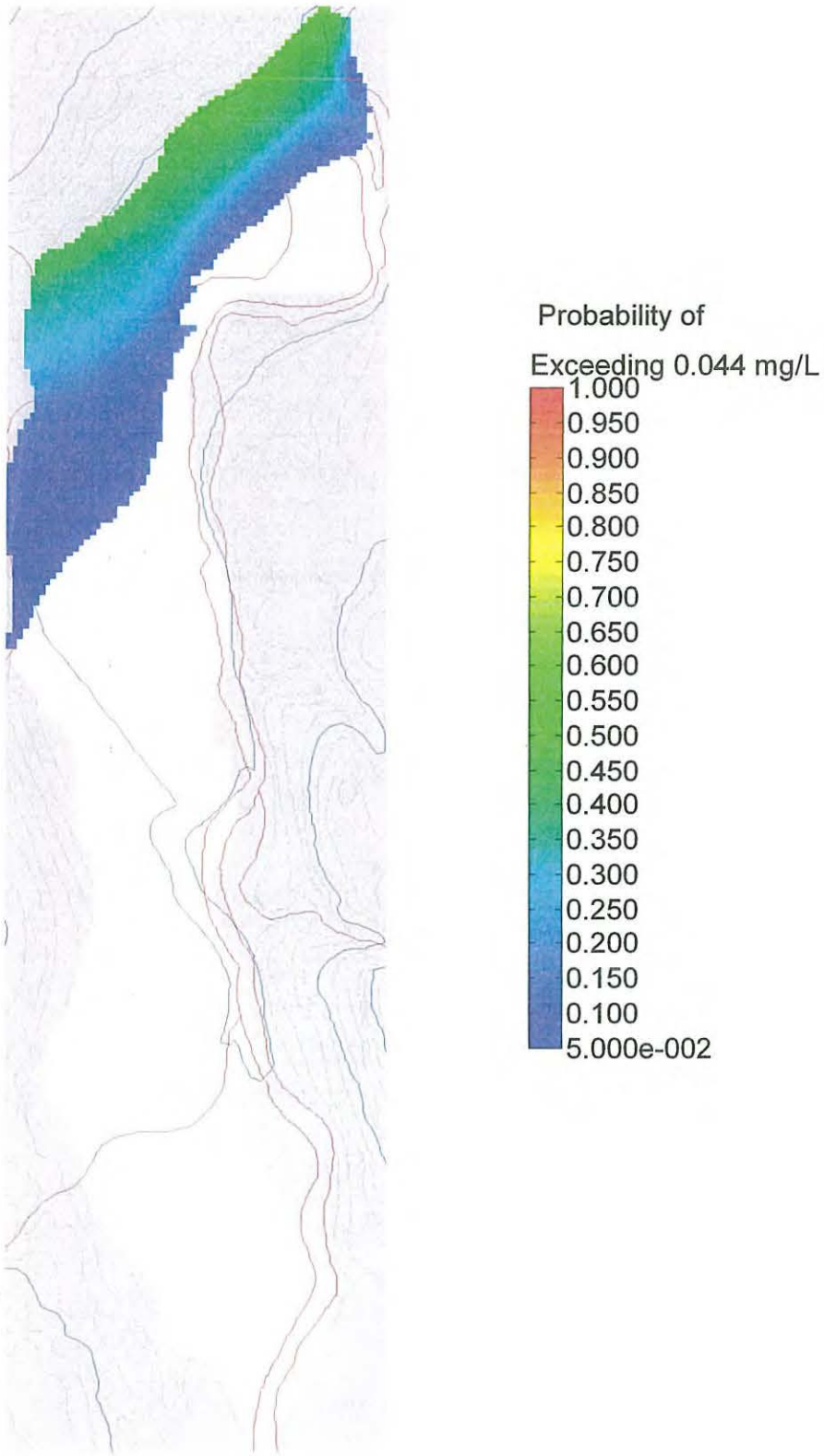

Figure 5–49. Probability of Exceeding 0.044 mg/L After 100 Years

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Table 5–7. Principal Component Loadings of Each Chemical Constituent Used in Pattern-Recognition Modeling of Geochemical Data at the Naturita Site

Chemical Constituent	Principal Component 1 Loadings, Unitless	Principal Component 2 Loadings, Unitless	Principal Component 3 Loadings, Unitless
Aluminum	0.170188	-0.017381	0.003615
Alkalinity as $CaCO_3$	0.274251	-0.113037	-0.031143
Boron	0.244010	0.147747	0.175510
Bromide	0.141018	0.302378	0.280969
Calcium	0.270638	-0.006266	-0.048917
Chloride	0.249546	-0.001928	0.146143
Dissolved oxygen	-0.086892	0.310780	0.291254
Iron	0.036257	-0.255583	-0.316834
Potassium	0.243880	0.198122	0.064084
Magnesium	0.281352	-0.063129	0.091898
Manganese	0.199061	0.097277	-0.252004
Sodium	0.281358	-0.073263	0.046984
Oxidation-reduction potential	-0.048781	0.175063	0.195769
pH	-0.134528	0.391981	0.102914
Silicon	0.247714	0.025142	-0.100777
Sulfate	0.280173	-0.103272	0.067179
Specific conductance	0.283692	-0.069284	0.090751
Strontium	0.268836	0.014925	0.180447
Water temperature	-0.100691	0.155468	0.376458
Uranium	0.267012	0.141107	-0.084516
Vanadium	0.132422	0.131755	-0.201817
Delta deuterium	-0.007406	-0.458933	0.377873
Delta oxygen-18	-0.049736	-0.425400	0.406542

Note: Loadings greater than 0.20 or less than -0.20 best explains the most probable geochemical processes controlling the elemental distribution in each principal component.

5.4.2 Hierarchical Cluster Analysis Results

The purpose of HCA is to group multivariate data so that underlying links between the groups can be discerned (Davis 1973; Meglan 1991). This grouping is accomplished by calculating a similarity distance of all variables in the data set between all possible pairs of samples. After sample distances have been computed, the two most similar samples are linked, and this linkage continues until all the samples and clusters have been linked. Identical samples would have a similarity value (SV) of 1.0, and the most dissimilar sample/cluster in the data set would have a SV of 0.0. Prior to HCA, the data were autoscaled and the complete linkage method was used to calculate the SVs between sample pairs (Infometrix 2000). Results of the HCA are displayed in the form of a dendogram constructed with the SV scale on top decreasing from 1.0 (most similar) to 0.0 (least similar) (Figure 5–51).

Six distinct data clusters (designated groups 1, 2, 3, 4, 5, and 6 &7) were distinguished using a SV = 0.66 and defined by the vertical line on the dendogram (Figure 5–51). Sample locations in each of the groups plot in distinct geographic regions of the site (Figure 5–50) that are related to similar geochemical and hydrologic processes. Group 1 is surface water in the San Miguel River. Group 2 is associated with water samples from wells at the southern edge of the site, immediately downgradient of the gravel pits and upgradient of the historical tailings and

associated facilities. Group 3 consists of water samples from well DM1 upgradient of the gravel pits and south of the study area boundary plus wells MAU03, MAU04, and MAU06 at the north end of the study area. Group 4 consists of water samples from wells in the center of the site and adjacent to the river. Group 5 consists of water samples from wells in the central part of the site; however, they are farther away from the San Miguel River than wells belonging to Group 4. Water samples from wells MAU01, MAU08, NAT25, and NAT26 are members of group 6&7 and are located in the northern half of the study and are, in general, farther removed from the San Miguel River than Group 5 wells.

The uranium concentrations for each group are distinctly different (Figure 5–52). The median uranium concentrations are lowest (median concentration < 14 µg/L) for locations in groups 1 and 2. Geographically, these locations represent the San Miguel River or areas upgradient of the former uranium processing facilities. Higher median uranium concentrations are present in locations classified in Group 3 (median concentration = 172 µg/L) and Group 4 (median concentration = 466 µg/L). Both Group 3 and 4 locations are downgradient from the former uranium processing facilities, but close to the San Miguel River where elevated river stage during seasonal snowmelt tends to create some localized flushing zones that could dilute the uranium concentration in the ground water. The uranium concentrations are highest at locations in groups 5 and 6&7 (median concentrations = 908 and 1,660 µg/L). Geographically, these locations are both downgradient of the former millsite and farther removed from the mixing influence of the San Miguel River than locations in groups 1–4 (Figure 5–50).

Age dating of water in each of the groups supports the interpretation of interaction with the San Miguel River and the observed uranium concentrations (Figure 5–52). Because water samples belonging to Group 1 represent surface water in the San Miguel River, they are assumed to have an age date of 2000. Unfortunately, no age dating was done on water samples from wells belonging to Group 2. Wells from Groups 3 and 4 are close to the San Miguel River and have relatively young recharge ages (1985 to 2000) and low median uranium concentrations, indicating significant mixing with recently recharged water from the San Miguel River. In contrast, Group 5 and Group 6&7 wells that are farther away from the San Miguel River have older recharge ages (1966 to 1991) and higher median uranium concentrations, indicating less mixing with recently recharged water from the San Miguel River. The youngest recharge age measured in Group 5 wells was 1991 and was measured in water from well NAT17, which is the farthest upgradient well in Group 5.

5.4.3 Principal Component Analysis Results

Results from the HCA of the multivariate data set (Table 1, Appendix G) indicate a significant clustering of the data that is directly related to the geographic distribution of the wells in terms of distance from the San Miguel River and relation to the tailings material. PCA was applied to the same data set and data groupings identified in the HCA to determine the underlying geochemical and hydrologic processes that may be controlling the observed variations in the individual chemical, isotopic, and physical constituents that were analyzed.

The goal of PCA is to find a new set of coordinate axes that are mutually orthogonal, onto which the multivariate data can be projected. Each new axis is referred to as a principal component (PC) and is independent of the other PCs. The number of PCs used to represent the multivariate data set is not exact; however, the first two or three PCs generally explain most of the variance from the original data matrix.

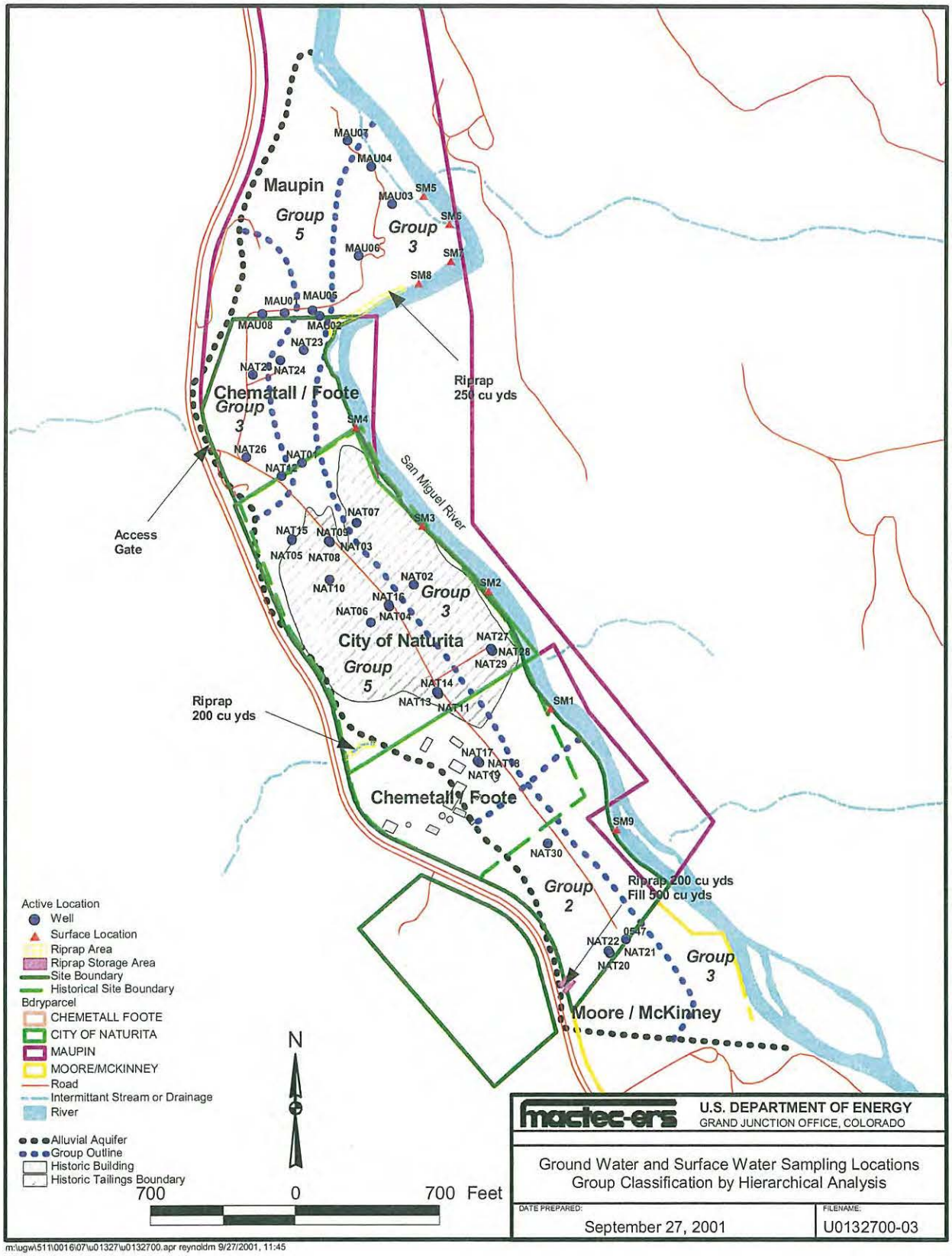

Figure 5–50. Location of Ground and Surface Water Sampling in Relation to Group Classification by Hierarchical Cluster Analysis

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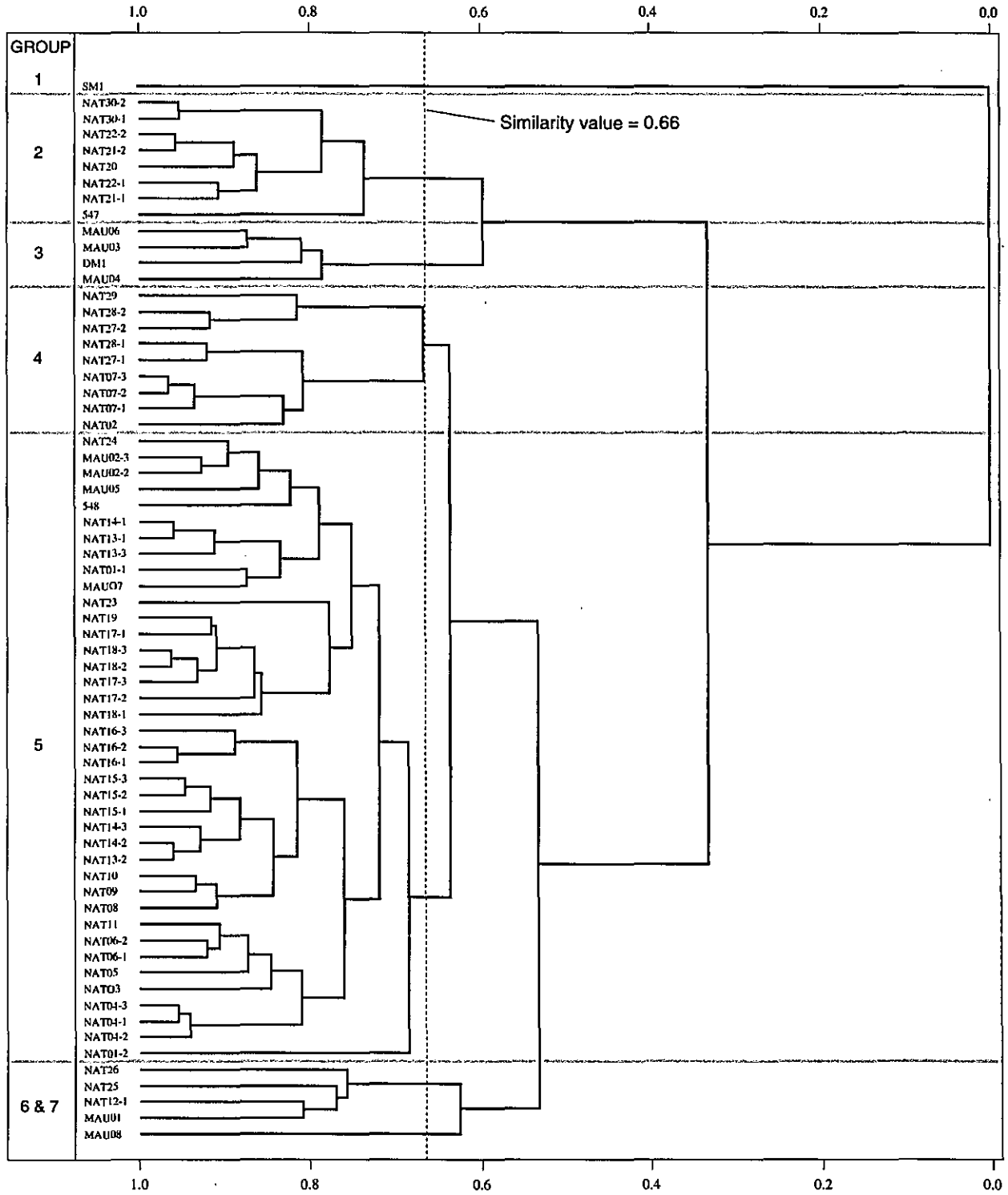

Figure 5–51. Dendogram Showing the Results of the Hierarchial Cluster Analysis Performed on the Multivariate Data Set Collected During June 2000, Naturita, Colorado. Each Group Consists of One or More Sample Sites Within the Study Area.

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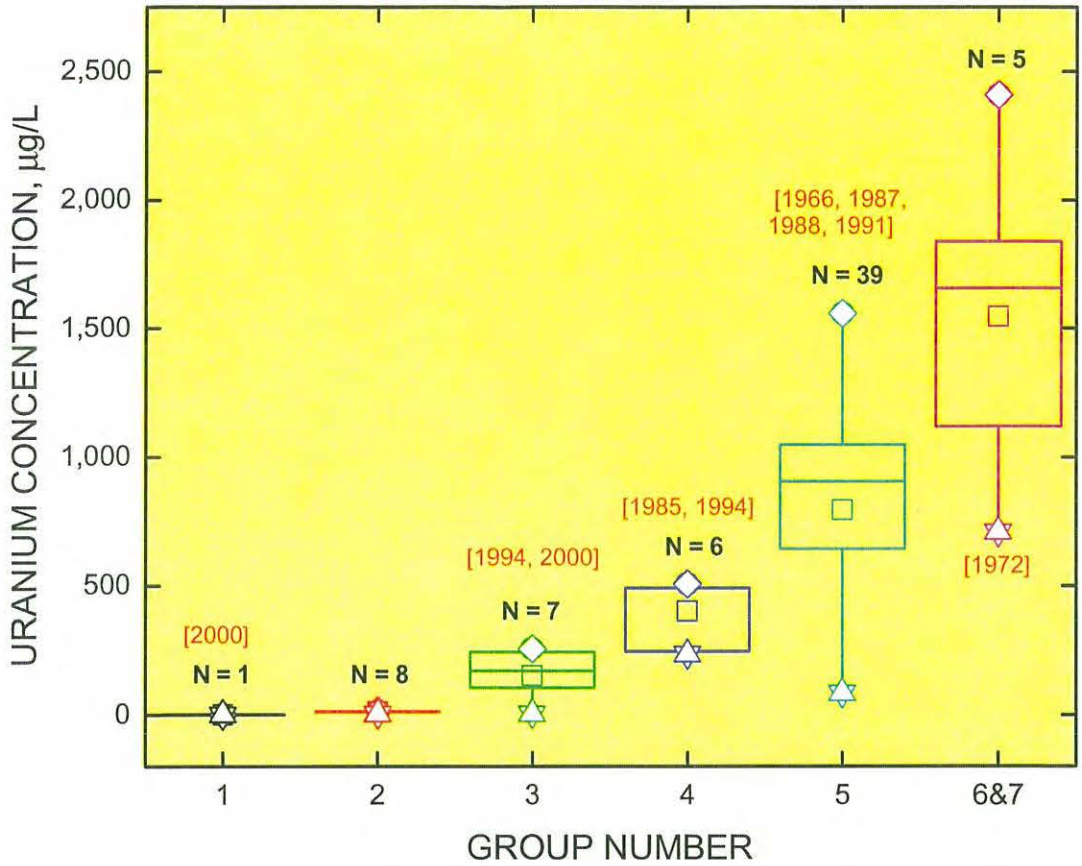
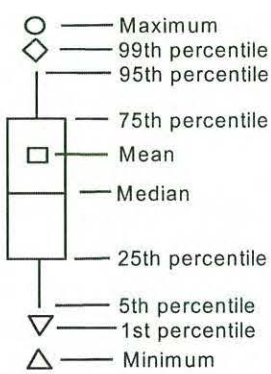


EXPLANATION



N = 6 -- Number of samples

[1994, 2000] – Date(s) of ground water recharge

Figure 5–52. Box Plots Comparing the Uranium Concentrations and Dates of Ground Water Recharge for Each Group Identified by the Hierarchical Cluster Analysis of Ground and Surface Water Data Collected at the Naturita Site

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During PCA, the multivariate data set is decomposed into two matrices consisting of loadings and scores for each of the PCs that were selected. The product of the scores and loadings matrices will reproduce the original data set. For example, if three PCs were selected to represent the original data matrix, each PC would have a loading value between ± 1.0 for each of the original variables. The PC loadings near –1.0 and + 1.0 are considered significant and are used to identify the chemical, physical, and isotopic constituents that compose each PC. The PC scores are simply the coefficients of the loadings used to transform the original responses from each data point onto the PC axis. Prior to PCA, the original data matrix was transformed into the base 10 logarithm of the original value and autoscaled. The first three PCs were found to best explain the original data set and accounted for 73 percent of the total variance.

Figure 5–53 shows the PC 1 and PC 2 scores. The two axes are linear combinations of the original multivariate data set consisting of 23 variables and 66 samples and can be thought of as a new set of plotting axes. Instead of each axis representing the concentration of a particular trace metal or other inorganic constituent, each axis represents combinations of the different chemical, physical, and isotopic constituents in the water samples, thereby representing geochemical or hydrologic footprints that could provide insight into natural attenuation processes at the site.

The suite of chemical constituents contained in each plotting axis can be used to determine what geochemical and hydrologic process is represented, such as the effect of uranium mill tailings or natural flushing from the San Miguel River. The x-axis in Figure 5–53 is referred to as PC 1 and best represents the ground water contamination from tailings material. Chemical constituents making a substantial positive contribution to PC 1 include alkalinity, boron, calcium, chlorine, potassium, magnesium, manganese, sodium, silicon, sulfate, specific conductance, strontium, and uranium (Table 5–7). Uranium is derived from the leaching of tailings material. The positive sulfate loading is probably related to the use of sulfuric acid in the ore processing and the dissolution of sulfate mineral phases in the soil below the mill tailings. Dissolution of carbonate mineral phases in the soil zone beneath the tailings pond could result in the elevated loadings for calcium, alkalinity, and strontium. The substantial positive -loadings for sodium and chloride may be related to the use of sodium chloride during salt roasting of the ore material at the site. Positive loadings for boron, chloride, magnesium, sodium, and specific conductance could also be related to the evaporation of tailings process water at the surface before infiltration into the alluvial aquifer.

The y-axis in Figure 5–53 is referred to as PC 2 and represents river flushing with limited evaporation. Chemical, physical, and isotopic constituents making a substantial positive and negative contribution to PC 2 include Br, dissolved oxygen, Fe (negative loading), K, pH, δD (negative loading), and $\delta^{18}O$ (negative loading) (Table 5–7). The geochemical association in PC 2 is consistent with what would be expected from significant amounts of river water flushing into the alluvial aquifer at the site. Water from the San Miguel River has pH values that are greater than 8.0 units and dissolved oxygen concentrations that exceed 8.0 mg/L (Table 1, Appendix G). The substantial negative loading for iron in PC 2 is consistent with the low solubility of iron under the oxidizing conditions characteristic of the San Miguel River. The substantial negative loadings for δD and $\delta^{18}O$ are reflective of the isotopically light values of water from the San Miguel River derived from high elevation snowmelt, prior to evaporative enrichment. The positive loading for bromide may be the result of domestic sewage effluent containing elevated concentrations of bromide entering the San Miguel River upstream of the site (Vengosh and Pankratov 1998, Davis and others 1998). It is also possible that part of the bromide and

potassium sources could be residual tracer that was injected into selected wells during May 2000; however, the concentration of the injected tracer compared to natural concentrations is not known.

The individual points in Figure 5–53 represent where individual water samples plot on the newly defined axes (PC 1 and PC 2). Samples from the six groups identified in the HCA show distinct clusters with respect to their PC 1 (tailings contamination) and PC 2 (river flushing) scores. Water samples belonging to Group 1 represent water from the San Miguel River and have the largest PC 2 scores (river flushing) and lowest PC 1 scores (tailings contamination) of all 66 samples. Water samples belonging to Groups 3 and 4 contain the largest overall river flushing scores, which are confirmed by their proximity to the San Miguel River. Water samples belonging to Group 2 have low PC 1 and 2 scores, indicating limited flushing from the San Miguel River and limited influence from uranium mill tailings. This classification is consistent with the location of Group 2 samples, which is upgradient of the historical tailings area and offset at least 250 ft from the San Miguel River and downgradient from a gravel pit (Figure 5–50).

Group 5 and 6&7 samples have the overall largest PC 1 scores (tailings contamination) (Figure 5–53). With the exception of wells NAT23, MAU02, MAU05, and MAU07, all the wells in these groups are relatively distant from the flushing influence of the San Miguel River and downgradient from the historical tailings area (Figure 5–50). Group 6+7 water samples have the largest PC 1 (tailings contamination) scores relative to all six-sample groups.

The PC 3 scores for the 66 water samples are plotted on the y-axis in Figure 5–54 and compared to PC 1 scores (tailings contamination) plotted on the x-axis. Water samples having large PC 3 scores appear to be influenced by strong evaporative effects. Chemical, physical, and isotopic constituents making a substantial positive or negative contribution to PC 3 include bromide, iron (negative loading), manganese (negative loading), dissolved oxygen, oxidation-reduction potential, water temperature, vanadium (negative loading), δD, and $\delta^{18}O$ (Table 5–7). The geochemical association in PC 3 is consistent with what would be expected from evaporation of surface water from the San Miguel River. The positive loadings for dissolved oxygen and oxidation-reduction potential, in combination with negative loadings for iron and manganese, indicate an oxidizing surface water source. The negative loadings for δD and $\delta^{18}O$ and positive loading for water temperature are consistent with isotopic enrichment of surface water by evaporation. As with PC 2, the positive loading for bromide may be an indicator of a domestic sewage component in water from the San Miguel River or could be related to the bromide that was used in a series of tracer tests at selected wells with low hydraulic conductivity during May 2000. Because of the conservative nature of bromide, evaporative processes could substantially increase its concentration in water. The negative loading for vanadium in PC 3 is not apparent.

The individual points in Figure 5–54 represent where individual water samples plot on the newly defined axes (PC 1 and PC 3). Water samples in Groups 2, 4, and 6+7 have the largest PC 3 scores. Group 2 water samples were collected from wells immediately downgradient from a series of gravel pits at the southern part of the site (Figure 5–50). The gravel pits intercept the water table in the alluvial aquifer and expose recently recharged water from the San Miguel River to potentially large amounts of evaporation (Figure 5–55). In general, PC 3 scores in Group 2 wells decrease in a downgradient direction from the gravel pits (Figure 5–54), which could be the result of mixing evaporated water from the gravel pit with nonevaporated water resident in the alluvial aquifer.

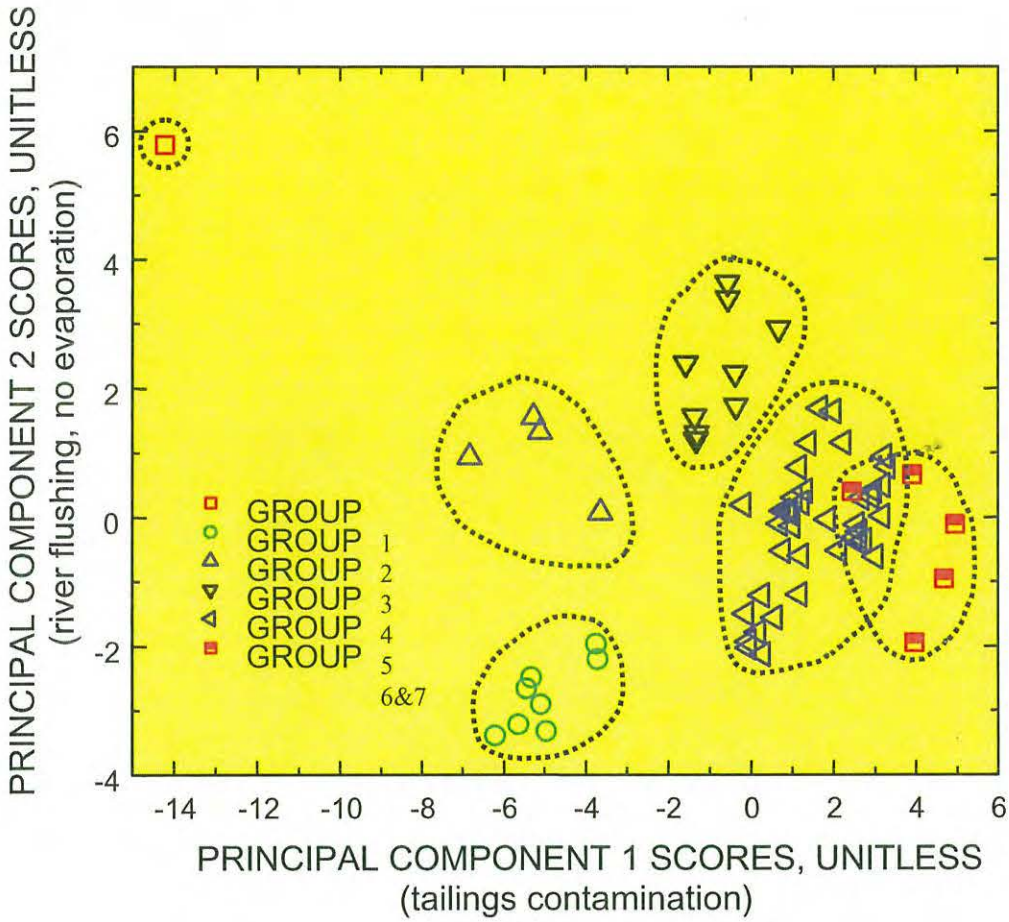

Figure 5–53. Principal Component 1 and 2 Scores for Ground and Surface Water Samples Collected at the Naturita Site

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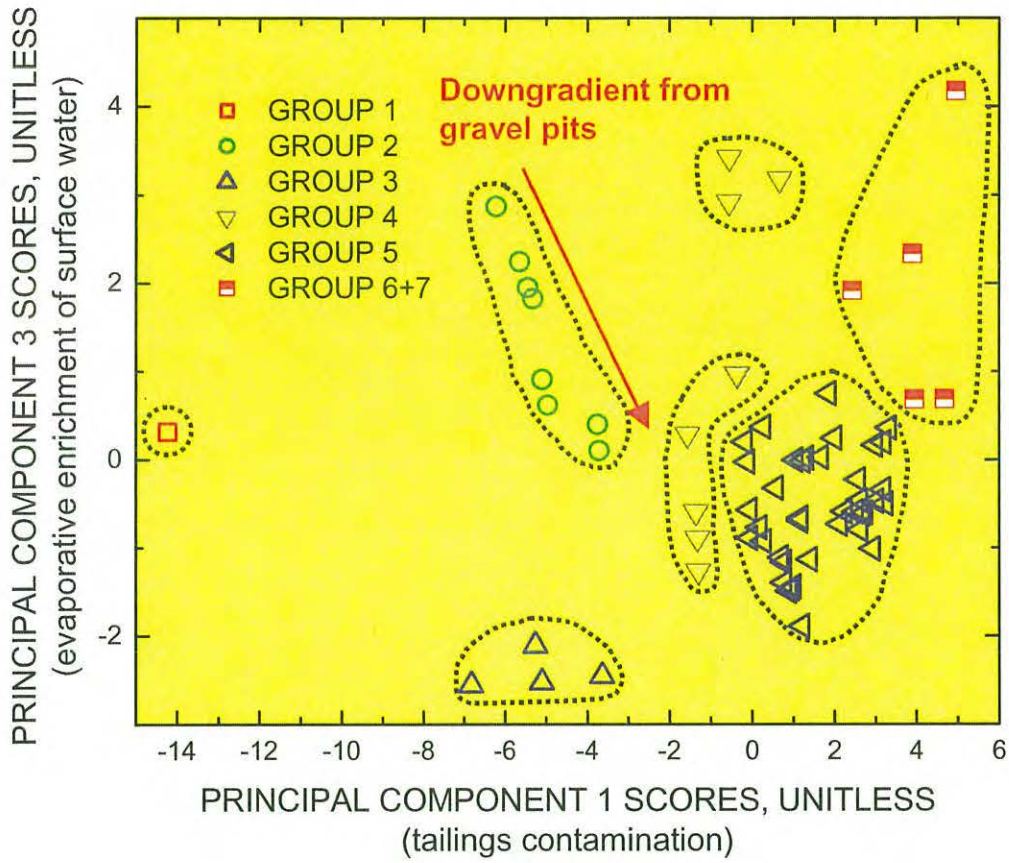

Figure 5–54. Principal Component 1 and 3 Scores for Ground and Surface Water Samples at the Naturita Site

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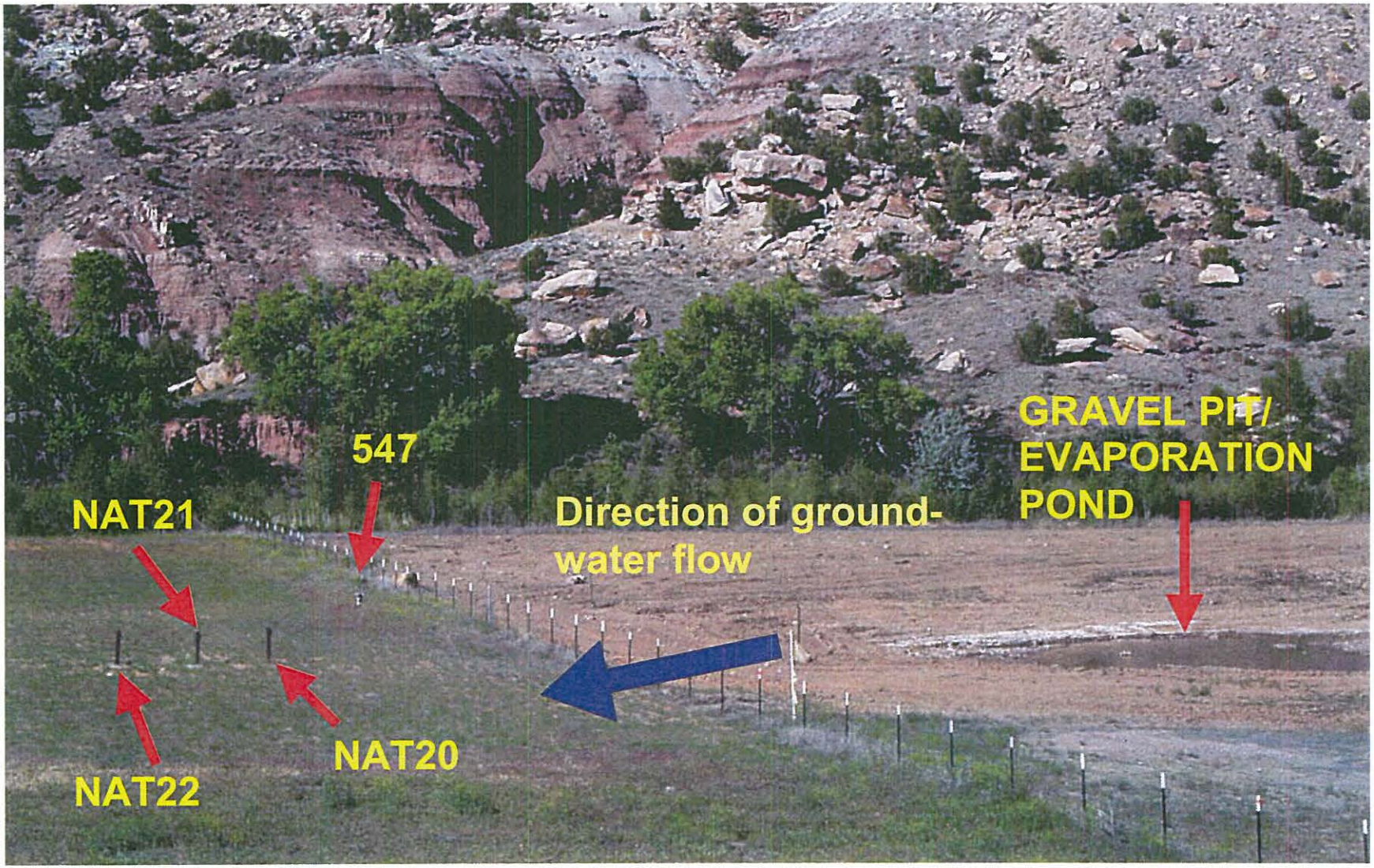

Figure 5–55. Photograph Showing the Location of the Gravel Pit Relative to the Direction of Ground Water Flow in the Alluvial Aquifer and Selected Monitoring Wells During May 2001, Naturita, Colorado

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A subset of samples in Group 4 has a large PC 3 score (Figure 5–54). This subset is composed of water samples collected from wells NAT27, NAT 28, and NAT 29, which are adjacent to the San Miguel River (Figure 5–50) and should not have a strong evaporative signal. It is unclear why a strong evaporative signal would exist this close to the San Miguel River. Part of this signal may be related to potassium bromide tracer tests conducted at these wells during May 2000; it is likely that the elevated bromide concentrations in wells NAT27, NAT 28, and NAT 29 (ranging from 0.08 to 0.15 mg/L) are from these tests. It is also possible that a smaller contributor to the evaporation signal in wells NAT27, NAT 28 and NAT 29 is from direct infiltration of ponded and evaporated water close to the wells. The wells are located in a surface depression adjacent to a berm along the San Miguel River (Figure 5–50). Significant ponding of water was observed in this area during summer 1999.

Group 6+7 wells are the third group that has elevated PC 3 scores (Figure 5–54). The five wells in this group are clustered in the extreme western part of the site. This is a discharge area for an ephemeral channel that brings surface water into this part of the site. Ponding and the potential for evaporation of surface water was noted in this part of the area during summer 1999. Direct recharge of surface water in this area on an intermittent basis could result in the observed evaporative signal.

5.4.4 Variations in Stable Isotope Values

The stable isotope values for δD and $\delta^{18}O$ determined from water samples collected during June 2000 were compared to the sample groupings determined from the pattern recognition modeling (Figure 5–56). Samples belonging to Groups 1 and 3 (San Miguel River and the alluvial aquifer adjacent to the river) have the lightest isotopic signature and plot close to the Global Meteoric Water Line (GMWL) (Craig 1961). The isotopically light values in Groups 1 and 3 samples indicate a high-elevation source water (snowmelt) to the San Miguel River. Groups 1 and 3 isotopic data plot almost directly on the GMWL, indicating no evaporation (Figure 5–56).

In contrast to Groups 1 and 3 members, the isotopic signature in Group 2 samples plots to the right of the GMWL and shows significant isotopic enrichment (Figure 5–56) of recharge water from the San Miguel River. Wells belonging to Group 2 plot along the evaporation trend line with a slope significantly less than the GMWL, which is characteristic of evaporative processes (Ingraham 1998). As indicated in the pattern recognition modeling results, it appears that the gravel pits immediately upgradient from the Group 2 wells are causing a significant isotopic enrichment by evaporation of ground water originally recharged from the San Miguel River. The highest amount of evaporative enrichment is in wells 0547 and NAT20, which are closest to the gravel pits (Figure 5–55). An intermediate amount of evaporative enrichment is indicated in the wells farther downgradient from the gravel pits (wells NAT21 and NAT22). Wells NAT30–1 and NAT 30–2 have the least amount of evaporative enrichment and are farthest downgradient from the gravel pits (about 800 ft).

The isotopic data indicate that evaporative loss of ground water from the gravel pits at the upgradient part of the site is occurring and could affect the natural flushing rates of uranium from the alluvial aquifer. The mass of ground water lost via evaporation from the gravel pits was estimated. A free-water surface evaporation rate of 53 inches per year, calculated for the Dolores–Ute Mountain area in western Colorado (Seiler 1998), was used and assumed to represent similar climatic conditions as the Naturita site. A gravel pit size of 78,400 square feet was estimated from the aerial photo taken of the site on April 15, 2001 (Plate 1). Because of

seasonal variations in the water table elevation, only part of the gravel pit will have standing water that can be evaporated, and this surface area will change as a function of changes in hydrologic conditions. Unfortunately, an aerial view of the extent of standing water on a daily or weekly resolution is not currently available. Assuming that, on average, 25 percent of the gravel pit area is subject to evaporative processes each year, approximately 650,000 gallons of water could be lost by surface evaporation of ground water exposed in the gravel pits. Currently it is unknown how the alluvial aquifer is responding to the evaporative water loss. For example, it is possible that increased inflow from the San Miguel River may be partly or fully compensating for the evaporative loss of the ground water from the gravel pits; however, this seems unlikely.

Based on the 2001 ground water flow model of the alluvial aquifer, annual ground water flux upgradient of the gravel pit is approximately 1.4 million gallons (G. Curtis, USGS, written communication, June 2001). The estimated annual evaporative loss (assuming 25 percent of the gravel pit area is subject to evaporation) is approximately 46 percent of the annual ground water flux moving through the alluvial aquifer immediately upgradient of the gravel pit. Future expansion of the gravel pit could potentially increase these estimated water losses, further affecting the natural flushing rates of uranium in the downgradient parts of the alluvial aquifer. Detailed pan evaporation measurements, monitoring of free-water areas, and ground water modeling of present and future gravel pit scenarios are needed before the impacts to uranium flushing rates can be fully assessed.

The observed isotopic enrichment between the average $\delta^{18}O$ value of recharge water and the $\delta^{18}O$ value observed in wells 0547 and NAT20 downgradient of the gravel pits can be used to estimate the amount of ground water loss. The following assumptions were used: (1) open system; (2) water vapor is instantaneously removed; and (3) a constant fractionation factor of 1.010 (newly formed vapor is always 10 permil (per thousand, i.e., percent × 0.1) lighter than the residual water). The observed isotopic enrichment of $\delta^{18}O$ was equal to approximately +5 permil for well 0547 and +4 permil for well NAT20 (Figure 5–57). With this observed isotopic enrichment, an evaporative ground water loss of approximately 44 percent is calculated for well 0547, and a ground water loss of 31 percent is calculated for well NAT20 (Figure 5–57).

The isotopic values of water samples belonging to Groups 4, 5, and 6+7 show some evaporative enrichment of water from the San Miguel River but are not as isotopically enriched as those of the Group 2 water samples (Figure 5–56). This is consistent with the hydrology of the northern part of the site, especially with respect to water samples belonging to Group 4. As discussed in the pattern recognition modeling results, Group 4 wells are close to the San Miguel River, and the geochemical footprints indicate the presence of flushing zones. The isotopic signature of samples belonging to Group 4 is very similar to the isotopic signature of water from the San Miguel River with limited evaporation (Figure 5–56).

Temporal variations in $\delta^{18}O$ and δD at selected wells within each group were compared to better understand the different seasonal hydrologic processes occurring at the Naturita site. Large seasonal variations in the isotopic values are observed in water from the San Miguel River (Figure 5–58); however, all the samples plot close to the GMWL, indicative of limited amounts of evaporation. For a given geographic region, there is an elevation effect in the isotopic composition of precipitation (Ingraham 1998). In general, the result of the elevation effect is that precipitation at higher elevations has a lighter isotopic composition than precipitation at lower

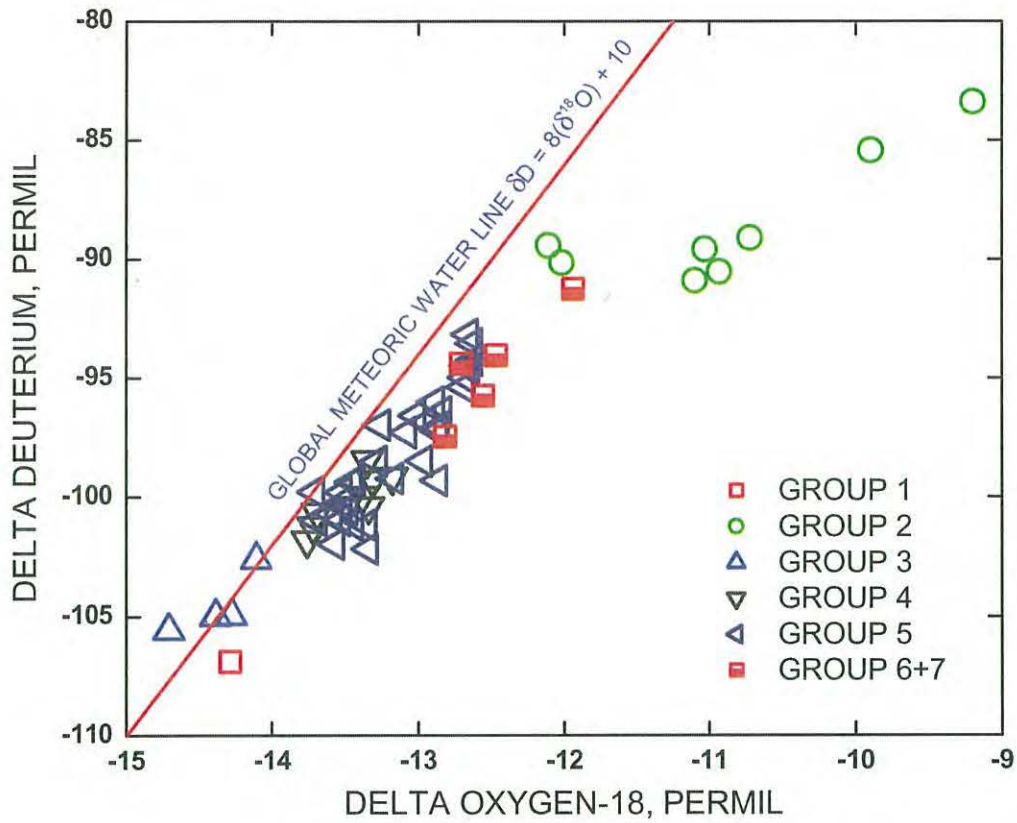

Figure 5–56. The $\delta^{18}O$ and δD Values In Ground and Surface Water Data Compared to Geochemical Groupings Identified by Pattern Recognition Modeling of Data Collected During June 2000, at the Naturita Site

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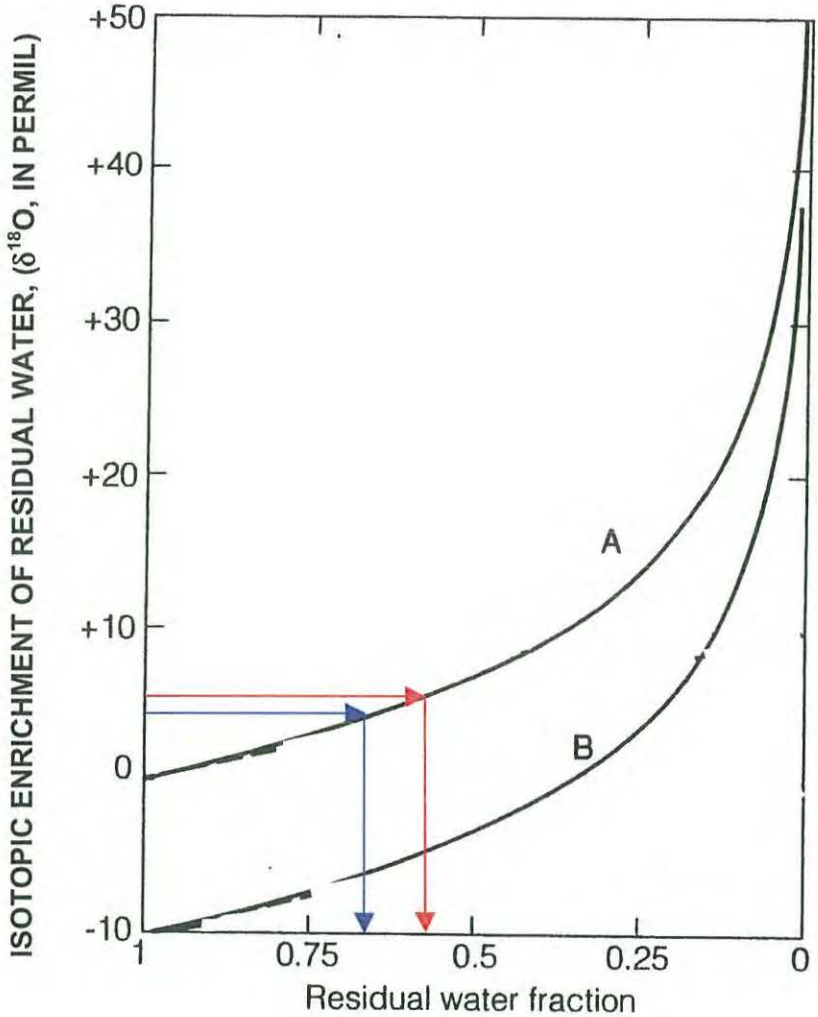

Figure 5–57. Isotopic Change Under Open-System Rayleigh Conditions for Evaporation with a Fractionation Factor = 1.01 for an Initial Liquid Composition of $\delta^{18}O$ = 0. The $\delta^{18}O$ of the Remaining Water (Line A) and the $\delta^{18}O$ of the Instantaneous Water Vapor Being Removed (Line B). Modified From Kendall and Caldwell (1998). Red Arrows Indicate Observed Isotopic Enrichment In Water From Well 0547 and Residual Water Fraction Remaining. Blue Arrows Indicate Observed Isotopic Enrichment in Water from Well NAT20 and Residual Water Fraction

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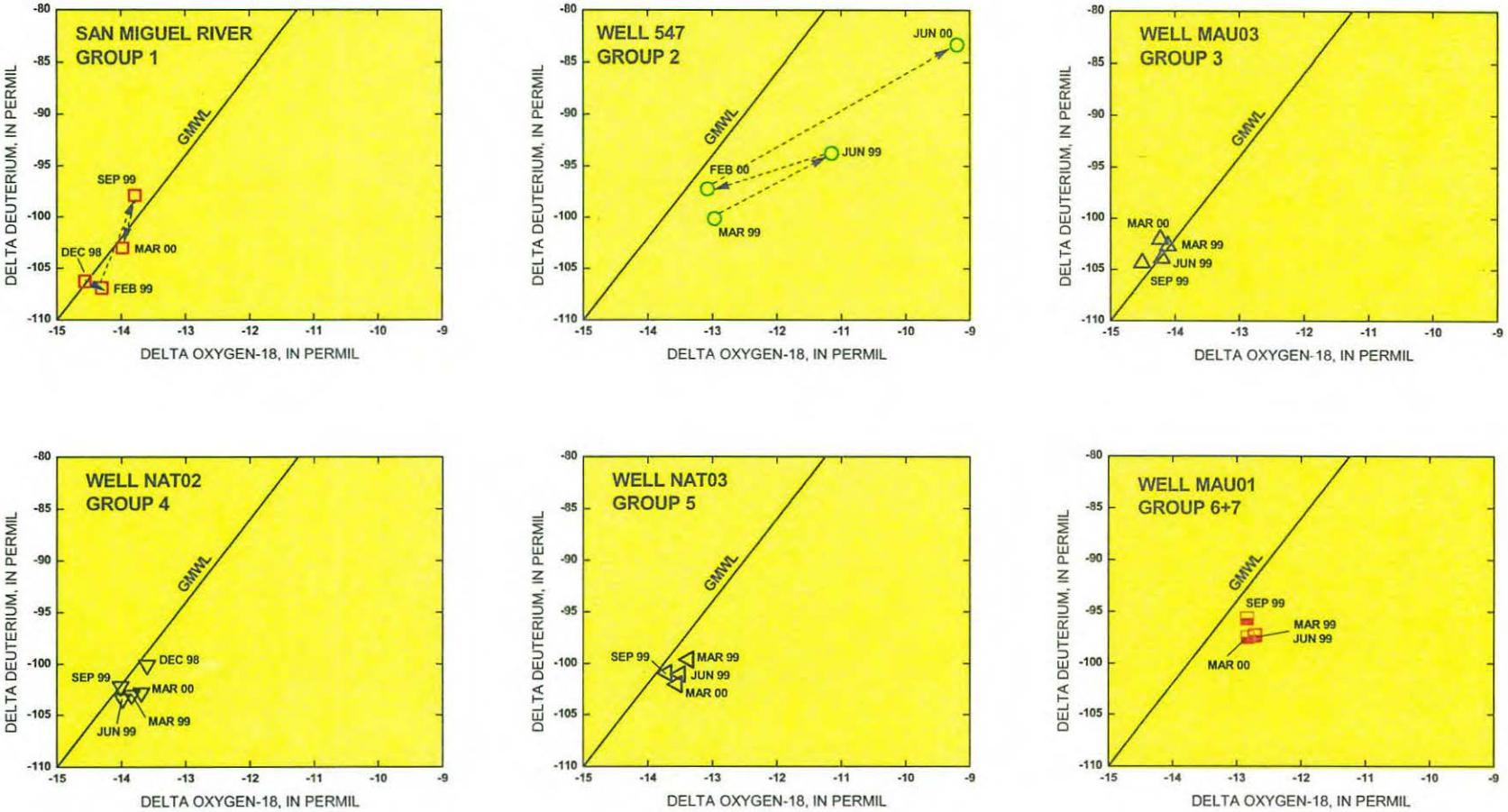

Figure 5–58. Variations in $\delta^{18}O$ and δD Values Over Time in Ground- and Surface-Water Data from Selected Sampling Sites Representative of Geochemical Groupings Identified by Pattern Recognition Modeling of the Data Collected During June 2000, at the Naturita Site [GMWL = global meteoric water line]

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elevations. The isotopically enriched values in water from the San Miguel River during September 1999 probably reflect isotopically enriched, lower-elevation precipitation events typical of the monsoonal storms that occur in southwestern Colorado from late July through September each year. Water from the San Miguel River collected at Telluride, Colorado (upstream from the Naturita site), during June 1999 had very light isotopic values ($\delta^{18}O = -16.44$ and $\delta D = -117.98$), reflective of snowmelt runoff from high-elevations areas of the watershed.

Large isotopic variations were also observed in well 0547 (Group 2) during the monitoring period from March 1999 through June 2000 (Figure 5–58). During times of potentially large evaporation rates in the gravel pits (June 1999 and June 2000), the isotopic signature was enriched and also deviated significantly from the GMWL, indicative of strong evaporative effects. In contrast, water samples collected during periods of low evaporations rates (March 1999 and February 2000) contained an isotopic signature that was much lighter and close to the GMWL (Figure 5–58). The temporal variations in the isotopic values in well 0547 indicate a strong hydrologic connection with ground water flowing through the gravel pit and also show the strong seasonal influence of evaporation.

The isotopic values for water from well MAU03 (Group 3) showed little variation over time and plotted close to the GMWL with an isotopic composition similar to that of water from the San Miguel River (Figure 5–58). As indicated during the pattern recognition modeling, water samples belonging to Group 3 contain element associations typical of river flushing zones. The elevated uranium concentrations in Group 3 samples (Figure 5–52) from wells MAU03, MAU04, and MAU06 on the Maupin property are inconsistent with the strong river influence indicated by the stable isotope data. This inconsistency may indicate a more localized uranium source to the ground water, perhaps from the river-deposited tailings in the supplemental standards area on the Maupin property. The young ground water age date (1994) determined in water collected from well MAU04 indicates that significant quantities of water from the San Miguel River may be entering the alluvial aquifer at the river bend on the Maupin property, possibly leaching uranium from the supplemental standards area as it flows in a northerly direction.

The seasonal isotopic variation in well NAT02 (Group 4) appears to indicate some river flushing during different river stages. The lightest isotopic composition was measured during June 1999 when the river stage was at the annual high. This could cause pressure-induced movement of ground water closer to the San Miguel River, presumably with a lighter isotopic signature, to areas of the aquifer farther removed from the river. In contrast, during low-flow conditions (December 1998) the lower river stage would cause a reverse trend, and the more isotopically enriched water in areas farther from the river would tend to have a flow component toward the river.

The seasonal isotopic variation in wells belonging to Groups 5 (well NAT03) and 6+7 (well MAU01) is small (Figure 5–58). As indicated during the pattern recognition modeling, water samples belonging to Groups 5 and 6+7 do not contain element associations typical of the river flushing zones, exemplified by Groups 3 and 4. The small seasonal variations in $\delta^{18}O$ and δD values support this conclusion.

5.4.5 Chloride Enrichment

The pattern recognition modeling and stable isotope results indicate that Group 2 wells are strongly influenced by evaporative processes. Variations in chloride concentration in wells belonging to Group 2 can be used to provide additional evidence to support the previous results. Ideally, chloride is not removed or supplied in significant quantities to ground water from interaction with rocks and is not precipitated until very high salinity is attained (Drever 1988). Under these assumptions, the chloride concentration in water is indicative of the amount of evaporation that has occurred since the water started out as rainfall. This is not always the case in arid and semiarid regions where salts containing chloride are periodically dissolved and precipitated during wet/dry cycles; however, chloride can still provide important information with respect to evaporative processes.

The changes in chloride concentrations in wells 0547 and NAT20 were compared to chloride concentrations in the San Miguel River (location SM1) from December 1998 through March 2001 (Figure 5–59). A strong seasonal variation in chloride concentration is observed in the San Miguel River. The chloride concentrations are lowest during snowmelt in May through June and highest during lower river stages in November through February. The elevated chloride concentrations during this time period are probably the result of shallow ground water inflow (slightly enriched in chloride from evaporation or water-rock interaction) and localized surface water contributions to the San Miguel River from intermittent channels that could contain chloride-bearing salt crusts.

Three peaks in chloride concentrations in well 0547 were observed during the monitoring period and occurred in the late winter/early spring (Figure 5–60) for three consecutive years (1999, 2000, and 2001). The concentrations were lowest in the fall. In general, the oscillations in chloride concentration were out of phase with respect to the $\delta^{18}O$ values (Figure 5–60). For example, the two most enriched $\delta^{18}O$ values, which occurred during June 1999 and June 2000, were out of phase with the lowest chloride concentration. The lack of correlation between the chloride and $\delta^{18}O$ data could indicate some nonconservative behavior with respect to chloride, for example higher baseline chloride concentrations from the deeper completion depth in well 0547 (20.3 ft below land surface). The chloride and $\delta^{18}O$ data become positively correlated (in phase) beginning in June 2000 (Figure 5–60).

Although the period of record is shorter, the $\delta^{18}O$ and chloride data from well NAT20 were positively correlated and in phase from March 2000 through November 2000 (Figure 5–60). The chloride concentration was highest in June 2000 and had a positive correlation with the highest evaporation enrichment shown by the stable isotope data during the same time period (Figure 5–60). Chloride concentrations were lowest during March 1999, November 2000, and February 2001 and support the lighter isotopic values that were observed during lower evaporation periods.

Changes in chloride concentration in well NAT20 can be used to estimate water lost by evaporation from the gravel pits. The difference in chloride concentration between the March and June 2000 sampling periods was used to estimate the approximate mass of ground water lost from evaporation. Between March and June 2000, the chloride concentration increased from 9.5 to 11 mg/L in well NAT20, equating to a 14 percent loss of ground water from evaporation.

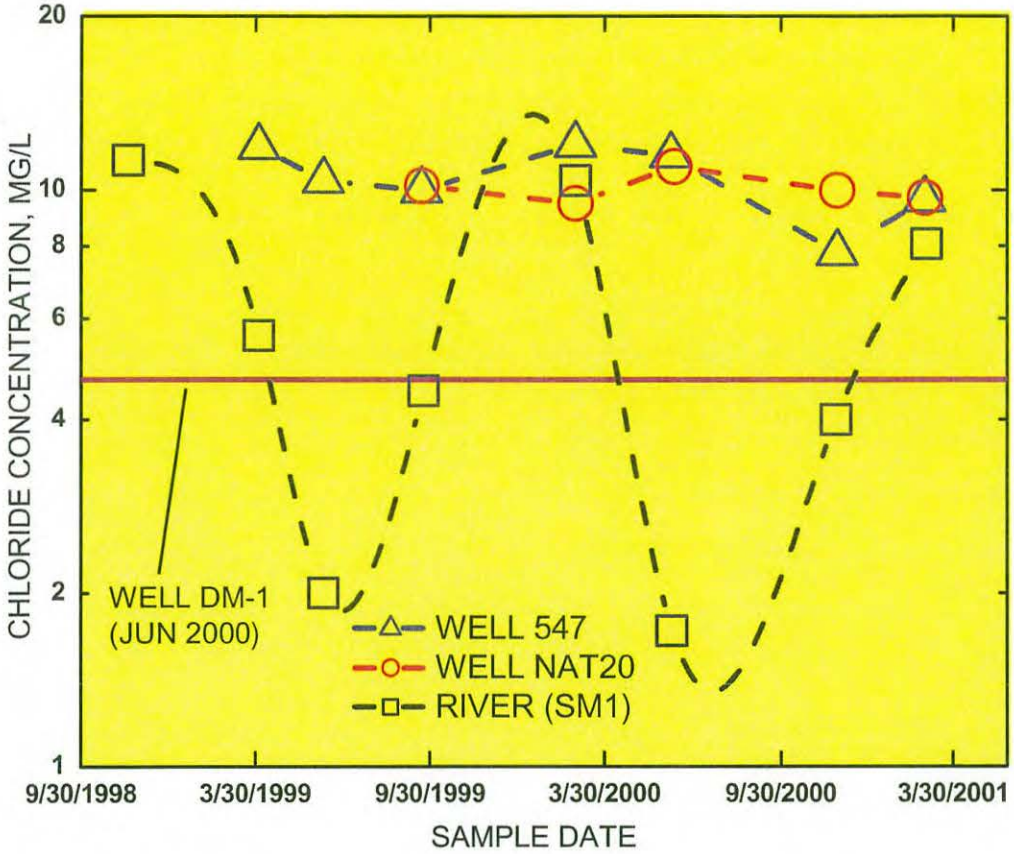

Figure 5–59. Variations in Chloride Concentration with Time in Wells 0547, NAT20, and DM1 Compared to Chloride Concentrations in the San Miguel River (location SM1), Naturita Site, Colorado. A Spline Function was Used to Display the Chloride Data from the San Miguel River

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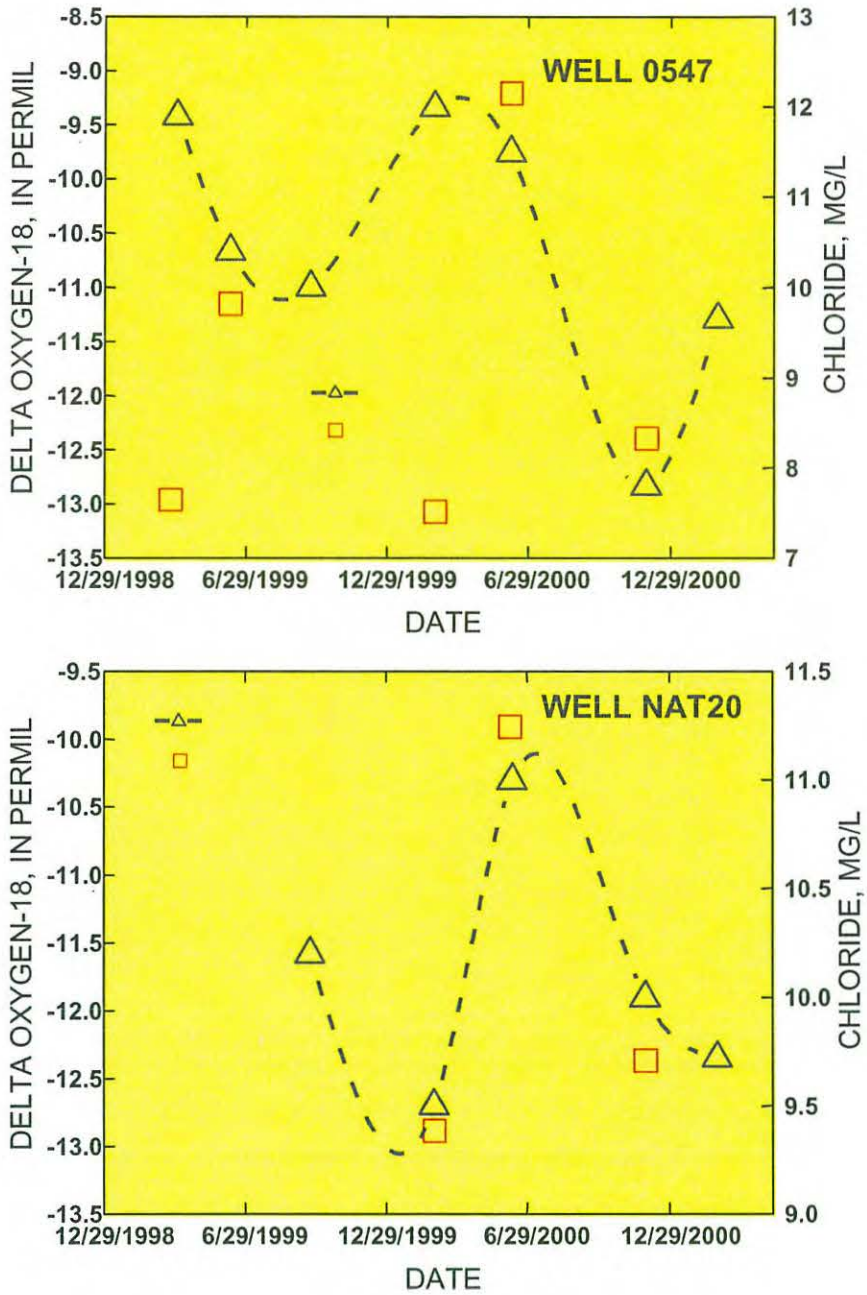

Figure 5–60. Variation in Chloride Concentration and $\delta^{18}O$ Values with Time in Water Samples from Wells 0547 and NAT20, Naturita Site, Colorado. A Spline Function was Used to Display the Chloride Data. The δD Data are not yet Available from the November 2000 Sampling Period

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The evaporative water loss calculated from the differences in chloride concentration is different from the evaporative loss calculated from the observed isotopic enrichment. For well NAT20 the evaporative water loss calculated from the $\delta^{18}O$ data is 31 percent, compared to a water loss of 14 percent calculated with the chloride data. Both methods indicate measurable loss of ground water from the gravel pits immediately upgradient. The calculated water loss from the isotopic data is probably more accurate because of potential contributions of small amounts of chloride to the ground water and surface water during wet/dry cycles in this semiarid environment.

5.4.6 Implications of Pattern Recognition Modeling, Stable Isotope, and Chloride Results to Natural Attenuation

DOE can use the insight gained from the pattern recognition modeling, stable isotope, and chloride data to evaluate specific ground water remediation and monitoring options at the Naturita site. The grouping of the data by HCA and PCA have identified specific geographic areas within the site that have similar geochemical and hydrologic processes. These areas should be considered individually when assessing particular remediation scenarios. Listed below are potential areas of concern that should be considered during the design of the final ground water remediation and monitoring plan.

All the data analysis (pattern recognition modeling, stable isotopes, and chloride) indicates that potentially significant amounts of ground water are being lost from gravel pits through free-water evaporation in the upgradient parts of the alluvial aquifer. As the gravel pits continue to expand in the future, the potential exists to increase the loss of ground water through evaporation. Loss of ground water in the upgradient parts of the alluvial aquifer could significantly decrease the rate that uranium flushes naturally from the aquifer. Additional, site-specific monitoring data to better quantify the evaporative loss in ground water coupled with ground water model simulations that include the gravel pit are needed to determine long-term effects on natural flushing processes.

Seasonal changes in evaporative loss of ground water from the site are indicated from the stable isotope and chloride data. One possible mitigation option would be to replace the evaporative losses of ground water. For example, during the peak evaporation times (determined from site-specific monitoring), water from the San Miguel River could be pumped into the open pits to compensate for evaporative water loss. This alternative could be much more cost effective than acquisition and restoration of the gravel pit.

The integration of stable isotope data ($\delta^{18}O$ and δD) during long-term site monitoring will be useful in assessing the progress of natural flushing at the site. For example, monitoring the location and movement of the evaporation-enriched ground water in the alluvial aquifer could be used to assess the success of any gravel pit remediation scenarios that may be instituted. Because of the nonconservative behavior of chloride observed in upgradient wells at the site, it is likely that stable isotopes will be the most reliable measurement of water evaporation effects in the alluvial aquifer.

Results of the pattern recognition modeling in combination with the ground water age dating indicate that the supplemental standard area on the Maupin property may be acting as a localized uranium source to the alluvial ground water.

Future pattern recognition modeling in combination with the determination of stable isotope values and age dating of the ground water should be considered to monitor the effects of the final land use on long-term natural flushing. For example, if a golf course is placed on the property, the surface irrigation could increase the natural flushing of the alluvial aquifer. This enhancement of natural flushing could be efficiently monitored using pattern recognition modeling in combination with the determination of selected chemical and isotopic constituents.

6.0 Summary of Human Health and Ecological Risk

6.1 Human Health Risks

A BLRA (DOE 1995) was previously prepared for the Naturita site. Most of the methodology used in that risk assessment followed standard EPA risk assessment protocol (EPA 1989a), though the BLRA did not calculate potential risks for noncarcinogenic constituents. Instead, calculated exposure intakes were compared with a range of contaminant doses associated with various adverse effects. Data used in that report were collected from 1989 to 1994. Since that time, additional data have been collected to more completely characterize the site and to represent more recent site conditions. Updated and revised toxicological data are also available for some site-related constituents. These new data were used to reevaluate the identified contaminants of potential concern (COPCs) and assessment of associated risks.

6.1.1 Summary of 1995 BLRA Methodology and Results

6.1.1.1 Ground Water

The BLRA identified 27 constituents at the Naturita site as being present at levels statistically above background concentrations. This initial list was screened to first eliminate constituents with concentrations within nutritional ranges and then to eliminate constituents of low toxicity and high dietary ranges. These two steps eliminated four and ten constituents, respectively, resulting in the following COPC list: antimony, arsenic, lead-210, manganese, molybdenum, polonium-210, radium-226, radium-228, selenium, sodium, sulfate, uranium, and vanadium. These contaminants were retained for further risk analysis.

A number of potential routes of exposure were evaluated: ingestion of ground water as drinking water in a residential setting, dermal contact with ground water while bathing, ingestion of meat and milk from ground-water-fed livestock, and contact with surface water and sediment where ground water discharges at the seep. Risks from ingestion of ground-water-irrigated produce were not calculated due to lack of sufficient data. Results of the exposure assessment indicated that intakes for all constituents were negligible from exposure routes other than drinking water. Therefore, only exposure through ingestion of ground water as drinking water was retained for more detailed evaluation. Both children and adults were considered as likely receptors.

Calculated exposure intakes were presented along with contaminant intakes associated with a range of adverse health effects. Potential risks associated with exposure to noncarcinogenic constituents were discussed qualitatively; carcinogenic risks were quantified and compared to EPA's acceptable risk range of 1×10^{-4} to 1×10^{-6}.

For sulfate, the most sensitive receptor population is infants. Results of the BLRA showed that infants exposed to the levels of sulfate in ground water at the Naturita site could experience significant adverse health effects due to severe diarrhea and dehydration.

Exposure intakes for the other noncarcinogenic contaminants in ground water were calculated for the receptors with the highest intake to body weight ratio—children between the ages of 1 and 10. Vanadium, manganese, and molybdenum were associated with the highest risks; concentrations of those constituents were consistently higher than recommended levels. Arsenic, uranium, and antimony concentrations exceeded EPA's acceptable intake levels (reference doses,

or RfDs) but were below levels known to produce adverse health effects. (The RfDs are generally established at levels below known toxicity values to account for uncertainty in toxicity studies and data.) Sodium and selenium concentrations were also typically below the dietary intake range. The BLRA (DOE 1995) provides detailed information on toxicity studies and effects.

Carcinogenic risks were calculated for adult exposure. Carcinogenic risks from to exposure to uranium and its daughter products exceeded the upper bound of EPA's acceptable risk range of 1×10^{-4} by approximately 1 order of magnitude. Risks from arsenic exposure were also more than an order of magnitude above this upper bound of the risk range.

6.1.1.2 Surface Water

It was assumed that children aged 9 to 10 years old could ingest and experience dermal contact with contaminated surface water and sediment at the seep downgradient of the site. No adverse health effects would be expected through this incidental exposure.

6.1.1.3 Meat and Milk Ingestion

Intakes were calculated for adult exposure to beef and milk from cattle watered with contaminated ground water and fed on contaminated forage. Intakes were determined to be negligible compared with direct ingestion of ground water, and associated risks were assumed to be insignificant.

6.1.2 BLRA Update

The original BLRA considered several potential routes of exposure to contaminants and eliminated as insignificant all except ingestion of ground water in a residential setting. Overall concentrations have declined for all COPCs since the time the BLRA was completed. Therefore, for this BLRA update, it is assumed that any pathway that was insignificant based on the original BLRA is still insignificant; risks will not be recalculated for those pathways (e.g., ingestion of meat and milk). Though not considered a likely scenario, risks from drinking water in a residential setting are recalculated using more recent monitoring data. In addition, to represent a more reasonable and likely exposure scenario, recreational use is considered, and risks are calculated assuming that the site becomes a golf course in the future. A scenario with children playing in the vicinity of the seep also is reevaluated using updated data from a location where exposure is more likely.

Risk calculations presented here follow EPA's *Risk Assessment Guidance for Superfund Methodology* (EPA 1989a), which involves determining a point estimate for excess cancer risk from current or potential carcinogenic exposures (risk is equal to lifetime intake times cancer slope factor) and a hazard quotient (HQ) for noncarcinogenic exposures (HQ is equal to exposure intake divided by reference dose). EPA's acceptable carcinogenic risk range is 1×10^{-4} to 1×10^{-6}, which is an excess cancer risk of 1 in 10,000 to 1 in 1,000,000 compared to the general population. Risks exceeding this range are potentially unacceptable. For noncarcinogenic exposures, an HQ exceeding 1 is potentially unacceptable. HQs from multiple contaminants and/or pathways are often summed to estimate cumulative noncarcinogenic risks; these summed HQs are referred to as a hazard index (HI). HIs greater than 1 also represent potentially unacceptable exposures. Therefore, it is possible for a number of individual contaminants to each

have "acceptable" HQs of less than 1 that, when summed, represent a potentially unacceptable cumulative risk. Figure 6-1 provides exposure intake equations and default assumptions used in intake calculations for this BLRA update.

Equations used in calculations

Chemicals: Ingestion from water: Intake (mg/kg-day) = (Cw × IRw × EF × ED)/(BW × AT)
Absorption from water: Intake (mg/kg-day) = (Cw × SA × PC × ET × EF × ED × CF)/(BW ×A T)
Ingestion from sediment (mg/kg-day) = (Cs × Csf × Irs × FI × EF × ED)/(BW × AT)

Radionuclides: Ingestion from water : Intake(lifetime in picocuries) = Cw × IRw × EF × ED
Absorption from water: Intake (mg/kg-day) = Cw × SA × PC × ET × EF × ED × CF
Ingestion from sediment (mg/kg-day) = Cs × Csf × Irs × FI × EF × ED

Residential Exposure Scenario—Ground Water Ingestion

Where

Cw = contaminant concentration in water
IRw = ingestion rate for water (2 L/day default for adults; 1.5 L/day for children 6-12 years; 0.64 L/day for infants)
EF = exposure frequency (350 days per year)
ED = exposure duration (30 years for adults, 7 years for children, and 1 year for infants for noncarcinogens; 30 years for carcinogens)
BW = body weight (70 kg for adults; 38.3 kg for children; 4 kg for infants)
AT = averaging time (365 days × ED for noncarcinogens; 365 days × 70 years for carcinogens)

Incidental Exposure Scenario—Surface Water and Sediment

Where

Cw = contaminant concentration in water
Cs = contaminant concentration in sediment
Csf = conversion factor (10^{-6} kg/mg)
IRw = ingestion rate for water (0.05 L/day for children and adults)
IRs = ingestion rate for sediments (100 mg/day for children and adults)
EF = exposure frequency (3 months per year at 7 days per week = 90 days, plus 3 months per year on weekends = 24 days; total = 114 days per year for children playing. 250 days per year for golf course worker)
ED = exposure duration (7 years for children aged 6–12 years playing on the floodplain; 30 years for golf course worker)
ET = Exposure time (1 h/day for children playing; 8 h/day for golf course worker)
BW = body weight (38.3 kg for children aged 6–12 years; 70 kg for adult)
AT = averaging time (365 days × ED for noncarcinogens; 365 days × 70 years for carcinogens)
SA = skin surface area available for contact (497 cm^2 body surface area for children 6–12 years old; 312 cm^2 for adult's arms and hands)
PC = dermal permeability constant (0.001 cm/h; same rate as water)
CF = volumetric conversion factor for water (1 L/1000 cm^3)
FI = fraction ingested from sediment (1.0, unitless; assumes all contaminant is ingested)

RfD = reference dose (chemical specific; mg/kg-day); HQ = Intake/RfD
SF = slope factor (chemical specific; unitless); Risk = intake × slope factor

All exposure factors from EPA 1989b unless otherwise noted.

Figure 6-1. Exposure Intake, Risk Equations, and Default Assumptions

In Figure 6-1, toxicological values used to estimate risks (reference doses and slope factors) are conservative values with uncertainty factors built in to be protective of sensitive populations.

Therefore, risks presented here are reasonable worst-case estimates and are likely much higher than those that actually exist.

In this update, which uses point-exposure doses, single values are used for each parameter required in the risk calculations. Calculations to determine contaminant intakes use standard exposure factors (EPA 1989b). The ground water and surface water data used to assess risks in this document are from the last two rounds of sampling at the site—November/December 2000 and February/March 2001. These data were used to give an up-to-date look at the site. Risk calculations performed for ground water use the 95 percent upper confidence level (UCL_{95}) on the mean concentrations to provide reasonable worst-case risk estimates for probable future ground water uses. Exposure to surface water represents the only potentially complete pathway that currently exists. Surface water concentrations used in the risk calculations are from sample location 0567, an area where seep water has ponded adjacent to the San Miguel River. This location is probably one of the most attractive locations along the river for children to play because of its accessibility and lack of thick vegetation and steep banks. Based on data collected in February 2001, it appears that constituents have concentrated in the pooled area due to evaporation; concentrations are typically higher than in the ground water that feeds the pool. Use of data from this location represents a most-likely and worst-case situation for evaluation of exposure to surface water. For sediment calculations, concentrations were the maximum obtained from all locations. No data sediment from location 0567 were available.

The same methodology was used to calculate carcinogenic risks for this BLRA update as was used in the original BLRA (i.e., receptors are adults with exposure averaged over 70 years). For all risk calculations, benchmarks for acceptable contaminant intakes (e.g., reference doses and slope factors) are the best available data from standard EPA sources (e.g., Integrated Risk Information System, Region III Risk-Based Concentration Table).

6.1.2.1 Ground Water

This BLRA update uses the COPC list from the original BLRA as a starting point to evaluate current data for ground water. These constituents are antimony, arsenic, lead-210, manganese, molybdenum, polonium-210, radium-226, radium-228, selenium, sodium, sulfate, uranium, and vanadium.

Historical data indicate that concentrations of antimony have declined through time to near the detection limit in most wells, with few exceptions. Monitoring for this constituent was discontinued upon completion of the original BLRA. It is assumed that antimony is still close to background concentrations and can be eliminated as a COPC. Monitoring for all radionuclides other than uranium was also discontinued after completion of the original BLRA. At that time most radionuclides (except uranium) had declined in concentration to levels that posed little incremental risk over background. Because most of the risk is associated with uranium, and most of the other radionuclides represent uranium daughter products, it is assumed that any compliance strategy that is protective of exposure to uranium will result in acceptable levels of exposure to all other radionuclides. The COPCs retained for further evaluation in this BLRA update are arsenic, manganese, molybdenum, selenium, sodium, sulfate, uranium, and vanadium.

Table 6–1 summarizes background, current plume, and historical plume data for each COPC in the alluvial ground water. Also included for comparison are the applicable UMTRA ground water standards (if available) and risk-based concentrations (RBCs; EPA 2001). The RBC for a given contaminant represents a concentration in drinking water that would be protective of human health provided

- Residential exposure is appropriate,
- Ingestion of contaminated drinking water is the only exposure pathway,
- The contaminant contributes nearly all the health risk, and
- EPA's risk level of 1×10^{-6} for carcinogens and an HQ of 1 for noncarcinogens is appropriate.

If any of these assumptions is *not* true, contaminant levels at or below RBCs cannot automatically be assumed to be protective. For example, if multiple contaminants are present in drinking water, a single contaminant may be below its RBC but still be a significant contributor to the total risk posed by drinking the water. However, if an RBC is exceeded, it is an indication that further evaluation of the contaminant is warranted. RBCs are intended for use in screening-level evaluations.

No standards or benchmarks have been established for sodium based on human health concerns. The secondary standard of 250 mg/L for sulfate is based on considerations of taste and odor and not on effects to human health. Because of the lack of toxicity data, potential risks from exposure to these two contaminants cannot be quantified. Exposure intakes are calculated for these constituents, but potential adverse effects are considered only qualitatively.

For the residential ground water pathway evaluated quantitatively in this BLRA update, both children and adults were evaluated as receptors. Children would be more sensitive receptors than adults due to higher intake to body weight ratios. Infants were also evaluated for exposure to sulfate in a residential scenario because they represent the most sensitive receptor population. Adults only were evaluated for the occupational exposure scenario (hypothetical golf course worker). Carcinogenic risks were calculated for adults only based on the much longer exposure duration and because risks are averaged over a lifetime.

6.1.2.2 Surface Water and Sediment

Two scenarios are evaluated for exposure to surface water and sediment in this BLRA update. Children are evaluated for exposure to contaminated surface water and sediment at location 0567. In addition, based on the likely future use of the Naturita site as a golf course, exposures and risks were calculated for a hypothetical golf course worker who could be exposed to contaminated ground water used for irrigation, water hazards, or some similar purpose. Conservative exposure assumptions were used in both instances. Carcinogenic risks were calculated for adults only.

Table 6–1. Naturita Alluvial Ground Water Data Summary 2000–2001

Contaminant	FOD[a]	Minimum (mg/L)	Maximum (mg/L)	Mean (mg/L)	UCL_{95} (mg/L)	UMTRA std (mg/L)	RBC (mg/L)
Arsenic						0.05	0.011N[e]
Background[b]	2/2	0.0006	0.0009	NA			0.000045C[f]
Current plume[c]	53/53	0.0005	0.064	0.013	0.017		
Historical Plume[d]	11/13	0.007	0.08	0.03			
Manganese						0.05[g]	1.7N
Background	5/5	0.18	0.32	0.26			
Current plume	51/54	<0.04	2.06	0.871	0.99		
Historical Plume	6/6	1.9	7.5	5.1			
Molybdenum						0.1	
Background	0/5	<0.02	NA	NA			
Current plume	20/54	<0.02	0.16	0.038	0.046		
Historical Plume	6/6	0.25	0.38	0.29			
Selenium						0.01	
Background	0/3	<0.0003	NA	NA			
Current plume	44/53	<0.0003	0.014	0.002	0.002		
Historical Plume	11/13	<0.005	0.08	0.01			
Sodium							
Background	5/5	18.2	25.1	23.7			
Current plume	54/54	29.8	1,050	210	257		
Historical Plume	6/6	801	1,080	997			
Sulfate						250[g]	
Background	4/4	131	282	229			
Current plume	54/54	260	1,700	697	774		
Historical Plume	6/6	1,030	1,450	1,200			
Uranium						0.044	
Background	5/5	0.004	0.009	0.007			
Current plume	54/54	0.004	2.49	0.773	0.91		
Historical Plume	13/13	1.0	5.2	2.2			
Vanadium							0.33N
Background	0/5	<0.019	NA	NA			
Current plume	26/54	<0.02	5.73	1.11	1.49		
Historical Plume	6/6	1.5	10.0	6.4			

Background well DM1
Plume wells: (USGS analyses) wells 0547, 0548, MAU03 through MAU08, NAT01-1, 02, 03, 04-1, 06-1, 08, 10, 11, 15-1, 16-1, 16, 20, 23 through 26, 27-2, 29, and 30-1.
[a]Frequency of detection
[b]Current background data collected 6/2000 through 3/2001
[c]Current plume data collected 11/2000 through 3/2001
[d]Historical data collected 1989 through 1994; wells 0616 and 0632 (as reported in DOE 1995)
[e]N= noncarcingenic risks
[f]C= carcinogenic risks
[g] Secondary drinking water standard
NA= Not enough data available

6.1.3 Results

6.1.3.1 Ground Water—Residential

Table 6–2 provides results of calculations for ingestion of ground water through residential use. Noncarcinogenic risks were calculated for both children and adults; risks are slightly higher for children because of their lower body weights. The greatest risks for both children and adults are from exposure to uranium, vanadium, and arsenic. Manganese, molybdenum, and selenium collectively make up only about 5 percent of the risk. From a risk perspective, selenium and molybdenum, and possibly manganese, could probably be eliminated as COPCs, though selenium and molybdenum exceed their respective UMTRA standards in at least one location. Background concentrations of manganese are approximately an order of magnitude higher than the Colorado secondary drinking water standard. Carcinogenic risks for both arsenic and uranium exceed the high end of EPA's acceptable risk range of 1×10^{-4} by factors of approximately 3 and 7, respectively.

Sodium and sulfate could not be evaluated quantitatively due to lack of toxicity data. A recent survey by EPA (1999a) indicated that no adverse affects resulted from exposures to sulfate of 500 mg/L or less in drinking water in any study conducted. Some studies of adult populations showed that negligible effects were associated with concentrations up to 1,200 mg/L. Infants are the receptors most sensitive to sulfate exposure. Sulfate levels present at the Naturita site could result in diarrhea and dehydration if ingested by infants on a regular basis. Only minor and temporary effects, if any, would be expected for adults exposed to those levels of sulfate.

Intakes of sodium based on concentrations at the Naturita site are well within typical dietary ranges. The National Research Council recommends that most healthy adults consume at least 500 mg/day and that sodium intake be limited to 2,400 mg/day. A Food and Drug Administration publication, *Scouting for Sodium and Other Nutrients Important to Blood Pressure* (FDA 95-2284), indicates that most adults tend to eat between 4,000 and 6,000 mg of sodium per day. Therefore, levels associated with the Naturita site, even with a residential scenario, would not be expected to result in significant adverse affects. The level of sodium ingested by children would be slightly less than 400 mg/day and for adults would be slightly higher than 500 mg/day.

6.1.3.2 Ground Water—Occupational

Table 6–3 provides calculations on exposure to ground water through occupational use. The assumption is made that a well is installed into the alluvial aquifer and used for drinking water in an occupational setting. Risks are calculated for a full-time worker exposed 5 days a week for the work year. One-half the daily intake of drinking water is consumed at work. Calculations show that risks for use of ground water in this manner would be unacceptable. The HI for that exposure route is approximately 6, and most of the risk is accounted for by uranium and vanadium. Carcinogenic risks are 5 times the high end of EPA's acceptable risk range; contributions from uranium and arsenic are approximately equal.

Table 6–2. Intake/Risk Calculation Spreadsheet (ground water ingestion pathway)

Naturita Site—Residential Exposure

Noncarcinogens—Ground Water Ingestion Only (children)

Contaminant		Cw[a]	Irw	EF	ED	BW	AT	Intake	RfD	HQ
Arsenic		0.017	1.5	350	7	38.3	2,555	0.0006	0.0003	2.128
Manganese		0.99	1.5	350	7	38.3	2,555	0.0372	0.047	0.791
Molybdenum		0.046	1.5	350	7	38.3	2,555	0.0017	0.005	0.346
Selenium		0.002	1.5	350	7	38.3	2,555	0.0001	0.005	0.015
Sodium		257	1.5	350	7	38.3	2,555	9.6516		
Sulfate		774	1.5	350	7	38.3	2,555	29.0676		
	infants	774	0.64	350	1	4	365	118.7507		
Uranium		0.91	1.5	350	7	38.3	2,555	0.0342	0.003	11.392
Vanadium		1.49	1.5	350	7	38.3	2,555	0.0560	0.007	7.994
									HI=	22.665

Noncarcinogens—Ground Water Ingestion Only (adults)

Contaminant	Cw	Irw	EF	ED	BW	AT	Intake	RfD	HQ
Arsenic	0.017	2	350	30	70	10,950	0.00047	0.0003	1.553
Manganese	0.99	2	350	30	70	10,950	0.02712	0.047	0.577
Molybdenum	0.046	2	350	30	70	10,950	0.00126	0.005	0.252
Selenium	0.002	2	350	30	70	10,950	5.47945E-05	0.005	0.011

Table 6–2 (continued). Intake/Risk Calculation Spreadsheet (ground water ingestion pathway)

Contaminant	Cw	Irw	EF	ED	BW	AT	Intake	RfD[2]	HQ
Sodium	257	2	350	30	70	10950	7.04109		
Sulfate	774	2	350	30	70	10950	21.20547		
Uranium	0.91	2	350	30	70	10950	0.02493	0.003	8.311
Vanadium	1.49	2	350	30	70	10950	0.04082	0.007	5.832
								HI =	16.535

Carcinogens—Ground Water Ingestion Only (adults)

Contaminant	Cw	Irw	EF	ED	BW	AT	Intake	SF	Risk
Arsenic	0.017	2	350	30	70	25,550	0.00019	1.5	2.99E-04
U-234+238[b] (pCi/L)	624.26	2	350	30	na	na	1.31E+07	5.32E-11	6.97E-04
								Total risk	9.97E-04

[a]Water concentrations used are UCL_{95} milligrams per liter

[b]Assumes equilibrium; 1 mg = 686 pCi; slope factor is average of U-234 and U-238

Cw = contaminant concentration in water
Irw = ingestion rate for water (L/day)
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (365 days × ED)
Intake = mg/kg-day per chemicals; pCi for radionuclides
SF = slope factor (chemical specific; unitless)
Risk = intake × slope factor

6.1.3.3 Surface Water and Sediment—Incidental Exposure

Table 6–3 and Table 6–4 present results of exposure to surface water and sediment. The surface water and sediment pathway assumes incidental exposure through surface water and sediment ingestion as well as dermal contact with surface water. Conservative assumptions are made regarding absorption and ingestion of contaminants and about exposure frequencies and durations. For both scenarios considered, risks summed for all contaminants and all pathways were well below the threshold HI of 1. Carcinogenic risks associated with the golf course worker scenario were within EPA's acceptable risk range. Because infants would not be exposed to sulfate through incidental exposure, sulfate intakes are not of concern for the surface water pathway. Sodium intakes are also acceptable given the more limited exposure compared to a residential scenario.

6.1.3.4 Uncertainty in the BLRA

Any risk assessment includes many sources of uncertainty, such as limited site characterization, uncertainty of future land use, and uncertainty in toxicity values used. Because of the conservative assumptions used in calculating risks, risks are most often overestimated for an exposure scenario. Some of the sources of uncertainty specific to this BLRA update are listed below along with their overall effect on estimates of site-related risks.

- *Toxicity data and contaminant interactions.* The toxicity values were obtained from EPA's Integrated Risk Information System (IRIS) database and represent the best data available. However, these values are often extrapolated from animal data or from laboratory tests conducted under conditions that differ from those under which actual exposure to environmental contaminants occurs. Most of the studies do not include data on more sensitive populations (e.g., children, the elderly). Uncertainty factors are often applied to these values to account for such circumstances. The RfDs for arsenic and selenium were developed using an uncertainty factor of 3; the RfD for molybdenum includes an uncertainty factor of 30. Uncertainty factors of 100 and 1,000 were applied in developing the RfDs for vanadium and uranium, respectively. Thus, the actual risks associated with vanadium and uranium are least understood. The application of highly conservative uncertainty factors may overestimate the risks.

- *Chemical interaction.* To get hazard indices and total carcinogenic risks, HQs and risks for all chemicals were simply summed. In reality, certain chemicals can have interactions that are synergistic or antagonistic. This is not accounted for by summing risks. Lack of data on chemical interaction could either overestimate or underestimate actual risks.

- *Future water and land use.* Risks were calculated assuming residential, occupational, and recreational exposure to ground water, surface water, and sediment. A residence is currently located in the contaminant plume for uranium, but ground water is not being used for drinking water. The presumed future use for the rest of the property associated with the plume is a golf course, but currently there are no complete pathways to ground water. The only potentially complete exposure pathway at present is exposure to surface water, though it is unlikely that this is actually occurring. Uses of the land could change in the future and would dictate the possible exposure scenarios. Risks presented here, particularly for a residential scenario, are overestimates based on current ground water and surface water exposures.

Table 6–3. Occupational Exposure Scenario, Hypothetical Golf Course Worker at the Naturita Site

Dermal Exposure Pathway

Noncarcinogens	Cw mg/L	SA cm^2	PC cm/h	CF L/cm^3	ET h/day	EF days/yr	ED yr	BW kg	AT days	Intake absorbed mg/kg-day	RfD mg/kg-day	HQ mg/kg-day
Arsenic	0.017	312	0.001	0.001	8	250	30	70	10,950	4.15E-07	0.0003	0.00138
Manganese	0.99	312	0.001	0.001	8	250	30	70	10,950	2.42E-05	0.047	0.00051
Molybdenum	0.046	312	0.001	0.001	8	250	30	70	10,950	1.12E-06	0.005	0.00022
Selenium	0.002	312	0.001	0.001	8	250	30	70	10,950	4.88E-08	0.005	0.00001
Sodium	257	312	0.001	0.001	8	250	30	70	10,950	6.28E-03		
Sulfate	774	312	0.001	0.001	8	250	30	70	10,950	1.89E-02		
Uranium	0.91	312	0.001	0.001	8	250	30	70	10,950	2.22E-05	0.003	0.00741
Vanadium	1.49	312	0.001	0.001	8	250	30	70	10,950	3.64E-05	0.007	0.00520
											HI =	0.01474

Carcinogens	Cw	SA	PC	Cf	ET	EF	ED	BW	AT	Intake absorbed	SF	Risk
Arsenic	0.017	312	0.001	0.001	8	250	30	70	10,950	4.15E-07	1.5	6.23E-07
Uranium (pCi/L)	624.26	312	0.001	0.001	8	250	30	na	na	1.17E+04	5.32E-11	6.22E-07
											Total risk	1.24E-06

Surface Water Ingestion—Incidental Exposure

Noncarcinogens	Cw	Irw	EF	ED	BW	AT	Intake	RfD	HQ
Arsenic	0.017	0.05	250	30	70	10,950	8.317E-06	0.0003	0.028
Manganese	0.99	0.05	250	30	70	10,950	0.00048	0.047	0.010
Molybdenum	0.046	0.05	250	30	70	10,950	2.25E-05	0.005	0.005
Selenium	0.002	0.05	250	30	70	10,950	9.785E-07	0.005	0.000
Sodium	257	0.05	250	30	70	10,950	0.12573		
Sulfate	774	0.05	250	30	70	10,950	0.37866		
Uranium	0.91	0.05	250	30	70	10,950	0.00044	0.003	0.148
Vanadium	1.49	0.05	250	30	70	10,950	0.00072	0.007	0.104

Table 6–3 (continued). Occupational Exposure Scenario, Hypothetical Golf Course Worker at the Naturita Site

Surface Water Ingestion—Incidental Exposure

Carcinogens	Cw	Irw	EF	ED	BW	AT	Intake	SF	Risk
Arsenic	0.017	0.05	250	30	70	10950	8.317E-06	1.5	1.25E-05
U-234+238	624.26	0.05	250	30	na	na	234,097.5	5.32E-11	1.25E-05
								Total Risk	2.49E-05

Sediment Ingestion—Incidental Exposure

Noncarcinogens	Csf	Cs-max	Irs	EF	ED	BW	AT	Intake	RfD	HQ
Arsenic	1.00E-05	2.83	100	250	30	70	10950	2.769E-05	0.0003	0.0923
Manganese	1.00E-05	498	100	250	30	70	10950	0.0048728	0.047	0.1037
Molybdenum	1.00E-05	2.19	100	250	30	70	10950	2.143E-05	0.005	0.0043
Selenium	1.00E-05	0.27	100	250	30	70	10950	2.642E-06	0.005	0.0005
Sodium	1.00E-05	244	100	250	30	70	10950	0.0023875		
Sulfate	1.00E-05	2464	100	250	30	70	10950	0.0241096		
Uranium	1.00E-05	12.5	100	250	30	70	10950	0.0001223	0.003	0.0408
Vanadium	1.00E-05	9.74	100	250	30	70	10950	9.53E-05	0.007	0.0136
									HI=	0.255

Carcinogens		Cw	Irw	EF	ED	BW	AT	Intake	SF	Risk
Arsenic	1.00E-05	2.83	100	250	30	70	10950	2.769E-05	1.5	1.85E-05
Uranium (pCi/L)	1.00E-05	8575	100	250	30	na	na	64,312.5	5.32E-11	3.42E-06
									Total risk	2.19E-05

Cumulative HI, all pathways = 0.56518
Cumulative risk, all pathways = 4.81E-05

Table 6–3 (continued). Occupational Exposure Scenario, Hypothetical Golf Course Worker at the Naturita Site

Ground Water Ingestion—Drinking Water

Nonarcinogens	Cw	Irw	EF	ED	BW	AT	Intake	RfD	HQ
Arsenic	0.017	1	250	30	70	10,950	0.00016	0.0003	0.554
Manganese	0.99	1	250	30	70	10,950	0.00968	0.047	0.206
Molybdenum	0.046	1	250	30	70	10,950	0.00045	0.005	0.090
Selenium	0.002	1	250	30	70	10,950	1.957E-05	0.005	0.004
Sodium	257	1	250	30	70	10,950	2.51467		
Sulfate	774	1	250	30	70	10,950	7.57338		
Uranium	0.91	1	250	30	70	10,950	0.00890	0.003	2.968
Vanadium	1.49	1	250	30	70	10,950	0.01457	0.007	2.083
								HI=	5.905

Carcinogens	Cw	Irw	EF	ED	BW	AT	Intake	SF	Risk
Arsenic[a]	0.017	1	250	30	70	10950	0.00016	1.5	2.50E-04
U-234+238 (pCi/L)[b]	624.26	1	250	30	na	na	4,681,950	5.32E-11	2.49E-04
								Total Risk	4.99E-04

[a]Based on 2000 & 2001 data; UCL_{95}

[b]Carcinogenic risks for uranium assumes 1 mg U = 686 pCi of U-234 + U-238; SF is average of U-234 and U-238

Table 6–4. Intake/Risk Calculation Spreadsheet (Surface Water/Sediment)

Naturita Site—Incidental Exposure at Location 0567

Noncarcinogens—Surface Water Ingestion Only (children)

	Cw	Irw	EF	ED	BW	AT	Intake	RfD	HQ
Arsenic	0.001	0.05	114	7	38.3	2,555	4.0774E-07	0.0003	0.001
Manganese	1.76	0.05	114	7	38.3	2,555	0.00071	0.047	0.015
Molybdenum	0	0.05	114	7	38.3	2,555	0	0.005	0.000
Selenium	0	0.05	114	7	38.3	2,555	0	0.005	0.000
Sodium	698	0.05	114	7	38.3	2,555	0.28460		
Sulfate	1,710	0.05	114	7	38.3	2,555	0.69723		
Uranium	1.06	0.05	114	7	38.3	2,555	0.00043	0.003	0.144
Vanadium	0	0.05	114	7	38.3	2,555	0	0.007	0.000
								HI=	0.161

Noncarcinogens—Sediment Ingestion Only (children)

	Csf	Cs-max	Irs	EF	ED	BW	AT	Intake	RfD	HQ
Arsenic	1.00E-05	2.83	100	114	7	38.3	2,555	2.30781E-05	0.0003	0.0769
Manganese	1.00E-05	498	100	114	7	38.3	2,555	0.00406	0.047	0.0864
Molybdenum	1.00E-05	2.19	100	114	7	38.3	2,555	1.7859E-05	0.005	0.0036
Selenium	1.00E-05	0.27	100	114	7	38.3	2,555	2.2018E-06	0.005	0.0004
Sodium	1.00E-05	244	100	114	7	38.3	2,555	0.00198		
Sulfate	1.00E-05	2,464	100	114	7	38.3	2,555	0.02009		
Uranium	1.00E-05	12.5	100	114	7	38.3	2,555	0.00010	0.003	0.0340
Vanadium	1.00E-05	9.74	100	114	7	38.3	2,555	7.94277E-05	0.007	0.0113
									HI=	0.2127

Table6–4 (continued). Intake/Risk Calculation Spreadsheet (Surface Water/Sediment)

Naturita Incidental Exposure—Dermal Exposure Pathway (child)

Noncarcingens	Cw mg/L	SA cm^2	PC cm/h	CF L/cm^3	ET h/day	EF days/yr	ED yr	BW kg	AT days	Intake absorbed mg/kg-day	RfD mg/kg-day	HQ mg/kg-day
Arsenic	0.001	497	0.001	0.001	1	114	7	38.5	2,555	0.00000	0.0003	1.34396E-05
Manganese	1.76	497	0.001	0.001	1	114	7	38.5	2,555	0.00001	0.047	0.00015
Molybdenum	0	497	0.001	0.001	1	114	7	38.5	2,555	0.00000	0.005	0
Selenium	0	497	0.001	0.001	1	114	7	38.5	2,555	0.00000	0.005	0
Sodium	698	497	0.001	0.001	1	114	7	38.5	2,555	0.00281		
Sulfate	1,710	497	0.001	0.001	1	114	7	38.5	2,555	0.00689		
Uranium	1.06	497	0.001	0.001	1	114	7	38.5	2,555	0.00000	0.003	0.00142
Vanadium	0	497	0.001	0.001	1	114	7	38.5	2,555	0.00000	0.007	0
											HI=	0.00158

Total risk from all pathways = 0.3750

Data used are from the February/March 2001 sampling round

Cw = contaminant concentration in water
Irw = ingestion rate for water (L/day)
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (365 days × ED)
Intake = mg/kg-day per chemicals; pCi for radionuclides
SF = slope factor (chemical specific; unitless)
Risk = intake × slope factor

- *Exposure parameters*. Exposure parameters for the residential scenario are default parameters used regularly by EPA. Most of the parameters are based on statistical analyses of population data. Actual exposures vary considerably. Numbers used represent values from the high end of the actual exposure distribution and are therefore conservative estimates. Because each parameter is set at the high end of its respective distribution, overall risks are probably overestimated.

6.1.4 Summary and Recommendations

Risk calculations show that the only unacceptable exposure pathway is ingestion of ground water as drinking water. Risks are unacceptable for both a residential and an occupational setting. This indicates that controls should be put in place to prevent use of alluvial ground water for drinking water until contamination is reduced to acceptable levels. Most of the risk is contributed by uranium and vanadium, and to a lesser degree by arsenic. The other constituents combined contribute only about 5 percent of the total risk. In both residential and occupational settings, carcinogenic and noncarcinogenic risk thresholds are exceeded. Risks could not be calculated quantitatively for sodium and sulfate, but it appears that the only potential adverse effect would be associated with infant exposure to ground water as drinking water.

Incidental exposure to ground water through non-drinking-water use in an occupational setting does not result in any unacceptable risks. This suggests that the aquifer could be used for irrigation or possibly some other type of industrial use. However, before the ground water is used for such a purpose, it is recommended that calculations be completed based on process-specific exposures.

Exposure of children to surface water and sediment while playing adjacent to the San Miguel River would not result in any unacceptable risks. This indicates that restrictions on access to the river and adjacent areas are not required based on discharge of ground water to the river.

Uranium, vanadium, and arsenic concentrations should continue to be monitored. Monitoring requirements for the remaining constituents is a risk management decision. Presumably any compliance strategy that prevents exposure to uranium, vanadium, and arsenic will likewise be protective of exposure to the remaining contaminants.

6.2 Ecological Risk Assessment

6.2.1 Introduction

Ecological risk assessment is a process that evaluates the likelihood of adverse ecological effects are occurring or may occur in the future as a result of exposure to one or more environmental stressors. A stressor is defined as any physical, chemical, or biological entity that can induce an adverse ecological response. The risk assessment process is outlined in EPA guidance documents, particularly the *Guidelines for Ecological Risk Assessment* (EPA 1998) and the *Framework for Ecological Risk Assessment* (EPA 1992). The Ecological Risk Assessment (ERA) for the Naturita site generally follows this EPA framework and guidance.

The overall goal of this risk assessment is to identify ecological COPCs (E-COPCs) that can be related to the dispersal of contaminants in the ground water underlying the millsite and to

characterize the potential for adverse effects of these E-COPCs on the ecosystem at the Naturita site. In particular, potential effects on special status species and sensitive environments are considered. This assessment is an update and expansion of the BLRA screening-level assessment conducted in 1995 (DOE 1995). However, it is still primarily a screening assessment to identify E-COPCs and areas in which future monitoring may be necessary. This section summarizes the BLRA findings and evaluates any data collected since the BLRA. This section will also apply data from new studies as well as updated ecological benchmarks and regulatory requirements that have been developed since completion of the BLRA.

Predicting the effects of chemicals on ecological receptors is complicated because of variable interactions and influences within an ecosystem. To a great extent, ecological risk assessment is an emerging science. Little data exist for most chemicals and their effects on ecological receptors. Therefore, attempting to integrate and evaluate individual and synergistic chemical effects with other stressors (predation, drought, disease, etc.) is problematic.

For ecological risks to occur, both a source and a pathway must exist for exposure of ecological receptors to contaminated ground water. The simplified ecological risk scenario gives a generalized overview of the ecological risk assessment process:

Source	→	Release	→	Contaminated Media	→	Pathway	→	Receptor	→	Effect
(mill tailings, RRM)		(into soil and ground water)		(ground water, surface water, and sediments)		(ingestion or absorption)		(plants and wildlife		(no effect, mortality, or nonlethal effects),

The following sections provide a summary of the BLRA and evaluation of potential risks based on a review of all relevant data, with emphasis on the 1998–2001 data.

6.2.2 Ecological Risk Assessment Process

As shown in Figure 6-2, the framework of the ERA contains three main components: (1) problem formulation, (2) analysis, and (3) risk characterization. The overall goal of the problem formulation is to "set the stage" for the analysis and risk characterization phases. In problem formulation, the need for a risk assessment is identified and the scope of the problem is defined. Available data are evaluated to identify potential stressors (in this case, the potential stressors are COPCs associated with the ground water at the Naturita millsite), key ecological receptors, and potential exposure pathways linking the receptors to the stressors. This information is used to develop a site conceptual model and risk hypotheses. Finally, assessment and measurement endpoints are defined for the specific determination of risk to these receptors and the environmental resources they represent. These endpoints are directly tied to overall management goals for the site.

The analysis phase of the ERA includes two concurrent steps—the exposure assessment and the effects characterization. In the exposure assessment, the potential for each receptor to be exposed to each stressor is evaluated and, where possible, quantified. The effects characterization describes the potential for the stressor to adversely affect the receptors that are exposed to it. Because the stressors at the Naturita site are chemical, the principal effects to ecological receptors will be toxicological; however, they may also include physical effects, such as those related to radiation.

The risk characterization phase evaluates (either qualitatively or quantitatively) the combined results of the exposure assessment and effects characterization to determine the potential for risk to the receptors due to their exposure to the stressors. A critical aspect of the risk characterization is the analysis of uncertainties associated with predictions of potential risk. Typically, uncertainties result from data gaps that necessitate the incorporation of assumptions into the analysis and risk characterization phases. In general, these assumptions are conservatively biased toward results that will lead to overestimations rather than underestimations of risk. The uncertainty analysis provides an analysis of these assumptions in terms of their potential for introducing significant bias in the risk estimation.

As described in the EPA guidance (EPA 1998), ecological risk assessment is an iterative process in which the evaluation of potential risks to ecological receptors is refined as additional data are collected to fill data gaps and reduce uncertainties. At the conclusion of each iteration (or "tier") in the process, decisions are made whether sufficient data have been collected and analyzed to proceed with risk management actions (if required), or whether additional data should be collected. Such a tiered approach to the ecological risk assessment process began at the Naturita site in 1995 with the screening-level BLRA (DOE 1995).

Subsequently, additional data have been collected from key environmental media specifically to characterize potential ecological risk. The ERA presented here provides an analysis of these new data as a refinement of the screening-level assessment. Sampling of ground water, surface water, and sediments for chemical analysis was conducted between 1998 and 2001 as discussed in Section 4.10, "Ecological Field Investigations."

6.2.2.1 Problem Formulation

The problem formulation phase in this risk assessment is represented in part by the information presented in the BLRA (DOE 1995). The BLRA was based on analytical data collected at the Naturita site before 1995. These data were reviewed to determine if concentrations of analytes in ground water, surface water, and sediment may pose a potential ecological risk. Information on the geologic setting, ground water hydrology, geochemistry, and habitats of the Naturita site were incorporated in the BLRA evaluation. Principal results of the BLRA included an initial screening of chemical analytes as E-COPCs and an assessment of potential risk to biota, including livestock and irrigated crops. The assessment of potential risk, however, was primarily qualitative. The BLRA provided a basis for the preparation of a characterization work plan (DOE 1998a).

Since the completion of the BLRA, additional samples have been collected at Naturita and at upgradient reference areas. These new analytical data are limited to data obtained from USGS. All available data gathered specifically for the ERA, which include the 1998–2001 sampling efforts, have been included in this update. Any other surface data collected after July 2001 will be addressed in the environmental assessment for the Naturita site as necessary.

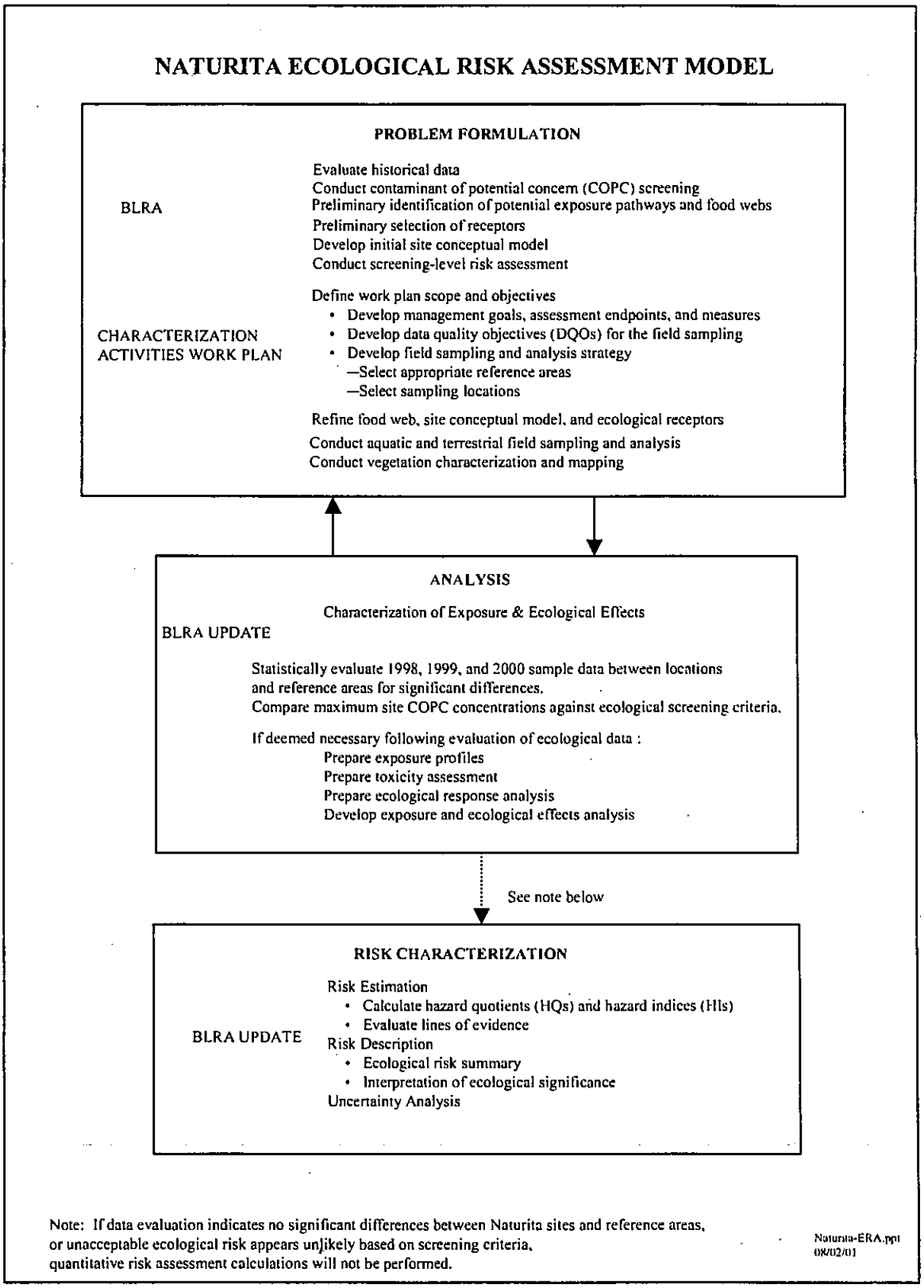

Figure 6-2. Naturita Ecological Risk Assessment Model

Potentially Affected Habitats and Populations

The millsite area is dominated by disturbed pastureland and a riparian community along the San Miguel River. Surrounding habitats are generally characterized as semiarid, influenced by the low to moderate annual precipitation. Flora and fauna of the Naturita millsite and surrounding areas were investigated between 1986 and 1994. Detailed information is provided in the *Environmental Assessment of Remedial Action at the Naturita Uranium Processing Site Near Naturita, Colorado* (DOE 1994), which documents the results of the investigations and lists the potential ecological receptors, including threatened or endangered species. Ecological characterization and surveys targeted terrestrial ecological receptors, with an emphasis on riparian plant communities and associated wildlife along the San Miguel River. Terrestrial wildlife such as foxes, coyotes, skunks, raccoons, deer, and rodents likely use the riparian habitats for foraging, resting, denning, and other activities. The area is also known to provide winter range for large mammals, including deer and elk. Drinking water sources such as the San Miguel River and tributaries are commonly available in or near these habitats, adding to their attractiveness to wildlife. Most, if not all, of the area (including riparian areas) is currently used as pastureland for livestock (primarily horses). Birds of the riparian habitats include resident and migratory species (e.g., bald eagle). The aquatic habitat of the San Miguel River is also used by waterfowl such as ducks and geese. The area is also suitable habitat for cold water game fish, primarily various trout species.

The BLRA identified several federally threatened or endangered species that may inhabit the former millsite area. Of the species originally listed, the only one for which there appears to be suitable habitat (located on private land) is the southwestern willow flycatcher. This is based on visual observations and the degree of human and livestock use of the site. Surveys were conducted at the site for this species through 1994, but no observations were documented.

A seep at location 0538 provides a small pond and criteria wetland of approximately one acre at the northeast end of the site. It is likely that amphibians, primarily frogs, inhabit this pond. This area is thought to be the most downgradient extent of contamination and will be the primary focus of ecological assessment. Because surface and near-surface expressions of the contaminated ground water are limited to this area, emphasis will be placed on receptors that may be present in this area. The areas and media currently considered to have potential ecological pathways also include the millsite (ground water), and surface water and sediments in and along the San Miguel River.

Summary of the 1995 Ecological Risk Assessment Results

In the 1995 BLRA (DOE 1995), the list of ground water constituents that were present in elevated levels in ground water (based on statistical comparisons between on-site and background well data) was used as starting point for identifying E-COPCs in those media for which ecological exposure pathways may exist. The water quality of samples from upgradient wells was considered to be representative of background conditions for the floodplain aquifer. The BLRA initially identified 27 ground-water-based constituents as E-COPCs for further evaluation. Additional media of concern included surface water, sediments, and vegetation (Figure 4–25). Based on this information, a screening-level assessment of ecological risks at the site evaluated potential exposure pathways, receptors, and potential adverse effects related to these constituents and media. No other contaminated media and subsequent pathways or effects were addressed in the BLRA. Of 27 initial E-COPCs, the list was reduced in Sections 3.0 and 7.0 of the BLRA to those constituents with concentrations that were elevated above background in affected media. These media-specific E-COPCs are indicated in Table 6–5. Concentrations of

E-COPCs in ground water, surface water, sediments, and vegetation were then compared to toxicity standards and guidelines (if available) for various ecological receptors.

In some cases the BLRA identified E-COPCs and media that required further evaluation. However, no sampling of any media was conducted between 1995 and 1997. Sampling resumed in 1998 for selected constituents in ground water, surface water, and sediments. Sampling from 1998 to the present will be discussed in subsequent sections of this document, with an emphasis on 2000 and 2001 data.

Table 6–5. Summary of Ecological Contaminants of Potential Concern in Ground Water, Surface Water, Sediments, and Vegetation from the BLRA (DOE 1995)

Constituents with Concentration Above Background in Ground Water[a]	Concentration Above Background in the San Miguel River Channel[b]	Concentration Elevated in San Miguel River Sediments[b]	Concentration Elevated in Vegetation[c]
Aluminum			
Ammonium			
Antimony			
Arsenic		X	X
Barium			
Boron			
Calcium			
Chloride			
Fluoride			
Magnesium			
Manganese		X	X
Molybdenum			
Nitrate			
Phosphate			
Potassium			
Selenium			X
Silica			
Silver			
Sodium			
Strontium			
Sulfate		X	
Uranium		X	
Vanadium		X	X
Radionuclides			
Lead-210			
Polonium-210			
Radium-226	X		
Radium-228			

[a]Ground water constituents with concentrations that exceeded background (reference area concentrations).
[b]Surface water constituents that exceeded background surface water areas (river and location 0531). Constituents were excluded that were either not detected in surface water or the maximum concentrations adjacent to and downgradient from the site were less than concentrations upgradient of the site.
[c]Selection of constituents was based on a screening benchmarks for plants where available (river channel and location 0531) because background samples were not taken.

Section 3.6 of the BLRA states that a statistical evaluation of water samples at surface locations identified no statistically significant elevated concentrations in downstream locations, indicating that ground water is not adversely affecting the San Miguel River. The one exception was a slight increase in radium-226 at one location adjacent to the site. Other radionuclides could not be thoroughly evaluated due to the lack of data. Mass balance calculations were also completed to further document that ground water was not influencing surface waters. The results indicated that only sodium, sulfate, and uranium had the potential to be detected in the San Miguel River. However, in all cases, the concentrations would be below standards for surface waters and would not affect the quality of the surface water in the San Miguel River under low-flow conditions. Therefore, the river was not considered an exposure point for environmental receptors. However, analysis of location 0538, referred to as a small pond in the BLRA, does show signs that ground water is reaching this location. The pond, which is within the river floodplain, has an outflow that empties into the San Miguel River. The BLRA states that water quality in the pond does not exceed any water quality criteria or available screening benchmarks for terrestrial plants or wildlife.

On the basis of one round of sediment sampling in 1994, concentrations of a few constituents (uranium, sulfate, and zinc) were higher in downstream river locations than upstream locations. (Zinc was not included in the original list of 27 E-COPCs, and therefore is not included in Table 6–5.) The BLRA indicates that the differences in upstream and downstream concentrations of uranium and sulfate in sediments are difficult to attribute to site contamination.

Sediments at location 0538 showed elevated levels of arsenic, manganese, sulfate, uranium, vanadium, and zinc. Arsenic, manganese, and zinc concentrations exceeded National Oceanic and Atmospheric Administration (NOAA) sediment screening benchmarks. The case is made that zinc concentrations at location 0538 (the seep), although elevated an order of magnitude above background, are unlikely to be attributed to site influence due to low zinc concentrations in site-related ground water. No sediment benchmarks were available for sulfate, uranium, and vanadium. In the case of both surface water and sediments, the BLRA states that insufficient water and sediment data were available to draw firm conclusions, and further data and evaluation were recommended.

Update of the 1995 Ecological COPCs

For the current risk assessment, additional data collected and information received subsequent to the 1995 BLRA are used to reevaluate the list of E-COPCs that are further assessed for potential ecological risk. Due to uncertainties associated with previous analyses, the initial list of 27 constituents identified as ground water E-COPCs in the 1995 BLRA are reconsidered in this update. Iron, tin, zinc, and thorium-230 are added, bringing the total number of constituents to 31 for preliminary risk evaluation. These 31 constituents are listed in Table 6–6. For the constituents for which sampling was not conducted during the 1998–2001 sampling events, the evaluation is based on pre-1995 data. Current benchmarks and assessment methodologies are applied as applicable to the evaluation of potential risk from identified E-COPCs.

Table 6–6. Preliminary Ecological Contaminants of Potential Concern in Ground Water

Constituents Considered For Preliminary Evaluation[a]	Exceed Background[b]	Retained As E-COPC	Rationale
Aluminum	Y	N	Only slightly elevated based on current data.
Ammonium	Y	N	Only slightly elevated based on 89–94 data.
Antimony	Y	N	Only slightly elevated based on 89–94 data.
Arsenic	Y	Y	Exceeds background by an order of magnitude.
Barium	Y	Y	Exceeds background by an order of magnitude.
Boron	Y	Y	Exceeds background by an order of magnitude.
Calcium	Y	N	Essential nutrient, not typically associated with RRM.
Chloride	Y	N	Low potential toxicity.
Fluoride	Y	N	Not typically associated with RRM.
Iron	Y	Y	Elevated by two orders of magnitude.
Magnesium	Y	N	Considered an essential nutrient.
Manganese	Y	Y	Elevated above background.
Molybdenum	Y	Y	Elevated above background.
Nitrate	Y	Y	Elevated above background.
Phosphate	Y	N	Low potential toxiciy.
Potassium	Y	N	Essential nutrient, not associated with RRM.
Selenium	Y	Y	Slightly elevated above background.
Silica	Y	N	Not typically associated with RRM.
Silver	Y	N	Small number of detects based on 89–94 data.
Sodium	Y	N	Considered an essential nutrient.
Strontium	Y	Y	Elevated at 4 times background.
Sulfate	Y	Y	Elevated at 8 times background.
Tin	Y	N	Small number of detects based on 89-94 data.
Uranium	Y	Y	Elevated above background.
Vanadium	Y	Y	Elevated above background.
Zinc	Y	Y	Elevated above background.
Radionuclides			
Lead-210	Y	Y	Based on 89–94 data.
Polonium-210	Y	Y	Based on 89–94 data.
Radium-226	Y	Y	Based on 89–94 data.
Radium-228	N	N	Based on 89–94 data.
Thorium-230	Y	Y	Based on 89–94 data.

[a]Ground water constituents that require further evaluation because they were E-COPCs under the BLRA, they were not fully evaluated under the BLRA, or current data justifies consideration as an E-COPC because maximum concentrations exceed background.

[b]Based on maximum concentrations of most recent (through March 2001) sampling. If no sampling was completed after 1994, then 89–94 data are used.

Constituents that are considered to be essential nutrients (as recognized in EPA 1989a) were excluded as E-COPCs. These included calcium, magnesium, potassium, and sodium. Chloride and phosphate were excluded from consideration as E-COPCs in the BLRA because of their low potential toxicities and are still excluded as E-COPCs for the same reason. However, at high concentrations in water, these anions and the four cations considered to be essential nutrients can contribute to adverse ecological effects due to high osmotic potentials, and some can affect the use of water by wildlife and livestock by imparting strong tastes to the water. These types of effects are not addressed in this risk assessment.

Sulfate is also an anion of relatively low potential toxicity in biota. High sulfate levels in water are known to cause diarrhea in humans and livestock; however, some evidence indicates that this effect is temporary, and the individual will acclimate to the high sulfate ingestion without a a long-term adverse effect (EPA 1999a). Sulfate-based salts are commonly used to test the toxicity of cationic elements, indicating a general lack of toxic potential of the sulfate anion, which would otherwise interfere with the test results. However, because of its high concentrations in the ground water associated with the millsite, sulfate has not been excluded from consideration as an E-COPC.

The radioactive elements in the decay chain of uranium-238 that have sufficiently long half-lives to accumulate at detectable levels in the environment are not specifically included in this evaluation. The maximum concentrations of these radionuclides, which include thorium-230, radium-226, polonium-210, and lead-210, exceed the maximum concentrations from background wells and are therefore identified as E-COPCs. Radium-228, which was also detected in ground water, did not exceed the maximum background concentration. The principal risk to ecological receptors from the radionuclides is from radiation resulting from their decay rather than their individual chemical toxicities.

E-COPCs were identified from the remaining list of constituents on the basis of their detection in recent samples from the Naturita site and comparisons of these concentrations to background values. The comparisons to background were performed separately for the San Miguel River, locations 0538/0560 seep and pond, sediments, and vegetation areas where ecological pathways may exist. "Recent" data were considered to be data from samples collected in 2000 and 2001, or the most recent year for which data are available for the analyte. In some cases only a small number of data points were available and statistical comparisons were not possible. Therefore, a comparison of maximum values was used to identify E-COPCs. A constituent was retained as an E-COPC if the maximum concentration detected in the surface water or sediment was greater than the maximum detected reference site concentration. Because the seep and pond near locations 0538 and 0560 are within the river floodplain but are distinct surface water features from the river, they are addressed separately from other river locations. In the case of vegetation, no additional sampling or reference samples were obtained. In some cases, a lack of detections was the criterion for eliminating a constituent from further consideration as an E-COPC.

Because nitrate and zinc were detected in less than 25 percent of samples collected during the 2000–2001 sampling of the floodplain alluvial ground water, their identification as millsite-related contaminants is questionable.

The 2000 and 2001 data from upstream sampling location 0531 were used as reference data for surface water and sediment samples from both the San Miguel River and the seep/pond.

For the vegetation samples, 1994 data were used because no samples have been taken since that time. These data are not evaluated as a separate medium, but are incorporated in the evaluation of risk associated with the E-COPCs identified for the areas in question.

E-COPCs Associated with Ground Water

Of the 31 constituents considered in this update, 13 nonradionuclides and 4 radionuclides are retained for evaluation to determine risks associated with ground water (Table 6–6). Based on the shallow depth to contaminated ground water at the site, it is possible that some plant roots could intercept ground water. Phreatophytes, including cottonwood, willow, and greasewood, have the potential to root into the shallow ground water. These plants grow at the site and are discussed in more detail in Section 4.10.1. The BLRA evaluated the potential for phytotoxic effects by comparing the UCL_{95} of the ground water concentrations to published plant toxicity benchmarks based on contaminant concentrations in solution. Because phytotoxicity comparison data were unavailable for 15 of the 24 E-COPCs, the potential for risk to phreatophytes could not be completely evaluated. However, the results indicated that plant concentrations did not exceed phytotoxicity standards for six of the nine constituents for which benchmark values were available. The three exceptions were arsenic, manganese, and vanadium.

The BLRA evaluated potential effects to wildlife using contaminated ground water in a livestock pond (i.e., animals drinking from the pond) and to fish stocked in the pond. The UCL_{95} ground water concentrations of the E-COPCs were compared with available water quality criteria. The UCL_{95} exceeded the water quality values, indicating that the water would be unacceptable for aquatic organisms because of chloride, manganese, selenium, and silver concentrations. Vanadium was also found to potentially pose a risk to organisms exposed to ground water in such a pond. No water quality criteria were available for 16 of the ground water E-COPCs.

The BLRA evaluated the effect of hypothetical use of ground water for irrigating agricultural crops. The UCL_{95} ground water concentrations for manganese, molybdenum, selenium, and silver exceeded the comparison criteria. No comparison criteria were available for 13 of the E-COPCs (excluding the four radionuclides).

E-COPCs Associated with Surface Water

The 13 nonradiological and 4 radiological constituents in ground water that were retained as E-COPCs were further evaluated as possible E-COPCs in surface water at the Naturita site based on the 2000–2001 data. Surface water data from the seep and pond (locations 0538 and 0560) were evaluated separately from the river data. Upstream river sampling location 0531 was used as the reference location for both areas. If concentrations in the downstream or pond samples exceeded the reference (background) concentrations, the E-COPC was retained for surface water evaluation. If the constituent was not detected, or the downstream concentration was less than or equal to the upstream location, it was eliminated as an E-COPC. The results of these evaluations for the river and the seep/pond location are presented in Table 6–7 and Table 6–8, respectively. Barium concentration in the river only marginally exceeded the background value and did not exceed background in the pond sample. Barium is questionably retained as an E-COPC in the river surface water.

Table 6–7. Constituents Retained for Evaluation in the San Miguel River Surface Water

Constituent	Maximum Concentration in Surface Water[a]		Selected as E-COPC?	Reason
	Site	Ref.		
Nonradiological Constituents				
Arsenic	0.0017	<0.0002	Yes	Exceeds background range
Barium	0.09	0.08	Yes	Exceeds background range
Boron	0.14	0.09	Yes	Exceeds background range
Iron	0.48	<0.03	Yes	Exceeds background range
Manganese	0.78	<0.04	Yes	Exceeds background range
Molybdenum	ND	<0.04	No	Not detected
Nitrate	0.11	0.05	Yes	Exceeds background range
Selenium	0.0018	0.001	Yes	Exceeds background range
Strontium	1.74	1.23	Yes	Exceeds background range
Sulfate	459	239	Yes	Exceeds background range
Uranium	0.44	0.002	Yes	Exceeds background range
Vanadium	ND	<0.04	No	Not detected
Zinc	0.1	<0.041	Yes	Exceeds background range
Radiological Constituents				
Lead-210	1.2	0.2	Yes	Exceeds background range
Polonium-210	ND	0.2	No	Not detected
Radium-226	0.6	0.1	Yes	Exceeds background range
Radium-228	23	1.1	Yes	Exceeds background range
Thorium-230	0.5	0.1	Yes	Exceeds background range

[a]In mg/L for nonradiological constituents and pCi/L for radiological constituents.
ND = not detected
Results are from the 2000–2001 sampling data.

Table 6–8. Constituents Retained for Evaluation for the 0567/0538 Seep and Pond Surface Water

Constituent	Maximum Concentration in Surface Water, mg/L		Selected as E-COPC?	Reason
	Site	Ref.		
Arsenic	0.001	<0.0002	Yes	Exceeds background range
Barium	0.04	0.08	No	Does not exceed background
Boron	0.17	0.09	Yes	Exceeds background range
Iron	0.22	<0.03	Yes	Exceeds background range
Manganese	1.76	<0.04	Yes	Exceeds background range
Molybdenum	<0.04	<0.04	No	Not detected
Nitrate	<0.02	0.05	No	Does not exceed background
Selenium	0.002	0.001	Yes	Exceeds background range
Strontium	4.37	1.23	Yes	Exceeds background range
Sulfate	1,710	239	Yes	Exceeds background range
Uranium	1.06	0.002	Yes	Exceeds background range
Vanadium	<0.04	<0.04	No	Not detected
Zinc	0.08	<0.041	Yes	Exceeds background range

Results are from the 2000–2001 sampling data.

Radiological analyses for surface water were limited to the San Miguel River. Of the four radionuclides identified as E-COPCs for ground water (lead-210, polonium-210, radium-226, and thorium-230), concentrations of all except polonium-210 exceeded the upstream concentration in the San Miguel River. In addition, the concentrations of radium-228 also exceeded its upstream concentration in the river; however, concentrations of this radionuclide have not exceeded background in ground water. Therefore, its identification as an E-COPC is questionable.

E-COPCs Associated with Sediments

As with the surface water, the sediment data from the 2000–2001 samples were evaluated for E-COPCs based on comparisons to data from the upstream river sampling location. Because of the lower number of data points, however, the sediment data were not segregated by the pond and river locations. Therefore, sediment is assessed as a single unit at the Naturita site. As described for the surface water evaluation, E-COPCs in sediment were defined as those constituents that exceeded the maximum reference site (location 0531) concentration. As Table 6–9 shows, this was true for 12 of the 13 constituents that were evaluated (the exception was nitrate, which was not analyzed in the sediment samples).

Table 6–9. Constituents Retained for Evaluation in Sediments

Constituent	Maximum Concentration in Surface Water, mg/kg		Selected as E-COPC?	Reason
	Site	Ref.		
Arsenic	2.83	1.83	Yes	Exceeds background range
Barium	97	75	Yes	Exceeds background range
Boron	5.83	4.45	Yes	Exceeds background range
Iron	3,519	2,307	Yes	Exceeds background range
Manganese	721	367	Yes	Exceeds background range
Molybdenum	2.19	<0.04	Yes	Exceeds background range
Nitrate	–	–	–	No data
Selenium	0.27	0.18	Yes	Exceeds background range
Strontium	195	112	Yes	Exceeds background range
Sulfate	2,464	1,150	Yes	Exceeds background range
Uranium	12.5	0.53	Yes	Exceeds background range
Vanadium	9.54	6.56	Yes	Exceeds background range
Zinc	171	117	Yes	Exceeds background range

Results are from the 2000–2001 sampling data.

Summary of E-COPCs for All Media

Table 6–10 presents a summary of the reevaluation of E-COPCs.

Table 6–10. Summary of Ecological Contaminants of Potential Concern at the Naturita Millsite

Alluvial Ground Water	Surface Water in the San Miguel River	Surface Water at Locations 0538 and 0560	River, Seep, and Pond Sediment
Arsenic	Arsenic	Arsenic	Arsenic
Barium	Barium	Boron	Barium
Boron	Boron	Iron	Boron
Iron	Iron	Manganese	Iron
Manganese	Manganese	Selenium	Manganese
Molybdenum	Nitrate	Strontium	Molybdenum
Nitrate	Selenium	Sulfate	Selenium
Selenium	Strontium	Uranium	Strontium
Strontium	Sulfate	Zinc	Sulfate
Sulfate	Uranium		Uranium
Uranium	Zinc		Vanadium
Vanadium	Lead-210		Zinc
Zinc	Radium-226		
Lead-210	Radium-228		
Polonium-210	Thorium-230		
Radium-226			
Thorium-230			

6.2.3 Ecological Site Conceptual Model

The conceptual model for an ERA is developed from information about stressors, predicted exposure pathways, and the potential effects of exposure on ecological receptors. Conceptual models consist of two principal components (EPA 1998):

- A set of risk hypotheses that provide descriptions of predicted relationships among stressor, exposure, and assessment endpoint response, along with the rationale for their selection.
- A diagram that illustrates the relationships presented in the risk hypotheses.

A complete exposure pathway is the mechanism by which a contaminant in an environmental medium (i.e., the source) can contact an ecological receptor. A complete exposure pathway includes

- A contaminant source,
- A release mechanism that allows contaminants to become mobile or accessible,
- A transport mechanism that moves contaminants away from the release,
- An ecological receptor, and
- A route of exposure (e.g., dermal or direct contact, inhalation, or ingestion).

Because the stressors at the Naturita site are chemical contaminants, the risk hypotheses are considered to be stressor-initiated.

As part of the initial problem formulation in the BLRA, a generalized site conceptual model was developed for the Naturita site. That model has since been revised to address current and potential exposure pathways based on all the available data (Figure 6-3). The movement of contaminated ground water from the millsite in various directions has resulted in surface and near-surface expressions of this ground water in the seep at location 0538. For this reason, risk hypotheses are developed separately for the San Miguel River and the seep and pond at locations 0538 and 0560.

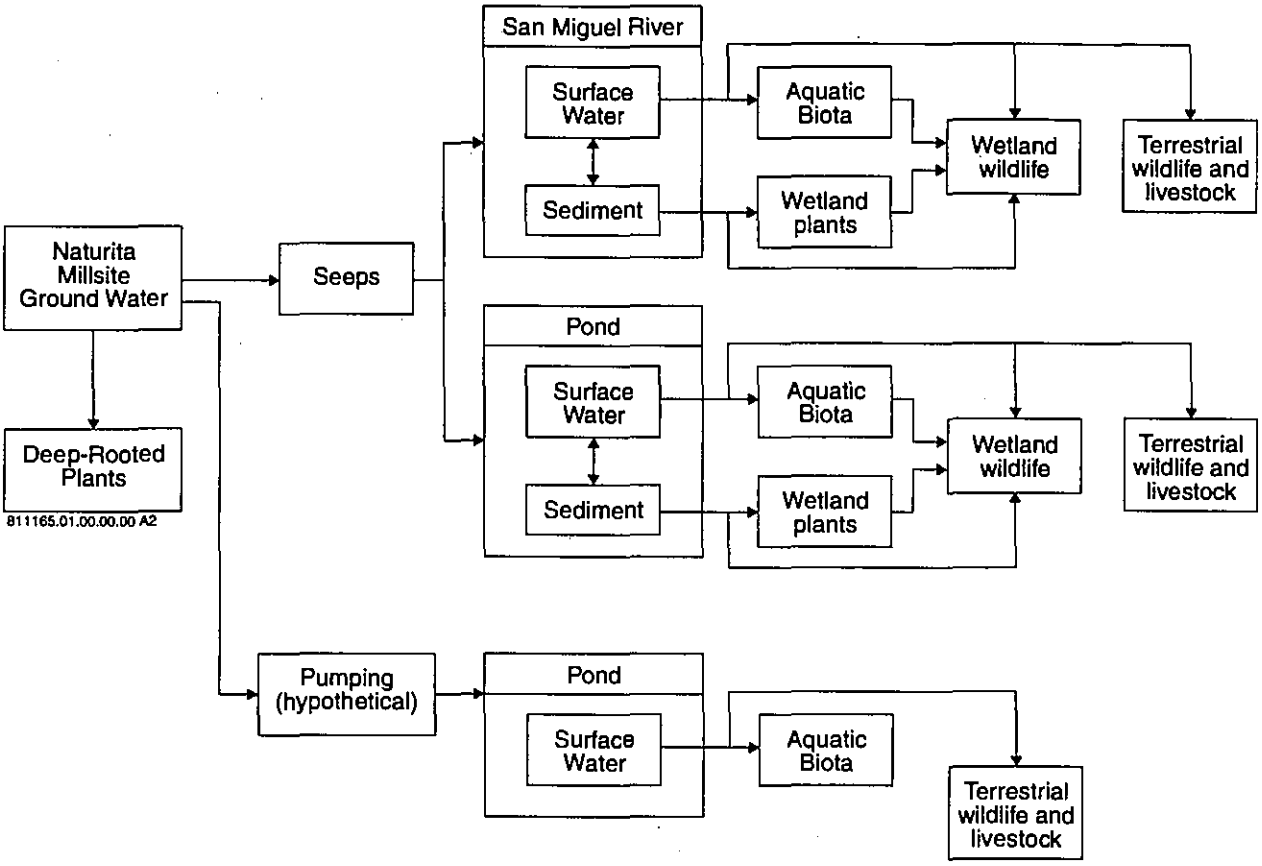

Figure 6-3. Naturita Ecological Site Conceptual Model

6.2.3.1 Risk Hypotheses Based on Current Exposure Scenarios

The following risk hypotheses are proposed for the Naturita site where complete exposure pathways to ecological receptors may exist based on the current site conditions. Roots of phreatophytes may take up contaminants in the shallow ground water of the San Miguel River floodplain. These contaminants may result in phytotoxic effects and they may be transported to plant tissues that are accessible to wildlife and foraging livestock. Contaminated ground water may be discharging at seeps (e.g., the seep feeding the pond at location 0538) and directly into the San Miguel River, thereby adversely affecting surface water and sediment quality of the area. Aquatic organisms in direct contact with these media may be affected and may provide a link for bioaccumulation of the contaminants up the food chain. Wildlife and livestock may be directly exposed to these contaminants through ingestion of this water and the food items exposed to the water and sediment and through incidental ingestion of the sediment.

6.2.3.2 Risk Hypotheses Based on Hypothetical Future Exposure Scenario

Without institutional controls, ground water could possibly be pumped and used for irrigation, livestock watering, or industry. This practice would create a source for ground water and surface water ingestion, direct contact with terrestrial vegetation, and deposition of ground water and surface water on the soil. The soil would then represent an additional source medium for ingestion and direct contact. Large-scale irrigation with ground water is not considered a likely future pathway because surface water is the main source of irrigation water in the Naturita area. As long as there is the possibility of pumping ground water for agricultural purposes, it is assumed that the potential exists for these two exposure pathways.

6.2.3.3 Ecological Receptors

Ecological receptors that could potentially be exposed to E-COPCs were identified in the BLRA (DOE 1995) and include mammalian and avian species. Section 6.2.2.1. summarizes the habitats and populations that may be affected by exposures to E-COPCs at the Naturita site. The food web for the Naturita site (Figure 6-4) illustrates the significant dietary interactions among the wetland and aquatic receptors. The food web also depicts the major trophic interactions and shows nutrient flow and transfer of matter and energy through the trophic levels. This food web model was developed from the species lists and the exposure pathways. The food web diagram portrays potential routes of E-COPCs from the ground water to biota at various trophic levels; potential receptor species are in specific areas identified as having potentially complete ecological exposure pathways. These areas and potential receptors are as follows:

The San Miguel River and Seep/Pond. The habitat of the river channel is primarily riparian. The potential receptors of these areas include

- Riparian plants that grow along the channel course and around the pond and seep.
- Aquatic receptors, including fish, aquatic invertebrates, and aquatic plants.
- Wetland wildlife, which may be exposed to E-COPCs in the seep/pond area and along the river as a result of drinking surface water and feeding on the aquatic organisms and wetland plants. Potential receptors include insectivorous birds, such as swallows, flycatchers, and

shorebirds; and piscivorous birds, such as belted kingfishers and herons. Mammals associated with wetland habitats include muskrats and raccoons.

- Terrestrial wildlife, which may be attracted to the surface water of the river and pond for drinking and may be exposed to E-COPCs in the seep/pond area and along the river as a result of drinking surface water. These may include small, local species and large, wide-ranging species.

Based on habitat conditions along the San Miguel River channel, the endangered southwestern willow flycatcher is considered a potential receptor at this location.

The San Miguel River Floodplain. The habitats of the San Miguel River floodplain are primarily terrestrial; however, many of the wildlife receptors in these habitats live and feed in close association with the aquatic habitats of the river and pond. These receptors include

- Terrestrial herbivores—The terrestrial wildlife that may be exposed to E-COPCs through the consumption of phreatophytes and wetland plants include rodents (e.g., white-footed mice, voles, and ground squirrels), lagomorphs (cottontails and jackrabbits), and mule deer. Evidence of beaver along the San Miguel River indicates that this herbivorous rodent is a potential receptor in the riparian habitat of the floodplain. Additional exposure in these receptors may result from the ingestion of water from the site.

- Terrestrial predators—Predators that may be exposed to E-COPCs through the consumption of terrestrial herbivorous prey include foxes, coyotes, skunks, snakes, and raptors. Many mammalian predators will also consume plant material, making them omnivores rather than strict carnivores.

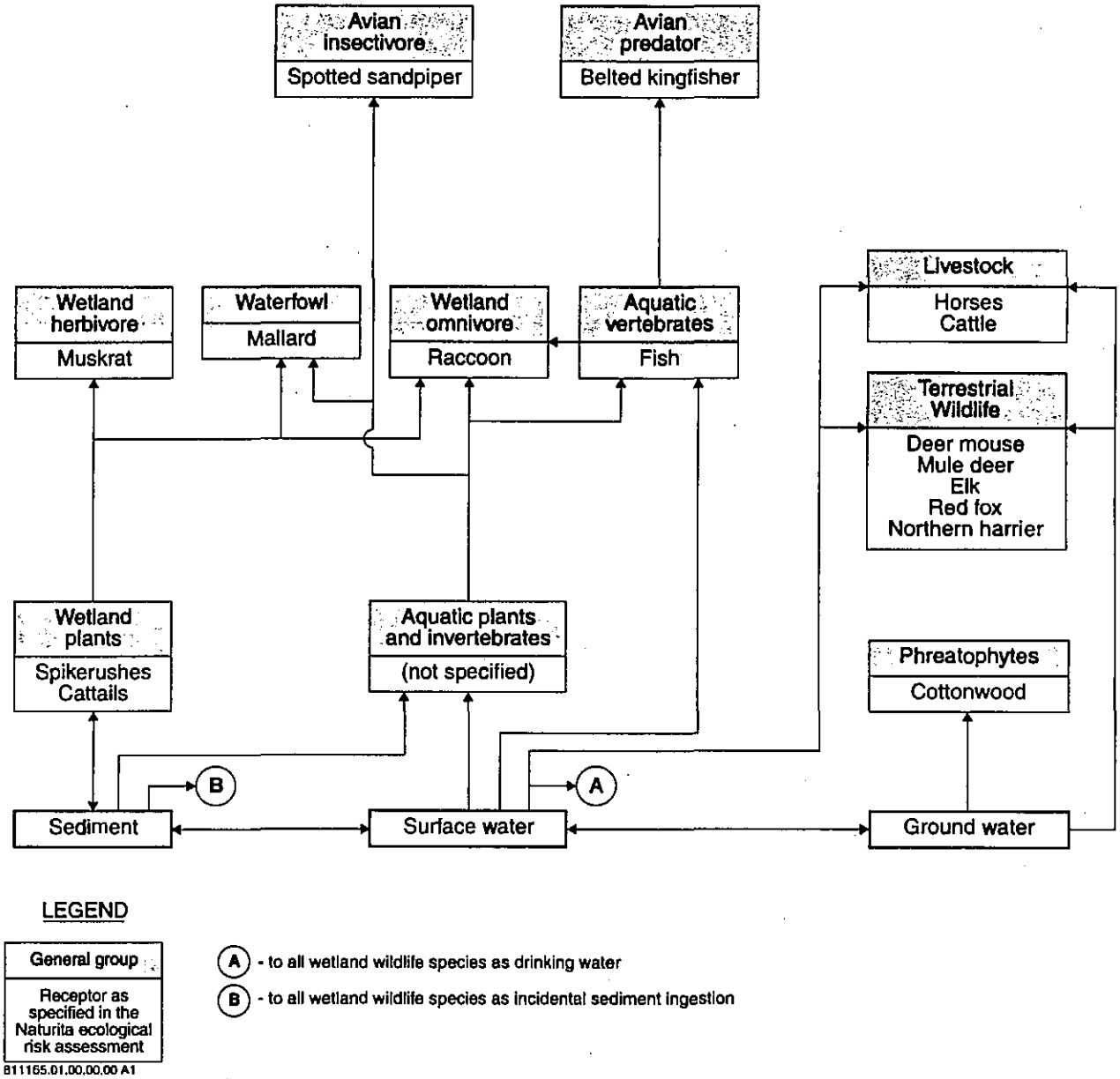

Figure 6-4. Generalized Food Web for Naturita Ecological Receptors

6.2.3.4 Management Goals and Endpoints

Table 6–11 presents the primary goals for protection of ecological resources at the Naturita site with respect to contaminants associated with ground water, and the assessment and measurement endpoints that will be used to evaluate potential risk to these resources in support of achieving these goals.

Table 6–11. Management Goals, Assessment Endpoints, and Measurement Endpoints for the Evaluation of Ecological Risks at the Naturita Site

Management Goals	Assessment Endpoints	Measurement Endpoints
Maintain the quality of aquatic habitats in the San Miguel River	Surface water quality of the San Miguel River	Concentrations of ecological COPCs in the surface water of the San Miguel River meet applicable water quality criteria or equivalent benchmarks for the protection of aquatic life.
	Sediment quality of the San Miguel River	Concentrations of ecological COPCs in the sediment of the San Miguel River meet applicable sediment quality benchmarks for the protection of benthic organisms.
Maintain habitat quality of the floodplain for the protection of wildlife diversity	Potential for adverse effects on survival and reproduction in wildlife from exposures to COPCs in various environmental media of the San Miguel River floodplain	Hazard quotients comparing estimated exposure to toxicity benchmarks for key indicator receptor species are less than unity.
	Surface water quality of the San Miguel River floodplain	Concentrations of ecological COPCs in the surface water of the San Miguel River floodplain meet applicable water quality criteria or equivalent benchmarks for the protection of aquatic life.
	Sediment quality of the San Miguel River floodplain	Concentrations of ecological COPCs in the sediment of the San Miguel River floodplain meet applicable sediment quality benchmarks for the protection of benthic organisms.
	Ground water quality of the San Miguel River floodplain	Concentrations of ecological COPCs in the ground water of the San Miguel River floodplain meet benchmarks for the protection of riparian plants.

6.2.4 Analysis

6.2.4.1 Exposure Assessment

Exposure Modeling and Assumptions

Only complete exposure pathways are quantitatively and qualitatively evaluated in an ecological risk assessment. In this assessment, the following potential exposure pathways were considered for evaluation:

- Surface water—ingestion and direct contact
- Soil—ingestion and direct contact
- Sediment—ingestion and direct contact
- Dietary—ingestion of forage or prey, as appropriate, by receptor

The contaminants associated with the Naturita site are inorganics and are principally associated with water (in dissolved form) and sediments (adsorbed to particles in these media). Estimations of potential exposures to key ecological receptors are based on the dominant pathways to these media for the specific receptor. Exposures in plants (both terrestrial plants and emergents) are dominated by direct contact with the soil or sediment in which they are rooted. Exposures to aquatic organisms (those that live within the water column) and benthic organisms (those that live within the sediment) are dominated by direct contact with the external media (water and sediment) in which they live, but in the cases of aquatic and benthic animals also include the ingestion of food associated with these media. In all these cases (plants and animals), potential exposure to an E-COPC is based on the concentration of that E-COPC in the media of principal contact (water, sediment, or soil).

Exposures in wildlife involve multiple potential pathways that may include ingestion of food, water, and sediment; direct contact and dermal absorption; and inhalation. In this assessment, the inhalation and dermal absorption pathways are assumed to be minor with respect to the combined exposures based on ingestion (food, water, and sediment ingestion). Most wildlife of the area have very little and infrequent direct dermal contact with potentially contaminated media due to their protective covers of feathers or fur and their habits and behaviors, such as preening and grooming, and (in the cases of most birds) living principally in trees and shrubs. Because the E-COPCs are not highly volatile, their occurrence in the air is principally related to dust particles. For the assessment of exposures to wildlife, however, dust inhalation was considered a minor exposure pathway relative to sediment ingestion. Although both dermal absorption and inhalation will contribute to the overall exposure in these receptors, these contributions are assumed to be included within the conservatisms incorporated in the estimation of exposures through the ingestion pathways.

In the estimation of ingestion-related exposure for the wildlife receptors, the E-COPCs are assumed to be 100 percent bioavailable and the receptors are assumed to be exposed only at the selected exposure point concentration, regardless of home range size or seasonal use patterns. The exposure through multiple ingestion pathways is modeled using the methods described in the EPA's *Wildlife Exposure Factors Handbook* (EPA 1993a). The basic model for estimating the daily intake of an E-COPC per kilogram of body weight (i.e., the estimated daily dose of the E-COPC) through these ingestion pathways is

$$D_x = \frac{\sum_{k=1}^{m}(C_k \cdot F_k \cdot I_k) + C_s \cdot F_s \cdot I_s + C_w \cdot F_w \cdot I_w}{W}$$

where

D_x = the estimated daily dose (mg/kg-day) of E-COPC x,
C_k = the concentration of E-COPC x in the k_{th} food type (mg/kg dry weight),
F_k = the fraction of the k_{th} food type that comes from the site,
I_k = the ingestion rate of the k_{th} food type (kg dry weight/day),
m = the number of food items in the receptor's diet,
C_s = the concentration of E-COPC x in the sedimentl (mg/kg dry weight),
F_s = the fraction of ingested sediment that comes from the site,
I_s = the ingestion rate of sediment (kg dry weight/day),

C_w = the concentration of E-COPC x in water (mg/L),
F_w = the fraction of the ingested water that comes from the site,
I_w = the ingestion rate of water (L/day), and
W = the body weight of the receptor (kg wet weight).

F_k, F_s, and F_w are commonly assumed to be the area use factor (the area of the site divided by the home range of the receptor or 1, whichever is smaller) but may also be modified by a seasonal use factor (number of days at the site divided by 365 days per year) if the home range is used for only part of the year. For estimating risk in this assessment, both area use and seasonal use are conservatively assumed to be 100 percent; therefore, F_k, F_s, and F_w are assumed to be 1.

For the purposes of estimating exposure in wildlife, the E-COPC concentrations in plants and small mammals were principally based on the empirically derived uptake models (nonlinear or linear) as recommended by Oak Ridge National Laboratory (Bechtel Jacobs Company 1998a, Sample and others 1998). The nonlinear form of the uptake model is

$$C_{organism} = B_0 \cdot C_{soil}^{B_1}$$

where

$C_{organism}$ = the concentration of the E-COPC in the plant or small mammal (mg/kg dry weight),
C_{soil} = the soil concentration of the E-COPC (mg/kg dry weight), and
B_0 and B_1 = empirically derived model parameters for the E-COPC and organism.

In the linear form of this model, B_1 is assumed to be exactly 1 and B_0 becomes a soil-to-organism transfer factor, where

$$C_{organism} = B_0 \cdot C_{soil}$$

In cases where parameters were not available in the Oak Ridge National Laboratory uptake model documents, soil-to-plant transfer factors from other literature sources (e.g., Baes and others 1984) were used in this linear model. For small mammals, soil-to-mammal transfer factors based on modeling information available in Sample and others (1998) were primarily used. Sandia National Laboratories data (IT Corporation 1999) was used as a secondary source of soil-to-mammal transfer factors. In some cases, small mammal concentrations were modeled from plant concentrations using food-to-mammal transfer factors from Baes and others (1984), NCRP (1989), and IAEA (1994). In this case, the model is of the form

$$C_{mammal} = B_0 \cdot C_{plant}$$

where

C_{mammal} = the concentration of the E-COPC in an herbivorous mammal (mg/kg dry weight),
C_{plant} = the concentration of the E-COPC in the plant material eaten by the mammal (mg/kg dry weight), and
B_0 = the food-to-mammal transfer factor (converted as necessary to be on a dry-weight to dry-weight basis).

For aquatic prey species (invertebrates and fish), linear uptake models based on bioaccumulation factors (BAFs) were used to estimate concentrations of E-COPCs in tissues. These models are of the form

$$C_{organism} = BAF \cdot C_{water}$$

where:

$C_{organism}$ = the concentration of the E-COPC in the invertebrate or fish prey species (mg/kg dry weight),
C_{water} = the concentration of the E-COPC in the water (mg/L), and
BAF = the bioaccumulation factor for the E-COPC.

BAFs account for all exposure pathways (dermal absorption, uptake through respiratory organs, and ingestion). In contrast, bioconcentration factors (BCFs) account for uptake through pathways other than ingestion. However, for most inorganic constituents, uptake through ingestion of water is insignificant, and BAFs are considered to be equal to BCFs. Therefore, BCFs are used as BAFs in this assessment when the latter values are not available. Whenever possible, however, BAFs and BCFs specific to either invertebrates or fish were used to model the concentrations in these respective prey types. Table 6–12 presents the uptake model parameters (B_0, B_1, BAF, and/or BCF values) used in modeling the concentrations of E-COPCs through the food chain at the Naturita site.

Key Indicator Receptors

Receptors used to evaluate risks were selected on the basis of their potential presence in the habitats of the site, their potential for exposure to E-COPCs in the media at the site, and their potential for conservatively representing potential exposures to a range of other receptors at the site. Potential receptors for the habitats identified as having potentially complete ecological pathways are discussed in Section 6.2.3.3. The indicator receptors are representative of key links in the food webs associate with these habitats.

These indicator receptors are as follows:

- Terrestrial habitats—deep-rooted plant (phreatophyte), deer mouse (herbivorous), red fox, mule deer, elk, northern harrier, cattle, horses
- Wetland habitats—wetland plant, muskrat, raccoon, mallard, spotted sandpiper, belted kingfisher
- Aquatic habitats—aquatic and benthic organisms

Terrestrial exposure pathways are on the floodplain. Deep-rooted plants (e.g., cottonwood) are considered to be the only potential receptors for E-COPCs in the ground water underlying the floodplain. For the terrestrial wildlife and livestock on the floodplain, surface water is the primary medium for E-COPC exposures, and therefore, risks to all terrestrial receptors are evaluated on the basis of potential consumption of drinking water from the various sources, including ground water being pumped to the surface. The terrestrial wildlife receptors used represent both mammals and birds; the mammals are represented by a range of body sizes, from a deer mouse to an elk. In addition, two classes of livestock (horses and cattle) are also used to evaluate potential risk from drinking water on the floodplain.

Table 6–12. Uptake Model Parameters and BAFs for Ecological Contaminants of Potential Concern

COPC	Uptake Model Parameters				BAF	
	Plants		Small mammals		Invertebrates	Fish
	B_0	B_1	B_0	B_1		
Arsenic	0.136[a]	0.564[a]	0.00351[b]	1.14[b]	73.0[n]	17.0[d]
Barium	0.15[e]	1.0[f]	0.0566[b]	1.0[f]	4.0[c]	4.0[g]
Boron	4.0[e]	1.0[f]	0.0008[e,h]	1.0[f]	1.0[i]	1.0[i]
Iron	0.004[e]	1.0[f]	0.621[b]	0.621[b]	200[c]	200[g]
Manganese	3.0[j]	1.0[f]	0.0205[b]	1.0[f]	65[k]	17.8[k]
Molybdenum	0.8[g]	1.0[f]	0.001[g,h]	1.0[f]	10[c]	10[g]
Nitrate	1.0[i]	1.0[i]	1.0[i]	1.0[i]	1.0[i]	1.0[i]
Selenium	0.508[a]	1.10[a]	0.660[b]	0.376[b]	269[l]	129[m]
Strontium	2.5[e]	1.0[f]	0.008[e,h]	1.0[f]	9.5[c]	9.5[f]
Sulfate	1.0[i]	1.0[i]	1.0[i]	1.0[i]	1.0[i]	1.0[i]
Uranium	0.023[g]	1.0[f]	0.033[n]	1.0[f]	27.1[c]	27.1[k]
Vanadium	0.0055[e]	1.0[f]	0.0123[b]	1.0[f]	3,000[o]	3,000[p]
Zinc	4.831[a]	0.555[a]	87.5[b]	0.0738[b]	1,130[q]	161[r]

[a]From Bechtel Jacobs Company (1998 a).
[b]From Sample and others (1998).
[c]Invertebrate bioaccumulation factor based on fish bioaccumulation factor.
[d]From Sample and others (1996).
[e]From Baes and others (1984).
[f]The uptake model is linear; therefore, B_1 = 1.0.
[g]From IAEA (1994).
[h]Based on uptake from food.
[i]Default value.
[j]From NCRP (1989).
[k]From EPA (2000a).
[l]Geometric mean of selenite BAF for water fleas based on 14-day exposure from AQUIRE (2000).
[m]From NMED (2000).
[n]From SNL (1999).
[o]From Neumann (1985).
[p]Fish bioaccumulation factor based on invertebrate bioaccumulation factor.
[q]From Eisler (1993).
[r]From EPA (1995)

For the wetland habitats, emergent plants, such as spikerush, are considered to be the primary producers and the muskrat and mallard are considered to be representative of herbivores that may consume such plants (both will also eat some animal prey). The raccoon represents an omnivore in this habitat. The spotted sandpiper represents an insectivorous bird, and the belted kingfisher represents an piscivorous bird. All animal prey of these wildlife receptors (the muskrat is the only one to be assumed to be purely herbivorous) are assumed to be aquatic invertebrates or fish.

Receptors in the aquatic habitats are not specified. Risk to these receptors is based on comparisons of the E-COPC concentrations in surface water and sediment to broad-based benchmark values, such as ambient water quality criteria (AWQC), that are protective of a wide range of aquatic and benthic organisms. For the San Miguel River, fish are assumed to be included as potential aquatic receptors within this broad categorization. All wildlife receptors are modeled as potential receptors of E-COPCs in surface water through the consumption of that water at all sites where surface water is present as a medium of concern.

The species-specific parameters used to model exposures to these key indicator receptors (wildlife only) are presented in Table 6–13.

6.2.4.2 Effects Characterization

The potential for adverse effects to ecological receptors resulting from exposures to E-COPCs at the Naturita site was evaluated through the comparison of the potential exposure in the receptor to a toxicity-based benchmark of exposure representing the threshold of potential adverse effects.

For aquatic and benthic receptors and plants, the exposure to an E-COPC is characterized by the concentration of that constituent in the medium (water, sediment, or soil) with which the receptor is principally in direct contact. Therefore, the benchmarks by which the potential for adverse effects is evaluated are also based on media concentrations. For surface water, either AWQC (EPA 1999b, Buchman 1999) or CDPHE Water Quality Standards (whichever was lower) were used as the principal benchmarks for evaluating potential risk to aquatic life. When neither was available for an E-COPC, Tier II secondary values (Suter and Tsao 1996) or other values (e.g., Haines and others 1994) were used. Sediment benchmarks were principally based on the lowest threshold effect levels (TELs) as presented in Buchman (1999), and supplemented from other sources (e.g., EPA 1996a, Jones and others 1997, and Haines and others 1994). Table 6–14 presents these water quality benchmarks.

Table 6–13. Exposure Parameters for Livestock and Wildlife Receptors

Receptor	Body Weight (kg)[a]	Food Ingestion Rate (kg [dry wt.]/day)[b]	Soil/Sediment Ingestion Rate (percent of food ingestion)[c]	Water Ingestion Rate (L/day)[d]	Dietary Composition (percent)[e]
Deer mouse (*Peromyscus maniculatus*)	0.0239[f]	NA	NA	0.00344	NA
Red fox (*Vulpes vulpes*)	4.54	NA	NA	0.386	NA
Mule deer (*Odocoileus hemionus*)	65[f]	NA	NA	4.24	NA
Elk (*Cervus canadensis*)	210[f]	NA	NA	12.2	NA
Northern harrier (*Circus cyaneus*)	0.180[g]	NA	NA	0.0187	NA
Muskrat (*Ondatra zibethicus*)	1.135	0.0772[h]	9.4[i]	0.111	Plant: 100
Raccoon (*Procyon lotor*)	5.74	0.289	9.4	0.477	Plant: 40 Invertebrate: 50 Fish: 10
Mallard (*Anas platyrhynchos*)	1.134	0.0592	3.3	0.0642	Plant: 90 Invertebrate: 10
Spotted sandpiper (*Actitis macularia*)	0.0425	0.00503	18[j]	0.0711	Invertebrate: 100
Belted kingfisher (*Ceryle alcyon*)	0.147	0.0128	2.0[k]	0.0163	Invertebrate: 20 Fish: 80

[a]From EPA (1993a), except where noted.
[b]Based on allometric equations from Nagy (1987), as presented in EPA (1993a), except where noted.
[c]From Beyer and others (1994). Data are species-specific except where noted.
[d]Based on allometric equations from Calder and Braun (1983), as presented in EPA (1993a), except where noted.
[e]Diets are generalized to emphasize specific trophic levels. Dietary compositions of the raccoon, mallard, and belted kingfisher are based on species-specific information presented in EPA (1993a) and Martin and others (1951) and have been rounded to increments of 10 percent.
[f]From Silva and Downing (1995).
[g]From Dunning (1993).
[h]Based on species-specific food intake rate from EPA (1993a), with assumed water content of food of 80 percent.
[i]Based on soil/sediment ingestion for raccoon from Beyer and others (1994).
[j]Based on the mean soil/sediment ingestion rate of four species of sandpipers as reported by Beyer and others (1994).
[k]No data available. Assumed value of 2 percent is based on the detection limit of the method used by Beyer and others (1994).

Table 6–14. Surface Water and Sediment Quality Benchmarks for Ecological Contaminants of Potential Concern for the Protection of Freshwater Aquatic Life

Contaminant of Potential Concern	Water Quality Benchmarks (mg/L)				Sediment Quality Benchmarks (mg/kg)	
	AWQC[a]	CDPHE SWQS[b]	Tier II[c]	Other	TEL[d]	Other
Arsenic	0.15	0.10	–	–	5.9	–
Barium	–	–	0.0039	50[e]	–	0.7[f]
Boron	–	0.75	0.0016	1.0[g]	–	–
Iron	1.0	1.0	–	–	188,400[h]	–
Manganese	–	1.0	0.08	–	630[h]	–
Molybdenum	–	–	0.24	–	–	4.0[i]
Nitrate	–	10[j]	–	177[k]	–	2,440[l]
Selenium	0.005	0.0046	–	–	–	5.0[m]
Strontium	–	–	1.5	–	–	49[f]
Sulfate	–	250[j]	–	100[n]	–	–
Uranium	–	1.5	0.0026	0.30[o]	–	–
Vanadium	–	–	0.019	–	–	50[f]
Zinc	0.12	0.118	–	–	123.1	–

[a]EPA AWQC (EPA 1999b, Buchman 1999). Hardness of 100 mg/L $CaCO_3$ was used for all hardness-dependent values.
[b]CDPHE Surface Water Quality Standard for aquatic life.
[c]Tier II secondary chronic value from Suter and Tsao (1996).
[d]Threshold effect level from Buchman (1999).
[e]Chronic criterion from Quebec (Haines and others 1994), presented in contrast to the Tier II secondary chronic value.
[f]Background value from Buchman (1999).
[g]From Eisler (1994).
[h]Lowest threshold effect levels from Buchman (1999).
[i]Sediment quality guideline for the protection of agricultural uses (from Haines and others 1994).
[j]Standard for the San Miguel River above Naturita Creek (mg/L as N).
[k]Guideline from British Columbia (Haines and others 1994) converted from µg N/L to mg NO_3/L.
[l]Lowest effect level (Ontario) for total kjeldahl nitrogen (from Haines and others 1994) and converted from mg N/L to mg NO_3/L.
[m]Sediment quality criterion from British Columbia (Haines and others 1994).
[n]Maximum concentration value (tentative) from British Columbia for the protection of aquatic life (Haines and others 1994).
[o]Maximum concentration value (British Columbia) for total uranium (from Haines and others 1994), presented in contrast to the Tier II secondary chronic value.
– = No value available.

For plants, toxicity benchmarks are based primarily on the information provided in Efroymson and others (1997). These benchmarks are based on lowest-observed-adverse-effect levels (LOAELs) using 20 percent reduction in growth as the endpoint. Both the soil-based and solution-based benchmarks were used. Soil-based benchmarks were used to evaluate risk to wetland plants exposed to sediments, and solution-based benchmarks were used to evaluate potential risk to phreatophytes that may be in contact with ground water. Although based on LOAELs, these benchmarks are considered conservative. The endpoint is sublethal, and reductions in plant growth may have no significant effect on the reproductive potential or the continued existence of a plant population. Further, these benchmarks are primarily based on studies in which the chemical of interest is added freshly to a soil (often as a soluble salt) and is

typically more bioavailable than the COPCs in field situations where they have had time to bind more strongly with soil particles. Table 6–15 presents the plant toxicity benchmarks.

Table 6–15. Plant Toxicity Benchmarks for Ecological COPC

COPC	Plant Toxicity Benchmark[a]	
	Soil (mg/kg)	Solution (mg/L)
Arsenic	10	0.001
Barium	500	–
Boron	0.5	1.0
Iron	–	10
Manganese	500	4.0
Molybdenum	2.0	0.5
Nitrate	–	–
Selenium	1.0	0.7
Strontium	–	–
Sulfate	–	–
Uranium	5.0	40
Vanadium	2.0	0.2
Zinc	50	0.4

[a]From Efroymson and others (1997).
– = No benchmark available.

For the wildlife receptors, no-observed-adverse-effect levels (NOAELs) for chronic oral exposure are used as benchmarks for toxic effects. The endpoints of particular interest in this assessment are those associated with reproductive health, development, and mortality. Therefore, NOAELs are defined as the maximum dosage tested that produced no effect that would be considered adverse to the receptor's survival, growth, or reproductive capacity. Because the NOAELs for the wildlife receptor species are based on NOAELs from test species, the latter are scaled to NOAELs specific to the wildlife receptor species using a power function of the ratio of body weights, as described by Sample and others (1996) and Sample and Arenal (1999). This scaling is based on the equation

$$NOAEL_W = NOAEL_T \left(\frac{BW_T}{BW_W}\right)^s$$

where

$NOAEL_W$ = the no-observed-adverse-effect level for the wildlife receptor species (mg/kg-day),
$NOAEL_T$ = the no-observed-adverse-effect level for the test species (mg/kg-day),
BW_T = the body weight of the test species (kg),
BW_W = the body weight of the wildlife receptor species (kg), and
s = the body weight scaling factor; (s = 0.06 for mammals –0.2 for birds (Sample and Arenal 1999).

Toxicity studies were considered to be chronic if they were conducted over a period of 26 weeks (one-half year) or more. This period represents the period of seasonal use by migratory and hibernating species and is sufficient time for small animals to complete their reproductive cycles.

Studies of lesser duration (i.e., 1 to 25 weeks) are considered subchronic, unless they specifically included reproductive effects as endpoints (Sample and others 1996). When only subchronic oral $NOAEL_T$ values were available, these are converted to chronic $NOAEL_T$ values by applying an uncertainty factor of 0.1 (Sample and others 1996).

When only a chronic LOAEL value was available for test data, an uncertainty factor of 0.1 was used to convert it to the chronic $NOAEL_T$. If only a subchronic LOAEL was available, then an uncertainty factor of 0.01 was used to estimate the chronic $NOAEL_T$. This uncertainty factor is the product of two uncertainty factors of 0.1, one to convert the subchronic value to a chronic value and the other to convert the LOAEL to an NOAEL.

When possible, NOAELs for the wildlife receptor species are derived from test species that are taxonomically close to the target receptor. NOAELs were not determined if toxicity data could not be found for test species within the same class. Therefore, NOAELs for mammalian receptors are derived only from mammalian test species data and NOAELs for avian receptors are derived only from avian test species data. These data are presented in Table 6–16 and Table 6–17, respectively.

6.2.5 Risk Characterization

The potential for risk to ecological receptors is determined through HQs, which are specific to a particular receptor for exposure to a particular E-COPC. An HQ is defined by

$$HQ = \frac{Exposure}{Benchmark}$$

For aquatic and benthic organisms and plants, exposures are equivalent to media concentrations (surface water or sediment) with which the organism is in contact. For wildlife and livestock, exposures are modeled from multiple pathways by the methods described in Section 6.2.4.1. The methods for determining toxicity benchmark values for these receptors are discussed in Section 6.2.4.2.

The value of the HQ is greater than 1.0 if the magnitude of the exposure is greater than the corresponding benchmark, and conversely, the HQ is less than or equal to 1.0 if the exposure is less than or equal to the benchmark. An HQ value less than or equal to 1.0 is interpreted as evidence of no potential risk to that receptor for that E-COPC. If the HQs for an E-COPC are less than unity for all receptors, that E-COPC is eliminated from further consideration as a potential ecological risk driver. However, because exposure for the screening of E-COPCs is conservatively estimated, an HQ value greater than unity is not interpreted as evidence of risk, but only as evidence that the potential for risk cannot be ruled out.

For the purposes of this evaluation, potential exposures were conservatively based on the maximum measured E-COPC in each medium of ecological concern (surface water, sediment, and soil), as appropriate to each area. In addition, the UCL_{95} concentrations were used to calculate HQs that better reflect average (yet still conservatively estimated) risks to receptors in these areas. Measured concentrations of E-COPCs in wetland plants as presented in the BLRA (DOE 1995) were used in the calculation of exposures to herbivores when such data were available. Sections 6.2.5.1 through 6.2.5.5 are summaries of the risk assessment results for specific media and associated receptor groups.

Table 6–16. Mammal Toxicity Benchmarks for Ecological Contaminants of Potential Concern

Contaminant of Potential Concern	Mammalian Test Data[a]			Mammalian Receptor NOAELs (mg/kg-day)							
	Test Species	Body weight (kg)	NOAEL (mg/kg-day)	Deer mouse	Red fox	Mule deer	Elk	Muskrat	Raccoon	Horse	Cow
Arsenic	Rabbit	4.40	0.396	0.541	0.395	0.337	0.314	0.430	0.390	0.298	0.298
Barium	Rat	0.435	5.1	6.07	4.43	3.78	3.52	4.81	4.37	3.34	3.34
Boron	Rat	0.35	28.0	32.9	24.0	20.5	19.1	26.1	23.7	18.1	18.1
Iron	–	–	–	–	–	–	–	–	–	–	–
Manganese	Rat	0.35	88.0	103	75.5	64.3	60.0	82.0	74.4	56.9	56.9
Molybdenum	Mouse	0.03	0.26	0.264	0.192	0.164	0.153	0.209	0.190	0.145	0.145
Nitrate	Guinea pig	0.86	507	629	459	391	365	499	452	346	346
Selenium	Rat	0.35	0.20	0.235	0.171	0.146	0.136	0.186	0.169	0.129	0.129
Strontium	Rat	0.35	263	309	226	192	179	245	222	170	170
Sulfate	–	–	–	–	–	–	–	–	–	–	–
Uranium	Mouse	0.028	3.07	3.10	2.26	1.93	1.80	2.46	2.23	1.71	1.71
Vanadium	Rat	0.26	0.21	0.242	0.177	0.151	0.141	0.192	0.174	0.133	0.133
Zinc	Rat	0.35	160	188	137	117	109	149	135	103	103

[a]From Sample and others (1996).

Table 6–17. Avian Toxicity Benchmarks for Ecological Contaminants of Potential Concern

Contaminant of Potential Concern	Avian Test Data[a]			Avian Receptor NOAELs (mg/kg-day)			
	Test Species	Body weight (kg)	NOAEL (mg/kg-day)	Northern harrier	Mallard	Spotted sandpiper	Belted kingfisher
Arsenic	Mallard	1.0	5.14	3.65	5.27	2.73	3.50
Barium	Chicken	0.121	20.8	22.5	32.5	16.9	21.6
Boron	Mallard	1.0	28.8	20.4	29.5	15.3	19.6
Iron	–	–	–	–	–	–	–
Manganese	Japanese quail	0.072	977	1,170	1,700	879	1,130
Molybdenum	Chicken	1.5	3.53	2.31	3.34	1.73	2.22
Nitrate	–	–	–	–	–	–	–
Selenium	Mallard	1.0	0.40	0.284	0.410	0.213	0.273
Strontium	–	–	–	–	–	–	–
Sulfate	–	–	–	–	–	–	–
Uranium	Black duck	1.25	16.0	10.9	15.7	8.14	10.4
Vanadium	Mallard	1.17	11.4	7.84	11.3	5.87	7.53
Zinc	Chicken	1.935	14.5	9.02	13.0	6.76	8.66

[a]From Sample and others (1996).
– = no benchmark value available

6.2.5.1 Risk to Aquatic Community Receptors

Table–6–18 presents the comparison of water concentrations from the San Miguel River, from the seep and pond at location 0538, and from the alluvial aquifer to water quality benchmarks for the protection of aquatic life. The river and the pond data represent existing surface water features at the Naturita site that contain aquatic communities. The comparisons with the ground water data are presented to evaluate the potential for ecological risk if ground water were to be used to feed a surface pond. In all three cases, comparisons are made with both the maximum measured concentration and (when data allowed) the UCL_{95} or an estimated mean value. The UCL_{95} or mean value was not estimated when 50 percent or more of the data points were nondetections. For both the San Miguel River and ground water, sufficient data points were available to calculate the UCL_{95}, which was used as a conservative estimate of the sample mean. In the case of the pond location, only two sample points were available. Therefore, the midpoint between these two values (providing both were detections) was used as the estimate of the sample mean.

Maximum concentrations measured in surface water samples from the San Miguel River exceeded water quality benchmarks for barium, strontium, and sulfate. Although the HQ for barium was 23.1, those for strontium and sulfate were both less than 2. In all three cases, the UCL_{95} values were within the range of upstream (background) concentrations. Although the HQs for strontium and sulfate decreased to values less than 1 based on the UCL_{95} concentrations, the HQ for barium only decreased to 13.3. This indicates that the Tier II secondary chronic value (0.0039 mg/L) used as the benchmark for this element probably significantly overestimates the potential risk from barium exposure. Also, the maximum barium concentration (0.09 mg/L) is only slightly above the maximum upstream measured value of 0.08 mg/L. Overall, the risk to aquatic communities in the San Miguel River near the site is insignificant.

Table–6–18. Hazard Quotients for Aquatic Communities Based Upon Comparison of Water Concentrations to Water Quality Benchmarks for the Protection of Aquatic Life

Contaminant of Potential Concern	Water Quality Benchmark (mg/L)	San Miguel River Surface Water				Seep/Pond Surface Water				Ground water[a]			
		Maximum		UCL_{95}		Maximum		Mean		Maximum		UCL_{95}	
		Conc. (mg/L)	Hazard Quotient	Conc. (mg/L)	Hazard Quotient	Conc. (mg/L)	Hazard Quotient	Conc. (mg/L)	Hazard Quotient	Conc. (mg/L)	Hazard Quotient	Conc. (mg/L)	Hazard Quotient
Arsenic	0.10[b]	0.0017	0.0170	0.0009	0.00900	0.001	0.0100	0.001	0.0100	0.064	0.640	0.017	0.170
Barium	0.0039[c]	0.09	**23.1**	0.052[d]	**13.3**	Not a COPC for this area and medium				0.1	**25.6**	0.030[d]	**7.69**
Boron	0.75[b]	0.14	0.187	0.068[d]	0.0907	0.17	0.227	0.097	0.129	0.45	0.600	0.141	0.188
Iron	1.0[b]	0.48	0.480	NC	NA	0.22	0.220	NC	NA	2.03	**2.03**	0.51	0.510
Manganese	1.0[b]	0.78	0.780	NC	NA	1.76	**1.76**	1.01	**1.01**	2.06	**2.06**	0.99	0.990
Molybdenum	0.24[c]	Not a COPC for this area and medium				Not a COPC for this area and medium				0.16	0.667	0.046	0.192
Nitrate	10[b]	0.11	0.0110	NC	NA	Not a COPC for this area and medium				3.56	0.356	0.31	0.0310
Selenium	0.0046[b]	0.0018	0.391	0.0009[d]	0.196	0.002	0.435	NC	NA	0.014	**3.04**	0.002	0.435
Strontium	1.5[c]	1.74	**1.16**	1.13[d]	0.753	4.37	**2.91**	2.23	**1.49**	4.65	**3.10**	2.56	**1.71**
Sulfate	250[b]	459	**1.84**	237[d]	0.948	1,710	**6.84**	793	**3.17**	1,700	**6.80**	774	**3.10**
Uranium	1.5[b]	0.44	0.293	0.081	0.0540	1.06	0.707	0.51	0.340	2.49	**1.66**	0.91	0.607
Vanadium	0.019[c]	Not a COPC for this area and medium				Not a COPC for this area and medium				5.73	**302**	1.49	**78.4**
Zinc	0.118[b]	0.1	0.847	NC	NA	0.08	0.678	NC	NA	0.09	0.763	NC	NA

[a]Ground water comparisons are made to evaluate potential risk associated with the use of ground water in a surface pond.
[b]Colorado Department of Public Health and Environment Surface Water quality Standard for aquatic life.
[c]Tier II secondary chronic value from Suter and Tsao (1996).
[d]Concentration is within background range.

ND = Not detected.
NC = Not calculated (frequency of detection less than 50%).
NA = Not applicable.
COPC = Contaminant of potential concern.
Hazard quotient values in **bold** are greater than 1.

Surface water from the seep and pond at location 0538 had maximum and mean concentrations exceeding water quality benchmarks for manganese, strontium, and sulfate. For manganese, the maximum HQ was less than 2 and the HQ for the mean was nearly equal to 1, indicating that the potential for risk from exposure to this element is very small. Strontium and sulfate also had relatively low HQs for the mean concentrations at this location (1.49 and 3.17, respectively).

Maximum concentrations for ground water exceeded the water quality benchmarks for barium, iron, manganese, selenium, strontium, sulfate, uranium, vanadium, and zinc. All of these HQs except those for barium and vanadium were less than 7. Based on the UCL_{95} concentrations, only barium, strontium, sulfate, and vanadium had HQs greater than unity. As described for the San Miguel River, the HQs for barium are probably overestimated by the Tier II secondary chronic value used as the benchmark. The maximum concentration for barium (0.1 mg/L) is only slightly above the concentration range measured in the San Miguel River upstream of the site, and the UCL_{95} concentration was within this range. The concentrations (and consequent HQs) for strontium and sulfate in the ground water are similar to those in the seep and pond at location 0538. Vanadium concentration appears to be significantly elevated in the ground water and may be the limiting factor in the use of ground water to feed surface ponds.

6.2.5.2 Risk to Benthic Community Receptors

Table–6–19 presents a comparison of the combined sediment concentration data from the San Miguel River and seep/pond at location 0538 to the available sediment quality benchmarks. Comparisons are made with both the maximum measured concentrations and the UCL_{95}s. The maximum sediment concentrations measured at the Naturita site exceeded corresponding sediment quality benchmarks for manganese and zinc. In both cases, as indicated by the low HQ values, the exceedances were relatively low. The maximum manganese concentration in sediment was from a sample collected at the seep/pond location, where manganese concentration in water also slightly exceeded the corresponding benchmark value. However, neither of the HQs for these two elements exceeded unity when based on the UCL_{95} sediment concentrations. Overall, risk to benthic communities associated with the site is insignificant.

6.2.5.3 Risk to Plant Receptors

Table–6–20 presents a comparison of the sediment concentration data and the ground water data to the available soil-based and solution-based plant toxicity benchmarks, respectively. Comparisons are made with both the maximum measured concentration and the UCL_{95}s. The sediment-based comparison evaluates potential risk to wetland plants that are in direct contact with the near-surface sediments along the shorelines of the river and seep/pond. The ground-water-based comparison evaluates potential risk to phreatophytes on the floodplain of the river that are in direct contact with alluvial ground water.

The maximum sediment concentrations measured at the Naturita site exceeded corresponding plant toxicity benchmarks for boron, manganese, molybdenum, uranium, vanadium, and zinc. However, based on the UCL_{95} concentrations, only boron, vanadium, and zinc exceeded plant toxicity benchmarks. In all three cases, the plant benchmark was also less than the upstream (background) sediment concentration. Boron, had a maximum measured concentration of 5.83 mg/kg and a UCL_{95} of 4.98; the corresponding HQs were 11.7 and 9.96, respectively. The background concentration was 4.45 mg/kg, which would produce an HQ of 8.90. Therefore, the magnitude of potential risk to plants from boron in site sediments is probably exaggerated by

Table–6–19. Hazard Quotients for Benthic Communities Based on Comparison of Sediment Concentrations to Sediment Quality Benchmarks

Contaminant of Potential Concern	Sediment Quality Benchmark (mg/kg)	Sediment[a]			
		Maximum		UCL_{95}	
		Concentration (mg/kg)	Hazard Quotient	Concentration (mg/kg)	Hazard Quotient
Arsenic	5.9	2.83	0.480	2.17	0.368
Barium	–	97	–	87	–
Boron	–	5.83	–	4.98	–
Iron	188,400	3,519	0.0187	2,948	0.0156
Manganese	630	721	**1.14**	459	0.729
Molybdenum	4.0	2.19	0.548	1.03	0.258
Nitrate	2,440	Not a COPC for this medium			
Selenium	5.0	0.27	0.0540	0.24	0.0480
Strontium	–	195	–	174	–
Sulfate	–	2,464	–	1,785	–
Uranium	–	12.5	–	4.29	–
Vanadium	–	9.54	–	5.90[b]	–
Zinc	123.1	171	**1.39**	121	0.983

[a]Sediment data are combined for the San Miguel River and the seep/pond location.
[b]Concentration is within background range.

– = No benchmark value available.
COPC = Contaminant of potential concern.
Hazard quotient values in **bold** are greater than 1.

the plant benchmark value. Similarly, the UCL_{95} of zinc (121 mg/kg) is only slightly above the background concentration value of 117 mg/kg, and that for vanadium is less than its corresponding background value of 6.56 mg/kg. Overall, the risk to wetland plants rooted in the near-surface sediments at the Naturita site is insignificant.

The maximum and UCL_{95} ground water concentrations measured at the Naturita site exceeded corresponding solution-based plant toxicity benchmarks for arsenic and vanadium. In both cases, the background concentration ranges for ground water were less than the corresponding plant benchmark. Therefore, contact with contaminated ground water at this site may pose a risk to phreatophytic plants growing on the floodplain.

6.2.5.4 Risk to Wetland Wildlife Receptors

Table–6–21 and Table–6–22 present the hazard quotients for the five wetland wildlife receptors based on exposures to E-COPCs in various media (surface water, sediment, and food) associated with the San Miguel River and seep/pond area, respectively. As available, exposures were estimated on the basis of maximum measured concentrations in each medium and the UCL_{95}s for each medium. Surface water and vegetation data were specific to the two areas. The sediment data used in the exposure estimations were combined as a single unit. Because only one vegetation sample was collected from the pond area, the same data were used in both the maximum and UCL_{95} exposure estimates for this area. Plant concentrations estimated from the sediment concentrations were used when no site-specific plant data were available.

Table–6–20. Hazard Quotients for Plants Based on Comparison of Sediment and Ground Water Concentrations to Plant Toxicity Benchmarks

Contaminant of Potential Concern	Soil-based Plant Benchmark (mg/kg)	Sediment				Solution-based Plant Benchmark (mg/L)	Ground water[a]			
		Maximum		UCL_{95}			Maximum		UCL_{95}	
		Conc. (mg/kg)	Hazard Quotient	Conc. (mg/kg)	Hazard Quotient		Conc. (mg/L)	Hazard Quotient	Conc. (mg/L)	Hazard Quotient
Arsenic	10	2.83	0.283	2.17	0.217	0.001	0.064	**64.0**	0.017	**17.0**
Barium	500	97	0.194	87	0.174	8.33	0.1	0.0120	0.030[b]	0.00360
Boron	0.5	5.83	**11.7**	4.98	**9.96**	1.0	0.45	0.450	0.141	0.141
Iron	–	3,519	–	2,948	–	10	2.03	0.203	0.51	0.0510
Manganese	500	721	**1.44**	459	0.918	4.0	2.06	0.515	0.99	0.248
Molybdenum	2.0	2.19	**1.10**	1.03	0.515	0.5	0.16	0.320	0.046	0.0920
Nitrate	–	Not a COPC for this area and medium				–	3.56	–	0.31	–
Selenium	1.0	0.27	0.270	0.24	0.240	0.7	0.014	0.0200	0.002	0.00286
Strontium	–	195	–	174	–	–	4.65	–	2.56	–
Sulfate	–	2,464	–	1,785	–	–	1,700	–	774	–
Uranium	5.0	12.5	**2.50**	4.29	0.858	40	2.49	0.0623	0.91	0.0228
Vanadium	2.0	9.54	**4.77**	5.90[b]	**2.95**	0.2	5.73	**28.7**	1.49	**7.45**
Zinc	50	171	**3.42**	121	**2.42**	0.4	0.09	0.225	NC	NA

[a]Ground water comparisons are made to evaluate potential risk to deep-rooted plants (phreatophytes) in direct contact with ground water.
[b]Concentration is within background range.

– = No plant toxicity benchmark available.
NC = Not calculated (frequency of detection less than 50%).
NA = Not applicable.
COPC = Contaminant of potential concern.
Hazard quotient values in **bold** are greater than 1.

Table–6–21. Hazard Quotients for Wetland Wildlife Along the San Miguel River[a]

Contaminant of Potential Concern	Muskrat		Raccoon		Mallard		Spotted Sandpiper		Belted Kingfisher	
	Maximum	UCL_{95}	Maximum	UCL_{95}	Maximum	UCL_{95}	Maximum	UCL_{95}	Maximum	UCL_{95}
Arsenic	**1.61**	**1.17**	0.556	0.404	0.0894	0.0650	0.0275	0.0198	0.00437	0.00265
Barium	0.336	0.301	0.178	0.158	0.0264	0.0236	0.126	0.112	0.0132	0.0101
Boron	0.0627	0.0534	0.0218	0.0183	0.0378	0.0321	0.0107	0.00820	0.00342	0.00185
Iron	–	–	–	–	–	–	–	–	–	–
Manganese	0.526	0.406	0.221	0.150	0.0166	0.0129	0.0244	0.0111	0.00540	0.000708
Molybdenum	0.717	0.397	0.267	0.145	0.0293	0.0164	0.0270	0.0127	0.00172	0.000807
Nitrate	0.0000216	NC	0.0000312	NC	–	–	–	–	–	–
Selenium	0.339	0.200	0.215	0.120	0.111	0.0644	0.298	0.159	0.270	0.136
Strontium	0.0543	0.0439	0.0240	0.0190	–	–	–	–	–	–
Sulfate	–	–	–	–	–	–	–	–	–	–
Uranium	0.271	0.194	0.357	0.115	0.0309	0.0210	0.215	0.0448	0.345	0.0638
Vanadium	**11.6**	**10.4**	**3.95**	**3.48**	0.134	0.120	0.0346	0.0214	0.00220	0.00136
Zinc	0.0456	0.0367	0.0419	0.0145	0.371	0.266	**2.52**	0.381	0.779	0.0243

[a]Exposure media include surface water specific to the San Miguel River, sediment from all potentially contaminated areas, and vegetation. Vegetation concentrations were based on site-specific data when available or were estimated from sediment concentrations.

– = No toxicity benchmark available.
NC = UCL not calculated (frequency of detection less than 50%).
Hazard quotient values in **bold** are greater than 1.

Table–6–22. Hazard Quotients for Wetland Wildlife at the Seep/Pond Area[a]

Contaminant of Potential Concern	Muskrat		Raccoon		Mallard		Spotted Sandpiper		Belted Kingfisher	
	Maximum	UCL_{95}	Maximum	UCL_{95}	Maximum	UCL_{95}	Maximum	UCL_{95}	Maximum	UCL_{95}
Arsenic	**7.80**	**7.79**	**2.57**	**2.56**	0.438	0.438	0.0253	0.0201	0.00315	0.00282
Barium	0.335	0.300	0.175	0.154	0.0263	0.0235	0.124	0.110	0.0102	0.00699
Boron	0.0628	0.0535	0.0219	0.0185	0.0378	0.0322	0.0113	0.00874	0.00404	0.00245
Iron	–	–	–	–	–	–	–	–	–	–
Manganese	**1.92**	**1.90**	0.704	0.666	0.0635	0.0631	0.0332	0.0201	0.0108	0.00625
Molybdenum	0.899	0.845	0.433	0.291	0.0376	0.0357	0.0582	0.0127	0.0570	0.000807
Nitrate	0.0000039	NC	0.0000057	NC	–	–	–	–	–	–
Selenium	0.339	0.337	0.226	0.114	0.111	0.104	0.328	0.0240	0.300	0.00153
Strontium	0.0401	0.0387	0.0251	0.0197	–	–	–	–	–	–
Sulfate	–	–	–	–	–	–	–	–	–	–
Uranium	0.683	0.640	0.848	0.507	0.0807	0.0728	0.472	0.223	0.827	0.398
Vanadium	**19.8**	**19.7**	**37.8**	**6.5**	0.285	0.229	**2.45**	0.0214	**4.71**	0.00136
Zinc	0.0456	0.0367	0.0372	0.0145	0.362	0.266	**2.12**	0.381	0.630	0.0243

[a]Exposure media include surface water specific to the seep and pond near location 0538, sediment from all potentially contaminated areas, and vegetation. Vegetation
concentrations were based on site-specific data when available or were estimated from sediment concentrations.

– = No toxicity benchmark available.
NC = UCL not calculated (frequency of detection less than 50%).
Hazard quotient values in b**old** are greater than 1.

Table–6–23. Hazard Quotients for Terrestrial Wildlife and Livestock from Drinking Water Along the San Miguel River[a]

Contaminant of Potential Concern	Deer Mouse		Red Fox		Mule Deer		Elk		Northern Harrier		Horse		Cow	
	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}
Arsenic	4.52E-04	2.39E-04	3.66E-04	1.94E-04	3.29E-04	1.74E-04	3.14E-04	1.66E-04	4.84E-05	2.56E-05	3.03E-04	1.61E-04	6.84E-04	3.62E-04
Barium	2.13E-03	1.23E-03	1.73E-03	9.99E-04	1.55E-03	8.98E-04	1.48E-03	8.57E-04	4.15E-04	2.40E-04	1.43E-03	8.28E-04	3.23E-03	1.87E-03
Boron	6.12E-04	2.97E-04	4.96E-04	2.41E-04	4.46E-04	2.17E-04	4.26E-04	2.07E-04	7.12E-04	3.46E-04	4.11E-04	2.00E-04	9.28E-04	4.51E-04
Iron	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Manganese	1.09E-03	NC	8.80E-04	NC	7.91E-04	NC	7.55E-04	NC	6.91E-05	NC	7.29E-04	NC	1.64E-03	NC
Molybdenum	Not a COPC for this medium and location													
Nitrate	2.52E-05	NC	2.04E-05	NC	1.83E-05	NC	1.75E-05	NC	–	–	1.69E-05	NC	3.81E-05	NC
Selenium	1.10E-03	5.51E-04	8.93E-04	4.47E-04	8.03E-04	4.02E-04	7.66E-04	3.83E-04	6.59E-04	3.29E-04	7.40E-04	3.70E-04	1.67E-03	8.35E-04
Strontium	8.10E-04	5.26E-04	6.57E-04	4.26E-04	5.90E-04	3.83E-04	5.63E-04	3.66E-04	–	–	5.44E-04	3.53E-04	1.23E-03	7.97E-04
Sulfate	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Uranium	2.04E-02	3.76E-03	1.66E-02	3.05E-03	1.49E-02	2.74E-03	1.42E-02	2.61E-03	4.21E-03	7.75E-04	1.37E-02	2.52E-03	3.09E-02	5.70E-03
Vanadium	Not a COPC for this medium and location													
Zinc	7.65E-05	NC	6.20E-05	NC	5.58E-05	NC	5.32E-05	NC	1.15E-03	NC	5.14E-05	NC	1.16E-04	NC

[a]Exposure limited to surface water specific to the San Miguel River.

– = No toxicity benchmark available.
NC = UCL not calculated (frequency of detection less than 50%).

Table–6–24. Hazard Quotients for Terrestrial Wildlife and Livestock from Drinking Water at the Seep/Pond Area[a]

Contaminant of Potential Concern	Deer Mouse		Red Fox		Mule Deer		Elk		Northern Harrier		Horse		Cow	
	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}
Arsenic	2.66E-04	2.66E-04	2.15E-04	2.15E-04	1.94E-04	1.94E-04	1.85E-04	1.85E-04	2.85E-05	2.85E-05	1.78E-04	1.78E-04	4.03E-04	4.03E-04
Barium	Not a COPC for this medium and location													
Boron	7.43E-04	4.24E-04	6.03E-04	3.44E-04	5.42E-04	3.09E-04	5.17E-04	2.95E-04	8.64E-04	4.93E-04	4.99E-04	2.85E-04	1.13E-03	6.43E-04
Iron	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Manganese	2.45E-03	1.41E-03	1.98E-03	1.14E-03	1.78E-03	1.02E-03	1.70E-03	9.77E-04	1.56E-04	8.94E-05	1.64E-03	9.44E-04	3.71E-03	2.13E-03
Molybdenum	Not a COPC for this medium and location													
Nitrate	Not a COPC for this medium and location													
Selenium	1.22E-03	NC	9.92E-04	NC	8.92E-04	NC	8.51E-04	NC	7.32E-04	NC	8.22E-04	NC	1.86E-03	NC
Strontium	2.03E-03	1.04E-03	1.65E-03	8.42E-04	1.48E-03	7.57E-04	1.41E-03	7.22E-04	–	–	1.37E-03	6.97E-04	3.08E-03	1.57E-03
Sulfate	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Uranium	4.92E-02	2.37E-02	3.99E-02	1.92E-02	3.58E-02	1.72E-02	3.42E-02	1.65E-02	1.01E-02	4.88E-03	3.30E-02	1.59E-02	7.46E-02	3.59E-02
Vanadium	Not a COPC for this medium and location													
Zinc	6.12E-05	NC	4.96E-05	NC	4.46E-05	NC	4.26E-05	NC	9.22E-04	NC	4.11E-05	NC	9.28E-05	NC

[a]Exposure limited to surface water specific to the seep and pond near location 0538.

– = No toxicity benchmark available.
NC = UCL not calculated (frequency of detection less than 50%).

Table–6–25. Hazard Quotients for Terrestrial Wildlife and Livestock from Drinking Pumped Ground Water[a]

Contaminant of Potential Concern	Deer Mouse		Red Fox		Mule Deer		Elk		Northern Harrier		Horse		Cow	
	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}	Max.	UCL_{95}
Arsenic	1.70E-02	4.52E-03	1.38E-02	3.66E-03	1.24E-02	3.29E-03	1.18E-02	3.14E-03	1.82E-03	4.84E-04	1.14E-02	3.03E-03	2.58E-02	6.84E-03
Barium	2.37E-03	7.11E-04	1.92E-03	5.76E-04	1.73E-03	5.18E-04	1.65E-03	4.94E-04	4.61E-04	1.38E-04	1.59E-03	4.77E-04	3.59E-03	1.06E-03
Boron	1.97E-03	6.16E-04	1.60E-03	5.00E-04	1.43E-03	4.49E-04	1.37E-03	4.29E-04	2.29E-03	7.17E-04	1.32E-03	4.14E-04	2.98E-03	9.34E-04
Iron	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Manganese	2.87E-03	1.38E-03	2.32E-03	1.12E-03	2.09E-03	1.00E-03	1.99E-03	9.58E-04	1.82E-04	8.77E-05	1.92E-03	9.25E-04	4.34E-03	2.09E-03
Molybdenum	8.73E-02	2.51E-02	7.08E-02	2.03E-02	6.36E-02	1.83E-02	6.07E-02	1.75E-02	7.20E-03	2.07E-03	5.86E-02	1.69E-02	1.32E-01	3.80E-02
Nitrate	8.14E-04	7.09E-05	6.60E-04	5.75E-05	5.94E-04	5.17E-05	5.66E-04	4.93E-05	–	–	5.47E-04	4.76E-05	1.23E-03	1.07E-04
Selenium	8.57E-03	1.22E-03	6.95E-03	9.92E-04	6.25E-03	8.92E-04	5.96E-03	8.51E-04	5.12E-03	7.32E-04	5.76E-03	8.22E-04	1.30E-02	1.86E-03
Strontium	2.16E-03	1.19E-03	1.[illegible]E-03	9.66E-04	1.58E-03	8.68E-04	1.51E-03	8.29E-04	–	–	1.45E-03	8.00E-04	3.28E-03	1.81E-03
Sulfate	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Uranium	1.16E-01	4.22E-02	9.37E-02	3.42E-02	8.42E-02	3.08E-02	8.03E-02	2.94E-02	2.38E-02	8.71E-03	7.76E-02	2.84E-02	1.75E-01	6.40E-02
Vanadium	**3.40E+00**	8.84E-01	**2.76E+00**	7.17E-01	**2.48E+00**	6.44E-01	**2.36E+00**	6.15E-01	7.59E-02	1.97E-02	**2.28E+00**	5.94E-01	**5.15E+00**	**1.34E+00**
Zinc	6.89E-05	NC	5.58E-05	NC	5.02E-05	NC	4.79E-05	NC	1.04E-03	NC	4.63E-05	NC	1.04E-04	NC

[a]Exposure limited to ground water under the assumption that is it pumped to the surface and made available to livestock and wildlife.

– = No toxicity benchmark available.
NC = UCL not calculated (frequency of detection less than 50%).
Hazard quotient values in **bold** are greater than 1.

Potential Risks from Radionuclides

Potential risks from radionuclides were evaluated using the screening-level benchmarks for aquatic biota (specifically large and small fish) derived for Oak Ridge National Laboratory (Bechtel Jacobs 1998b), based on the methodology for estimating dose rates for aquatic biota developed by Blaylock and others (1993). Radiological analyses in surface water and ground water samples from the Naturita site between 1989 and 1994 have included four uranium-238 daughters (radium-226, thorium-230, lead-210, and polonium-210), as well as radium-228. As shown in Table 6–26, these five radionuclides have been identified as E-COPCs in the San Miguel River surface water, and all except radium-228 have been identified as E-COPCs in the ground water (based on comparisons to background or upstream sample results). Table 6–26 presents the comparison (as HQs) of the maximum concentrations of these radionuclides to their screening benchmark values. Although no benchmark was available for radium-228, it is clear from the HQs for the other radiological COPCs that doses to aquatic biota (specifically to fish) from uranium-238 daughters at the Naturita site are negligible.

Table 6–26. Hazard Quotients for Radiological E-COPCs

COPC	Surface Water (San Miguel River)			Ground Water		
	Benchmark Value[a] (pCi/L)[b]	Maximum Measured Activity (pCi/L)	Hazard Quotient	Benchmark Value[a] (pCi/L)[b]	Maximum Measured Activity (pCi/L)	Hazard Quotient
Lead-210	30,600	1.2	3.92×10^{-5}	30,600	13.5	4.41×10^{-4}
Polonium-210	725	ND	–	725	4.5	0.00620
Radium-226	160	0.6	0.00375	160	28.6	0.17
Radium-228	NB	23	NB	Not an E-COPC for ground water		
Thorium-230	413	0.5	0.00121	413	0.9	0.00218

[a]Benchmark is the minimum for large and small fish (from Bechtel Jacobs 1998b)
[b]Picocuries per liter
NB = No benchmark available
ND = Not detected

Potential Risks to Sensitive Species

As stated in Section 6.2.2.1, the endangered southwestern willow flycatcher has the potential for occurring in the riparian habitat along the San Miguel River at or near the Naturita site. The diet of this species consists principally of flying insects, at least some of which possibly are being exposed to water or sediment at the site during their development. The spotted sandpiper, modeled as having a diet consisting entirely of invertebrates exposed to surface water at either the San Miguel River or the seep/pond area, conservatively represents potential exposure and risk to the southwestern willow flycatcher, should it occur at the site. Because the HQs for the spotted sandpiper are low at both of these areas (maximum HQs not exceeding 3, and all HQs based on the UCL_{95} concentration or mean concentration being less than unity), the potential for risk to the southwestern willow flycatcher is also expected to be very low.

Ecological Risk Summary

For the purpose of summarization, the receptors are categorized into six groups: aquatic organisms, benthic organisms, upland plants, wetland plants, terrestrial wildlife and livestock, and wetland wildlife. Further, the potential risk to each group based on the HQs was categorized as follows:

- None: HQs are less than or equal to 1 for both the maximum and UCL_{95} concentrations.
- Very low: Maximum HQs are less than 10 but greater than 1; UCL_{95}-based HQs are less than 1.
- Low: Both maximum and UCL_{95}-based HQs are less than 10, but greater than 1.
- Medium-Low: Maximum HQ is greater than or equal to 10 but less than 100; UCL_{95}-based HQs are less than 10.
- Medium: Both maximum and UCL_{95}-based HQs are greater than or equal to 10 but less than 100.
- High: Maximum HQ is greater than or equal to 100 but less than 1,000; UCL_{95}-based HQs are greater than 10.
- Very high: Maximum HQs are greater than or equal to 1,000.

Table 6–27 presents the results of this categorization of potential risk. In the cases where multiple receptors are included in the receptor group (i.e., the terrestrial and wetland wildlife groups), the risk is based on the highest worst-case risk result among the receptors. Because many conservatisms were incorporated in the calculation of these HQs, including the use of maximum and UCL_{95} values as exposure point concentrations, the use of conservative toxicity benchmarks, such as water quality criteria and NOAELs, and the assumption of 100 percent area and seasonal use, the HQs are expected to overestimate actual risk to most individual receptors, and therefore, risks categorized as medium-low to none are not expected to represent significant potential risks to populations of nonsensitive species. However, for those receptor groups that may include sensitive species, risk categorizations of medium-low to low are still considered to be of concern.

In the San Miguel River, the highest potential ecological risk may be associated with barium in surface water. However, the maximum concentration of barium measured in surface water from the river at the site (0.09 mg/L) only slightly exceeded the maximum concentration measured at the upstream reference location (0.08 mg/L). The latter concentration also exceeded the Tier II value that was used as the benchmark for potential risk (0.0016 mg/L). Therefore, a similar level of risk would be predicted for the reference area as was predicted for the site. For this reason, it is highly likely that the Tier II value for barium is highly conservative and overestimates potential risk to aquatic receptors, and it is likely that barium in the river water is not significantly above background levels.

Table 6–27. Summary of Potential Ecological Risks at the Naturita Site[a]

COPC	Aquatic Organisms	Benthic Organisms	Deep-Rooted Plants	Wetland Plants	Terrestrial Wildlife and Livestock	Wetland Wildlife
(principal exposure media)	surface water	sediment	ground water	sediment	ground water	surface water sediment food
San Miguel River						
Arsenic	none	none	NA	none	none	low
Barium	medium	–	NA	none	none	none
Boron	none	–	NA	medium-low	none	none
Iron	none	none	NA	–	–	–
Manganese	none	very low	NA	very low	none	none
Molybdenum	NA	none	NA	very low	NA	none
Nitrate	none	NA	NA	NA	none[b]	none[b]
Selenium	none	none	NA	none	none	none
Strontium	very low	–	NA	–	none[b]	none[b]
Sulfate	very low	–	NA	–	–	–
Uranium	none	–	NA	very low	none	none
Vanadium	NA	–	NA	low	NA	low
Zinc	none	very low	NA	low	none	very low
Seep/Pond						
Arsenic	none	none	NA	none	none	low
Barium	NA	–	NA	none	NA	none
Boron	none	–	NA	medium-low	none	none
Iron	none	none	NA	–	–	–
Manganese	low	very low	NA	very low	none	low
Molybdenum	NA	none	NA	very low	NA	none
Nitrate	NA	NA	NA	NA	NA	none[b]
Selenium	none	none	NA	none	none	none
Strontium	low	–	NA	–	none[b]	none[b]
Sulfate	low	–	NA	–	–	–
Uranium	none	–	NA	very low	none	none
Vanadium	NA	–	NA	low	NA	medium
Zinc	none	very low	NA	low	none	very low
Ground Water						
Arsenic	none	NA	medium	NA	none	NA
Barium	medium-low	NA	none	NA	none	NA
Boron	none	NA	none	NA	none	NA
Iron	very low	NA	none	NA	–	NA
Manganese	very low	NA	none	NA	none	NA
Molybdenum	–	NA	none	NA	none	NA
Nitrate	none	NA	–	NA	none[b]	NA
Selenium	very low	NA	none	NA	none	NA
Strontium	low	NA	–	NA	none[b]	NA
Sulfate	low	NA	–	NA	–	NA
Uranium	very low	NA	none	NA	none	NA
Vanadium	high	NA	medium-low	NA	low	NA
Zinc	none	NA	none	NA	none	NA

[a]See text for definition of risk categories.
[b]Avian benchmark not available. Risk based on mammalian receptors only.
– = No hazard quotients available
NA = Not applicable to this area

For the seep/pond area at sampling location 0538, the potential exposure of wetland wildlife to vanadium is the principal ecological risk concern. This is primarily due to the risks predicted for the two mammalian receptors, the muskrat and raccoon. Vanadium was also the primary risk driver associated with ground water if it were to be pumped to a surface pond. In addition, the levels of arsenic in ground water may adversely affect deep-rooted plants on the floodplain area.

Risks were considered low if all HQs based on maximum concentrations were less than 10, very low if all HQs based on UCL_{95} concentrations were less than 1, and none if all HQs (based on maximum and UCL_{95} concentrations) were less than 1. E-COPCs showing no or very low risk are dropped from further consideration, and those with low risks are also dropped provided that the receptors showing the low risk do not include or represent potential risks to endangered or threatened species. Because conservative assumptions and values have been incorporated into the exposure models and toxicity benchmarks, HQs are expected to overestimate the actual risks posed by these E-COPCs. Therefore, HQs less than 10 are expected to be protective of populations and communities, but may not be protective of individuals in the cases where threatened or endangered species may be exposed. Of the E-COPCs that have HQs greater than 10, barium at the San Miguel River and boron are only marginally above background levels, and risk may be exaggerated by the corresponding benchmark values used in the assessment. Incremental risks above background posed by these constituents are insignificant; therefore further monitoring is not warranted. Vanadium in the ground water, which may be reflected in the seep/pond area, is the principal constituent of ecological concern at the Naturita site. High arsenic concentrations in ground water are also of concern with respect to potential effects on plants. Continued monitoring of vanadium and arsenic is recommended. The potential for risk to the endangered southwestern willow flycatcher is considered to be very low at this site; exposures to vanadium and zinc are of primary concern for this species.

7.0 Ground Water Compliance Strategy

7.1 Compliance Strategy Selection Process

The framework defined in the PEIS (DOE 1996) governs selection of the strategy to achieve compliance with EPA ground water standards. Stakeholder review of the final PEIS is documented and supported by the Record of Decision (Federal Register [FR] v. 62, No. 81, 1997). Figure 7–1 and Figure 7–2 present summaries of the framework used to determine the appropriate ground water compliance strategies for the Naturita site. The framework considers human health and environmental risk, stakeholder input, and cost. A step-by-step approach in the PEIS results in the selection of one of three general compliance strategies:

- *No remediation*—Compliance with the EPA ground water protection standards would be met without altering the ground water or cleaning it up in any way. This strategy could be applied for those constituents at or below maximum concentration limits (MCLs) or background levels or for those constituents above MCLs or background levels that qualify for supplemental standards or ACLs, as defined in Section 2.2 of this SOWP, "EPA Ground Water Protection Standards."

- *Natural flushing*—This strategy would allow natural ground water movement and geochemical processes to decrease contaminant concentrations to regulatory limits. The natural flushing strategy can be applied where ground water compliance could be achieved within 100 years, where effective monitoring and institutional controls can be maintained, and where the ground water is not currently and is not projected to be a source for a public water system.

- *Active ground water remediation*—This strategy would require engineered ground water remediation methods such as gradient manipulation, ground water extraction and treatment, land application, phytoremediation, and in situ ground water treatment to achieve compliance with EPA standards.

7.2 Naturita PEIS Compliance Selection Framework Analysis

The UMTRA Project regulations provide for several ways to comply with the ground water protection standards for Subpart B of 40 CFR 192.12(c). These include meeting the provisions of 40 CFR 192.02(c)(3) or a supplemental standard established under 40 CFR 192.22. The provisions of 40 CFR 192.02(c)(3) include: (1) the background level of the constituent in ground water; (2) the MCL for any constituents listed in Table 1 to Subpart A; or (3) an ACL established pursuant to paragraph (c)(3)(ii) of that section.

Section 6.0 established arsenic, uranium, and vanadium as the COPCs for the Naturita site. Section 6.3 summarizes this evaluation and provides explanations for eliminating other constituents. Only the final COPCs for the Naturita site are discussed further in this section.

Proposed Compliance Strategies for the Naturita Site

Two compliance strategies are proposed for the Naturita site.

- Natural flushing with application of institutional controls (ICs) and monitoring for arsenic.

- No remediation and the application of ACLs, ICs, and monitoring for uranium and vanadium.

Figure 7–1 and Table 7–1 for arsenic and Figure 7–2 and Table 7–2 for uranium and vanadium show these strategies as outlined by the PEIS framework.

7.3 Detailed Explanation of Compliance Strategies

7.3.1 Natural Flushing for Arsenic with Institutional Controls

Arsenic presents only a marginal risk because of its limited extent. However, because it is highly toxic to organisms in small quantities, it has been retained as a COPC. Only two ground water locations, NAT03 at 0.052 mg/L and NAT08 at 0.057 mg/L, contain average arsenic levels above the UMTRA MCL of 0.05 mg/L, although levels at location NAT11 rose to 0.052 during the February 2001 sampling event. The area with elevated arsenic concentrations is within the vanadium and uranium plumes. It is also located beneath the former tailings pile and is considered to be milling-related contamination. The plume map for arsenic (Figure 7–3) shows a very small area where the concentration is thought to be above the MCL. Time/concentration graphs of nearby wells, now abandoned, show relatively low levels of arsenic (around 0.01 mg/L) until 1997 and 1998, when the concentrations increased to a maximum of 0.04 mg/L and decreased back to 0.01 mg/L (Figure 7–4). The time/concentration plots for vanadium and, to a lesser degree, uranium show similar trends (Figure 7–5). The increased concentrations in ground water occurred during or just after surface remedial action and are thought to be related to mobilization of constituents during this disturbance. Therefore, arsenic concentrations in the small plume area may decrease to pre-surface remediation concentrations over the next few years to levels below MCLs.

To quantify this assumption, modeling of arsenic was also performed. Ground water flow is toward the north to northeast in this area, and application of MODFLOW software indicates that transport and attenuation of arsenic to levels below 0.05 mg/L will occur in approximately 10 years, well within the 100-year period allowed for natural flushing. Even if the flushing action is inhibited by extraction of ground water at the upgradient gravel mining operation, the arsenic plume is so limited in size and the 100-year timeframe is long enough that natural flushing should achieve cleanup goals. The future monitoring will be ongoing until cleanup objectives are met. The current plume for arsenic will probably flow northeast toward the San Miguel River before concentrations decrease to acceptable levels. Contamination will not leave the site area during the flushing period but should dissipate to levels below the MCL before entering the San Miguel River. Proposed ICs for the site will ensure safety to humans and the environment during this period.

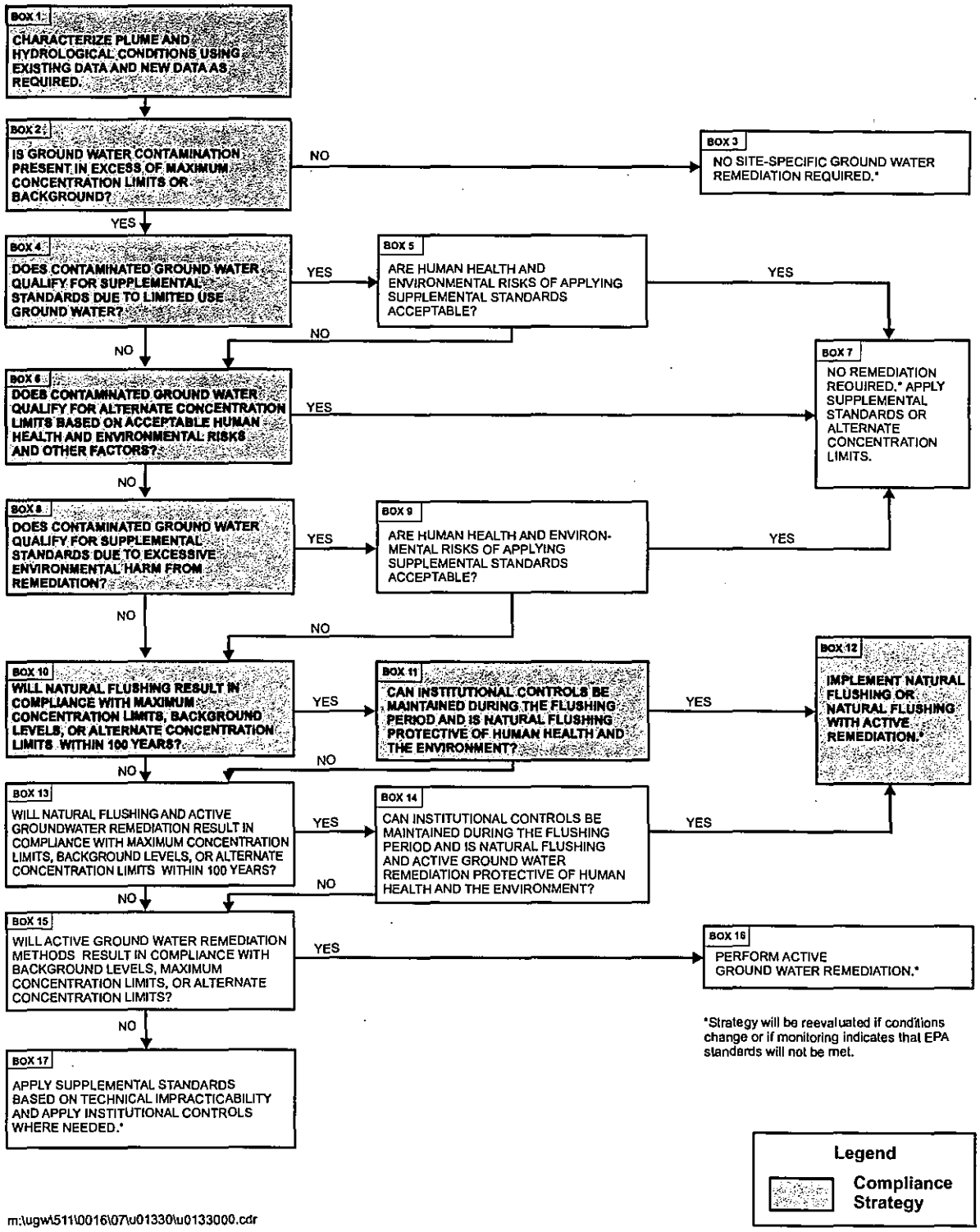

Figure 7–1. Summary of Natural Flushing Compliance Strategy for Arsenic in Ground Water.

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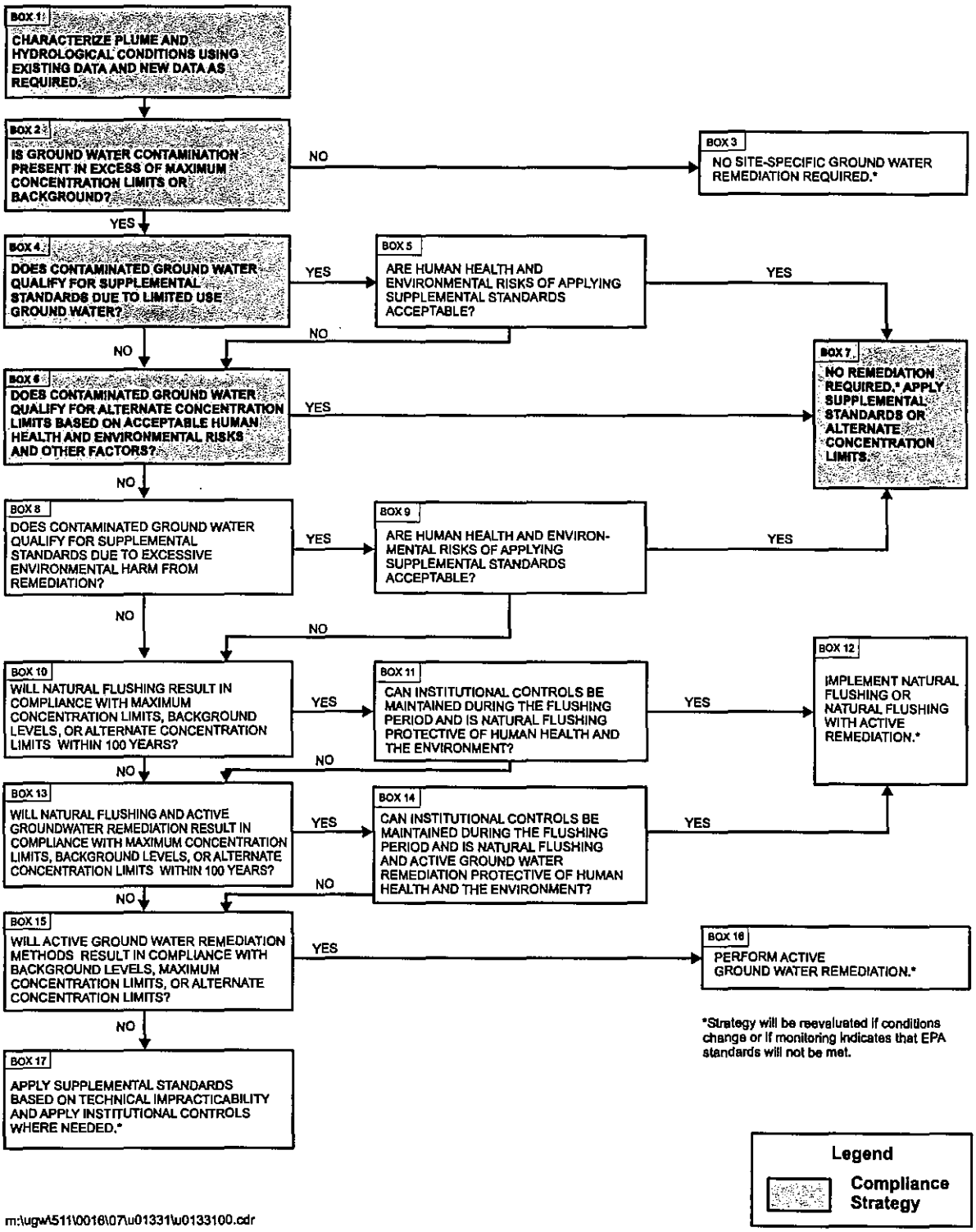

Figure 7–2. Summary of No Remediation Compliance Strategy and Application of Alternate Concentration Limits for Uranium and Vanadium in Ground Water.

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Table 7–1. Explanation of the Natural Flushing Strategy for Arsenic at the Naturita Site

Box Figure 7–1	Action or Question	Result of Decision
Box 1	Characterize plume and hydrologic conditions.	See Site Conceptual Model in Section 5. Move to Box 2.
Box 2	Is ground water contamination present in excess of UMTRA MCLs or background?	Arsenic concentration exceeds UMTRA MCLs or risk based concentrations. Move to Box 4.
Box 4	Does ground water qualify for supplemental standards due to limited use ground water?	Alluvial ground water does not meet any criteria for limited use. Move to Box 6.
Box 6	Does ground water qualify for ACLs based on acceptable human health and environmental risks and other factors?	Because the ground water is not currently being used, ACLs would be protective. However, since arsenic will naturally flush, it is not being carried through the ACL process. Move to Box 8.
Box 8	Does contaminated ground water qualify for supplemental standards due to excessive environmental harm from remediation?	No. Move to Box 10.
Box 10	Will natural flushing result in compliance with UMTRA MCLs, background, or ACLs within 100 years?	Ground water modeling shows that arsenic will flush to concentrations below the UMTRA MCL within 100 years. Move to Box 11.
Box 11	Can institutional controls be maintained during the flushing period and is the compliance strategy protective of human health and the environment?	The final compliance strategy is protective of human health and the environment. Institutional controls will be in place soon and will prevent the use of ground water for human consumption. After 100 years, ground water will have levels of arsenic that will be below UMTRA MCLs. Move to Box 12 and implement natural flushing for arsenic.
Box 12		Implement natural flushing for arsenic.

Table 7–2. Explanation of the No Remediation Compliance Strategy and Application of Alternate Concentration Limits for Uranium and Vanadium at the Naturita Site

Box Figure 7–2	Action of Question	Result of Decision
Box 1	Characterize plume and hydrologic conditions.	See Site Conceptual Model in Section 5. Move to Box 2.
Box 2	Is ground water contamination present in excess of UMTRA MCLs or background?	Uranium, and vanadium concentrations exceed UMTRA MCLs or risk based concentrations. Move to Box 4.
Box 4	Does ground water qualify for supplemental standards due to limited use ground water?	Alluvial ground water does not meet any criteria for limited use. Move to Box 6.
Box 6	Does ground water qualify for ACLs based on acceptable human health and environmental risks and other factors?	Yes. No one is currently using the water for any purpose. Institutional controls can be placed on affected ground water to prohibit improper use in perpetuity. Move to Box 7.
Box 7		No remediation required. Apply supplemental standards or alternate concentration limits. Action levels for U = 3 mg/L, for V = 6 mg/L.

7.3.2 Alternate Concentration Limits

Unlike arsenic, modeling of uranium and vanadium indicates they will not flush to acceptable levels during the 100-year natural flushing period. However, because the water is not currently being used, contaminant concentrations in the ground water do not pose a threat to human health or the environment. Alternate concentration limits are therefore proposed for uranium and vanadium. On the basis of an act recently passed in the State of Colorado (Senate Bill 01-145), perpetual environmental covenants can be created that place restrictions on land use, including drilling and pumping of ground water. An environmental covenant is being developed to restrict the use of alluvial ground water for drinking water purposes for properties affected by site-related contamination. This will assure protectiveness of human health and the environment for as long as necessary.

Figure 7–6 shows that uranium has the most extensive areal distribution of the three COPCs. Concentrations above 0.044 mg/L extend from the former location of milling buildings northward into the vicinity property, to the northern terminus of the floodplain where it intersects the San Miguel River. However, the highest concentrations of uranium, located below the former tailings pile, have apparently migrated only as far north as the northern boundary of the site and have begun to encroach on the southernmost side of the vicinity property. The plume map for vanadium (Figure 7–7) shows a much smaller areal distribution. It is confined to the southern half of the area within the footprint of the former tailings pile and has shown little, if any, migration in the 60 years since vanadium milling first began. This distribution of uranium and vanadium is consistent with measured K_ds, ground water modeling predictions, and observations at other UMTRA ground water sites. All indicators are that vanadium is more immobile than uranium and is more strongly adsorbed by alluvial materials. Therefore, it is unlikely that removal of vanadium from the alluvial aquifer would be effective.

Evidence exists that mill tailings from the site have been eroded by the San Miguel River over time and redeposited downstream of the mill site. These deposits may serve as a continuing source of ground water contamination. Figure 3–1 and Figure 3–2 are aerial photographs from 1954 and 1966, respectively, that show a distributary channel for the San Miguel River cutting through the vicinity property floodplain. Repeated spring runoff and periods of flooding probably deposited tailings in this area.

Despite the persistence of uranium and vanadium in the soils and presence of a potential continuing source of ground water contamination, concentrations of these constituents have significantly declined over time. Recent maximum concentrations are approximately half of historical highs. It is probable that concentrations will continue to decline until soil and ground water interactions reach equilibrium; at that time ground water concentrations will probably level off. Modeling was not conducted to determine the contaminant concentrations that would be present at that time.

The environmental covenant will ensure that no improper use of contaminated alluvial ground water will occur. As discussed in Section 6.2, exposures of ecological receptors to current site-related ground water contamination discharging to seeps or the San Miguel River do not pose any significant risks. Calculations included in the BLRA (DOE 1995) indicated that even at very low river stages, contaminants discharging from the ground water are diluted by a factor of approximately 4000- to 5000-fold. Because of this dilution, historical maximum contaminant concentrations were demonstrated to have a negligible effect on the San Miguel River water quality. Because current concentrations are considerably less than those historical highs and are expected to continue to decline, there should be no future adverse impact to ecological receptors. Therefore, current contaminant concentrations in the ground water are protective of the environment.

An ACL of 3 mg/L is proposed for uranium; 6 mg/L is the proposed ACL for vanadium. These values are the approximate maximum concentrations detected in recent sampling rounds. These are protective of human health because of the lack of exposure pathway. They are action level ACLs that will be protective of the environment based on the significant dilution effect of the San Miguel River. The ACLs will be met at the points of compliance (POC), which are considered to be any well in the monitoring network. Maintaining these concentrations will result in acceptable levels at the points of exposure (POE) in the San Miguel River. Monitoring will ensure the protectiveness of the ACLs and is discussed further in Section 7.7.

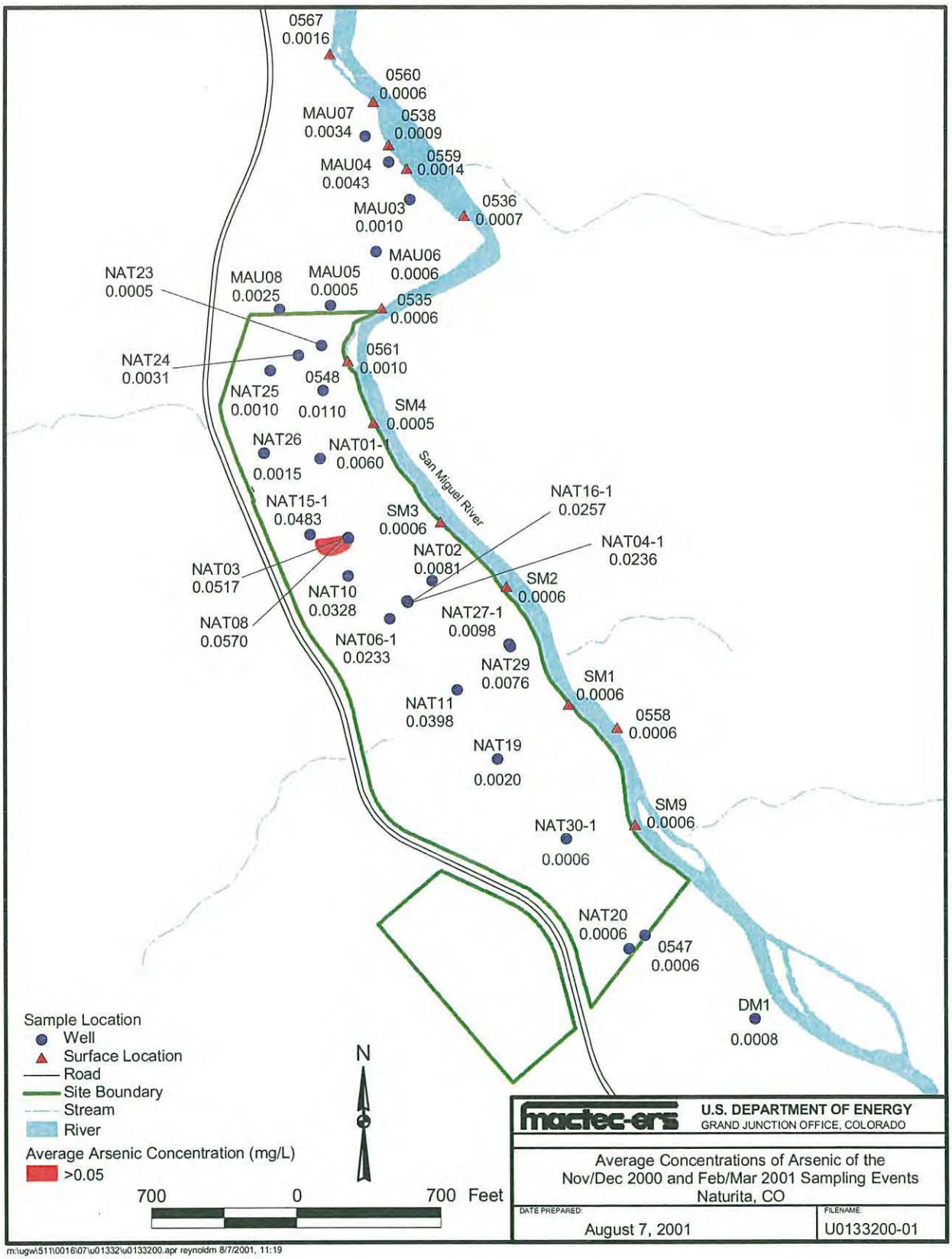

Figure 7–3. Average Concentrations of Arsenic from the Nov/Dec 2000 and Feb/Mar 2001 Samples

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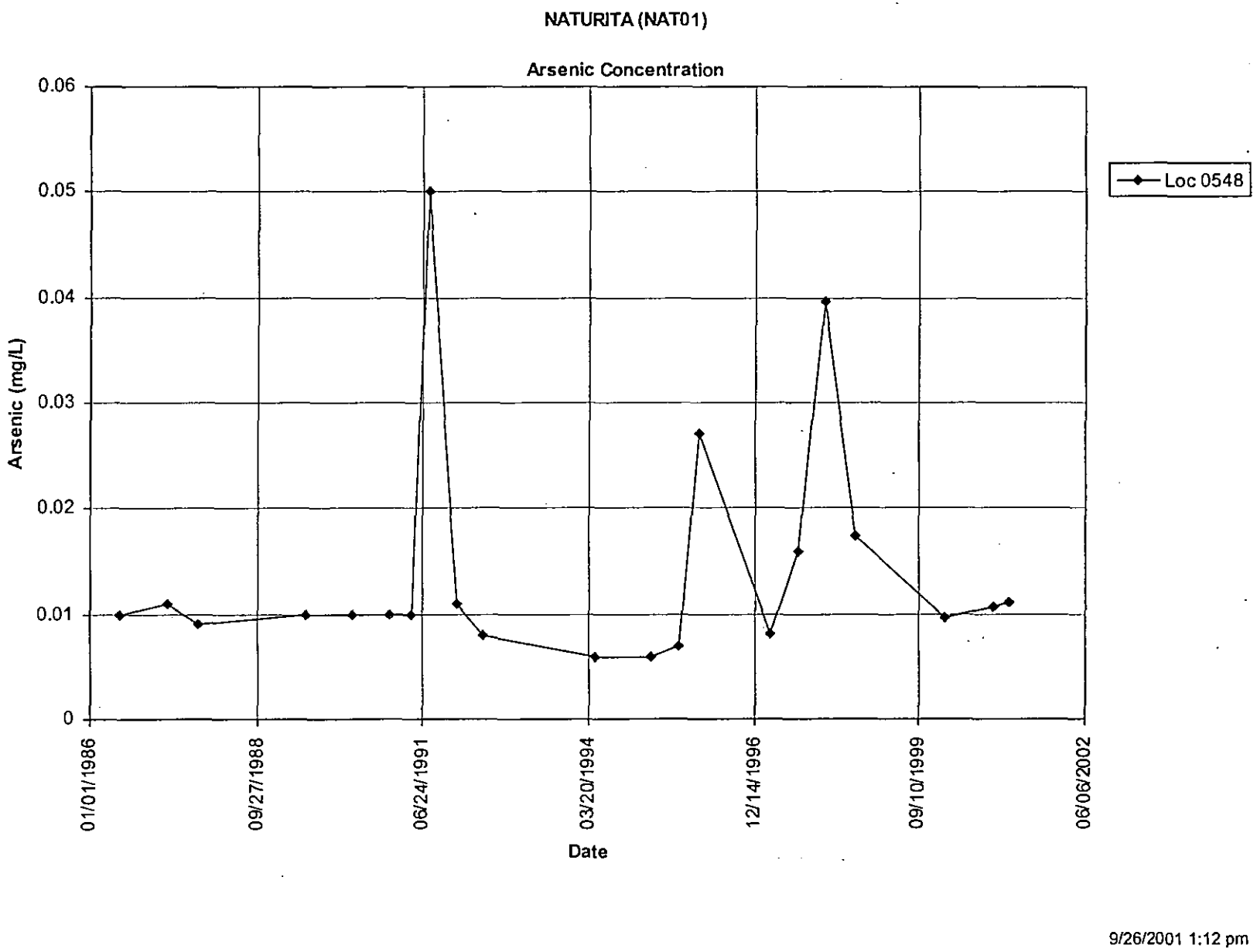

Figure 7–4. Time/Concentration Graph of Arsenic

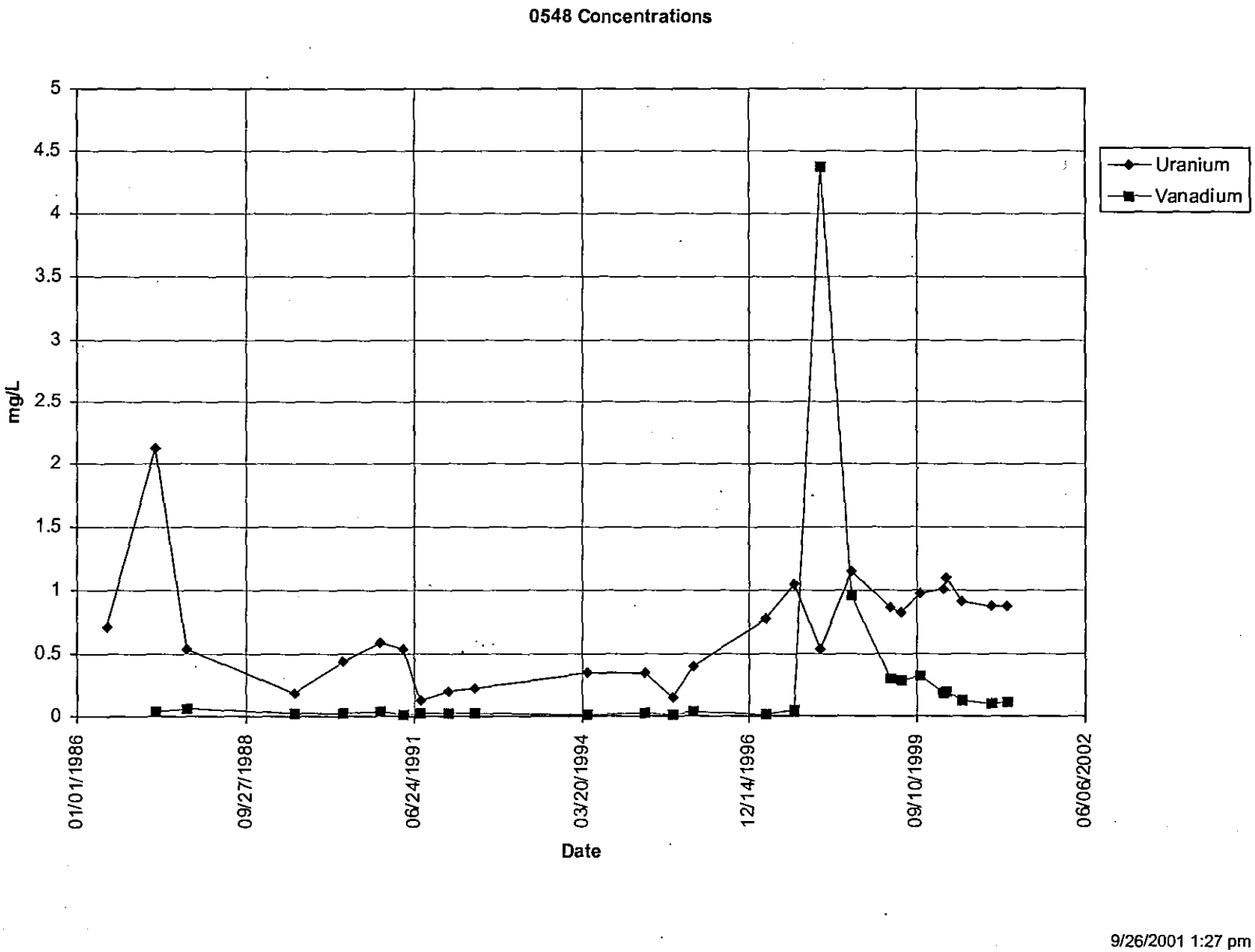

Figure 7–5. Time/Concentration Graph of Uranium and Vanadium

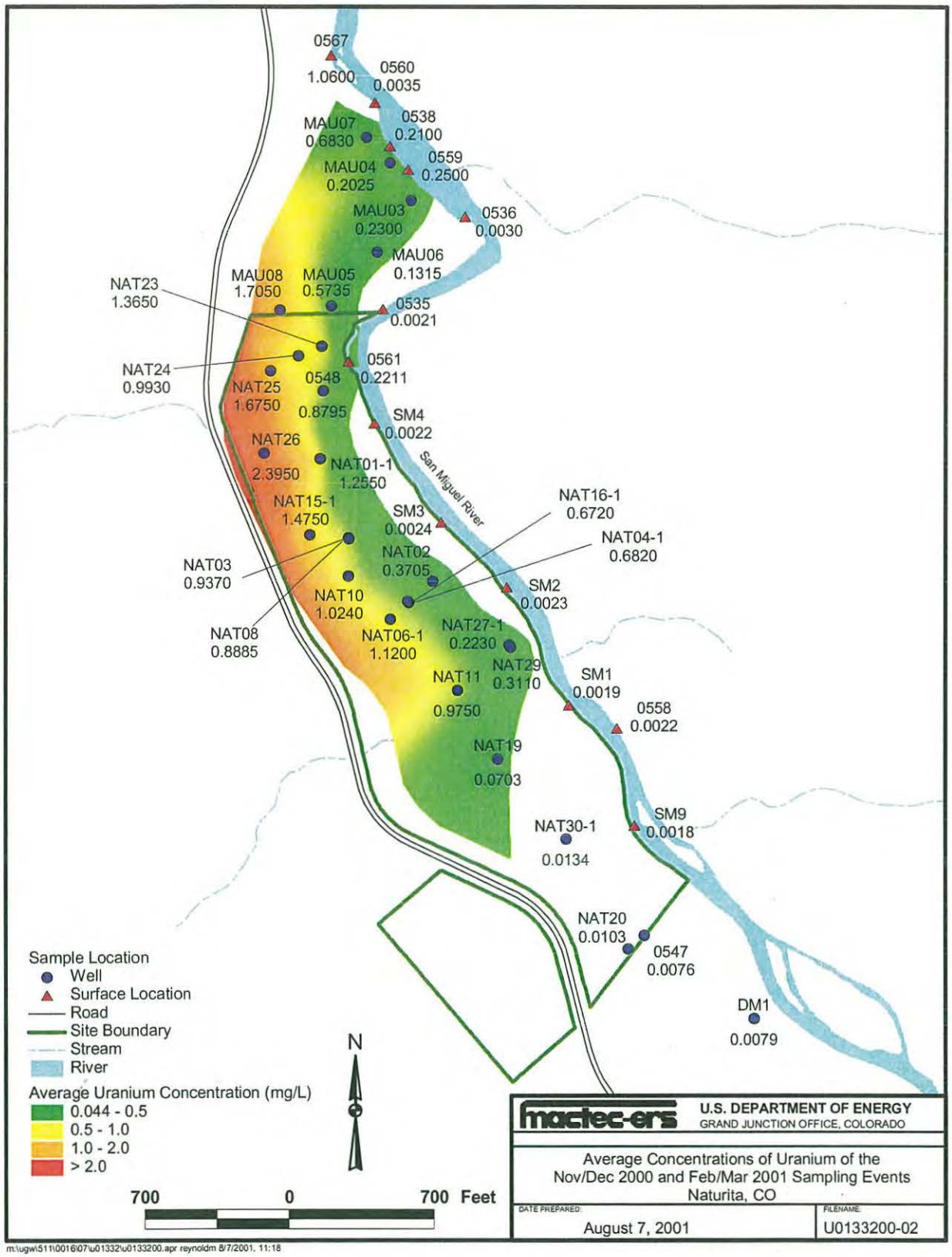

Figure 7–6. Average Concentrations of Uranium from the Nov/Dec 2000 and Feb/Mar 2001 Samples

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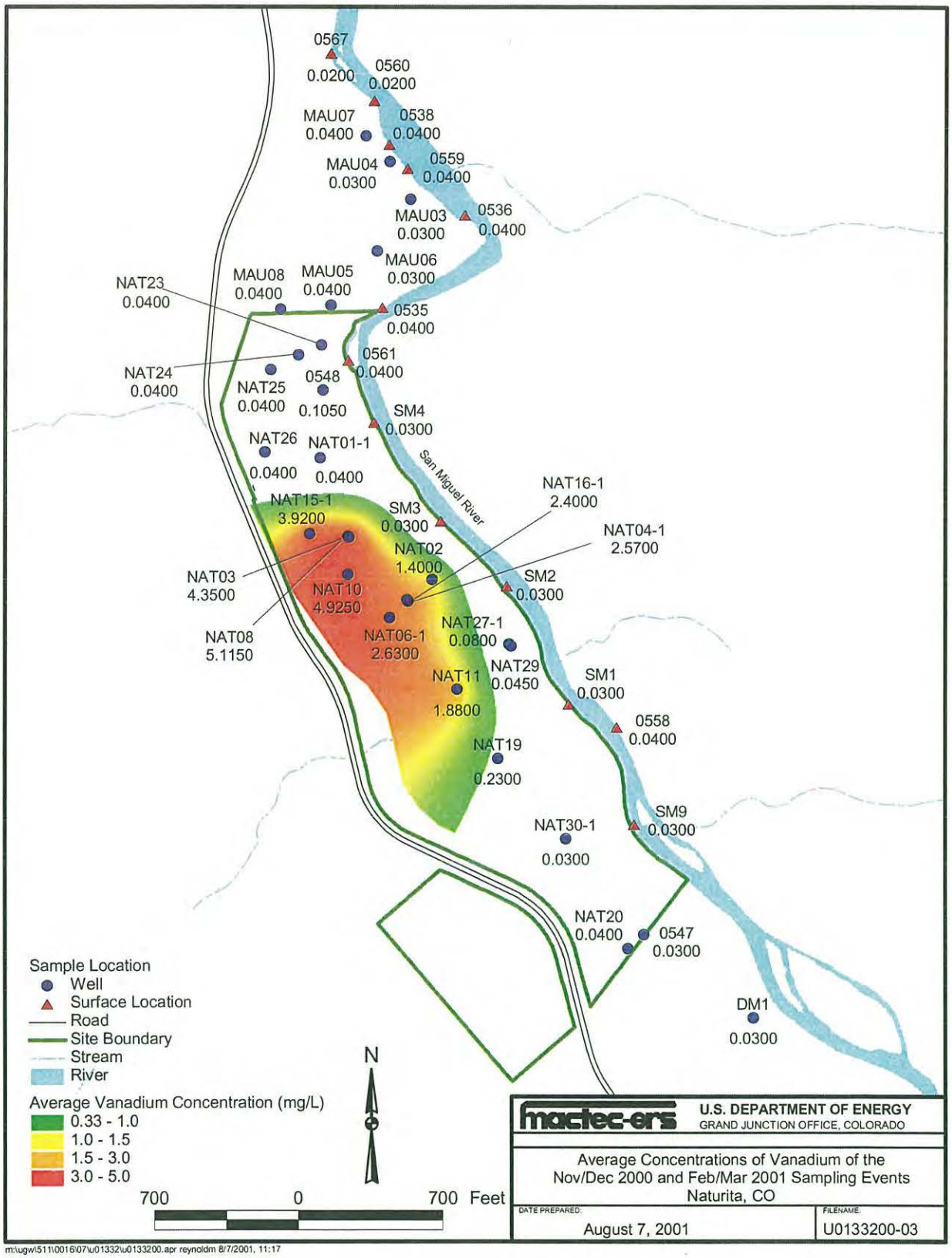

Figure 7–7. Average Concentrations of Vanadium from the Nov/Dec 2000 and Feb/Mar 2001 Samples

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7.4 Interim Actions

Several interim actions were completed during 2001. DOE provided 200 cubic yards of riprap and 500 cubic yards of clean dirt to the site and stored it along the southwest corner at the request of Montrose County. This material is to be used by the county in case the San Miguel River floods the site during spring runoff or a storm event.

A second interim action was to armor the riverbank with riprap along a stretch of the adjoining vicinity property to prevent future erosion and prohibit exposure of RRM left on the property. This was considered important to protect monitoring wells that may become flooded during spring runoff or storm events if the riverbank failed.

A third action was to repair and armor an eroded culvert on the west side of the site that passes under Highway 141 and drains valleys to the west. Plate 1 shows the locations of these interim action areas.

A fourth action will be drilling a water well for the Maupin family and supplying water to the household. The well will be completed in the Entrada Formation, several hundred feet into bedrock.

7.5 Future Land Use

Growth in this part of western Colorado has been very slow and has historically been linked with mining production. Mining is not expected to experience significant regrowth, but tourism may become increasingly important. Ranching is the other industry of western Colorado that has been and will be important. The millsite is currently safe for livestock grazing, and part of it is used for this purpose. The town of Naturita is several miles south of the site and is not expected to expand to the area of the millsite in the near future.

The City of Naturita has expressed considerable interest in the old millsite as the future location of a municipal golf course. The City owns the central portion of the site and is actively pursuing ownership or transfer of property at the north and south ends of the site, owned by Chemetall Foote Corporation. This mining company has not developed plans for their property and is currently considering transferring it to state or local government. DOE is facilitating discussions between the landowners to expedite this decision.

It is likely that the gravel mining operation upgradient of the former millsite will expand. This expansion could affect alluvial ground water flow in an increasingly pronounced manner. Withdrawal and evaporation of alluvial ground water would be expected to inhibit any natural flushing of the ground water system.

The Maupin family, who owns the downgradient vicinity property, plans to continue ranching. Because restrictions will be placed on the use of alluvial ground water on their property because of site-related contamination, DOE is providing them with a well drilled into the deeper, clean aquifer. This will provide the family with a water source of acceptable quality for any use and preclude the need to tap into the contaminated alluvial aquifer.

7.6 Institutional Controls

Institutional controls (ICs) will be placed on ground water that is currently contaminated or may be potentially affected in the future. As noted in Section 7.3.2, the State of Colorado permits the placement of a perpetual environmental covenant, on properties affected by contamination to restrict unacceptable activities, including the drilling or pumping of ground water. Environmental covenants are legally enforceable restrictions on land use and therefore meet the definition of institutional controls under UMTRCA. The area to be covered by ICs is shown in Figure 7–8. The ICs will prevent the use of water for drinking water purposes. Other uses of ground water may be permitted, however, rates of possible ground water withdrawl are greatly limited by the thinness of the saturated zone. It is assumed that potential water users will have water rights to the San Miguel River and that this readily available water source would be used as necessary (e.g., for irrigation purposes).

7.7 Future Monitoring

Monitoring is planned to ensure continued protection of human health and the environment. Monitoring wells DM1, NAT08, NAT26, MAU08, MAU07, the domestic well to be installed on the Maupin property, and surface locations 0531, 0556, SM2, and SM4 will be monitored for arsenic, uranium, and vanadium (Table 7–3, Figure 7–9). If DM1 is destroyed by expansion of the gravel operation, a suitable location for a new background well will be selected.

Table 7–3. Summary of Future Monitoring Requirements

Location	Monitoring Purpose	Analytes	Frequency
Well DM1	Background ground water	Arsenic, uranium, vanadium, TDS, field parameters	Annually for 5 years; afterwards every 3 years for 30 years. Monitoring requirements will be reevaluated at that time, but are anticipated to take place at a frequency of no less than every 10 years.
Well NAT08	Maximum V concentration; POC well		
Well NAT26	Maximum U concentration; POC well		
Well MAU08	U plume; POC well		
Well MAU07	Last well before ground water enters the San Miguel River; POC well		
Maupin water well	Only private well on site		
Surface 0531	Upgradient San Miguel River; POE		
Surface 0533	Downgradient San Miguel River; POE		
Surface SM2 and SM4	San Miguel River adjacent to contaminant plume(s); POE locations		

The sampling frequency is once every year for the first 5 years following NRC's acceptance of the Ground Water Compliance Action Plan. Thereafter, sampling would be conducted every 3 years for the next 30 years. At that time, monitoring requirements will be reevaluated, but is expected to take place at a frequency of no less than every 10 years. The total duration of the monitoring is unknown at this time but may be up to 100 years. Monitoring would include a period examination of land use to ensure the effectiveness of the ICs in preventing improper ground water use.

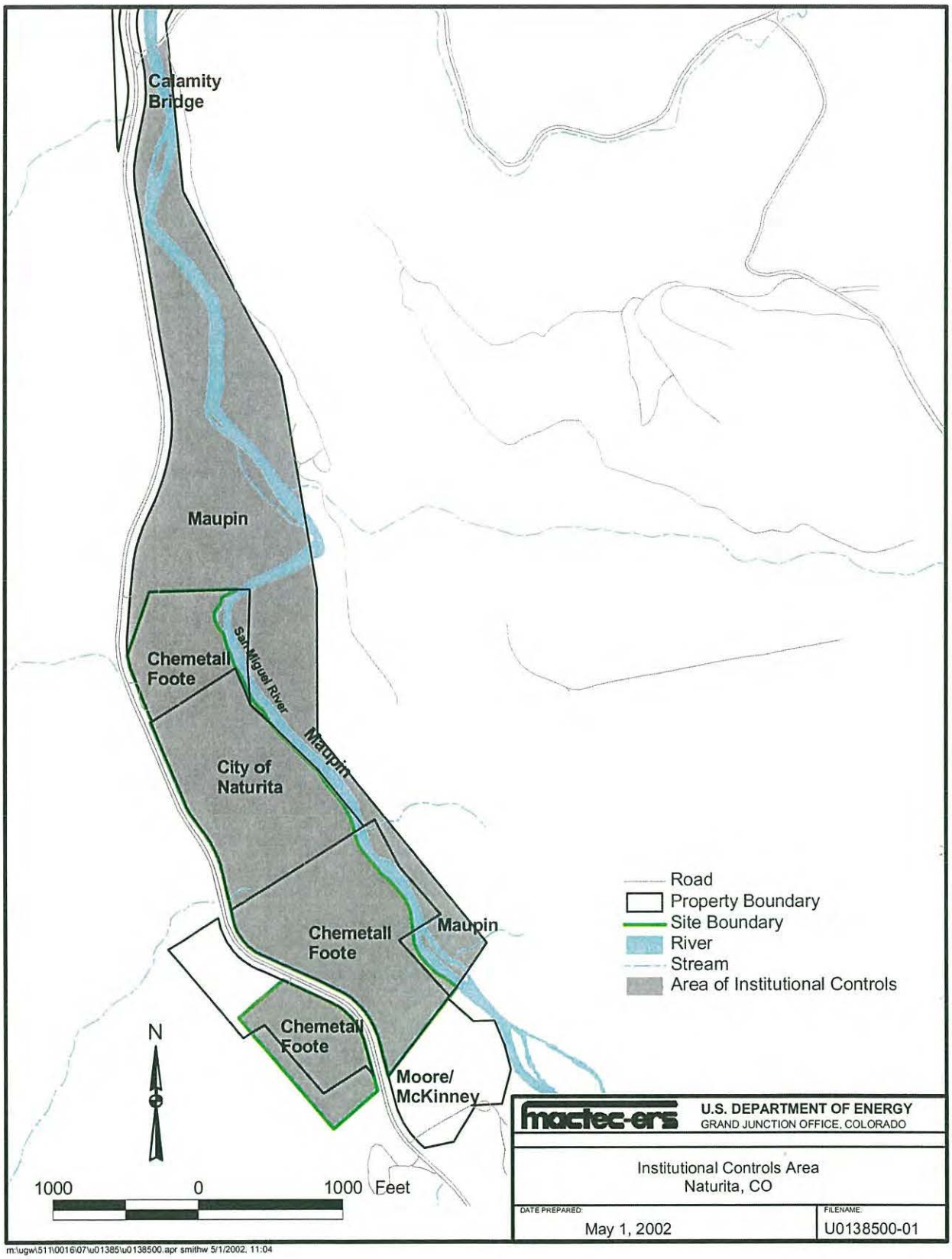

Figure 7–8. Institutional Controls Boundary

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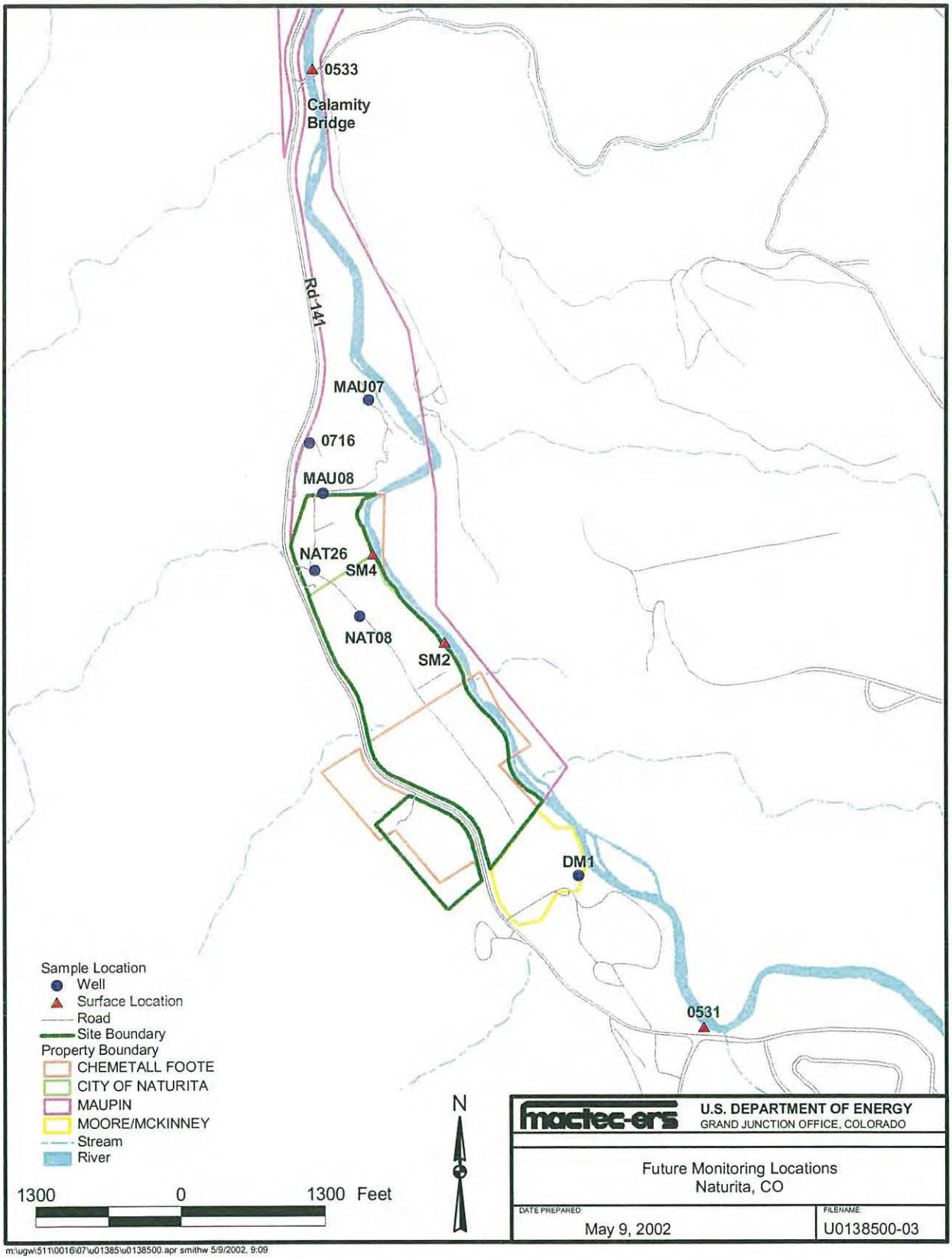

Figure 7–9. Future Monitoring Locations

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8.0 Corrective Action Assessment

As part of the ACL process, NRC recommends the implementation of a Corrective Action Assessment (NRC 1996). This assessment should address (1) practicable corrective actions; (2) technical feasibility of corrective actions; (3) corrective action costs and benefits; and (4) selection of a practicable corrective action that would achieve hazardous constituent concentrations that are ALARA. The following corrective active assessment is provided to satisfy this need.

8.1 Practicable Corrective Actions

During the surface program, tailings and other RRM were removed from the Naturita site, first to extract uranium from the tailings, and second to mitigate exposure to contaminated soils. From 1977 to 1979, mill tailings were removed and taken to the Coke Oven site several miles south and leached to extract residual uranium. Surface remedial action was performed from fall 1994 until fall of 1998, when approximately 771,400 cubic yards of RRM was removed and placed in the Upper Burbank engineered repository near Uravan, Colorado, 15 miles to the northwest. A number of areas containing RRM were left under the application of supplemental standards.

Uranium dissolved in ground water beneath the former millsite has been migrating downgradient to the north and has begun to intercept the southern boundary of the adjoining vicinity property. The vanadium plume has not moved or has moved very little since milling ceased over 40 years ago. Transport modeling predicts that concentrations of uranium will require 135 years to reach the UMTRA MCL of 0.044 mg/L and concentrations of vanadium will require more than 1,000 years to reach a human health risk-based concentration of 0.33 mg/L.

Human heath and ecological risk assessments have demonstrated that there is currently no adverse impact to human health or the environment because of site-related contamination in ground water on or downgradient from the Naturita site. This situation is not expected to change in the future.

The area of the ACL application extends from the southern boundary of the site on both sides of the San Miguel River floodplain to a point about 3,600 feet past the northern site boundary to the Calamity Bridge (Figure 7–8). Any site-related contaminated ground water is thought to exit the system into the San Miguel River at this northern terminus.

Two alternatives for treating contaminated ground water at Naturita were compared to the no remediation alternative. They are (1) conventional pump-and-treat technologies plus (2) the physical removal of RRM left on the site under surface supplemental standards application.

8.1.1 Pump and Treat

The most common approach to mitigating ground water contamination is an active ground water withdrawal and ex situ treatment process (commonly referred to as the pump-and-treat method). One or more pumping wells are typically installed to hydraulically capture the contaminant plume, and the water is pumped through some type of treatment system. The ground water must be treated until contaminant concentrations are below acceptable limits and the treated water can be reinjected or allowed to mix with surface water, or until concentrations are reduced so that natural flushing will decrease ground water contaminants to acceptable concentrations. This

scenario is considered for the Naturita site. Pump-and-treat methods are typically time consuming and costly because of the complex nature of contaminant transport processes in heterogeneous media. Two methods—treatment with zero valent iron (ZVI) and distillation—will be discussed. Depending on the cleanup criteria, some pump-and-treat operations have not been able to meet their technical objectives because of heterogeneity and sorption characteristics of the aquifer matrix. Despite the potential shortcomings, it is still considered the baseline technology for a comparison of alternatives.

Evaporation as a treatment option was dismissed because this method would require a large evaporation pond, and no land in the nearby area is available for this purpose, assuming all current and future land use plans do not change.

8.1.2 Surface Remediation

Mill-related materials were left in place at some locations, both on and off site, through the application of supplemental standards during surface remediation. Though transport modeling for vanadium and uranium did not include this additional source material, its presence would further contribute to the inability to effectively perform ground water remediation. Therefore, removal of the remaining source material, especially in the areas left on site that are 1 ft below the water table and areas near the San Miguel River on site and on the vicinity property, would be required in addition to a pump-and-treat remedy.

8.1.3 No Remediation

An alternative to active remediation is no remediation in conjunction with an application for supplemental standards for vanadium and uranium. Since there is no current or projected risk to human health and the environment because of site-related contamination in ground water or surface water at the Naturita site, this alternative would comply with the ground water protection standards. Also, ground water in the uppermost aquifer is not a current or potential source of drinking water, and it is proposed that access to ground water will be prohibited by ICs.

8.2 Technical Feasibility of Corrective Actions

8.2.1 Pumping

A pumping scenario can often be formulated as a classical optimization problem. Optimization modeling problems inherently require considerable time and effort. Before developing an optimization model, DOE took a much simpler approach to determine if there was any reasonable possibility that this strategy would succeed.

Modeling the pumping of water from the shallow alluvial aquifer at the Naturita site presented the first unexpected problem of a pump-and-treat scenario. Details of the modeling are presented in Appendix F.

Four existing wells that show high concentrations of either uranium or vanadium were selected as potential pumping locations. These wells (MAU08, NAT01–1, NAT03, and NAT06–1) were to be pumped at the highest sustainable rate.

Modeling determined the maximum pump rate that could be sustained, with all wells pumped simultaneously, without drying up the area in the vicinity of any of the wells. These values are shown in Table 8–1.

Table 8–1. Maximum Simultaneous Pump Rates

Well	Pump Rate	
	gpm	ft^3/day
MAU08	0.5	96.25
NAT01–1	5	962.5
NAT03	2	385.
NAT06–1	3	577.5

Three scenarios were modeled to determine if pumping could reduce the uranium levels to those required for natural flushing to complete the cleanup. Only the results of pumping each well at the maximum sustainable rate shown in Table 8–1 are presented here. Table 8–2 shows the maximum remaining concentration at selected years for natural flushing (i.e., no pumping) and the maximum pumping rate scenarios.

Table 8–2. Maximum Remaining Uranium Concentration

Years	Maximum Remaining Concentration (mg/L)			
	Natural Flushing	Run 1	Run 2	Run 3
0	2.5220	2.5220	2.5220	2.5220
5	2.4266	2.4358	2.4476	2.5043
10	2.3683	2.3797	2.3954	2.4873
15	2.2993	2.3285	2.3519	2.4594
25	2.0257	2.1147	2.1884	2.4077
50	1.3047	1.3527	1.4707	2.0998
60	1.0439	1.0400	1.1552	1.9028
70	0.78606	0.75038	0.85610	1.6842
80	0.55612	0.51044	0.60078	1.4563
90	0.37134	0.33101	0.40296	1.2332
100	0.23654	0.20698	0.26095	1.0258

The results were unexpected and somewhat counterintuitive. Intuitively, it would seem that if the aquifer is pumped, the maximum remaining concentration would decrease with time and would be less than if the aquifer were not pumped. However, the results predict just the opposite. As more water is extracted from the aquifer, the higher the maximum remaining concentration.

Two factors, the saturated thickness and the low hydraulic conductivity, are thought to cause the unexpected results. If pumping draws down the aquifer water level to the point that the aquifer around a well is almost dry, no water is moving through the aquifer matrix. All the water that flows toward the well is extracted from the well. The cone of depression that develops around each well will leave much of the aquifer matrix dry. With no water moving through the aquifer near the well, contaminants remain adsorbed to the matrix.

If these modeling results are accurate, pumping for even 100 years will not reduce the concentration of uranium and vanadium to the required levels such that 100 years of natural flushing would complete the cleanup.

A possible solution to this pumping problem is some type of gradient manipulation. To achieve an effective solution, water would be introduced along the western side of the floodplain and would be allowed to percolate into the ground. Another possible aid would be irrigation of the floodplain as would be accomplished if a golf course were established on the site. A golf course has been proposed as a possible land use. Both scenarios were considered during initial modeling, but both were ultimately ineffective toward achieving contaminant concentrations that would allow natural flushing. The effectiveness of any form of gradient manipulation is complicated by water loss at the gravel mining operation and its influence on ground water flow. Nonetheless, some other form of gradient manipulation would be necessary to achieve effective pumping at the site.

8.2.2 Treatment by Zero Valent Iron

The most feasible treatment technology would use zero valent iron (ZVI) to reduce the uranium and vanadium concentrations in the ground water. Assuming that an adequate stream of contaminated ground water could be extracted from the aquifer, it would be pumped through a piping collection gallery to the treatment facility. Because of the cold climate, the treatment unit would need to be housed to prevent the extracted water from freezing.

A pilot study was conducted at the New Rifle UMTRA site near Rifle, Colorado, using ZVI to treat vanadium contamination (DOE 2001). The pilot plant treated 2.9 million gallons of ground water over 10 months. A treatment system similar to the one at Rifle could be used at Naturita. The treatment unit consisted of very fine grained ZVI filings inside a steel tank. The ZVI removed the uranium and vanadium in a reaction similar to the dynamics that occur in a PeRT wall. Uranium and vanadium are removed through reductive precipitation as the contaminated water contacts the ZVI. Because carbonates precipitate onto the ZVI and lower the iron's hydraulic conductivity, the ZVI filings need to be replaced periodically. Results from Rifle indicate that about 650 pounds of ZVI are required to treat 100,000 gallons of water. One pore volume of contaminated water for the uranium plume at Naturita, which is larger than the vanadium plume, is estimated to be 22,700,000 gallons, requiring about 35,000 pounds of ZVI for treatment.

Cleanup may require numerous pore volumes, especially for the smaller vanadium plume, which is estimated to be 9.5 million gallons. (A pore volume is only one method to estimate the amount of water to be treated. In reality, many pore volumes would need to be withdrawn from a small radius around extraction wells before other areas of the plume contribute sufficient contaminant mass to reduce the total contaminant load.)

Results of this pilot test suggest that 1) little effect on extraction of vanadium from the aquifer was observed as evidenced by the lack of changes in vanadium concentrations from the extraction well. This is thought to be due to the high sorption of vanadium to the aquifer matrix; and 2) the treatment system of flowing ground water through a ZVI reactor column decreased vanadium by 6 fold and further treatment of removing iron in downstream settling tanks removed vanadium by an additional 17 fold.

8.2.3 Treatment by Distillation

Alternatives evaluations for other UMTRA sites typically include distillation as one of the treatment alternatives. This method recovers more treated water than any other technology, and the treated water is of higher quality than that produced by any other technology. Volumes of water to be treated are the same as those for the ZVI alternative.

In a simple distillation process, water is vaporized by heating it to its boiling point. The water vapors are then condensed and recovered as clean water. Nonvolatile contaminants such as nitrates, sulfates, uranium, vanadium, and other components of TDS will not evaporate. Instead, they concentrate in the evaporation chamber and must be removed at an appropriate rate. If no volatile contaminants are present, the condensed water will be of high quality and can be used for nearly any purpose. The concentrate, or brine, may be taken off site for disposal; or, it may be evaporated to dryness, and the residue can then be disposed of as a solid.

Distillation is an expensive treatment technology to implement because of the significant capital costs of distillation equipment. However, distillation does recover almost all the water, and the product water is of high quality. Because the Naturita ground water does not contain volatile contaminants, the condensate from a distillation system would be of such high quality that the concentrations of contaminants would be orders of magnitude below regulatory standards for drinking water.

Commercial distillation units are self-contained and include all instrumentation required for monitoring and controlling the operation. The units are designed for outdoor operation, and no building is required other than the control building for the operators.

In general, commercial distillation systems are reliable and require a low level of oversight and only scheduled maintenance during their operating life. Operation of the distillation system would require a minimum of managerial and technical supervision. The acid pretreatment system can operate unattended, although periodic replenishing of the acid would be required. The cost estimate for operation of the distillation system allows for two full-time employees 7 days a week on day shift for operation and maintenance.

For optimal performance, the distillation system should be operated as continuously as possible. However, it is expected that the flow rate produced by the extraction system would be variable. To dampen variations in the extraction rate and produce a constant flow rate of feed to the distillation unit, a feed tank of approximately 10,000-gallon capacity would be erected at the site immediately adjacent to the treatment unit. Water from the extraction system would flow into the feed tank, and the distillation unit would take its feed from the tank; the level in the feed tank would be allowed to vary as needed.

The distillation process generates concentrated brine continuously. The brine discharged from the distillation unit is expected to contain no more than about 10-percent suspended solids. Because a 10-percent solids-loading is low enough that disposal is impractical without further concentration, the brine must be evaporated to dryness. Preliminary calculations indicate that a small, spray-enhanced solar evaporation pond would be more cost-effective than a larger solar evaporation pond for this purpose.

The proposed location of the distillation unit is somewhere on the southwestern flank of the site, above the 500-year flood level. It should be in an area that would not conflict with proposed future land use because it will be in place for an estimated 10 years. The location of the evaporation pond is problematic. Its size should be minimized, and its location would probably be on the site toward the south end.

8.2.4 Limiting Factor for ZVI and Distillation Remedies

Extraction of vanadium contamination from the subsurface is extremely difficult. The high K_d for this constituent causes it to be tightly adsorbed to the substrate and requires large amounts of water to flush through the system before it is removed. Other methods of vanadium extraction could be tried (example, use of a lixiviate), but analysis of the current test at Rifle suggests that pumping will be required for an indeterminate time. The unknown duration of pumping required to remove vanadium from the alluvial system is an important factor for this ACL application.

8.2.5 Surface Remediation

During surface remediation from 1994 to 1998, approximately 771,400 cubic yards of RRM was removed to the Upper Burbank Repository near Uravan (DOE 1998b). This material originated from 52 acres on the site, 195 acres off the site from windblown areas, and at least 11 acres from the contiguous vicinity property to the north. An estimated 93,602 cubic yards of RRM was removed from this vicinity property (DOE 1999a). However, a large amount of RRM was left on site and on the adjacent vicinity property.

Table 8–3 lists the five general areas where RRM was left on site and on the vicinity property under applications for supplemental standards (DOE 1998b) (Figure 8–1). The rationale for leaving the materials in place is specific to each application but generally includes (1) low radiological hazard, (2) increased risk of injury to workers along steep slopes and near high voltage lines, (3) environmental harm to wetland areas, and (4) low radiological hazard from contaminants remaining below the water table and associated high cost of pumping, storing, and treating contaminated water. The rationale for leaving contamination on the vicinity property adjoining the millsite, downgradient and to the north, was the same as (1), (2), and (3) above, but the property owner also requested that mature trees on the property along the river be left undisturbed (DOE 1999a).

Table 8–3. Surface Supplemental Standards Areas and Volumes

Area Description	Area (acres)	Volume (cubic yards)
On site, steep slopes	6.5	5,243
Wetland areas along the river	1.1	4,350
Steep areas along the highway	0.2	190
Power poles	0.2	1,260
On site, >1 ft below the water table	0.4	1,200
Vicinity property	5.1	50,000[a]

[a]Based on an estimate from the vicinity property completion report. All RRM remaining was estimated at 37,520 cubic yards, and because the volume removed was twice the estimate, 75,000 cubic yards is probably left. This is considered a conservative volume estimate. A small part of this volume is along the highway and most is in the floodplain. The 50,000 cubic yard figure is 2/3 of the total estimated volume.

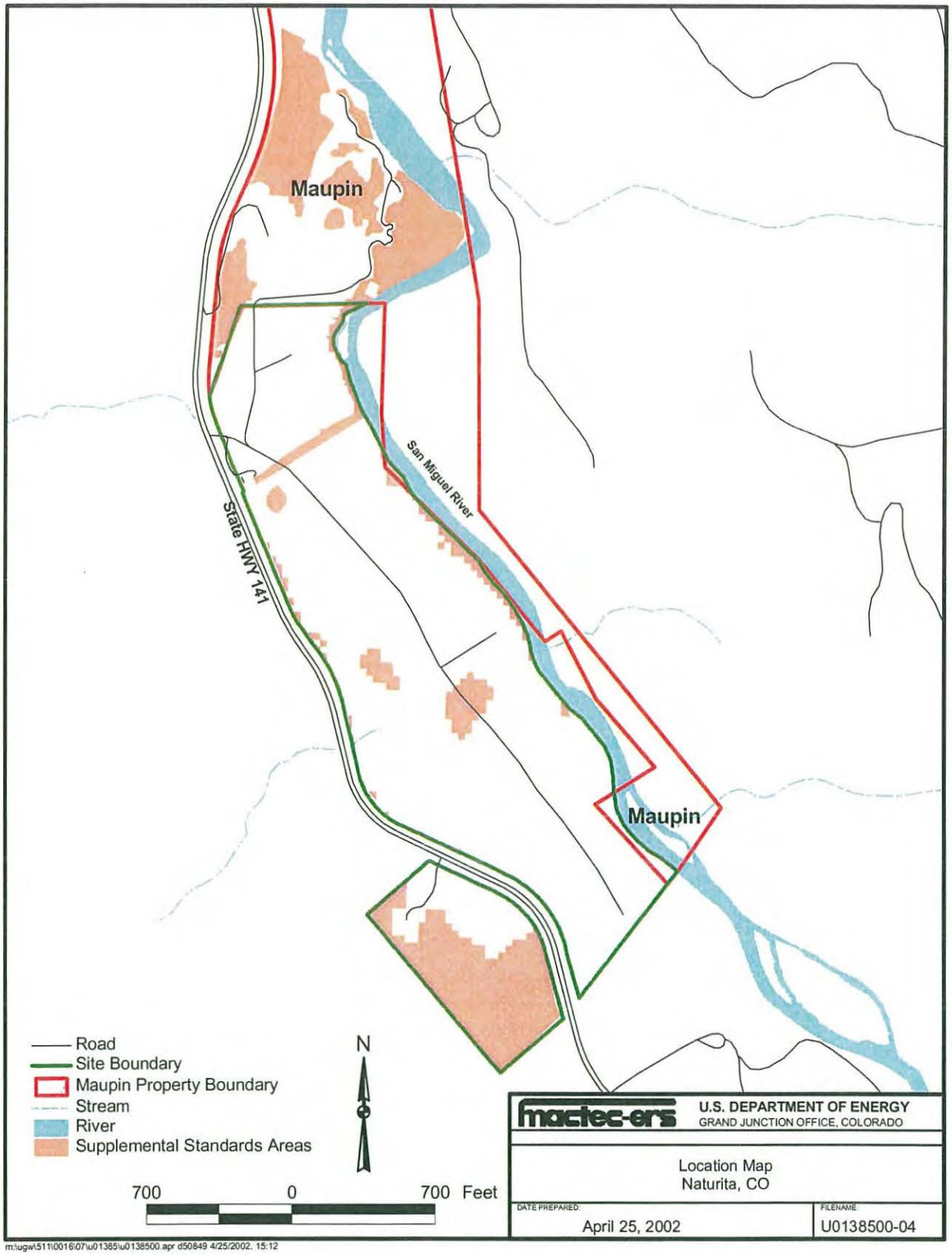

Figure 8–1. Locations of Surface Project Supplemental Standards

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The proposed surface action would invoke criterion (b) in 40 CFR 192.21, Criteria for Applying Supplemental Standards, whereby "... remedial actions... would directly produce health and environmental harm that is clearly excessive compared to health and environmental benefits, now or in the future..." In other words, the same criteria for leaving RRM under application of supplemental standards 3 years ago would still apply. The potential danger to laborers working along the high voltage power line still exists, the potential harm to riparian areas and habitats along the San Miguel River has not changed, and the low risk to people and the environment from contaminated ground water associated with the RRM is still low and is expected to remain low. Also, the owner of the vicinity property would still like to preserve the trees along the San Miguel River.

If the material were removed, the Cheney Disposal Cell, located 105 miles from the site, would be the repository for the 75,000 cubic yards of tailings from the site and vicinity property. The truck haul along Colorado Highway 141 to the Cheney Disposal Cell presents an additional hazard. This is a standard 24-ft-wide highway, which is also a scenic byway, that passes through 40 miles of deep, sinuous, redrock canyons, heavily traveled by tourists. The estimated number of loads from standard 22-cubic-yard belly-dump trucks is 2,600 round trips. This translates into an estimated 23,400 highway hours assuming a 9-hour round trip, or 546,000 miles assuming a 210-mile round trip. Based on tables from the U.S. Department of Transportation (DOT 1999), this might be expected to cause 0.01 fatal accidents and 0.4 injuries to people driving the large trucks in average terrain. This estimate does not account for persons in passenger cars or other vehicles that might be associated with potential accidents and does not account for permitting and permission from the State of Colorado to haul RRM along this stretch of highway. Hazards presented by transporting the tailings support the application of supplemental standards to the contaminated materials remaining on site and on the vicinity property.

8.2.6 No Remediation

This alternative would require few additional activities at the site. Monitoring as a best management practice would be continued. Institutional controls, also as a best management practice, would be imposed to prevent access to contaminated ground water for drinking purposes. Providing the landowner downgradient of the site with a reliable source of drinking water is proposed to ensure a safe source of domestic water.

8.3 Corrective Action Costs and Benefits

Cost estimates are provided in this section for 1) pumping and treating using ZVI and by distillation, 2) additional surface remediation, and 3) no remediation.

8.3.1 Pumping and Treating by ZVI and by Distillation

8.3.1.1 Pumping

Regardless of whether treatment is by distillation or by ZVI, pumping and gradient manipulation systems would be required to effectively remove ground water. A system of four 4-inch-diameter 15-ft-deep extraction wells with pumps, associated electrical infrastructure, and buried piping would be required to remove contaminated water from the ground to a treatment facility on the southwestern portion of the site. The estimated cost, based these elements and engineering support, is $125,000.

An additional cost of pumping would be gradient manipulation of the aquifer to successfully extract contamination from the floodplain. The simplest method to achieve this would be diversion of water from the San Miguel River to a channel along the base of the scarp on the west side of the site. The infiltration zone would need to extend from the southern end of the site to a point near the northern terminus in the vicinity property (Maupin property) where the floodplain intersects the river. This is about 6,000 ft of infiltration trench. Costs of engineering and construction are estimated to be $250,000.

Discussions with the Colorado State Engineer's Office and the U.S. Army Corps of Engineers would be held to determine the need for a permit to withdraw water from the San Miguel River and to evaluate the substance of a 404 Nationwide Permit. Work plans, permitting, and discussions with key regulators are estimated to cost $50,000.

The costs for pumping the gradient manipulation are shown with the discussions of Treatment by Distillation and Treatment by ZVI. See Table 8–4 and Table 8–5.

Table 8–4. Cost Estimate for Pump and Treat, Distillation Operation

Item	Cost
Remedial design/permitting/construction management	$150,000
Well installation/piping/permitting	$125,000
Gradient manipulation/permitting	$300,000
Treatment facility	$2,500,000
Operation and maintenance (10 years at $82,000/yr)	$820,000
Monitoring/sampling costs (10 years at $1,500/yr)	$15,000
Subtotal	$3,910,000
Contingency @ 30%	$1,173,000
Total cost	$5,083,000

Table 8–5. Cost Estimate for Pump and Treat, ZVI Operation

Item	Cost
Remedial design/permitting/construction management	$150,000
Well installation/piping/permitting	$125,000
Gradient manipulation/permitting	$300,000
Treatment facility	$800,000
Cost of ZVI @ $0.40/pound (@ 650 lb/100,000 gallons for 80 million gallons	$208,000
Operation and maintenance (10 years at $50,000/yr)	$500,000
Monitoring/sampling costs (10 years at $1,500/yr)	$15,000
Subtotal	$2,098,000
Contingency @ 30%	$629,400
Total cost	$2,727,400

8.3.1.2 Treatment by Distillation

The cost estimate for this analysis includes

- Remedial design/permitting/procurement/construction management; includes preparing permits for discharge to the river, developing a hydrologic model of the plume, bidding and awarding a contract, and construction oversight of subcontractors hired to install the system.
- Construction of a 1.5-acre evaporation pond.
- A treatment facility— garage style building, electrical controls, distillation system, associated piping and valves.
- Operation and maintenance costs: utilities for the building, electricity for well pumps, part-time labor to operate the system, and professional labor to assess the plume.

Monitoring and sampling costs: labor to sample the wells and discharge effluent and analytical laboratory costs.

Table 8–4 shows a summary breakdown of the cost estimate for the distillation option. Operating and monitoring costs are shown as the present worth value of operating the system for 10 years.

8.3.1.3 Treatment by ZVI

The cost estimate for this analysis includes

- Remedial design/permitting/construction management; includes preparing permits for discharge to the river, developing a hydrologic model of the plume, and construction oversight of subcontractors hired to install the system.
- Well installation and piping—includes well development, vaults, electrical service to each well, and discharge piping from the wells to the treatment facility.
- Treatment facility—garage style building, electrical controls, steel tank containing ZVI filings, 10-year supply of ZVI, piping, and valves.
- Operation and maintenance costs: utilities for the building, electricity for well pumps, purchase and disposal of ZVI, part-time labor to operate the system, and professional labor to assess the plume.
- Monitoring and sampling costs: labor to sample wells and discharge effluent and analytical laboratory costs.

8.3.1.4 Vanadium Removal

This analysis applies for a 10-year period, a normal and reasonable duration for active treatment of most ground water problems. The actual duration required to pump and treat vanadium is unknown at this time. Results from the Rifle pilot test are incomplete. Therefore, the costs for distillation or ZVI treatment could be many times the amount shown in this analysis.

8.3.2 Surface Remediation

Removing remaining source material would be required in addition to one of the pump and treat scenarios if the ground water restoration is to be successful. The estimated cost of removing the source material is based on an extrapolation of costs from previous surface removal and also includes the cost of hauling RRM to the Cheney Disposal Cell near Grand Junction. The time that would be spent acquiring Department of Transportation permits and dealing with political issues of moving RRM along a scenic byway is difficult to calculate.

The best available information about the costs of removing RRM is from the Naturita vicinity property completion report (DOE 1999a). The cost estimate was based on partial removal of RRM from the open areas. Supplemental standards were used to justify leaving RRM along the river and along steep slopes of the highway. The estimated cost to remove this "easily accessible" RRM was $1,567,000 based on removal of 56,690 cubic yards of contaminated materials (the estimated remaining volume was 37,520 cubic yards). The actual volume of material removed was 93,602 (DOE 1999a). The volume of RRM removed was twice the estimated volume and nearly equal to the total estimated volume of tailings at the site under a complete removal scenario (94,210 cubic yards), which had an estimated cost of $4,492,000. Therefore, an estimated cost to remove the remaining tailings from the site could be between $4.5 million and $9 million. This range is based on (1) doubling the estimated volume of remaining tailings, (2) greater difficulty in accessing and removing the remaining RRM, (3) the increased cost of moving the material to the Cheney Disposal Cell instead of the cell at Uravan (an estimated $40/cubic yard transportation cost for an estimated 75,000 cubic yards = $3,000,000), and (4) inflation of 3.3 percent per year since 1996. This cost would probably be closer to the higher estimate because of the labor intensive methods required for removing tailings from the steep embankments along the highway and the costs of dealing with political issues of transporting RRM along the highway. Even the removal of materials only along the San Miguel River could be close to the lower number because the depth of tailings is greater than originally estimated. The estimated total cost of removing RRM from the vicinity property floodplain is $7,000,000.

The cost of cleaning up the wetland area along the millsite would probably be about one fifth the cost for the vicinity property because the wetland has approximately one fifth the area (48,627 square feet versus 221,129 square feet). Therefore, the cost might range from $900,000 to $1,800,000. If the riprap along the river and flood control dike were replaced, the cost might be closer to this higher number. The estimated cost of cleaning up the wetland is $1,200,000.

The cost of digging up RRM below the water table in the 0.4-acre area on site considers removal and storage of about 4,000 cubic yards of clean fill, excavation of RRM for an additional 3 ft below the water table to include a minimum of 1,800 cubic yards of RRM, drying saturated RRM sediments before shipment, piping and treatment of contaminated water through the same ZVI facility discussed in Section 8.6.1, and transportation of RRM to the Cheney Disposal Cell. These estimated costs are shown in Table 8–6.

Table 8–6. Estimated Costs for Removal of RRM from 1 Ft Below the Water Table on the 0.4 Acre Area

Description	Cost
Excavation of 4,000 cy clean fill ($10/cy)	$40,000
Excavation of 1,800 cy of RRM (+10%) ($12/cy)	$24,000
Drying (windrow) of 1,800 cy of RRM before shipment ($10/cy)	$18,000
Pumping/piping system to treatment facility for contaminated ground water	$20,000
Transportation of 1,800 cy (+10%) RRM to disposal cell @ $40/cy	$79,000
Haul clean fill and place in site (1,980 cy @ $15/cy)	$30,000
Contingency at 30%	$63,000
Total cost	$274,000

cy = cubic yard

The cost of removing RRM left around power poles would be similar to the previous estimate except for treatment of contaminated water. Table 8–7 shows the cost breakdown.

Table 8–7. Cost Breakdown of Removing RRM Left Around Power Poles

Description	Cost
Excavation of 1,260 cy of RRM (+10%) ($12/cy)	$17,000
Transportation of 1,260 cy RRM (+10%) to disposal cell at $40/cy	$55,000
Haul clean fill and place in site (1,260 cy +10% @ $15/cy)	$21,000
Contingency at 30%	$30,000
Total cost	$123,000

cy = cubic yards

The total cost for removing RRM from the site and the vicinity property is summarized in Table 8–8.

Table 8–8. Total Cost for Removing RRM

Description	Cost
Vicinity property	$7,000,000
Wetlands	$1,200,000
Greater than 1 ft below ground water	$274,000
Power poles	$123,000
Total	$8,597,000

8.3.2.1 Total Costs for Pump and Treat and Remediation Alternatives

The total costs for both cleanup strategies are shown in Table 8–9.

Table 8–9. Total Cost for Both Cleanup Strategies

Description	Cost
Pump and treat, distillation	$5,083,000
Surface remediation	$8,597,000
Total	**$13,680,000**
Pump and treat, ZVI	$2,727,400
Surface remediation	$8,597,000
Total	**11,324,400**

8.3.3 No Remediation

Few costs are associated with the no remediation alternative. Monitoring of ground water at several monitoring wells and surface water locations along the San Miguel River would be ongoing. The estimated cost for ten samples, collected once per year, for 5 years and subsequently every 3 years for the following 30 years, and analyses for the three COPCs is $2,100 per sample round, or $105,000.

A second, one-time cost would be the installation of a drinking water well for the family in the adjoining vicinity property. This area is or will be in the plume migrating off the site, and the occupants currently haul water from a public source in Naturita. The well would be drilled into potable water in the Entrada Formation approximately 600 ft below the surface. The cost includes drilling, completion, development, and plumbing of a well for drinking water into the home. The estimated cost is $50,000.

8.4 Practicable Corrective Action

The practicable corrective action for the Naturita site is implementation of ACLs for uranium and vanadium. Associated with this is an institutional control that will restrict access to ground water in the ACL area and monitoring to ensure that no harm is occurring to humans and the environment. The analysis presented in Section 6 demonstrates that an ACL approach is protective of human health and the environment for the Naturita site under the following scenario.

The IC area, shown in Figure 7–8, follows the site boundary along the south and extends northward to include the vicinity property (Maupin property) to the Calamity Bridge. The boundary also extends to the floodplain on the east by the San Miguel River across from the former millsite and north to the Calamity Bridge. The owners of property in the ACL area are Chemetall-Foote (a mining company), the City of Naturita, and the Maupin family. DOE would request that the State of Colorado, specifically, the Colorado Department of Public Health and Environment (CDPHE) implement an Environmental Covenant with the three property owners. This voluntary agreement would be for perpetuity and would exclude use of ground water for human consumption. Discussions have already begun with the County and the Maupin family. DOE will also facilitate the transfer of Chemetall-Foote's property to Montrose County. These discussions have also begun.

Members of the Maupin family are living in the IC area. Currently, they haul drinking water from a city well in Naturita. A large portion of their property in within the IC boundary and will receive the proposed environmental covenant. They will not be able to drill a domestic well in the alluvial aquifer or use an existing alluvial well for domestic purposes. Therefore, DOE proposes to drill a deep water well into potable water about 600 ft beneath the surface and provide the family with a clean source of drinking water. Upper sandstone units within the Morrison Formation contain high total dissolved solids and potentially could contain uraniferous water; therefore, the Morrison Formation will be cased off to prevent any possible cross contamination.

Contaminants are not expected to migrate beyond the IC area because (1) impermeable bedrock mudstones from the Brushy Basin Member of the Morrison Formation are effective barriers to westward migration, (2) the IC area extends downstream to the point where any surface

expression of tailings were identified and any possible ground water contamination could occur, and (3) a slight upward hydraulic gradient in the Brushy Basin sediments beneath the site prevents downward migration. Ground water flow on the former millsite is to the north and east; therefore, most contaminants eventually flush into the San Miguel River to the east. Any contamination that may exist on the east side of the San Miguel River farther downstream from the site, will eventually flow into the river by the time the Calamity Bridge is encountered.

The three alternative corrective action strategies evaluated for the Naturita site are (1) a conventional pump-and-treat scenario based on a ZVI collection gallery and a distillation process for active cleanup of the aquifer, (2) surface remedial action to remove uranium and vanadium from ground water. If the cost of implementing a corrective action is greater than the benefits of the outcome, the alternative may be inappropriate or inefficient. The costs for implementing a pump-and-treat system using distillation with surface remediation is approximately $13.7 million (for the first 10 years); the cost of implementing a pump-and-treat system using ZVI and surface remediation is approximately $11 million (for the first 10 years), and (3) no remediation in conjunction with ACLs is approximately $50K (for 50 years). The first two alternatives are inappropriate from a cost benefit perspective and do not provide practicable risk reduction.

Current and future risks to human health and the environment are minimal and are lower than the risk to workers that would result from implementing these remedial actions. Therefore, no remediation in conjunction with an ACL application for uranium and vanadium is the preferred alternative.

The proposed ACL was developed in the basis of the potential for ground water to contribute contamination to surface water. The POE is any point along the San Miguel River and receptors would be organisms living in the river waters and being exposed to surface water and sediment. The proposed value for uranium at the POE is the UMTRA MCL of 0.044 mg/L; the proposed value for vanadium is 0.330 mg/L. Calculations in the 1995 BLRA (DOE 1995) considered the effect of contaminated ground water seeping into the San Miguel River. The highest concentrations of contaminants were used in the calculation and were assumed to attenuate slightly before they entered the river near surface location 0538. A statistical 20-year low flow for the river was also used in the estimate. Results showed that increases of uranium and vanadium concentrations in the river water were 0.001 mg/L uranium and 0.002 mg/L vanadium. These increases are insufficient to cause an increase in human health or ecological risks.

8.4.1 Proposed Implementation Measures

In order for the ACL application to be effective the following criteria are proposed.

- Institutional controls will be implemented through an environmental covenant with the State to ensure that no one drinks the water. This IC will remain in effect for perpetuity or until concentrations of contaminants at the site fall below acceptable levels.

- DOE will monitor ground water along the San Miguel River and at proposed monitoring wells locations

Monitoring is planned to ensure continued protection of human health and the environment.. Monitoring wells DM1, NAT08, NAT26, MAU08, MAU07, and the domestic well 716, to be installed on the Maupin property, along with surface locations 0531, SM2, SM4, and 533 will be

monitored for arsenic, uranium, and vanadium. DM1 is a background ground water location; if it is removed by expansion of the gravel mining operation, a suitable location will be selected for installation of a new background well. NAT08 contains the maximum vanadium concentration (2.47 mg/L), NAT26 contains the maximum uranium concentration (2.39 mg/L), MAU08 shows the maximum northern concentration for uranium, and the proposed Maupin well will be monitored to verify that no contaminants have migrated into the deeper aquifer. Surface location 0531 is upgradient on the San Miguel River, SM2 is east of the maximum vanadium concentrations along the river, SM4 is east of the maximum uranium concentrations along the river, and 0533 is the downgradient location on the San Miguel River.

Monitoring would be conducted annually for the next 5 years and every 3 years after that for the next 30 years. At the end of this time DOE will evaluated the levels of contaminants to determine if a change in the monitoring plan should be made. If concentrations drop below 0.044 mg/L for uranium and below 0.33 mg/L for vanadium, monitoring will be discontinued. According to modeling, this could require up to 135 years for uranium and far more time for vanadium.

The City of Naturita and Montrose County are considering construction of a golf course on the site if adequate land is obtained from the mining companies. The golf course is only in the discussion stages at this time, but the proposed environmental covenant would prevent anyone from using ground water within the IC boundary for drinking purposes. One family is living in the area of contaminated ground water. They haul water from a public water source in Naturita. DOE proposes to drill and install a domestic well for the family as a permanent source of drinking water.

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End of current text

Appendix A

Monitoring Well Logs

BOREHOLE LOG NAT01-0547

PROJECT UMTRA GROUND WATER	SURFACE ELEV. (FT NGVD) 5305.67
LOCATION _, CO	BIT SIZE(S) (IN)
SITE NATURITA	DRILLING METHOD ROTARY
WELL NUMBER 0547	SAMPLING METHOD
NORTH COORD. (FT) 586374.78	WATER LEVEL (FT BTOC) 6.57 on 06/16/1986
EAST COORD. (FT) 1107853.64	LOGGED BY Dupuy, J.
HOLE DEPTH (FT) 23.00	REMARKS Approximately 10.0 ft. Northwest of fience line, lower terrace.
DATE DRILLED 06/05/1986	

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	5305					0-8.0 ft. SAND (SP); unconsolidated sand with cobbles.
5	5300					
						8.0-11.0 ft. GRAVEL (GP); cobble layer.
10	5295					11.0-13.0 ft. CLAY (CL); gummy clay layer 2.0 ft thick.
						13.0-16.0 ft. SILTSTONE (SI); dark brown siltstone and mudstone.
15	5290					16.0-23.0 ft. SANDSTONE (SS); sandstone stringer. 17.0-23.0 ft. Dark brownish-red sandstone
20	5285					
						Total Depth 23.0 ft.

BOREHOLE LOG NAT01-0548

PROJECT	UMTRA GROUND WATER	**SURFACE ELEV. (FT NGVD)**	5291.03
LOCATION	, CO	**BIT SIZE(S) (IN)**	
SITE	NATURITA	**DRILLING METHOD**	AUGER/ROTARY
WELL NUMBER	0548	**SAMPLING METHOD**	
NORTH COORD. (FT)	588998.73	**WATER LEVEL (FT BTOC)**	8.05 on 06/17/1986
EAST COORD. (FT)	1106297.08	**LOGGED BY**	Dupuy, J.
HOLE DEPTH (FT)	23.00	**REMARKS**	
DATE DRILLED	06/09/1986 to 06/11/1986		

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	5290					0-10 ft. CLAY EY SILT (ML), alluvial material, no cobbles. Damp @ 4.0 ft.
5	5285					
10	5280					10-13 ft. SANDY GRAVEL (GW-SW), with some cobbles and clay, becomes mostly gravel at depth.
15	5275					13-19 ft. GRAVEL (GW), some sand with cobbles, river alluvium.
20	5270					19-23 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SILTSTONE; bedrock with some mudstone, reddish-brown in color.
						Total Depth 23.0 ft.

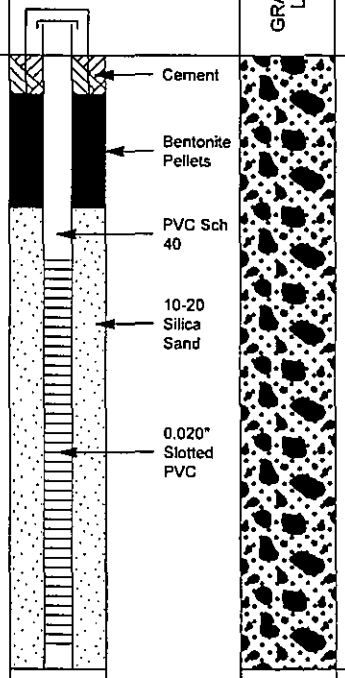
MONITORING WELL COMPLETION LOG NAT01-DM1

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	585973.91	DATE DRILLED	07/06/1999
LOCATION	, CO	EAST COORD. (FT)	1108381.41	SURFACE ELEV. (FT NGVD)	5307.58
SITE	NATURITA	HOLE DEPTH (FT)	8.00	TOP OF CASING (FT)	5310.81
WELL NUMBER	DM1	WELL DEPTH (FT)	8.00	MEAS. PT. ELEV. (FT)	5310.81
				SLOT SIZE (IN)	0.020
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-3.23	to	2.67
WELL SCREEN:	2 in. Slotted PVC	2.67	to	7.67
SUMP/END CAP:	2 in. PVC	7.67	to	8.0
SURFACE SEAL:	Cement	0.0	to	0.5
GROUT:				
SEAL:	Bentonite Pellets	0.5	to	2.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	2.0	to	8.0

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-8 ft. SANDY GRAVEL (GW-SW), river gravel with sand.
	5305						
5							
	5300						
							Total Depth 8.0 ft.
10							



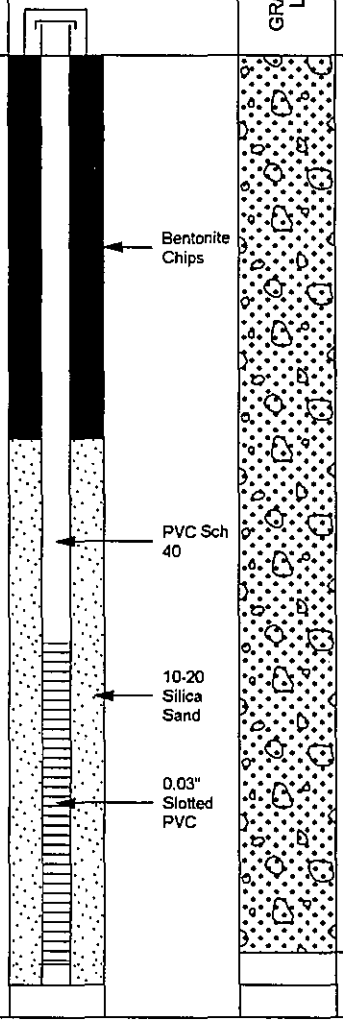
MONITORING WELL COMPLETION LOG NAT01-MAU01

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	589391.84	DATE DRILLED	10/18/1998
LOCATION	, CO	EAST COORD. (FT)	1106198.83	SURFACE ELEV. (FT NGVD)	5287.99
SITE	NATURITA	HOLE DEPTH (FT)	14.50	TOP OF CASING (FT)	5289.68
WELL NUMBER	MAU01	WELL DEPTH (FT)	14.50	MEAS. PT. ELEV. (FT)	5289.68
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	9.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-1.69	to	9.17
WELL SCREEN:	2 in. Slotted PVC	9.17	to	14.17
SUMP/END CAP:	2 in. PVC Sch 40	14.17	to	14.5
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Chips	0.0	to	6.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	6.0	to	14.5

DRILLING METHOD	AUGER
SAMPLING METHOD	
DATE DEVELOPED	
WATER LEVEL (FT BGS)	
LOGGED BY	Holmes
REMARKS	

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-14 ft. ALLUVIUM
	5285				Bentonite Chips		
5							
	5280				PVC Sch 40		
10					10-20 Silica Sand		
					0.03" Slotted PVC		
	5275						
							Total Depth 14.0 ft



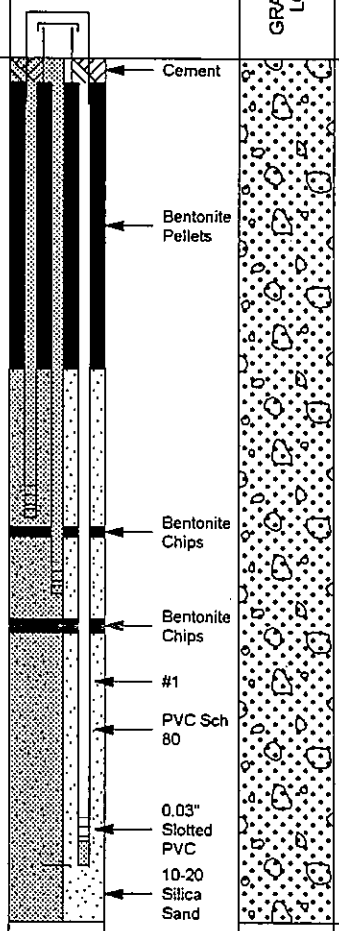
MONITORING WELL COMPLETION LOG NAT01-MAU02-1

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	589379.50	DATE DRILLED	10/18/1998
LOCATION	, CO	EAST COORD. (FT)	1106368.48	SURFACE ELEV. (FT NGVD)	5287.33
SITE	NATURITA	HOLE DEPTH (FT)	18.00	TOP OF CASING (FT)	5289.42
WELL NUMBER	MAU02-1	WELL DEPTH (FT)	16.83	MEAS. PT. ELEV. (FT)	5289.42
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	9.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.09	to	15.82
WELL SCREEN:	0.5 in. Slotted PVC	15.82	to	16.32
SUMP/END CAP:	0.5 in. PVC Sch 80	16.32	to	16.83
SURFACE SEAL:	Cement	0.0	to	0.5
GROUT:				
SEAL:	Bentonite Chips	11.67	to	12.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	12.0	to	18.0

DRILLING METHOD AUGER
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes
REMARKS Cluster of 3 casings: MAU02-1 casing and screen depths provided; MAU02-2 casing is from 0 to 10.5 ft. and screened to 11.0 ft.; MAU02-3 casing is from 0 to 8.91 ft. and screened to 9.41 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-18 ft. ALLUVIUM
							Total Depth 18.0 ft.



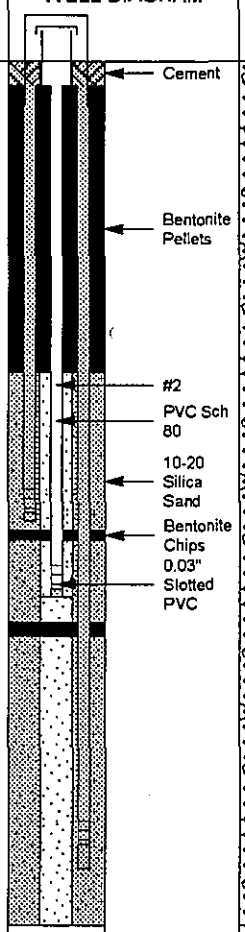
MONITORING WELL COMPLETION LOG NAT01-MAU02-2

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	589379.50	DATE DRILLED	10/18/1998
LOCATION	, CO	EAST COORD. (FT)	1106368.48	SURFACE ELEV. (FT NGVD)	5287.33
SITE	NATURITA	HOLE DEPTH (FT)	18.00	TOP OF CASING (FT)	5289.40
WELL NUMBER	MAU02-2	WELL DEPTH (FT)	11.17	MEAS. PT. ELEV. (FT)	5289.40
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	9.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.07	to	10.5
WELL SCREEN:	0.5 in. Slotted PVC	10.5	to	11.0
SUMP/END CAP:	0.5 in. PVC Sch 80	11.0	to	11.17
SURFACE SEAL:	Cement	0.0	to	0.5
GROUT:				
SEAL:	Bentonite Chips	9.75	to	10.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	10.0	to	18.0

DRILLING METHOD AUGER
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes
REMARKS Cluster of 3 casings: MAU02-2 casing and screen depths provided; MAU02-1 casing is from 0 to 15.82 ft. and screened to 16.32 ft.; MAU02-3 casing is from 0 to 8.91 ft. and screened to 9.41 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-18 ft. ALLUVIUM
	5285						
5							
	5280						
10							
	5275						
15							
	5270						
							Total Depth 18.0 ft.



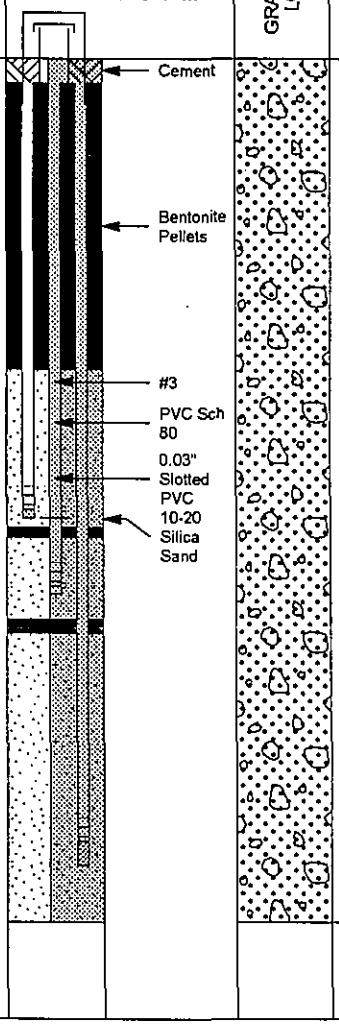
MONITORING WELL COMPLETION LOG NAT01-MAU02-3

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	589379.50	DATE DRILLED	10/18/1998
LOCATION	, CO	EAST COORD. (FT)	1106368.48	SURFACE ELEV. (FT NGVD)	5287.33
SITE	NATURITA	HOLE DEPTH (FT)	18.00	TOP OF CASING (FT)	5289.40
WELL NUMBER	MAU02-3	WELL DEPTH (FT)	9.58	MEAS. PT. ELEV. (FT)	5289.40
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	9.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.07	to	8.91
WELL SCREEN:	0.5 in. Slotted PVC	8.91	to	9.41
SUMP/END CAP:	0.5 in. PVC Sch 80	9.41	to	9.58
SURFACE SEAL:	Cement	0.0	to	0.5
GROUT:				
SEAL:	Bentonite Pellets	0.5	to	6.5
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	6.5	to	18.0

DRILLING METHOD AUGER
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes
REMARKS Cluster of 3 casings: MAU02-3 casing and screen depths provided; MAU02-1 casing is from 0 to 15.82 ft. and screened to 16.32 ft.; MAU02-2 casing is from 0 to 10.5 ft. and screened to 11.0 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	5285				Cement; Bentonite Pellets		0-18 ft. ALLUVIUM
5							
	5280				#3; PVC Sch 80; 0.03" Slotted PVC; 10-20 Silica Sand		
10							
	5275						
15							
	5270						Total Depth 18.0 ft.



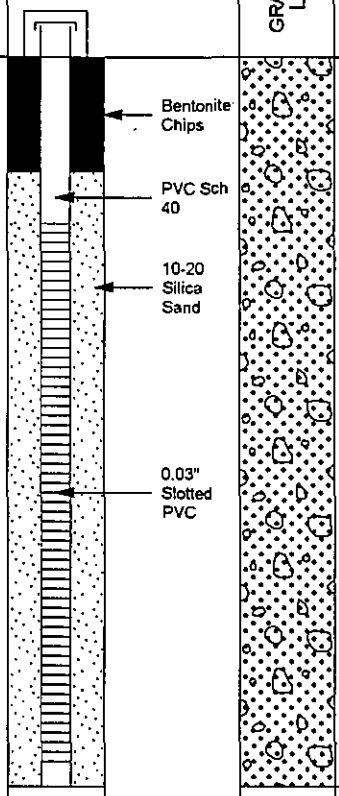
MONITORING WELL COMPLETION LOG NAT01-MAU03

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	589917.28	DATE DRILLED	10/19/1998
LOCATION	, CO	EAST COORD. (FT)	1106720.41	SURFACE ELEV. (FT NGVD)	5280.17
SITE	NATURITA	HOLE DEPTH (FT)	9.50	TOP OF CASING (FT)	5282.52
WELL NUMBER	MAU03	WELL DEPTH (FT)	9.50	MEAS. PT. ELEV. (FT)	5282.52
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	10.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.35	to	2.17
WELL SCREEN:	2 in. Slotted PVC	2.17	to	9.17
SUMP/END CAP:	2 in. PVC Sch 40	9.17	to	9.5
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Chips	0.5	to	1.5
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	1.5	to	9.5

DRILLING METHOD AUGER
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes
REMARKS

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	5280						0-9.5 ft. ALLUVIUM
5	5275						
10	5270						Total Depth 9.5 ft.



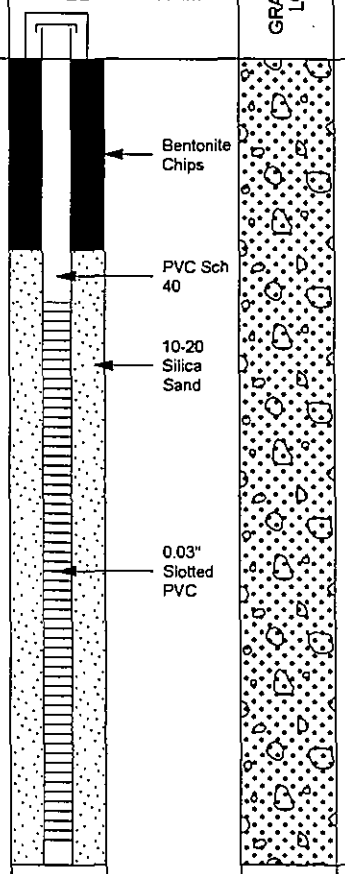
MONITORING WELL COMPLETION LOG NAT01-MAU04

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	590098.35	DATE DRILLED	10/19/1998
LOCATION	, CO	EAST COORD. (FT)	1106618.36	SURFACE ELEV. (FT NGVD)	5278.76
SITE	NATURITA	HOLE DEPTH (FT)	10.50	TOP OF CASING (FT)	5280.56
WELL NUMBER	MAU04	WELL DEPTH (FT)	10.50	MEAS. PT. ELEV. (FT)	5280.56
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	9.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-1.8	to	3.17
WELL SCREEN:	2 in. Slotted PVC	3.17	to	10.17
SUMP/END CAP:	2 in. PVC Sch 40	10.17	to	10.5
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Chips	0.0	to	2.5
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	2.5	to	10.5

DRILLING METHOD AUGER
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes
REMARKS

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-10.5 ft. ALLUVIUM
	5275						
5							
	5270						
10							
							Total Depth 10.5 ft.



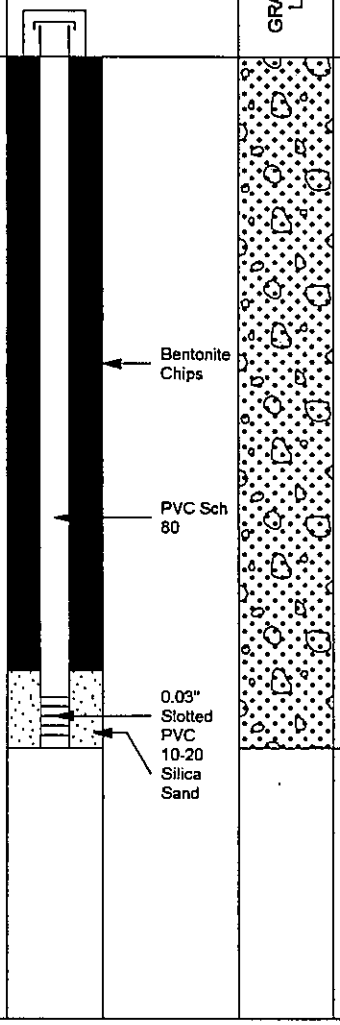
MONITORING WELL COMPLETION LOG NAT01-MAU05

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	589407.28	DATE DRILLED	10/18/1998
LOCATION	, CO	EAST COORD. (FT)	1106334.48	SURFACE ELEV. (FT NGVD)	5286.95
SITE	NATURITA	HOLE DEPTH (FT)	9.00	TOP OF CASING (FT)	5289.20
WELL NUMBER	MAU05	WELL DEPTH (FT)	9.00	MEAS. PT. ELEV. (FT)	5289.20
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	9.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.25	to	8.17
WELL SCREEN:	2 in. Slotted PVC	8.17	to	8.67
SUMP/END CAP:	2 in. PVC Sch 40	8.67	to	9.0
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Chips	0.0	to	8.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	8.0	to	9.0

DRILLING METHOD AUGER
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes
REMARKS

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-9 ft. ALLUVIUM
	5285						
5					Bentonite Chips		
					PVC Sch 80		
	5280						
					0.03" Slotted PVC 10-20 Silica Sand		
							Total Depth 9.0 ft.
10							
	5275						



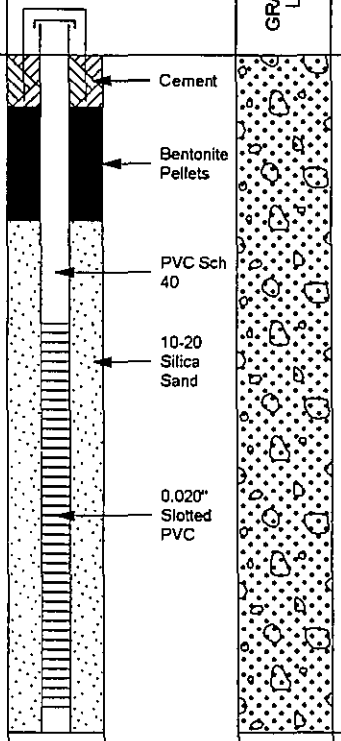
MONITORING WELL COMPLETION LOG NAT01-MAU06

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	589667.72	DATE DRILLED	07/01/1999
LOCATION	, CO	EAST COORD. (FT)	1106557.81	SURFACE ELEV. (FT NGVD)	5284.16
SITE	NATURITA	HOLE DEPTH (FT)	8.83	TOP OF CASING (FT)	5286.60
WELL NUMBER	MAU06	WELL DEPTH (FT)	8.83	MEAS. PT. ELEV. (FT)	5286.60
				SLOT SIZE (IN)	0.020
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.44	to	3.5
WELL SCREEN:	2 in. Slotted PVC	3.5	to	8.5
SUMP/END CAP:	2 in. PVC Sch 40	8.5	to	8.83
SURFACE SEAL:	Cement	0.0	to	0.67
GROUT:				
SEAL:	Bentonite Pellets	0.67	to	2.16
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	2.16	to	8.83

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-8.83 ft. ALLUVIUM
	5280						
5							
	5275						Total Depth 8.83 ft.
10							



macTec-ers

U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION OFFICE, COLORADO

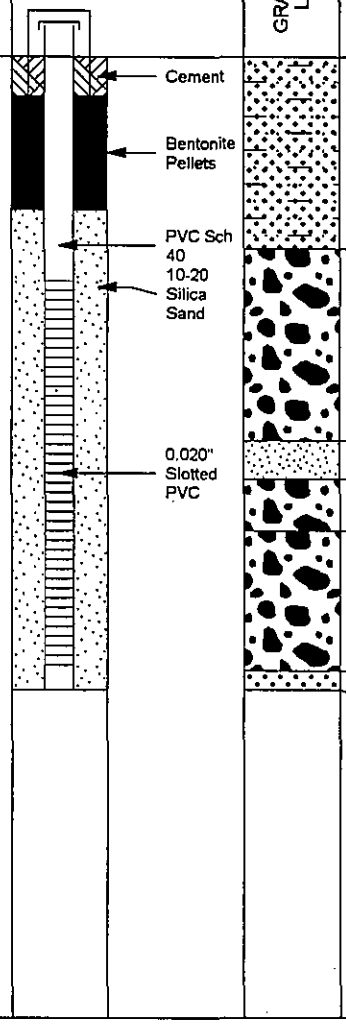
MONITORING WELL COMPLETION LOG NAT01-MAU07

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	590223.12	DATE DRILLED	07/01/1999
LOCATION	, CO	EAST COORD. (FT)	1106502.56	SURFACE ELEV. (FT NGVD)	5278.11
SITE	NATURITA	HOLE DEPTH (FT)	8.25	TOP OF CASING (FT)	5280.88
WELL NUMBER	MAU07	WELL DEPTH (FT)	8.25	MEAS. PT. ELEV. (FT)	5280.88
				SLOT SIZE (IN)	0.020
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.77	to	2.92
WELL SCREEN:	2 in. Slotted PVC	2.92	to	7.92
SUMP/END CAP:	2 in. PVC Sch 40	7.92	to	8.25
SURFACE SEAL:	Cement	0.0	to	0.5
GROUT:				
SEAL:	Bentonite Pellets	0.5	to	2.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	2.0	to	8.25

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
					Cement		0-2.5 ft. SILTY SAND (SM).
					Bentonite Pellets		
					PVC Sch 40		
	5275				10-20 Silica Sand		2.5-5 ft. GRAVEL (GW), some cobbles.
5					0.020" Slotted PVC		5-5.5 ft. SAND (SP)
							5.5-6.17 ft. GRAVEL (GW), some small cobbles.
							6.17-8 ft. BOULDERS and GRAVEL.
	5270						8-8.25 ft. SAND (SW), some silt with large boulder@8.25 ft.
							Total Depth 8.25 ft.
10							



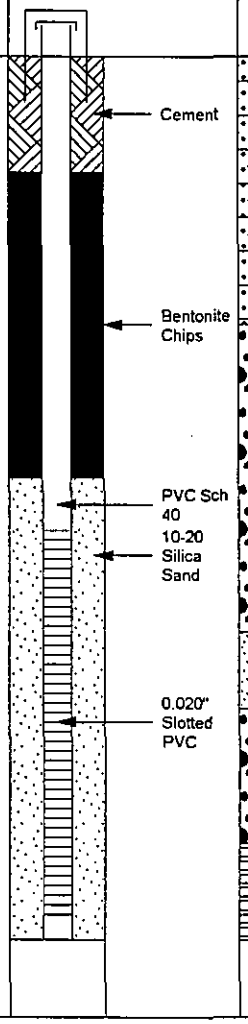
MONITORING WELL COMPLETION LOG NAT01-MAU08

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	589388.55	DATE DRILLED	07/01/1999
LOCATION	, CO	EAST COORD. (FT)	1106088.62	SURFACE ELEV. (FT NGVD)	5288.27
SITE	NATURITA	HOLE DEPTH (FT)	11.50	TOP OF CASING (FT)	5291.19
WELL NUMBER	MAU08	WELL DEPTH (FT)	11.50	MEAS. PT. ELEV. (FT)	5291.19
				SLOT SIZE (IN)	0.020
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.92	to	6.17
WELL SCREEN:	2 in. Slotted PVC	6.17	to	11.17
SUMP/END CAP:	2 in. PVC Sch 40	11.17	to	11.5
SURFACE SEAL:	Cement	0.0	to	1.5
GROUT:				
SEAL:	Bentonite Chips	1.5	to	5.5
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	5.5	to	11.5

DRILLING METHOD	HAMMER CASING ADVANCE
SAMPLING METHOD	
DATE DEVELOPED	
WATER LEVEL (FT BGS)	
LOGGED BY	Holmes/Rowland
REMARKS	

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-3.5 ft. SILTY SAND (SM).
	5285						3.5-7.5 ft. GRAVEL (GW), some cobbles.
5							
							7.5-8.5 ft. SAND (SP), some clay.
	5280						8.5-10.25 ft. GRAVEL (GW), some small cobbles with sand.
10							10.25-11.5 ft.. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE, bedrock..
							Total Depth 11.5 ft.



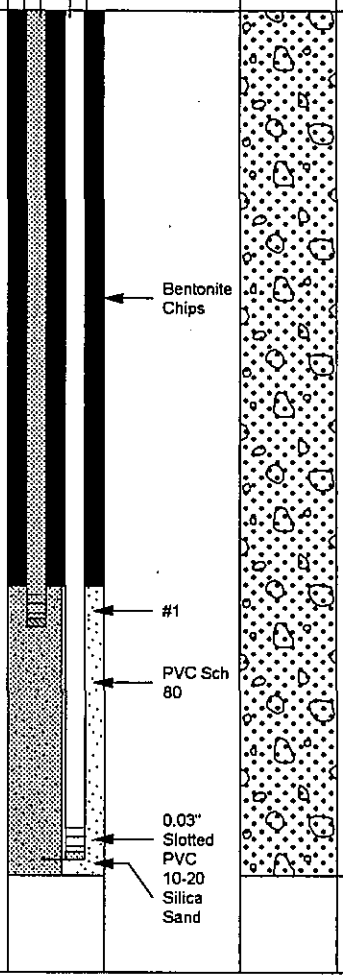
MONITORING WELL COMPLETION LOG NAT01-NAT01-1

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	588672.47	DATE DRILLED	10/15/1998
LOCATION	, CO	EAST COORD. (FT)	1106284.10	SURFACE ELEV. (FT NGVD)	5292.84
SITE	NATURITA	HOLE DEPTH (FT)	18.00	TOP OF CASING (FT)	5295.46
WELL NUMBER	NAT01-1	WELL DEPTH (FT)	17.67	MEAS. PT. ELEV. (FT)	5295.46
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	14.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.62	to	17.0
WELL SCREEN:	0.5 in. Slotted PVC	17.0	to	17.5
SUMP/END CAP:	0.5 in. PVC Sch 80	17.5	to	17.67
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Chips	0.0	to	12.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	12.0	to	18.0

DRILLING METHOD AUGER
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes
REMARKS Cluster of 2 casings: NAT01-1 casing and screen depths provided; NAT01-2 casing is from 0 to 12.16 and screened to 12.66 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-18 ft. ALLUVIUM
	5290						
5					Bentonite Chips		
	5285						
10							
	5280				#1		
					PVC Sch 80		
15							
					0.03" Slotted PVC		
	5275				10-20 Silica Sand		
							Total Depth 18.0 ft.



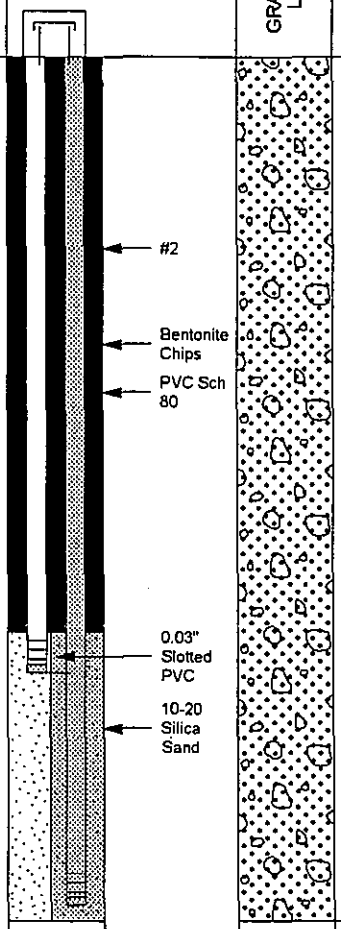
MONITORING WELL COMPLETION LOG NAT01-NAT01-2

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	588672.47	DATE DRILLED	10/15/1998
LOCATION	, CO	EAST COORD. (FT)	1106284.10	SURFACE ELEV. (FT NGVD)	5292.84
SITE	NATURITA	HOLE DEPTH (FT)	18.00	TOP OF CASING (FT)	5295.29
WELL NUMBER	NAT01-2	WELL DEPTH (FT)	12.66	MEAS. PT. ELEV. (FT)	5295.29
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	14.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.45	to	12.16
WELL SCREEN:	0.5 in. Slotted PVC	12.16	to	12.66
SUMP/END CAP:	0.5 in. PVC Sch 80	12.66	to	12.83
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Chips	0.0	to	12.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	12.0	to	18.0

DRILLING METHOD AUGER
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes
REMARKS Cluster of 2 casings: NAT01-2 casing and screen depths provided; NAT01-1 casing is from 0 to 17 and screened to 17.5 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-18 ft. ALLUVIUM
	5290						
5							
	5285						
10							
	5280						
15							
	5275						
							Total Depth 18.0 ft.



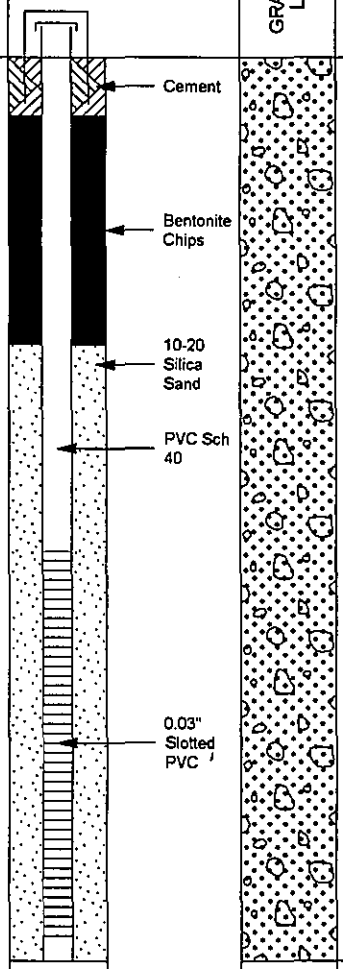
MONITORING WELL COMPLETION LOG NAT01-NAT02

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	588084.64	DATE DRILLED	10/16/1998
LOCATION	, CO	EAST COORD. (FT)	1106827.76	SURFACE ELEV. (FT NGVD)	5291.98
SITE	NATURITA	HOLE DEPTH (FT)	11.75	TOP OF CASING (FT)	5294.09
WELL NUMBER	NAT02	WELL DEPTH (FT)	11.75	MEAS. PT. ELEV. (FT)	5294.09
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	9.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.11	to	6.42
WELL SCREEN:	2 in. Slotted PVC	6.42	to	11.42
SUMP/END CAP:	2 in. PVC Sch 40	11.42	to	11.75
SURFACE SEAL:	Cement	0.0	to	0.75
GROUT:				
SEAL:	Bentonite Chips	0.75	to	3.75
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	3.75	to	11.75

DRILLING METHOD AUGER
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes
REMARKS

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-11.75 ft. ALLUVIUM
	5290						
5							
	5285						
10							
	5280						Total Depth 11.75 ft.



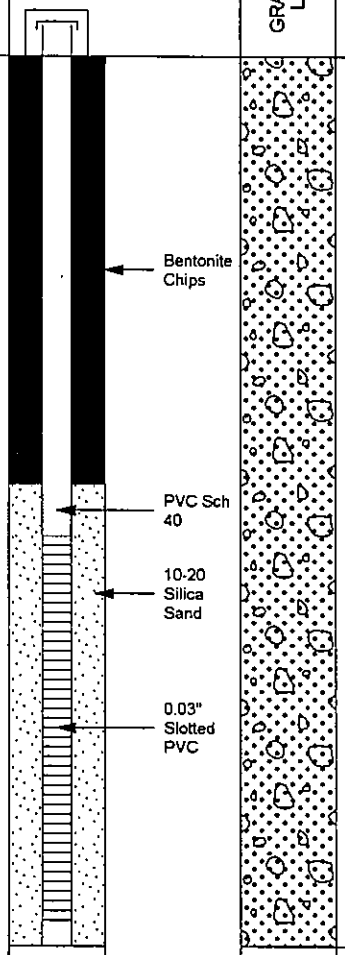
MONITORING WELL COMPLETION LOG NAT01-NAT03

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	588292.94	DATE DRILLED	10/17/1998
LOCATION	, CO	EAST COORD. (FT)	1106419.18	SURFACE ELEV. (FT NGVD)	5291.27
SITE	NATURITA	HOLE DEPTH (FT)	11.58	TOP OF CASING (FT)	5293.05
WELL NUMBER	NAT03	WELL DEPTH (FT)	11.58	MEAS. PT. ELEV. (FT)	5293.05
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	9.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-1.78	to	6.25
WELL SCREEN:	2 in. Slotted PVC	6.25	to	11.25
SUMP/END CAP:	2 in. PVC Sch 40	11.25	to	11.58
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Chips	0.0	to	5.58
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	5.58	to	11.58

DRILLING METHOD	AUGER
SAMPLING METHOD	
DATE DEVELOPED	
WATER LEVEL (FT BGS)	
LOGGED BY	Holmes
REMARKS	

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	5290				Bentonite Chips		0-11.58 ft. ALLUVIUM
5	5285				PVC Sch 40; 10-20 Silica Sand; 0.03" Slotted PVC		
10	5280						
							Total Depth 11.58 ft.



MONITORING WELL COMPLETION LOG NAT01-NAT04-1

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587979.79	DATE DRILLED	10/17/1998
LOCATION	, CO	EAST COORD. (FT)	1106710.73	SURFACE ELEV. (FT NGVD)	5293.08
SITE	NATURITA	HOLE DEPTH (FT)	17.00	TOP OF CASING (FT)	5295.24
WELL NUMBER	NAT04-1	WELL DEPTH (FT)	12.67	MEAS. PT. ELEV. (FT)	5295.24
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	9.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 40	-2.16	to	12.0
WELL SCREEN:	0.5 in. Slotted PVC	12.0	to	12.5
SUMP/END CAP:	0.5 in. PVC Sch 40	12.5	to	12.67
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Pellets	11.16	to	11.5
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	11.5	to	17.0

DRILLING METHOD AUGER
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes
REMARKS Cluster of 3 casings: NAT04-1 casing and screen depths provided; NAT04-2 casing is from 0 to 9.67 ft. and screened to 10.17 ft.; NAT04-3 casing is from 0 to 8.17 ft. and screened to 8.67 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-14 ft. ALLUVIUM
	5290				Bentonite Pellets		
5							
	5285				Bentonite Chips		
10					#1 PVC Sch 40		
					Bentonite Chips		
	5280				0.03" Slotted PVC		
							14-17 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION; SHALE
15					10-20 Silica Sand		
							Total Depth 17.0 ft.
	5275						

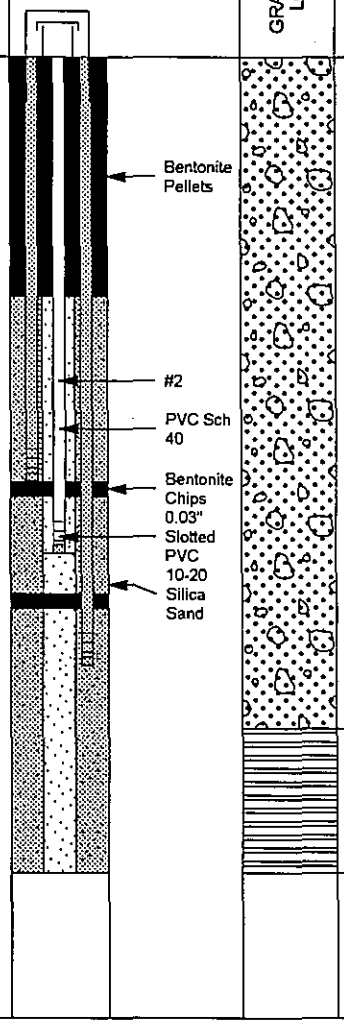
MONITORING WELL COMPLETION LOG NAT01-NAT04-2

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587979.79	DATE DRILLED	10/17/1998
LOCATION	, CO	EAST COORD. (FT)	1106710.73	SURFACE ELEV. (FT NGVD)	5293.08
SITE	NATURITA	HOLE DEPTH (FT)	17.00	TOP OF CASING (FT)	5295.28
WELL NUMBER	NAT04-2	WELL DEPTH (FT)	10.34	MEAS. PT. ELEV. (FT)	5295.28
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	9.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 40	-2.2	to	9.67
WELL SCREEN:	0.5 in. Slotted PVC	9.67	to	10.17
SUMP/END CAP:	0.5 in. PVC Sch 40	10.17	to	10.34
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Chips	9.16	to	8.83
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	8.83	to	17.0

DRILLING METHOD AUGER
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes
REMARKS Cluster of 3 casings: NAT04-2 casing and screen depths provided; NAT04-1 casing is from 0 to 12 ft. and screened to 12.5 ft.; NAT04-3 casing is from 0 to 8.17 ft. and screened to 8.67 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-14 ft. ALLUVIUM
	5290						
5							
	5285						
10							
	5280						
							14-17 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION; SHALE
15							
	5275						Total Depth 17.0 ft.



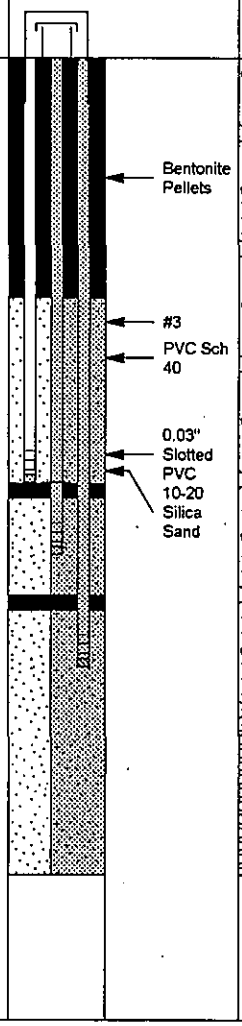
MONITORING WELL COMPLETION LOG NAT01-NAT04-3

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587979.79	DATE DRILLED	10/17/1998
LOCATION	, CO	EAST COORD. (FT)	1106710.73	SURFACE ELEV. (FT NGVD)	5293.08
SITE	NATURITA	HOLE DEPTH (FT)	17.00	TOP OF CASING (FT)	5295.28
WELL NUMBER	NAT04-3	WELL DEPTH (FT)	8.84	MEAS. PT. ELEV. (FT)	5295.28
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	9.0

WELL INSTALLATION		INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 40	-2.2	to	8.17
WELL SCREEN:	0.5 in. Slotted PVC	8.17	to	8.67
SUMP/END CAP:	0.5 in. PVC Sch 40	8.67	to	8.84
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Chips	0.0	to	5.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	5.0	to	17.0

DRILLING METHOD AUGER
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes
REMARKS Cluster of 3 casings: NAT04-3 casing and screen depths provided; NAT04-1 casing is from 0 to 12 ft. and screened to 12.5 ft; NAT04-2 casing is from 0 to 9.67 ft. and screened to 10.17 ft..

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-14 ft. ALLUVIUM
	5290						
5							
	5285						
10							
	5280						
							14-17 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION; SHALE
15							
	5275						Total Depth 17.0 ft.



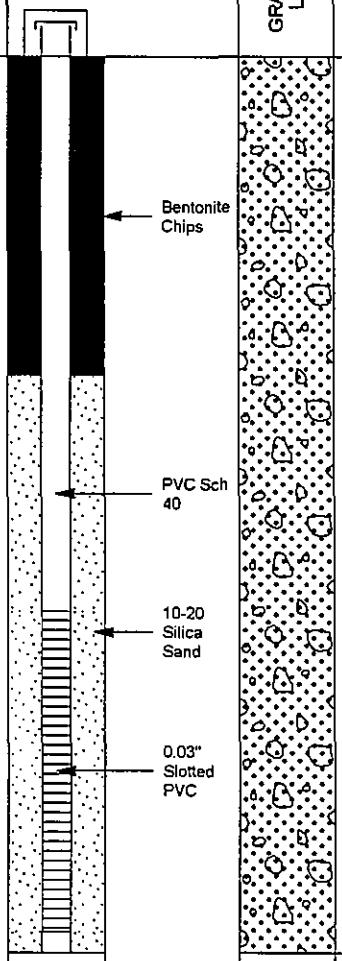
MONITORING WELL COMPLETION LOG NAT01-NAT05

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	588299.51	DATE DRILLED	10/17/1998
LOCATION	, CO	EAST COORD. (FT)	1106235.48	SURFACE ELEV. (FT NGVD)	5292.33
SITE	NATURITA	HOLE DEPTH (FT)	14.00	TOP OF CASING (FT)	5294.42
WELL NUMBER	NAT05	WELL DEPTH (FT)	14.00	MEAS. PT. ELEV. (FT)	5294.42
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	9.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.09	to	8.67
WELL SCREEN:	2 in. Slotted PVC	8.67	to	13.67
SUMP/END CAP:	2 in. PVC Sch 40	13.67	to	14.0
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Chips	0.0	to	5.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	5.0	to	14.0

DRILLING METHOD AUGER
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes
REMARKS

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-14 ft. ALLUVIUM
	5290				Bentonite Chips		
5							
	5285				PVC Sch 40		
					10-20 Silica Sand		
10							
					0.03" Slotted PVC		
	5280						
							Total Depth 14.2 ft.



MONITORING WELL COMPLETION LOG NAT01-NAT06-1

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587901.18	DATE DRILLED	10/19/1998
LOCATION	, CO	EAST COORD. (FT)	1106621.36	SURFACE ELEV. (FT NGVD)	5293.57
SITE	NATURITA	HOLE DEPTH (FT)	12.50	TOP OF CASING (FT)	5296.41
WELL NUMBER	NAT06-1	WELL DEPTH (FT)	12.33	MEAS. PT. ELEV. (FT)	5296.41
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	9.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.84	to	11.66
WELL SCREEN:	0.5 in. Slotted PVC	11.66	to	12.16
SUMP/END CAP:	0.5 in. PVC Sch 80	12.16	to	12.33
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Chips	0.0	to	5.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	5.0	to	12.5

DRILLING METHOD AUGER
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes
REMARKS Cluster of 3 casings: NAT06-1 casing and screen depths provided; NAT06-2 casing is from 0 to 9.25 ft. and screened to 9.75 ft.; NAT06-3 casing is from 0 to 5.41 ft. and screened to 5.91 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-12.5 ft. ALLUVIUM
	5290						
5							
	5285						
10							
	5280						Total Depth 12.5 ft.

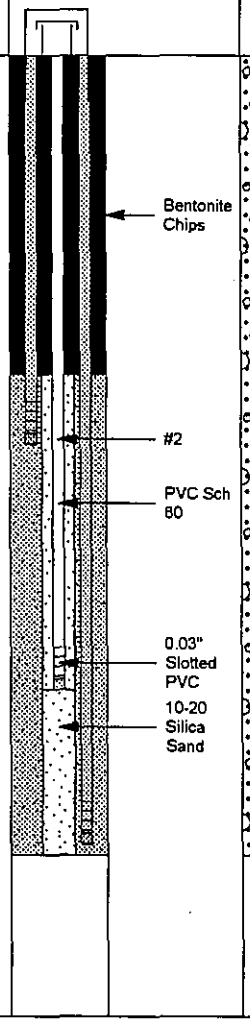
MONITORING WELL COMPLETION LOG NAT01-NAT06-2

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587901.18	DATE DRILLED	10/19/1998
LOCATION	, CO	EAST COORD. (FT)	1106621.36	SURFACE ELEV. (FT NGVD)	5293.57
SITE	NATURITA	HOLE DEPTH (FT)	12.50	TOP OF CASING (FT)	5296.41
WELL NUMBER	NAT06-2	WELL DEPTH (FT)	9.92	MEAS. PT. ELEV. (FT)	5296.41
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	9.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.84	to	9.25
WELL SCREEN:	0.5 in. Slotted PVC	9.25	to	9.75
SUMP/END CAP:	0.5 in. PVC Sch 80	9.75	to	9.92
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Chips	0.0	to	5.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	5.0	to	12.5

DRILLING METHOD AUGER
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes
REMARKS Cluster of 3 casings: NAT06-2 casing and screen depths provided; NAT06-1 casing is from 0 to 11.66 ft. and screened to 12.16 ft.; NAT06-3 casing is from 0 to 5.41 ft. and screened to 5.91 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-12.5 ft. ALLUVIUM
5	5290						
10	5285						
	5280						Total Depth 12.5 ft.



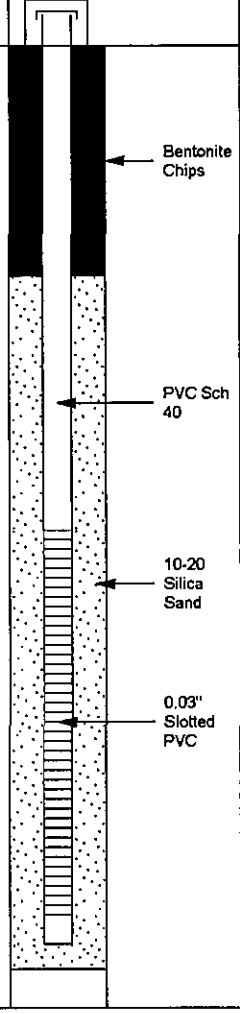
MONITORING WELL COMPLETION LOG NAT01-NAT08

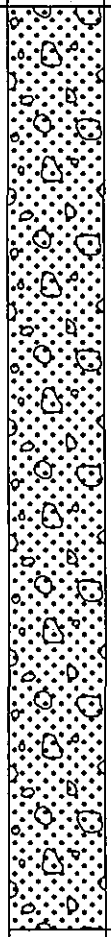
PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	588288.72	DATE DRILLED	10/20/1998
LOCATION	, CO	EAST COORD. (FT)	1106422.26	SURFACE ELEV. (FT NGVD)	5291.13
SITE	NATURITA	HOLE DEPTH (FT)	12.00	TOP OF CASING (FT)	5292.73
WELL NUMBER	NAT08	WELL DEPTH (FT)	11.67	MEAS. PT. ELEV. (FT)	5292.73
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	12.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	4 in. PVC Sch 40	-1.6	to	6.3
WELL SCREEN:	4 in. Slotted PVC	6.3	to	11.3
SUMP/END CAP:	4 in. PVC Sch 40	11.3	to	11.67
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Chips	0.0	to	3.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	3.0	to	12.0

DRILLING METHOD AUGER
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes
REMARKS

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	5290				Bentonite Chips		0-12 ft. ALLUVIUM
5					PVC Sch 40		
	5285				10-20 Silica Sand		
					0.03" Slotted PVC		
10							
	5280						
							Total Depth 12.0 ft.





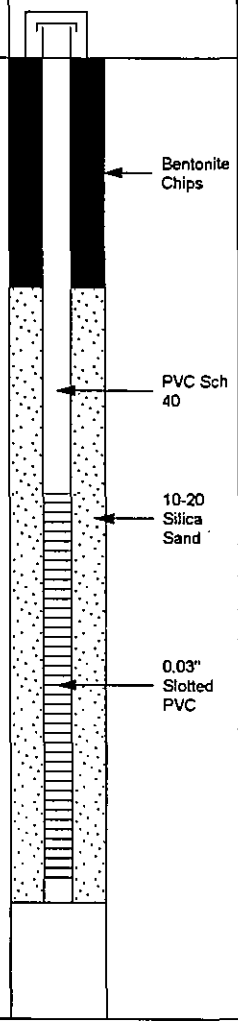
MONITORING WELL COMPLETION LOG NAT01-NAT09

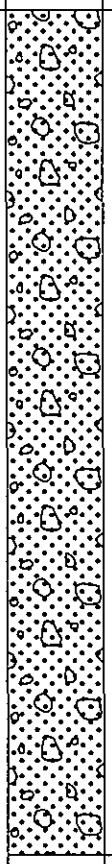
PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	588296.86	DATE DRILLED	10/20/1998
LOCATION	, CO	EAST COORD. (FT)	1106415.59	SURFACE ELEV. (FT NGVD)	5291.26
SITE	NATURITA	HOLE DEPTH (FT)	11.00	TOP OF CASING (FT)	5293.11
WELL NUMBER	NAT09	WELL DEPTH (FT)	11.00	MEAS. PT. ELEV. (FT)	5293.11
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	9.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-1.85	to	5.67
WELL SCREEN:	2 in. Slotted PVC	5.67	to	10.67
SUMP/END CAP:	2 in. PVC Sch 40	10.67	to	11.0
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Chips	0.0	to	3.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	3.0	to	11.0

DRILLING METHOD AUGER
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes
REMARKS

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-11 ft. ALLUVIUM
	5290				Bentonite Chips		
					PVC Sch 40		
5							
	5285				10-20 Silica Sand		
					0.03" Slotted PVC		
10							
	5280						Total Depth 11.0 ft.





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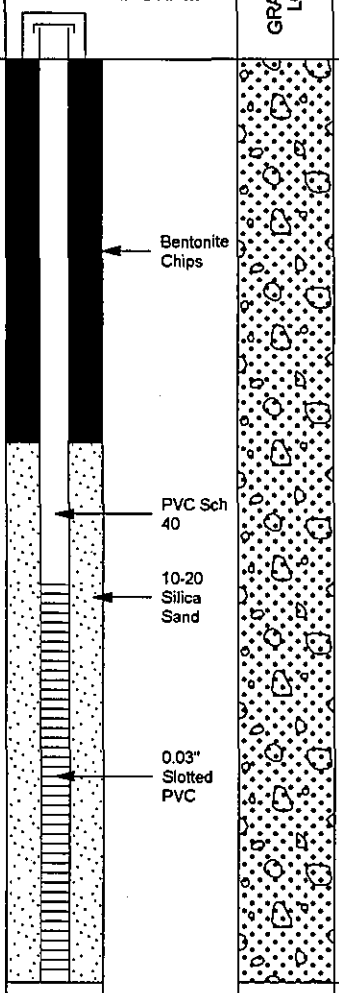
MONITORING WELL COMPLETION LOG NAT01-NAT10

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	588109.13	DATE DRILLED	10/20/1998
LOCATION	, CO	EAST COORD. (FT)	1106419.25	SURFACE ELEV. (FT NGVD)	5291.93
SITE	NATURITA	HOLE DEPTH (FT)	12.00	TOP OF CASING (FT)	5294.21
WELL NUMBER	NAT10	WELL DEPTH (FT)	12.00	MEAS. PT. ELEV. (FT)	5294.21
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	9.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.28	to	6.83
WELL SCREEN:	2 in. Slotted PVC	6.83	to	11.83
SUMP/END CAP:	2 in. PVC Sch 40	11.83	to	12.0
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Chips	0.0	to	5.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	5.0	to	12.0

DRILLING METHOD	AUGER
SAMPLING METHOD	
DATE DEVELOPED	
WATER LEVEL (FT BGS)	
LOGGED BY	Holmes
REMARKS	

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-12 ft. ALLUVIUM
	5290				Bentonite Chips		
5					PVC Sch 40		
	5285				10-20 Silica Sand		
					0.03" Slotted PVC		
10							
	5280						
							Total Depth 12.0 ft.



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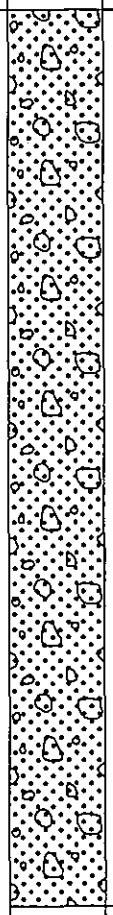
MONITORING WELL COMPLETION LOG NAT01-NAT11

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587557.46	DATE DRILLED	10/21/1998
LOCATION	, CO	EAST COORD. (FT)	1106948.06	SURFACE ELEV. (FT NGVD)	5296.19
SITE	NATURITA	HOLE DEPTH (FT)	14.00	TOP OF CASING (FT)	5298.49
WELL NUMBER	NAT11	WELL DEPTH (FT)	14.00	MEAS. PT. ELEV. (FT)	5298.49
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	10.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.3	to	8.67
WELL SCREEN:	2 in. Slotted PVC	8.67	to	13.67
SUMP/END CAP:	2 in. PVC Sch 40	13.67	to	14.0
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Chips	0.0	to	6.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	6.0	to	14.0

DRILLING METHOD AUGER
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes
REMARKS

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-14 ft. ALLUVIUM
	5295						
5					Bentonite Chips		
	5290						
					PVC Sch 40		
					10-20 Silica Sand		
10							
	5285				0.03" Slotted PVC		
							Total Depth 14.0 ft.



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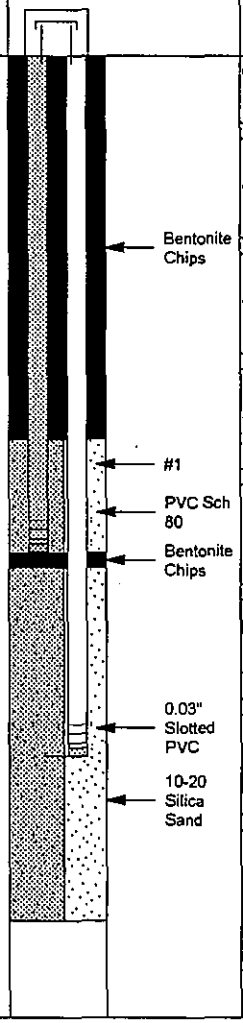
MONITORING WELL COMPLETION LOG NAT01-NAT12-1

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	588608.43	DATE DRILLED	10/21/1998
LOCATION	, CO	EAST COORD. (FT)	1106183.99	SURFACE ELEV. (FT NGVD)	5294.5
SITE	NATURITA	HOLE DEPTH (FT)	18.00	TOP OF CASING (FT)	5296.35
WELL NUMBER	NAT12-1	WELL DEPTH (FT)	14.58	MEAS. PT. ELEV. (FT)	5296.35
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	9.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-1.85	to	13.91
WELL SCREEN:	0.5 in. Slotted PVC	13.91	to	14.41
SUMP/END CAP:	0.5 in. PVC Sch 80	14.41	to	14.58
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Chips	10.66	to	11.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	11.0	to	18.0

DRILLING METHOD AUGER
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes
REMARKS Cluster of 2 casings: NAT12-1 casing and screen depths provided; NAT12-2 casing is from 0 to 9.66 ft. and screened to 10.16 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-17.5 ft. ALLUVIUM
5	5290						
10	5285						
15	5280						
	5275						17.5-18.0 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION; SHALE
							Total Depth 18.0 ft.



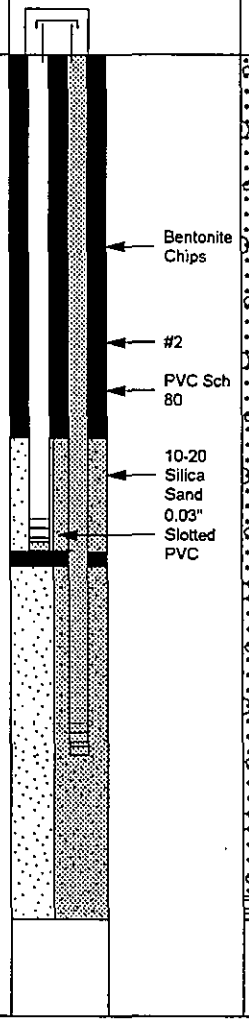
MONITORING WELL COMPLETION LOG NAT01-NAT12-2

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	588608.43	DATE DRILLED	10/21/1998
LOCATION	, CO	EAST COORD. (FT)	1106183.99	SURFACE ELEV. (FT NGVD)	5294.50
SITE	NATURITA	HOLE DEPTH (FT)	18.00	TOP OF CASING (FT)	5296.35
WELL NUMBER	NAT12-2	WELL DEPTH (FT)	10.33	MEAS. PT. ELEV. (FT)	5296.35
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	9.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-1.85	to	9.66
WELL SCREEN:	0.5 in. Slotted PVC	9.66	to	10.16
SUMP/END CAP:	0.5 in. PVC Sch 80	10.16	to	10.33
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Chips	0.0	to	8.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	8.0	to	18.0

DRILLING METHOD AUGER
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes
REMARKS Cluster of 2 casings: NAT12-2 casing and screen depths provided; NAT12-1 casing is from 0 to 13.91 ft. and screened to 14.41 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-17.5 ft. ALLUVIUM
5	5290				Bentonite Chips; #2; PVC Sch 80		
10	5285				10-20 Silica Sand; 0.03" Slotted PVC		
15	5280						
							17.5-18.0 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION; SHALE
							Total Depth 18.0 ft.
	5275						



MONITORING WELL COMPLETION LOG NAT01-NAT13-1

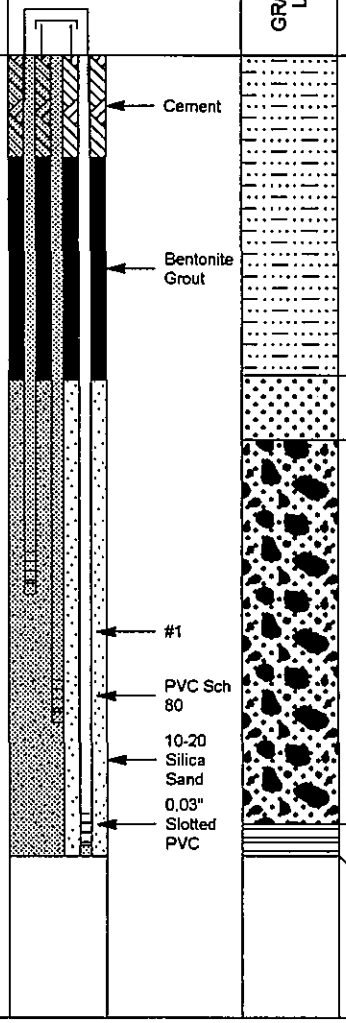
PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587562.60	DATE DRILLED	06/30/1999
LOCATION	, CO	EAST COORD. (FT)	1106943.70	SURFACE ELEV. (FT NGVD)	5296.24
SITE	NATURITA	HOLE DEPTH (FT)	12.50	TOP OF CASING (FT)	5298.99
WELL NUMBER	NAT13-1	WELL DEPTH (FT)	12.50	MEAS. PT. ELEV. (FT)	5298.99
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.75	to	11.83
WELL SCREEN:	0.5 in. Slotted PVC	11.83	to	12.33
SUMP/END CAP:	0.5 in. PVC Sch 80	12.33	to	12.5
SURFACE SEAL:	Cement	0.0	to	1.58
GROUT:	Bentonite Grout	1.58	to	5.08
SEAL:				
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	5.08	to	12.5

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings. NAT13-1 casing and screen depths provided; NAT13-2 casing is from 0 to 9.75 and screened to 10.25 ft.; NAT13-3 casing is from 0 to 7.75 and screened to 8.25 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	5295				Cement; Bentonite Grout		0-5 ft. SILT (ML), some gravel and cobbles.
5							5-6 ft. SAND (SW), moist.
	5290				#1; PVC Sch 80		6-12 ft. SANDY GRAVEL (GW-SW), sand with gravel cobbles and boulders.
10	5285				10-20 Silica Sand; 0.03" Slotted PVC		12-12.5 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; very hard drilling.

Total Depth 12.5 ft.



MONITORING WELL COMPLETION LOG NAT01-NAT13-2

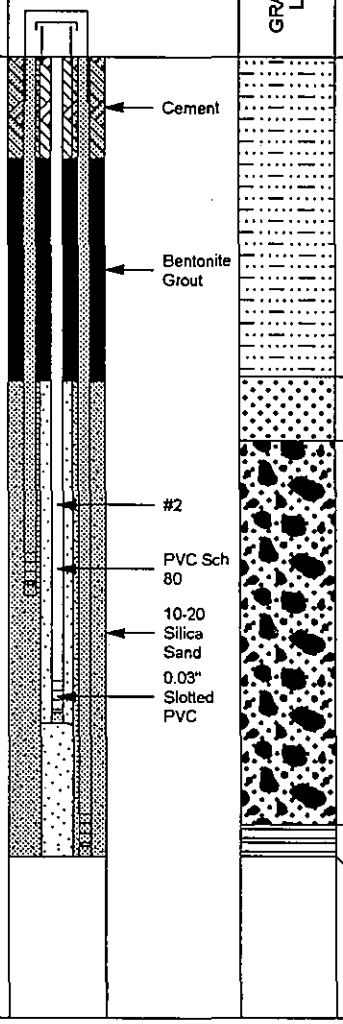
PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587562.60	DATE DRILLED	06/30/1999
LOCATION	, CO	EAST COORD. (FT)	1106943.70	SURFACE ELEV. (FT NGVD)	5296.24
SITE	NATURITA	HOLE DEPTH (FT)	12.50	TOP OF CASING (FT)	5298.93
WELL NUMBER	NAT13-2	WELL DEPTH (FT)	10.42	MEAS. PT. ELEV. (FT)	5298.93
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.69	to	9.75
WELL SCREEN:	0.5 in. Slotted PVC	9.75	to	10.25
SUMP/END CAP:	0.5 in. PVC Sch 80	10.25	to	10.42
SURFACE SEAL:	Cement	0.0	to	1.58
GROUT:	Bentonite Grout	1.58	to	5.08
SEAL:				
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	5.08	to	12.5

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings. NAT13-2 casing and screen depths provided; NAT13-1 casing is from 0 to 11.83 and screened to 12.33 ft.; NAT13-3 casing is from 0 to 7.75 and screened to 8.25 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	5295				Cement; Bentonite Grout		0-5 ft. SILT (ML), some gravel and cobbles.
5							5-6 ft. SAND (SW), moist.
	5290				#2; PVC Sch 80; 10-20 Silica Sand		6-12 ft. SANDY GRAVEL (GW-SW), sand with gravel cobbles and boulders.
10	5285				0.03" Slotted PVC		12-12.5 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; very hard drilling.

Total Depth 12.5 ft.



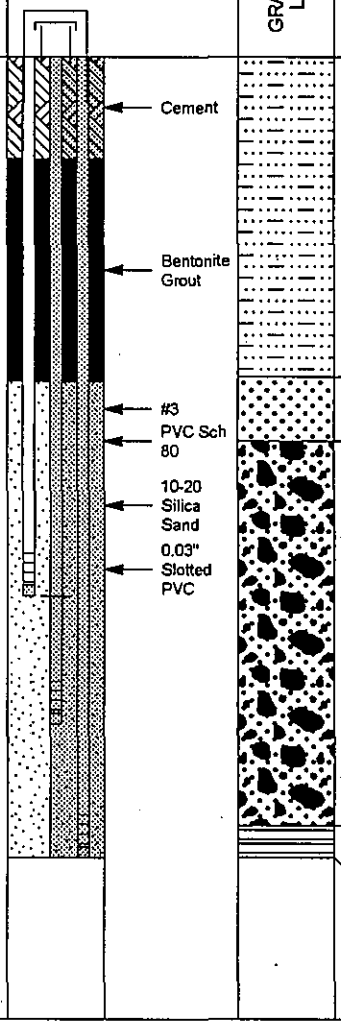
MONITORING WELL COMPLETION LOG NAT01-NAT13-3

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587562.60	DATE DRILLED	06/30/1999
LOCATION	, CO	EAST COORD. (FT)	1106943.70	SURFACE ELEV. (FT NGVD)	5296.24
SITE	NATURITA	HOLE DEPTH (FT)	12.50	TOP OF CASING (FT)	5298.99
WELL NUMBER	NAT13-3	WELL DEPTH (FT)	8.42	MEAS. PT. ELEV. (FT)	5298.99
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.75	to	7.75
WELL SCREEN:	0.5 in. Slotted PVC	7.75	to	8.25
SUMP/END CAP:	0.5 in. PVC Sch 80	8.25	to	8.42
SURFACE SEAL:	Cement	0.0	to	1.58
GROUT:	Bentonite Grout	1.58	to	5.08
SEAL:				
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	5.08	to	12.5

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings. NAT13-3 casing and screen depths provided; NAT13-1 casing is from 0 to 11.83 and screened to 12.33 ft.; NAT13-2 casing is from 0 to 9.75 and screened to 10.25 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	5295				Cement; Bentonite Grout		0-5 ft. SILT (ML), some gravel and cobbles.
5					#3 PVC Sch 80		5-6 ft. SAND (SW), moist.
	5290				10-20 Silica Sand; 0.03" Slotted PVC		6-12 ft. SANDY GRAVEL (GW-SW), sand with gravel cobbles and boulders.
10	5285						12-12.5 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; very hard drilling.
							Total Depth 12.5 ft.



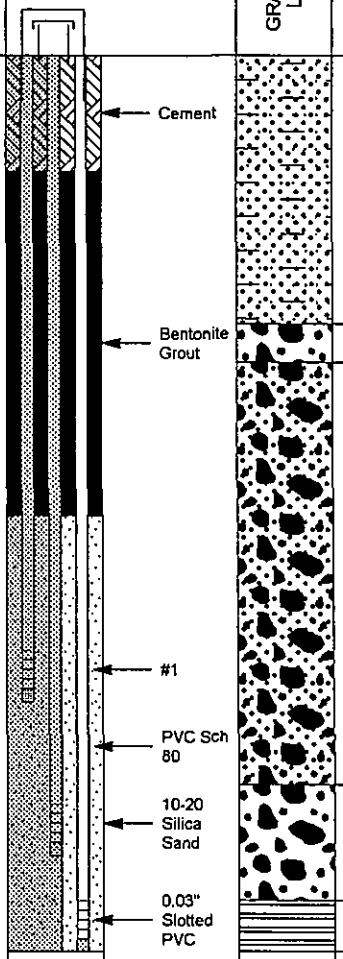
MONITORING WELL COMPLETION LOG NAT01-NAT14-1

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587568.48	DATE DRILLED	06/30/1999
LOCATION	, CO	EAST COORD. (FT)	1106939.85	SURFACE ELEV. (FT NGVD)	5296.22
SITE	NATURITA	HOLE DEPTH (FT)	11.66	TOP OF CASING (FT)	5299.32
WELL NUMBER	NAT14-1	WELL DEPTH (FT)	11.66	MEAS. PT. ELEV. (FT)	5299.32
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-3.1	to	11.0
WELL SCREEN:	0.5 in. Slotted PVC	11.0	to	11.5
SUMP/END CAP:	0.5 in. PVC Sch 80	11.5	to	11.66
SURFACE SEAL:	Cement	0.0	to	1.5
GROUT:	Bentonite Grout	1.5	to	6.0
SEAL:				
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	6.0	to	11.66

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings. NAT14-1 casing and screen depths provided; NAT14-2 casing is from 0 to 9.75 ft. and screened to 10.25 ft.; NAT14-3 casing is from 0 to 7.75 ft. and screened to 8.25 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	5295				Cement		0-3.5 ft. SILTY SAND (SM)
					Bentonite Grout		3.5-4 ft. GRAVEL (GW), cobbles.
5	5290				#1		4-9.5 ft. SANDY GRAVEL (GW-SW), sand with gravel.
					PVC Sch 80		
10					10-20 Silica Sand		9.5-11 ft. GRAVEL (GW), gravel with cobbles.
	5285				0.03" Slotted PVC		11-11.66 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; very hard drilling.
							Total Depth 11.66 ft.



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U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION OFFICE, COLORADO

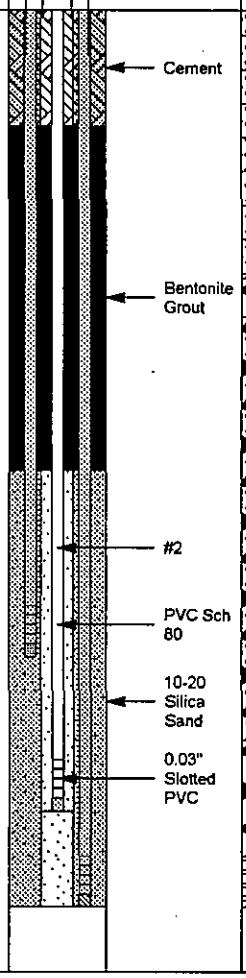
MONITORING WELL COMPLETION LOG NAT01-NAT14-2

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587568.48	DATE DRILLED	06/30/1999
LOCATION	, CO	EAST COORD. (FT)	1106939.85	SURFACE ELEV. (FT NGVD)	5296.22
SITE	NATURITA	HOLE DEPTH (FT)	11.66	TOP OF CASING (FT)	5299.31
WELL NUMBER	NAT14-2	WELL DEPTH (FT)	10.42	MEAS. PT. ELEV. (FT)	5299.31
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-3.09	to	9.75
WELL SCREEN:	0.5 in. Slotted PVC	9.75	to	10.25
SUMP/END CAP:	0.5 in. PVC Sch 80	10.25	to	10.42
SURFACE SEAL:	Cement	0.0	to	1.5
GROUT:	Bentonite Grout	1.5	to	6.0
SEAL:				
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	6.0	to	11.66

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings. NAT14-2 casing and screen depths provided; NAT14-1 casing is from 0 to 11 ft. and screened to 11.5 ft.; NAT14-3 casing is from 0 to 7.75 ft. and screened to 8.25 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	5295				Cement		0-3.5 ft. SILTY SAND (SM)
					Bentonite Grout		3.5-4 ft. GRAVEL (GW), cobbles.
5							4-9.5 ft. SANDY GRAVEL (GW-SW), sand with gravel.
	5290				#2		
					PVC Sch 80		
					10-20 Silica Sand		
10					0.03" Slotted PVC		9.5-11 ft. GRAVEL (GW), gravel with cobbles.
	5285						11-11.66 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; very hard drilling.
							Total Depth 11.66 ft.



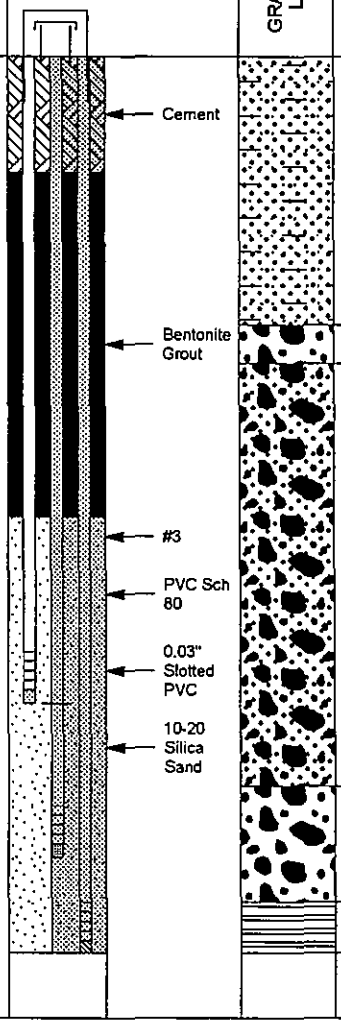
MONITORING WELL COMPLETION LOG NAT01-NAT14-3

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587568.48	DATE DRILLED	06/30/1999
LOCATION	, CO	EAST COORD. (FT)	1106939.85	SURFACE ELEV. (FT NGVD)	5296.22
SITE	NATURITA	HOLE DEPTH (FT)	11.66	TOP OF CASING (FT)	5299.31
WELL NUMBER	NAT14-3	WELL DEPTH (FT)	8.42	MEAS. PT. ELEV. (FT)	5299.31
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-3.09	to	7.75
WELL SCREEN:	0.5 in. Slotted PVC	7.75	to	8.25
SUMP/END CAP:	0.5 in. PVC Sch 80	8.25	to	8.42
SURFACE SEAL:	Cement	0.0	to	1.5
GROUT:	Bentonite Grout	1.5	to	6.0
SEAL:				
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	6.0	to	11.66

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings. NAT14-3 casing and screen depths provided; NAT14-1 casing is from 0 to 11 ft. and screened to 11.5 ft; NAT14-2 casing is from 0 to 9.75 ft. and screened to 10.25 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	5295				Cement		0-3.5 ft. SILTY SAND (SM)
					Bentonite Grout		3.5-4 ft. GRAVEL (GW), cobbles.
5							4-9.5 ft. SANDY GRAVEL (GW-SW), sand with gravel.
	5290				#3		
					PVC Sch 80		
					0.03" Slotted PVC		
					10-20 Silica Sand		
10							9.5-11 ft. GRAVEL (GW), gravel with cobbles.
	5285						11-11.66 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; very hard drilling.
							Total Depth 11.66 ft.



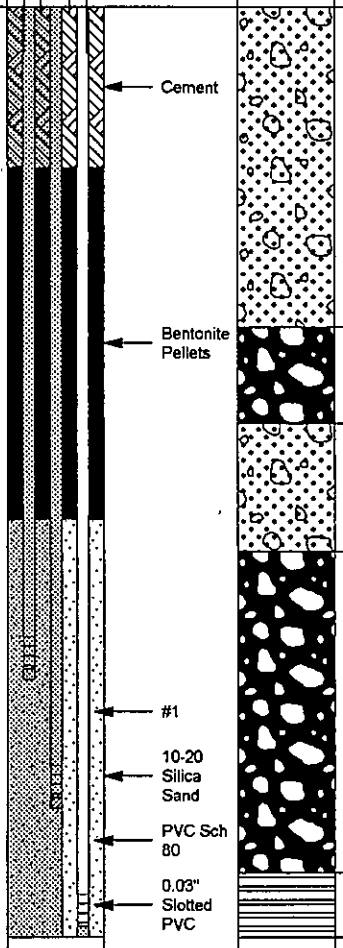
MONITORING WELL COMPLETION LOG NAT01-NAT15-1

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	588305.94	DATE DRILLED	07/01/1999
LOCATION	, CO	EAST COORD. (FT)	1106235.04	SURFACE ELEV. (FT NGVD)	5292.57
SITE	NATURITA	HOLE DEPTH (FT)	14.50	TOP OF CASING (FT)	5294.93
WELL NUMBER	NAT15-1	WELL DEPTH (FT)	14.50	MEAS. PT. ELEV. (FT)	5294.93
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.36	to	13.83
WELL SCREEN:	0.5 in. Slotted PVC	13.83	to	14.33
SUMP/END CAP:	0.5 in. PVC Sch 80	14.33	to	14.5
SURFACE SEAL:	Cement	0.0	to	2.5
GROUT:				
SEAL:	Bentonite Pellets	2.5	to	8.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	8.0	to	14.5

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings. NAT15-1 casing and screen depths provided; NAT15-2 casing is from 0 to 11.83 ft and screened to 12.5 ft.; and NAT15-3 casing is 0 to 9.83 and screened to 10.5 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-5 ft. GRAVELLY SAND (SW-GW), 70% sand.
	5290				Cement		
5					Bentonite Pellets		5-6.5 ft. BOULDERS AND COBBLES.
							6.5-8.5 ft. GRAVELLY SAND (SW-GW).
	5285						
							8.5-13.5 ft. BOULDERS AND COBBLES.
10					#1		
					10-20 Silica Sand		
	5280				PVC Sch 80		
					0.03" Slotted PVC		13.5-14.5 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; very hard drilling.
							Total Depth 14.5 ft.



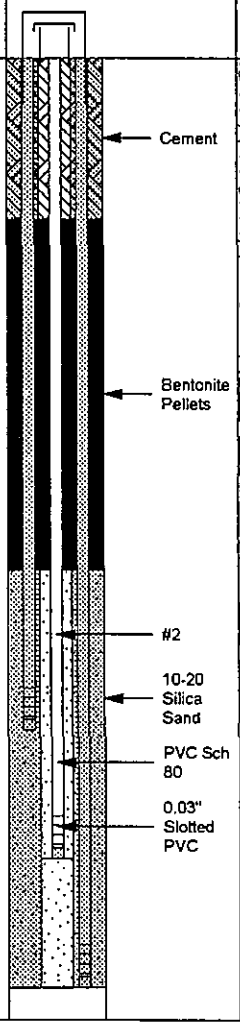
MONITORING WELL COMPLETION LOG NAT01-NAT15-2

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	588305.94	DATE DRILLED	07/01/1999
LOCATION	, CO	EAST COORD. (FT)	1106235.04	SURFACE ELEV. (FT NGVD)	5292.57
SITE	NATURITA	HOLE DEPTH (FT)	14.50	TOP OF CASING (FT)	5294.96
WELL NUMBER	NAT15-2	WELL DEPTH (FT)	12.50	MEAS. PT. ELEV. (FT)	5294.96
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.39	to	11.83
WELL SCREEN:	0.5 in. Slotted PVC	11.83	to	12.33
SUMP/END CAP:	0.5 in. PVC Sch 80	12.33	to	12.5
SURFACE SEAL:	Cement	0.0	to	2.5
GROUT:				
SEAL:	Bentonite Pellets	2.5	to	8.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	8.0	to	14.5

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings. NAT15-2 casing and screen depths provided; NAT15-1 casing is from 0 to 13.83 ft. and screened to 14.33 ft.; and NAT15-3 casing is 0 to 9.83 ft. and screened to 10.5 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-5 ft. GRAVELLY SAND (SW-GW), 70% sand.
5	5290						5-6.5 ft. BOULDERS AND COBBLES.
	5285						6.5-8.5 ft. GRAVELLY SAND (SW-GW).
10	5280						8.5-13.5 ft. BOULDERS AND COBBLES.
							13.5-14.5 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; very hard drilling.
							Total Depth 14.5 ft.



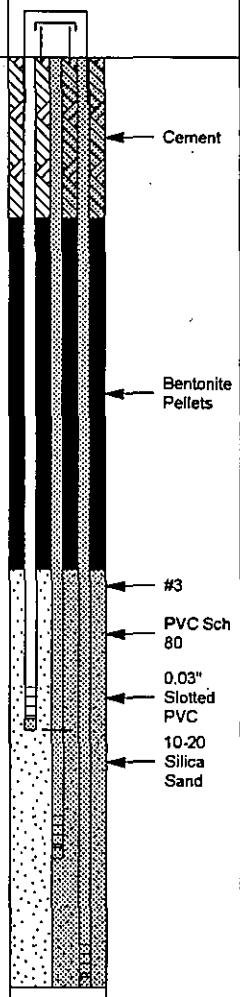
MONITORING WELL COMPLETION LOG NAT01-NAT15-3

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	588305.94	DATE DRILLED	07/01/1999
LOCATION	, CO	EAST COORD. (FT)	1106235.04	SURFACE ELEV. (FT NGVD)	5292.57
SITE	NATURITA	HOLE DEPTH (FT)	14.50	TOP OF CASING (FT)	5294.95
WELL NUMBER	NAT15-3	WELL DEPTH (FT)	10.50	MEAS. PT. ELEV. (FT)	5294.95
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.38	to	9.83
WELL SCREEN:	0.5 in. Slotted PVC	9.83	to	10.33
SUMP/END CAP:	0.5 in. PVC Sch 80	10.33	to	10.5
SURFACE SEAL:	Cement	0.0	to	2.5
GROUT:				
SEAL:	Bentonite Pellets	2.5	to	8.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	8.0	to	14.5

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings. NAT15-3 casing and screen depths provided; NAT15-1 casing is from 0 to 13.83 ft. and screened to 14.33 ft.; and NAT15-2 casing is 0 to 11.83 ft. and screened to 12.5 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-5 ft. GRAVELLY SAND (SW-GW), 70% sand.
5	5290						5-6.5 ft. BOULDERS AND COBBLES.
	5285						6.5-8.5 ft. GRAVELLY SAND (SW-GW).
10	5280						8.5-13.5 ft. BOULDERS AND COBBLES.
							13.5-14.5 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; very hard drilling.
							Total Depth 14.5 ft.



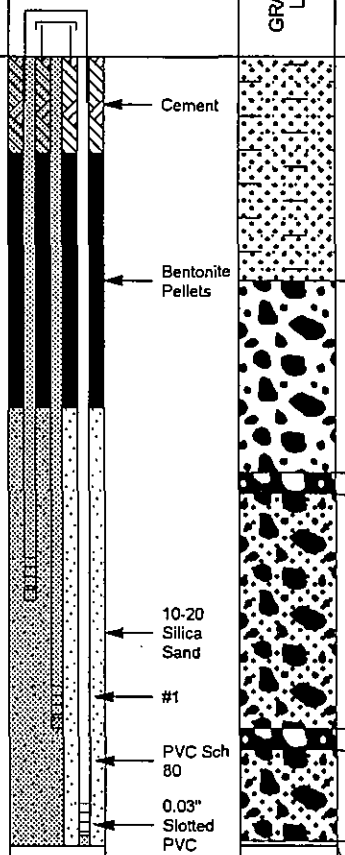
MONITORING WELL COMPLETION LOG NAT01-NAT16-1

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587987.01	DATE DRILLED	07/02/1999
LOCATION	, CO	EAST COORD. (FT)	1106706.27	SURFACE ELEV. (FT NGVD)	5293.14
SITE	NATURITA	HOLE DEPTH (FT)	12.33	TOP OF CASING (FT)	5295.82
WELL NUMBER	NAT16-1	WELL DEPTH (FT)	12.33	MEAS. PT. ELEV. (FT)	5295.82
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.68	to	11.66
WELL SCREEN:	0.5 in. Slotted PVC	11.66	to	12.16
SUMP/END CAP:	0.5 in. PVC Sch 80	12.16	to	12.33
SURFACE SEAL:	Cement	0.0	to	1.5
GROUT:				
SEAL:	Bentonite Pellets	1.5	to	5.5
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	5.5	to	12.33

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings. NAT16-1 casing and screen depths provided; NAT16-2 casing is from 0 to 9.83 ft. and screened to 10.33 ft.; and NAT16-3 casing is from 0 to 7.83 ft. and screened to 8.33 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-3.5 ft. SILTY SAND (SM).
	5290						3.5-6.5 ft. GRAVEL (GW), some cobbles.
5							
							6.5-6.83 ft. BOULDERS.
							6.83-10.5 ft. SANDY GRAVEL (GW-SW), some cobbles.
	5285						
10							10.5-10.83 ft. BOULDERS.
							10.83-12.25 ft. SANDY GRAVEL (GW-SW), sand, gravel and cobbles.
							12.25-12.33 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; very hard drilling.
	5280						Total Depth 12.33 ft.



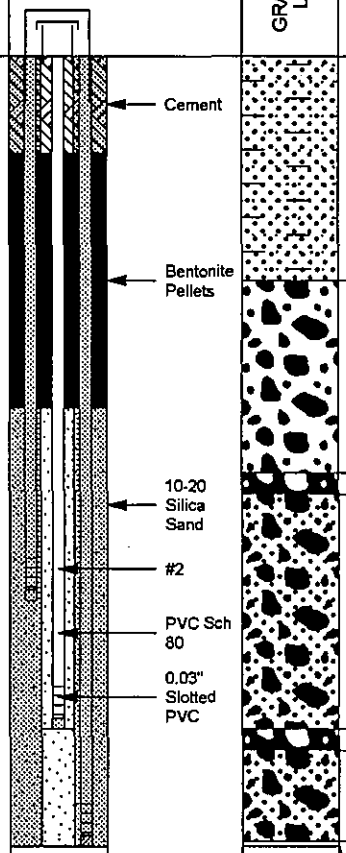
MONITORING WELL COMPLETION LOG NAT01-NAT16-2

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587987.01	DATE DRILLED	07/02/1999
LOCATION	, CO	EAST COORD. (FT)	1106706.27	SURFACE ELEV. (FT NGVD)	5293.14
SITE	NATURITA	HOLE DEPTH (FT)	12.33	TOP OF CASING (FT)	5295.75
WELL NUMBER	NAT16-2	WELL DEPTH (FT)	10.50	MEAS. PT. ELEV. (FT)	5295.75
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.61	to	9.83
WELL SCREEN:	0.5 in. Slotted PVC	9.83	to	10.33
SUMP/END CAP:	0.5 in. PVC Sch 80	10.33	to	10.5
SURFACE SEAL:	Cement	0.0	to	1.5
GROUT:				
SEAL:	Bentonite Pellets	1.5	to	5.5
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	5.5	to	12.33

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings. NAT16-2 casing and screen depths provided; NAT16-1 casing is from 0 to 11.66 ft. and screened to 12.16 ft.; and NAT16-3 casing is from 0 to 7.83 ft. and screened to 8.33 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-3.5 ft. SILTY SAND (SM).
	5290						3.5-6.5 ft. GRAVEL (GW), some cobbles.
5							
							6.5-6.83 ft. BOULDERS.
							6.83-10.5 ft. SANDY GRAVEL (GW-SW), some cobbles.
	5285						
10							
							10.5-10.83 ft. BOULDERS.
							10.83-12.25 ft. SANDY GRAVEL (GW-SW), sand, gravel and cobbles.
							12.25-12.33 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; very hard drilling.
	5280						Total Depth 12.33 ft.



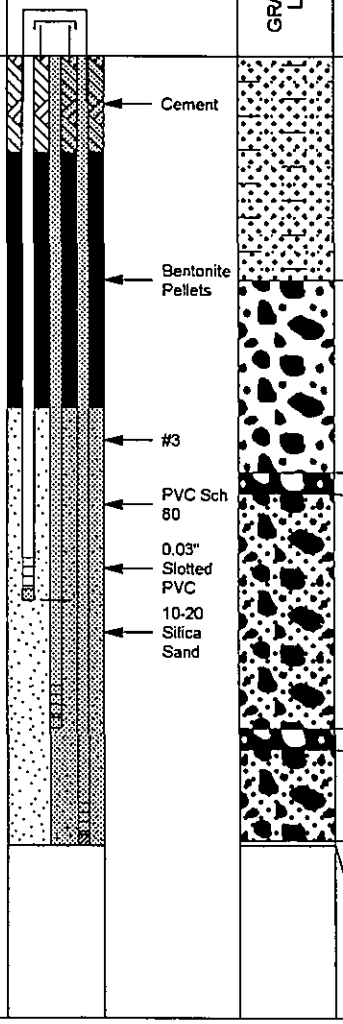
MONITORING WELL COMPLETION LOG NAT01-NAT16-3

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587987.01	DATE DRILLED	07/02/1999
LOCATION	, CO	EAST COORD. (FT)	1106706.27	SURFACE ELEV. (FT NGVD)	5293.14
SITE	NATURITA	HOLE DEPTH (FT)	12.33	TOP OF CASING (FT)	5295.75
WELL NUMBER	NAT16-3	WELL DEPTH (FT)	8.50	MEAS. PT. ELEV. (FT)	5295.75
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.61	to	7.83
WELL SCREEN:	0.5 in. Slotted PVC	7.83	to	8.33
SUMP/END CAP:	0.5 in. PVC Sch 80	8.33	to	8.5
SURFACE SEAL:	Cement	0.0	to	1.5
GROUT:				
SEAL:	Bentonite Pellets	1.5	to	5.5
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	5.5	to	12.33

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings. NAT16-3 casing and screen depths provided; NAT16-1 casing is from 0 to 11.66 ft. and screened to 12.33 ft.; and NAT16-2 casing is from 0 to 9.83 ft. and screened to 10.33 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-3.5 ft. SILTY SAND (SM).
	5290						3.5-6.5 ft. GRAVEL (GW), some cobbles.
5							
							6.5-6.83 ft. BOULDERS.
							6.83-10.5 ft. SANDY GRAVEL (GW-SW), some cobbles.
	5285						
10							
							10.5-10.83 ft. BOULDERS.
							10.83-12.25 ft. SANDY GRAVEL (GW-SW), sand, gravel and cobbles.
							12.25-12.33 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; very hard drilling.
	5280						Total Depth 12.33 ft.



mactec-ers

U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION OFFICE, COLORADO

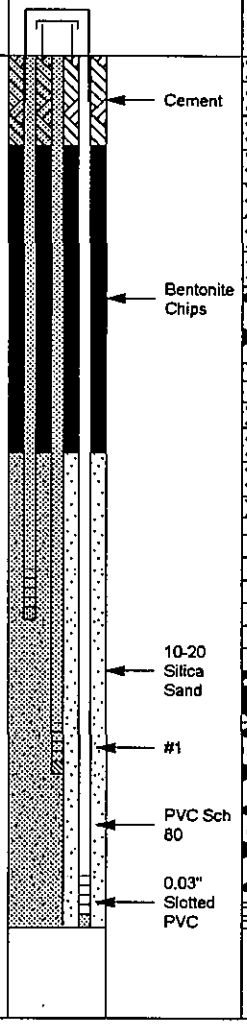
MONITORING WELL COMPLETION LOG NAT01-NAT17-1

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587235.58	DATE DRILLED	07/02/1999
LOCATION	, CO	EAST COORD. (FT)	1107135.98	SURFACE ELEV. (FT NGVD)	5298.41
SITE	NATURITA	HOLE DEPTH (FT)	11.33	TOP OF CASING (FT)	5300.74
WELL NUMBER	NAT17-1	WELL DEPTH (FT)	11.33	MEAS. PT. ELEV. (FT)	5300.74
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.33	to	10.66
WELL SCREEN:	0.5 in. Slotted PVC	10.66	to	11.16
SUMP/END CAP:	0.5 in. PVC Sch 80	11.16	to	11.33
SURFACE SEAL:	Cement	0.0	to	1.16
GROUT:				
SEAL:	Bentonite Chips	1.16	to	5.16
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	5.16	to	11.33

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings: NAT17-1 casing and screen depths provided; NAT17-2 casing is from 0 to 8.67 ft. and screened to 9.17 ft.; and NAT17-3 casing is from 0 to 6.67 ft. and screened to 7.17 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
					Cement		0-3 ft. SILTY SAND (SM).
	5295				Bentonite Chips		3-4 ft. GRAVEL (GW), some cobbles.
							4-4.5 ft. SILT (ML).
5							4.5-6 ft. SILTY SAND (SM)
							6-8 ft. SILT (ML)
	5290				10-20 Silica Sand		8-8.66 ft. BOULDERS
					#1		8.66-11 ft. GRAVEL (GW), some gravel.
10					PVC Sch 80		
					0.03" Slotted PVC		11-11.33 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE
							Total Depth 11.33 ft.



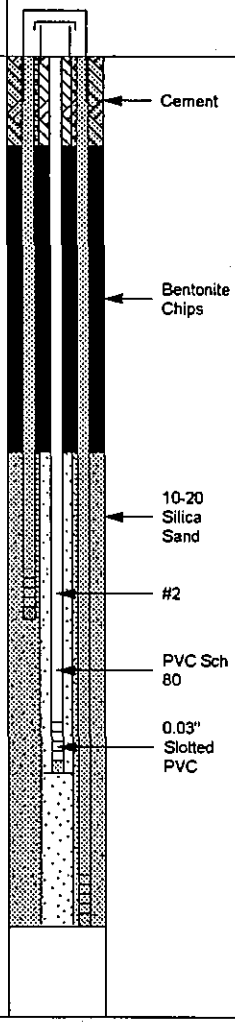
MONITORING WELL COMPLETION LOG NAT01-NAT17-2

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587235.58	DATE DRILLED	07/02/1999
LOCATION	, CO	EAST COORD. (FT)	1107135.98	SURFACE ELEV. (FT NGVD)	5298.41
SITE	NATURITA	HOLE DEPTH (FT)	11.33	TOP OF CASING (FT)	5300.74
WELL NUMBER	NAT17-2	WELL DEPTH (FT)	9.17	MEAS. PT. ELEV. (FT)	5300.74
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.33	to	8.67
WELL SCREEN:	0.5 in. Slotted PVC	8.67	to	9.17
SUMP/END CAP:	0.5 in. PVC Sch 80	9.17	to	9.34
SURFACE SEAL:	Cement	0.0	to	1.16
GROUT:				
SEAL:	Bentonite Chips	1.16	to	5.16
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	5.16	to	11.33

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings: NAT17-2 casing and screen depths provided; NAT17-1 casing is from 0 to 10.66 ft. and screened to 11.16 ft.; and NAT17-3 casing is from 0 to 6.67 ft. and screened to 7.17 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-3 ft. SILTY SAND (SM).
	5295						3-4 ft. GRAVEL (GW), some cobbles.
							4-4.5 ft. SILT (ML).
							4.5-6 ft. SILTY SAND (SM)
5							
							6-8 ft. SILT (ML)
	5290						8-8.66 ft. BOULDERS
							8.66-11 ft. GRAVEL (GW), some gravel.
10							
							11-11.33 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE
							Total Depth 11.33 ft.



MONITORING WELL COMPLETION LOG NAT01-NAT17-3

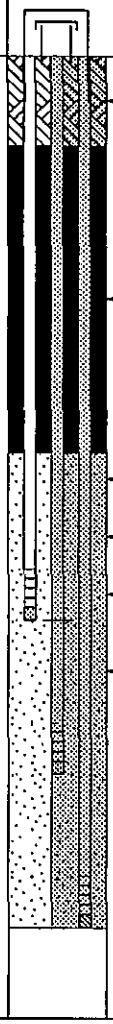
PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587235.58	DATE DRILLED	07/02/1999
LOCATION	, CO	EAST COORD. (FT)	1107135.98	SURFACE ELEV. (FT NGVD)	5298.41
SITE	NATURITA	HOLE DEPTH (FT)	11.33	TOP OF CASING (FT)	5300.74
WELL NUMBER	NAT17-3	WELL DEPTH (FT)	7.17	MEAS. PT. ELEV. (FT)	5300.74
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.33	to	6.67
WELL SCREEN:	0.5 in. Slotted PVC	6.67	to	7.17
SUMP/END CAP:	0.5 in. PVC Sch 80	7.17	to	7.34
SURFACE SEAL:	Cement	0.0	to	1.16
GROUT:				
SEAL:	Bentonite Chips	1.16	to	5.16
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	5.16	to	11.33

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings: NAT17-3 casing and screen depths provided; NAT17-1 casing is from 0 to 10.66 ft. and screened to 11.16 ft.; and NAT17-2 casing is from 0 to 8.67 ft. and screened to 9.17 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
					Cement		0-3 ft. SILTY SAND (SM).
	5295				Bentonite Chips		3-4 ft. GRAVEL (GW), some cobbles.
							4-4.5 ft. SILT (ML).
5					#3		4.5-6 ft. SILTY SAND (SM)
					PVC Sch 80		6-8 ft. SILT (ML)
					0.03" Slotted PVC		
					10-20 Silica Sand		
	5290						8-8.66 ft. BOULDERS
10							8.66-11 ft. GRAVEL (GW), some gravel.
							11-11.33 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE

Total Depth 11.33 ft.



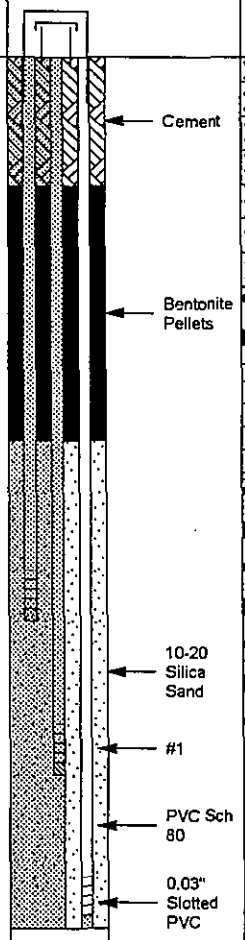
MONITORING WELL COMPLETION LOG NAT01-NAT18-1

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587229.97	DATE DRILLED	07/02/1999
LOCATION	, CO	EAST COORD. (FT)	1107140.96	SURFACE ELEV. (FT NGVD)	5298.51
SITE	NATURITA	HOLE DEPTH (FT)	11.33	TOP OF CASING (FT)	5301.19
WELL NUMBER	NAT18-1	WELL DEPTH (FT)	11.33	MEAS. PT. ELEV. (FT)	5301.19
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.68	to	10.66
WELL SCREEN:	0.5 in. Slotted PVC	10.66	to	11.16
SUMP/END CAP:	0.5 in. PVC Sch 80	11.16	to	11.33
SURFACE SEAL:	Cement	0.0	to	1.67
GROUT:				
SEAL:	Bentonite Pellets	1.67	to	5.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	5.0	to	11.33

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings: NAT18-1 casing and screen depths provided; NAT18-2 casing is from 0 to 8.67 ft. and screened to 9.17 ft.; and NAT18-3 casing is from 0 to 6.67 ft. and screened to 7.17 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-3 ft. SILTY SAND (SM).
	5295						3-4 ft. GRAVEL (GW), some cobbles.
							4-5.5 ft. SILT (ML).
5							5.5-9 ft. GRAVEL (GW), some cobbles.
	5290						9-11 ft. BOULDERS, some cobbles.
10							11-11.3 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE
							Total Depth 11.33 ft.



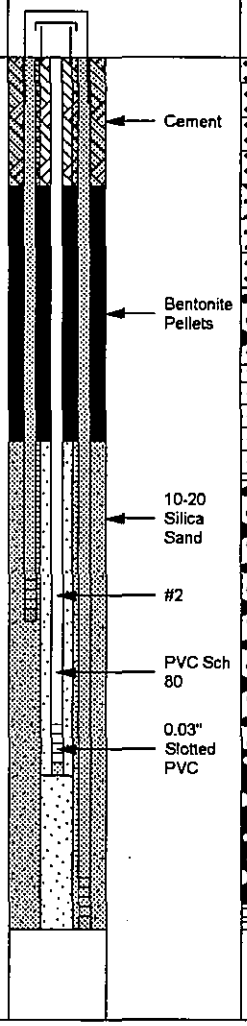
MONITORING WELL COMPLETION LOG NAT01-NAT18-2

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587229.97	DATE DRILLED	07/02/1999
LOCATION	, CO	EAST COORD. (FT)	1107140.96	SURFACE ELEV. (FT NGVD)	5298.51
SITE	NATURITA	HOLE DEPTH (FT)	11.33	TOP OF CASING (FT)	5301.19
WELL NUMBER	NAT18-2	WELL DEPTH (FT)	9.34	MEAS. PT. ELEV. (FT)	5301.19
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.68	to	8.67
WELL SCREEN:	0.5 in. Slotted PVC	8.67	to	9.17
SUMP/END CAP:	0.5 in. PVC Sch 80	9.17	to	9.34
SURFACE SEAL:	Cement	0.0	to	1.67
GROUT:				
SEAL:	Bentonite Pellets	1.67	to	5.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	5.0	to	11.33

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings: NAT18-2 casing and screen depths provided; NAT18-1 casing is from 0 to 10.66 ft. and screened to 11.16 ft.; and NAT18-3 casing is from 0 to 6.67 ft. and screened to 7.17 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-3 ft. SILTY SAND (SM).
	5295						3-4 ft. GRAVEL (GW), some cobbles.
							4-5.5 ft. SILT (ML).
5							5.5-9 ft. GRAVEL (GW), some cobbles.
	5290						
							9-11 ft. BOULDERS, some cobbles.
10							11-11.3 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE
							Total Depth 11.33 ft.



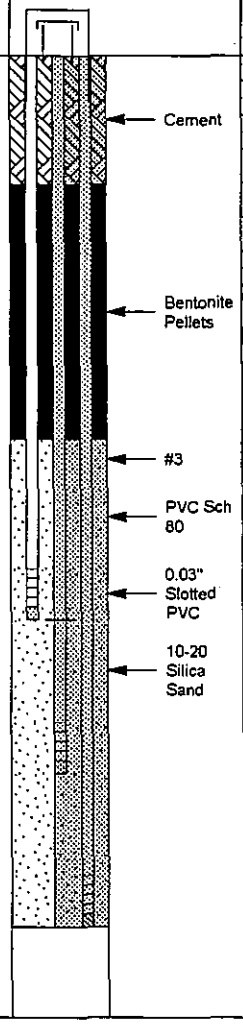
MONITORING WELL COMPLETION LOG NAT01-NAT18-3

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587229.97	DATE DRILLED	07/02/1999
LOCATION	, CO	EAST COORD. (FT)	1107140.96	SURFACE ELEV. (FT NGVD)	5298.51
SITE	NATURITA	HOLE DEPTH (FT)	11.33	TOP OF CASING (FT)	5301.19
WELL NUMBER	NAT18-3	WELL DEPTH (FT)	7.34	MEAS. PT. ELEV. (FT)	5301.19
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.68	to	6.67
WELL SCREEN:	0.5 in. Slotted PVC	6.67	to	7.17
SUMP/END CAP:	0.5 in. PVC Sch 80	7.17	to	7.34
SURFACE SEAL:	Cement	0.0	to	1.67
GROUT:				
SEAL:	Bentonite Pellets	1.67	to	5.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	5.0	to	11.33

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings: NAT18-3 casing and screen depths provided; NAT18-1 casing is from 0 to 9.33 ft. and screened to 9.83 ft.; and NAT18-2 casing is from 0 to 8.67 ft. and screened to 9.17 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-3 ft. SILTY SAND (SM).
	5295						3-4 ft. GRAVEL (GW), some cobbles.
							4-5.5 ft. SILT (ML).
5							5.5-9 ft. GRAVEL (GW), some cobbles.
	5290						9-11 ft. BOULDERS, some cobbles.
10							11-11.3 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE
							Total Depth 11.33 ft.



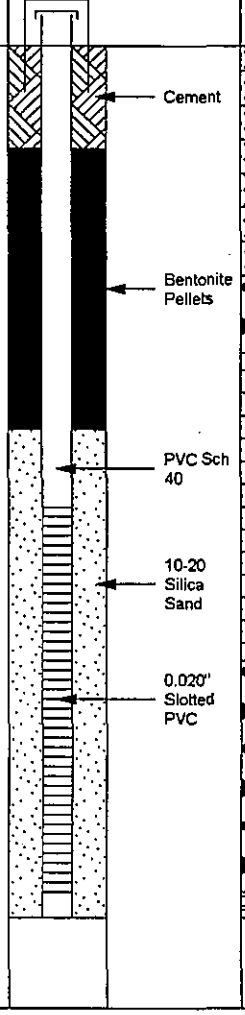
MONITORING WELL COMPLETION LOG NAT01-NAT19

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587224.44	DATE DRILLED	07/02/1999
LOCATION	, CO	EAST COORD. (FT)	1107145.63	SURFACE ELEV. (FT NGVD)	5298.67
SITE	NATURITA	HOLE DEPTH (FT)	11.33	TOP OF CASING (FT)	5301.36
WELL NUMBER	NAT19	WELL DEPTH (FT)	11.33	MEAS. PT. ELEV. (FT)	5301.36
				SLOT SIZE (IN)	0.020
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.69	to	6.0
WELL SCREEN:	2 in. Slotted PVC	6.0	to	11.0
SUMP/END CAP:	2 in. PVC Sch 40	11.0	to	11.33
SURFACE SEAL:	Cement	0.0	to	1.33
GROUT:				
SEAL:	Bentonite Pellets	1.33	to	5.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	5.0	to	11.33

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-3 ft. SILTY SAND (SM).
	5295						3-4 ft. GRAVEL (GW), some cobbles.
5							4-8 ft. SILT (ML).
	5290						8-11 ft. GRAVEL (GW), some cobbles.
10							11-11.33 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE
							Total Depth 11.33 ft.



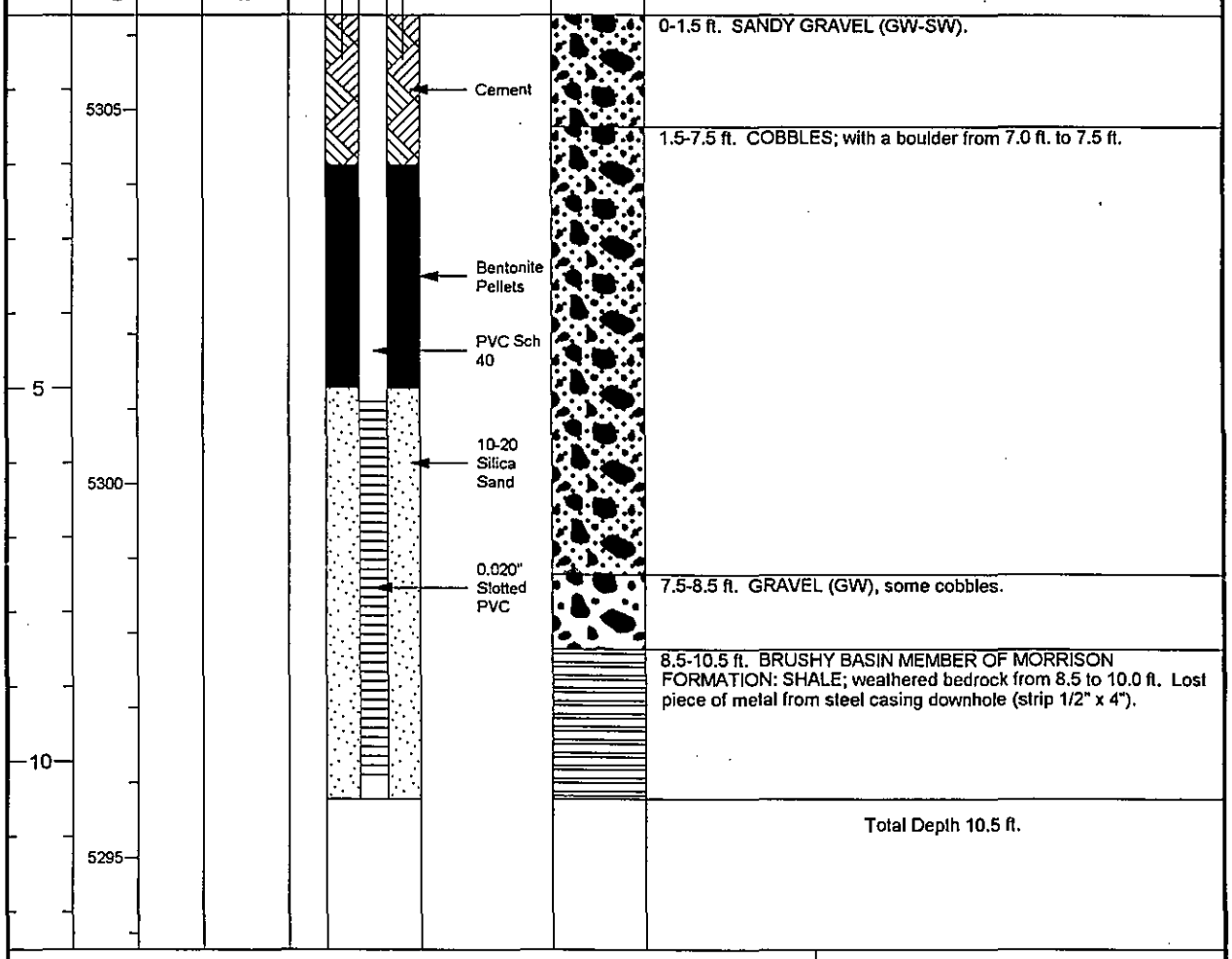
MONITORING WELL COMPLETION LOG NAT01-NAT20

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	586308.35	DATE DRILLED	07/03/1999
LOCATION	, CO	EAST COORD. (FT)	1107776.56	SURFACE ELEV. (FT NGVD)	5306.28
SITE	NATURITA	HOLE DEPTH (FT)	10.50	TOP OF CASING (FT)	5309.29
WELL NUMBER	NAT20	WELL DEPTH (FT)	10.50	MEAS. PT. ELEV. (FT)	5309.29
				SLOT SIZE (IN)	0.020
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-3.01	to	5.17
WELL SCREEN:	2 in. Slotted PVC	5.17	to	10.17
SUMP/END CAP:	2 in. PVC Sch 40	10.17	to	10.5
SURFACE SEAL:	Cement	0.0	to	2.0
GROUT:				
SEAL:	Bentonite Pellets	2.0	to	5.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	5.0	to	10.5

DRILLING METHOD	HAMMER CASING ADVANCE
SAMPLING METHOD	
DATE DEVELOPED	
WATER LEVEL (FT BGS)	
LOGGED BY	Holmes/Rowland
REMARKS	

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-1.5 ft. SANDY GRAVEL (GW-SW).
	5305				Cement		1.5-7.5 ft. COBBLES; with a boulder from 7.0 ft. to 7.5 ft.
					Bentonite Pellets		
					PVC Sch 40		
5							
	5300				10-20 Silica Sand		
					0.020" Slotted PVC		7.5-8.5 ft. GRAVEL (GW), some cobbles.
							8.5-10.5 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; weathered bedrock from 8.5 to 10.0 ft. Lost piece of metal from steel casing downhole (strip 1/2" x 4").
10							
	5295						Total Depth 10.5 ft.



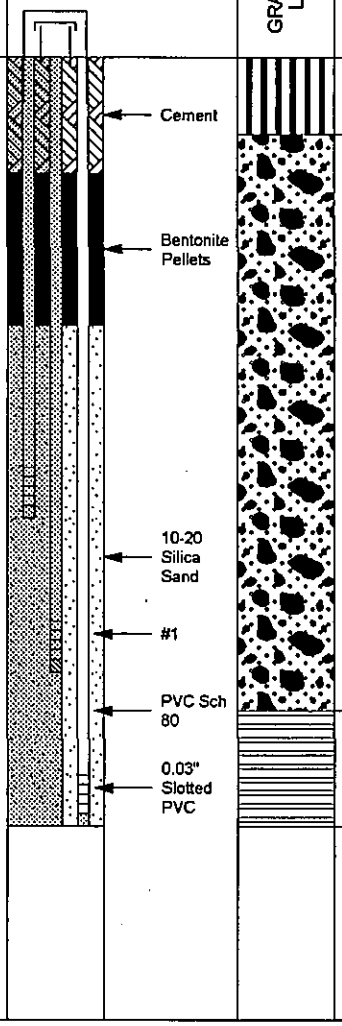
MONITORING WELL COMPLETION LOG NAT01-NAT21-1

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	586313.05	DATE DRILLED	07/03/1999
LOCATION	, CO	EAST COORD. (FT)	1107772.43	SURFACE ELEV. (FT NGVD)	5306.29
SITE	NATURITA	HOLE DEPTH (FT)	10.00	TOP OF CASING (FT)	5309.07
WELL NUMBER	NAT21-1	WELL DEPTH (FT)	10.00	MEAS. PT. ELEV. (FT)	5309.07
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.78	to	9.33
WELL SCREEN:	0.5 in. Slotted PVC	9.33	to	9.83
SUMP/END CAP:	0.5 in. PVC Sch 80	9.83	to	10.0
SURFACE SEAL:	Cement	0.0	to	1.5
GROUT:				
SEAL:	Bentonite Pellets	1.5	to	3.5
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	3.5	to	10.0

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings: NAT21-1 casing and screen depths provided; NAT21-2 casing is from 0 to 7.33 ft. and screened to 7.83 ft.; and NAT21-3 casing is from 0 to 5.33 ft. and screened to 5.83 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-1 ft. ELASTIC SILT (MH), some clay.
	5305						1-8.5 ft. SANDY GRAVEL (GW-SW), small gravel with large grained sand. Gravel increases to cobble size with depth and sand decreases.
5							
	5300						
							8.5-10.0 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; weathered bedrock.
10							Total Depth 10.0 ft.
	5295						



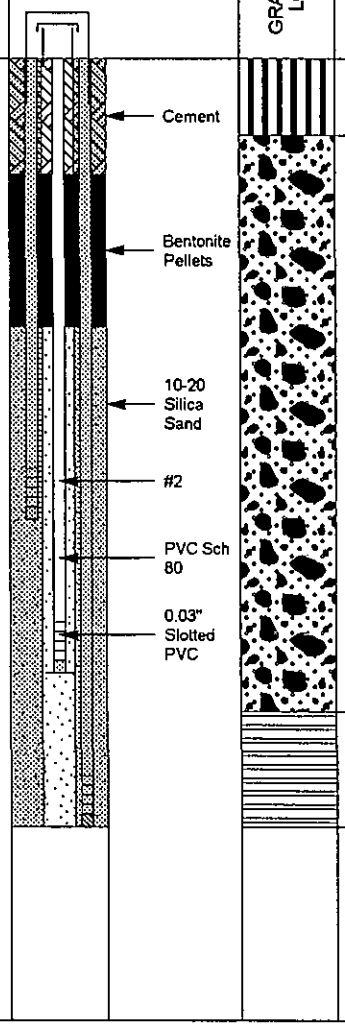
MONITORING WELL COMPLETION LOG NAT01-NAT21-2

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	586313.05	DATE DRILLED	07/03/1999
LOCATION	, CO	EAST COORD. (FT)	1107772.43	SURFACE ELEV. (FT NGVD)	5306.29
SITE	NATURITA	HOLE DEPTH (FT)	10.00	TOP OF CASING (FT)	5309.07
WELL NUMBER	NAT21-2	WELL DEPTH (FT)	8.00	MEAS. PT. ELEV. (FT)	5309.07
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.78	to	7.33
WELL SCREEN:	0.5 in. Slotted PVC	7.33	to	7.83
SUMP/END CAP:	0.5 in. PVC Sch 80	7.83	to	8.0
SURFACE SEAL:	Cement	0.0	to	1.5
GROUT:				
SEAL:	Bentonite Pellets	1.5	to	3.5
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	3.5	to	10.0

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings: NAT21-2 casing and screen depths provided; NAT21-1 casing is from 0 to 9.33 ft. and screened to 9.83 ft.; and NAT21-3 casing is from 0 to 5.33 ft. and screened to 5.83 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-1 ft. ELASTIC SILT (MH), some clay.
	5305						1-8.5 ft. SANDY GRAVEL (GW-SW), small gravel with large grained sand. Gravel increases to cobble size with depth and sand decreases.
5	5300						
							8.5-10.0 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; weathered bedrock.
10	5295						Total Depth 10.0 ft.



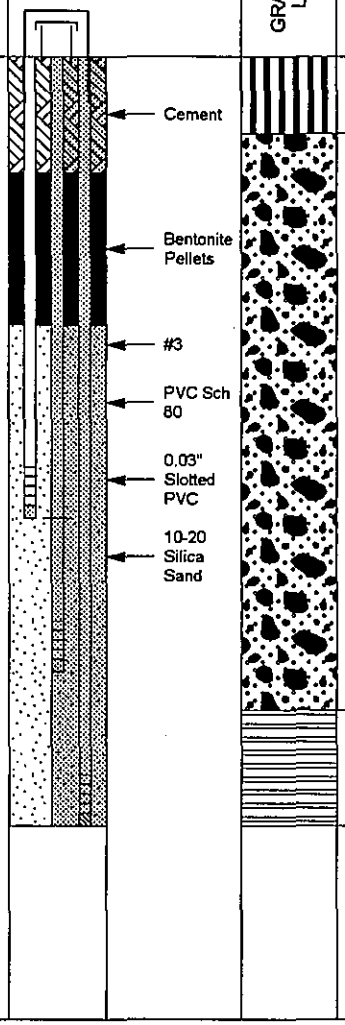
MONITORING WELL COMPLETION LOG NAT01-NAT21-3

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	586313.05	DATE DRILLED	07/03/1999
LOCATION	, CO	EAST COORD. (FT)	1107772.43	SURFACE ELEV. (FT NGVD)	5306.29
SITE	NATURITA	HOLE DEPTH (FT)	10.00	TOP OF CASING (FT)	5309.07
WELL NUMBER	NAT21-3	WELL DEPTH (FT)	6.00	MEAS. PT. ELEV. (FT)	5309.07
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.78	to	5.33
WELL SCREEN:	0.5 in. Slotted PVC	5.33	to	5.83
SUMP/END CAP:	0.5 in. PVC Sch 80	5.83	to	6.0
SURFACE SEAL:	Cement	0.0	to	1.5
GROUT:				
SEAL:	Bentonite Pellets	1.5	to	3.5
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	3.5	to	10.0

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings: NAT21-3 casing and screen depths provided; NAT21-1 casing is from 0 to 9.33 ft. and screened to 9.83 ft.; and NAT21-2 casing is from 0 to 7.33 ft. and screened to 7.83 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-1 ft. ELASTIC SILT (MH), some clay.
	5305						1-8.5 ft. SANDY GRAVEL (GW-SW), small gravel with large grained sand. Gravel increases to cobble size with depth and sand decreases.
5	5300						
							8.5-10.0 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; weathered bedrock.
10	5295						Total Depth 10.0 ft.



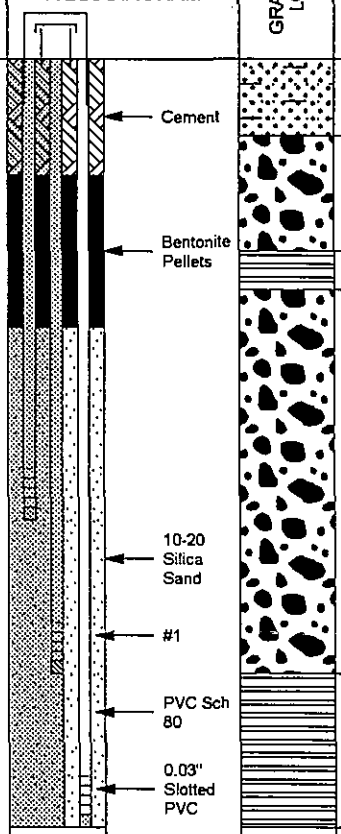
MONITORING WELL COMPLETION LOG NAT01-NAT22-1

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	586318.78	DATE DRILLED	07/04/1999
LOCATION	, CO	EAST COORD. (FT)	1107768.24	SURFACE ELEV. (FT NGVD)	5306.29
SITE	NATURITA	HOLE DEPTH (FT)	10.00	TOP OF CASING (FT)	5309.05
WELL NUMBER	NAT22-1	WELL DEPTH (FT)	10.00	MEAS. PT. ELEV. (FT)	5309.05
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.76	to	9.33
WELL SCREEN:	0.5 in. Slotted PVC	9.33	to	9.83
SUMP/END CAP:	0.5 in. PVC Sch 80	9.83	to	10.0
SURFACE SEAL:	Cement	0.0	to	1.5
GROUT:				
SEAL:	Bentonite Pellets	1.5	to	3.5
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	3.5	to	10.0

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings: NAT22-1 casing and screen depths provided; NAT22-2 casing is from 0 to 7.33 ft. and screened to 7.83 ft.; and NAT22.3 casing is from 0 to 5.33 ft. and screened to 5.83 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-1 ft. SILTY SAND (SM). Light tan in color.
	5305						1-2.5 ft. GRAVEL (GW), samll gravel and small cobbles. Light tan in color.
							2.5-3 ft. SHALE, some small size gravel. Light tan in color.
							3-8 ft. GRAVEL (GW), gravel increases in size with depth. Color changes to dark brown.
5							
	5300						
							8-10 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; weathered bedrock with large cobbles the first few inches. Dark gray in color.
10							Total Depth 10.0 ft.
	5295						



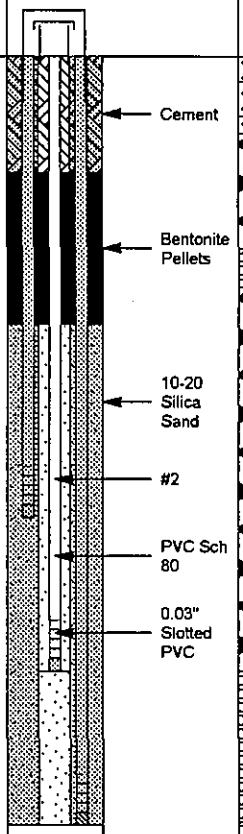
MONITORING WELL COMPLETION LOG NAT01-NAT22-2

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	586318.78	DATE DRILLED	07/04/1999
LOCATION	, CO	EAST COORD. (FT)	1107768.24	SURFACE ELEV. (FT NGVD)	5306.29
SITE	NATURITA	HOLE DEPTH (FT)	10.00	TOP OF CASING (FT)	5309.05
WELL NUMBER	NAT22-2	WELL DEPTH (FT)	8.00	MEAS. PT. ELEV. (FT)	5309.05
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.76	to	7.33
WELL SCREEN:	0.5 in. Slotted PVC	7.33	to	7.83
SUMP/END CAP:	0.5 in. PVC Sch 80	7.83	to	8.0
SURFACE SEAL:	Cement	0.0	to	1.5
GROUT:				
SEAL:	Bentonite Pellets	1.5	to	3.5
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	3.5	to	10.0

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings: NAT22-2 casing and screen depths provided; NAT22-1 casing is from 0 to 9.33 ft. and screened to 9.83 ft.; and NAT22.3 casing is from 0 to 5.33 ft. and screened to 5.83 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-1 ft. SILTY SAND (SM). Light tan in color.
	5305						1-2.5 ft. GRAVEL (GW), samll gravel and small cobbles. Light tan in color.
							2.5-3 ft. SHALE, some small size gravel. Light tan in color.
							3-8 ft. GRAVEL (GW), gravel increases in size with depth. Color changes to dark brown.
5							
	5300						
							8-10 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; weathered bedrock with large cobbles the first few inches. Dark gray in color.
10							Total Depth 10.0 ft.
	5295						



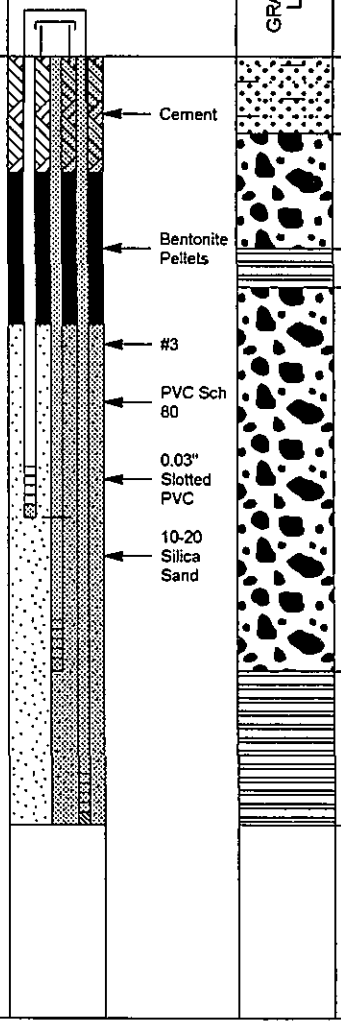
MONITORING WELL COMPLETION LOG NAT01-NAT22-3

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	586318.78	DATE DRILLED	07/04/1999
LOCATION	, CO	EAST COORD. (FT)	1107768.24	SURFACE ELEV. (FT NGVD)	5306.29
SITE	NATURITA	HOLE DEPTH (FT)	10.00	TOP OF CASING (FT)	5309.05
WELL NUMBER	NAT22-3	WELL DEPTH (FT)	6.00	MEAS. PT. ELEV. (FT)	5309.05
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.76	to	5.33
WELL SCREEN:	0.5 in. Slotted PVC	5.33	to	5.83
SUMP/END CAP:	0.5 in. PVC Sch 80	5.83	to	6.0
SURFACE SEAL:	Cement	0.0	to	1.5
GROUT:				
SEAL:	Bentonite Pellets	1.5	to	3.5
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	3.5	to	10.0

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings: NAT22-2 casing and screen depths provided; NAT22-1 casing is from 0 to 9.33 ft. and screened to 9.83 ft.; and NAT22-2 casing is from 0 to 7.33 ft. and screened to 7.83 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-1 ft. SILTY SAND (SM). Light tan in color.
	5305						1-2.5 ft. GRAVEL (GW), samll gravel and small cobbles. Light tan in color.
							2.5-3 ft. SHALE, some small size gravel. Light tan in color.
							3-8 ft. GRAVEL (GW), gravel increases in size with depth. Color changes to dark brown.
5	5300						8-10 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; weathered bedrock with large cobbles the first few inches. Dark gray in color.
10	5295						Total Depth 10.0 ft.



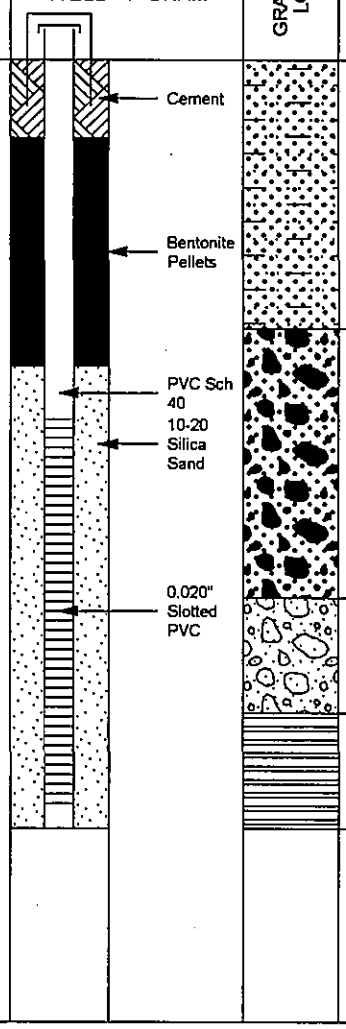
MONITORING WELL COMPLETION LOG NAT01-NAT23

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	589215.25	DATE DRILLED	07/05/1999
LOCATION	, CO	EAST COORD. (FT)	1106290.35	SURFACE ELEV. (FT NGVD)	5287.81
SITE	NATURITA	HOLE DEPTH (FT)	10.00	TOP OF CASING (FT)	5290.19
WELL NUMBER	NAT23	WELL DEPTH (FT)	10.00	MEAS. PT. ELEV. (FT)	5290.19
				SLOT SIZE (IN)	0.020
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.38	to	4.67
WELL SCREEN:	2 in. Slotted PVC	4.67	to	9.67
SUMP/END CAP:	2 in. PVC Sch 40	9.67	to	10.0
SURFACE SEAL:	Cement	0.0	to	1.0
GROUT:				
SEAL:	Bentonite Pellets	1.0	to	4.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	4.0	to	10.0

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-3.5 ft. SILTY SAND (SM), light tan in color.
	5285						
							3.5-7 ft. SANDY GRAVEL (GW-SW), fine sand with some silt. Light tan in color.
5							
	5280						7-8.5 ft. SANDY GRAVEL (GP-SP), coarse grained sand. Dark brown in color.
							8.5-10 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; weathered bedrock. Dark brown in color.
10							Total Depth 10.0 ft.



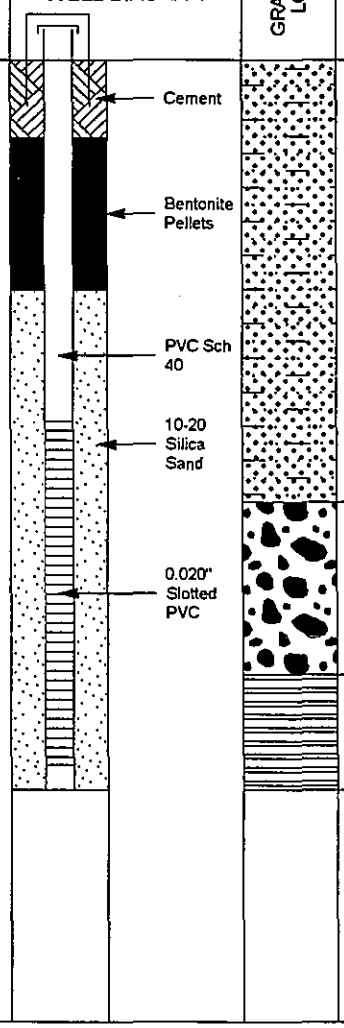
MONITORING WELL COMPLETION LOG NAT01-NAT24

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	589167.42	DATE DRILLED	07/05/1999
LOCATION	, CO	EAST COORD. (FT)	1106178.07	SURFACE ELEV. (FT NGVD)	5289.81
SITE	NATURITA	HOLE DEPTH (FT)	9.50	TOP OF CASING (FT)	5292.34
WELL NUMBER	NAT24	WELL DEPTH (FT)	9.50	MEAS. PT. ELEV. (FT)	5292.34
				SLOT SIZE (IN)	0.020
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.53	to	4.7
WELL SCREEN:	2 in. Slotted PVC	4.7	to	9.17
SUMP/END CAP:	2 in. PVC Sch 40	9.17	to	9.5
SURFACE SEAL:	Cement	0.0	to	1.0
GROUT:				
SEAL:	Bentonite Pellets	1.0	to	3.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	3.0	to	9.5

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-5.75 ft. SILTY SAND (SM), dark brown in color.
5	5285						
							5.75-8 ft. GRAVEL (GW), some cobbles.
							8-9.5 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; weathered bedrock.
10	5280						Total Depth 9.5 ft.



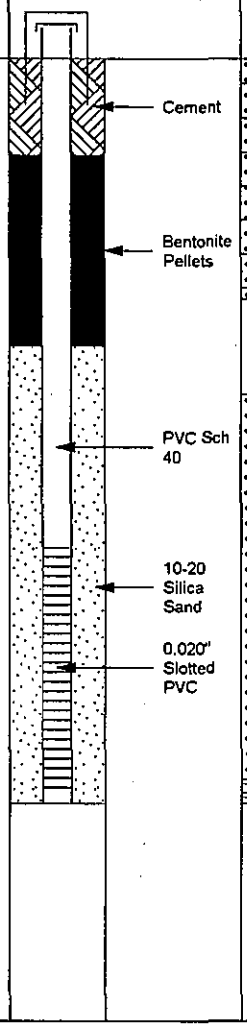
MONITORING WELL COMPLETION LOG NAT01-NAT25

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	589095.59	DATE DRILLED	07/05/1999
LOCATION	, CO	EAST COORD. (FT)	1106042.99	SURFACE ELEV. (FT NGVD)	5294.08
SITE	NATURITA	HOLE DEPTH (FT)	15.50	TOP OF CASING (FT)	5296.55
WELL NUMBER	NAT25	WELL DEPTH (FT)	15.50	MEAS. PT. ELEV. (FT)	5296.55
				SLOT SIZE (IN)	0.020
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.47	to	10.17
WELL SCREEN:	2 in. Slotted PVC	10.17	to	15.17
SUMP/END CAP:	2 in. PVC Sch 40	15.17	to	15.5
SURFACE SEAL:	Cement	0.0	to	2.0
GROUT:				
SEAL:	Bentonite Pellets	2.0	to	6.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	6.0	to	15.5

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-5 ft. SILTY SAND (SM), dark bown.
5	5290						5-7 ft. ELASTIC SILT (MH), light brown in color.
10	5285						7-15 ft. SAND (SW), fine to medium grained, light brown in color.
15	5280						15-15.5 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; light brown in color.
	5275						Total Depth 15.5 ft.



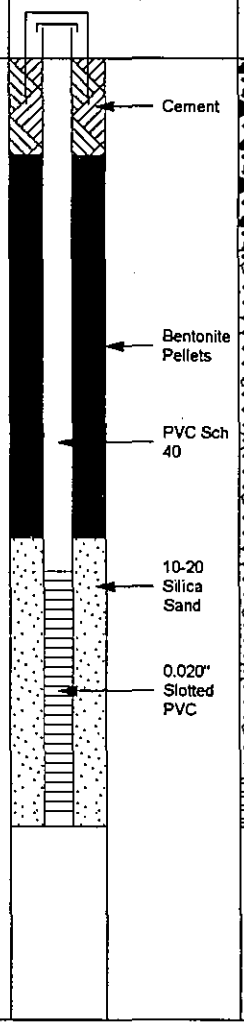
MONITORING WELL COMPLETION LOG NAT01-NAT26

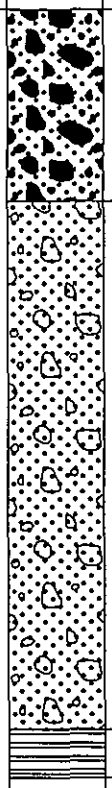
PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	588699.25	DATE DRILLED	07/05/1999
LOCATION	, CO	EAST COORD. (FT)	1106014.15	SURFACE ELEV. (FT NGVD)	5297.90
SITE	NATURITA	HOLE DEPTH (FT)	16.00	TOP OF CASING (FT)	5300.21
WELL NUMBER	NAT26	WELL DEPTH (FT)	16.00	MEAS. PT. ELEV. (FT)	5300.21
				SLOT SIZE (IN)	0.020
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.31	to	10.67
WELL SCREEN:	2 in. Slotted PVC	10.67	to	15.67
SUMP/END CAP:	2 in. PVC Sch 40	15.67	to	16.0
SURFACE SEAL:	Cement	0.0	to	2.0
GROUT:				
SEAL:	Bentonite Pellets	2.0	to	10.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	10.0	to	16.0

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-4 ft. SANDY GRAVEL (GW-SW), dark brown.
	5295						
5							4-15 ft. GRAVELLY SAND (SW-GW), coarse sand with small gravel, dark brown.
	5290						
10							
	5285						
15							15-16 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; dark brown weathered bedrock.
							Total Depth 16.0 ft.
	5280						





mactec-ers

U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION OFFICE, COLORADO

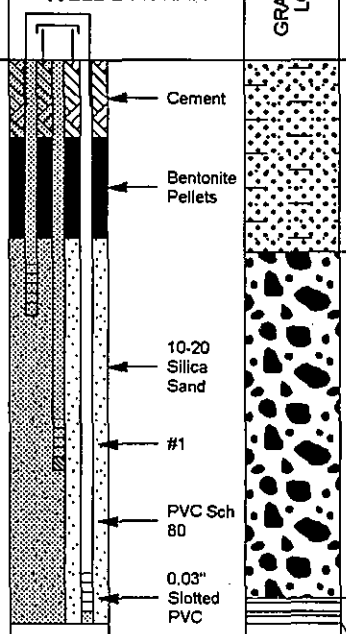
MONITORING WELL COMPLETION LOG NAT01-NAT27-1

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587776.30	DATE DRILLED	07/05/1999
LOCATION	, CO	EAST COORD. (FT)	1107200.51	SURFACE ELEV. (FT NGVD)	5294.56
SITE	NATURITA	HOLE DEPTH (FT)	7.33	TOP OF CASING (FT)	5297.53
WELL NUMBER	NAT27-1	WELL DEPTH (FT)	7.33	MEAS. PT. ELEV. (FT)	5297.53
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.97	to	6.66
WELL SCREEN:	0.5 in. Slotted PVC	6.66	to	7.16
SUMP/END CAP:	0.5 in. PVC Sch 80	7.16	to	7.33
SURFACE SEAL:	Cement	0.0	to	1.0
GROUT:				
SEAL:	Bentonite Pellets	1.0	to	2.33
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	2.33	to	7.33

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings: NAT27-1 casing and screen depths provided; NAT27-2 casing is from 0 to 4.66 ft. and screened to 5.16 ft.; and NAT27-3 casing is from 0 to 2.66 ft. and screened to 3.16 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-2.5 ft. SILTY SAND (SM), light brown in color.
							2.5-7 ft. GRAVEL (GW), some cobbles with coarse sand, light brown in color.
							7-7.33 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE
							Total Depth 7.33 ft.
5	5290						
10	5285						

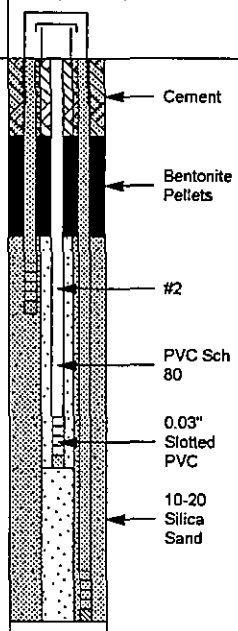


MONITORING WELL COMPLETION LOG NAT01-NAT27-2

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587776.30	DATE DRILLED	07/05/1999
LOCATION	, CO	EAST COORD. (FT)	1107200.51	SURFACE ELEV. (FT NGVD)	5294.56
SITE	NATURITA	HOLE DEPTH (FT)	7.33	TOP OF CASING (FT)	5297.50
WELL NUMBER	NAT27-2	WELL DEPTH (FT)	5.33	MEAS. PT. ELEV. (FT)	5297.50
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.94	to	4.66
WELL SCREEN:	0.5 in. Slotted PVC	4.66	to	5.16
SUMP/END CAP:	0.5 in. PVC Sch 80	5.16	to	5.33
SURFACE SEAL:	Cement	0.0	to	1.0
GROUT:				
SEAL:	Bentonite Pellets	1.0	to	2.33
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	2.33	to	7.33

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings: NAT27-2 casing and screen depths provided; NAT27-1 casing is from 0 to 6.66 ft. and screened to 7.16 ft.; and NAT27-3 casing is from 0 to 2.66 ft. and screened to 3.16 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-2.5 ft. SILTY SAND (SM), light brown in color.
							2.5-7 ft. GRAVEL (GW), some cobbles with coarse sand, light brown in color.
							7-7.33 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE
							Total Depth 7.33 ft.
5	5290						
10	5285						

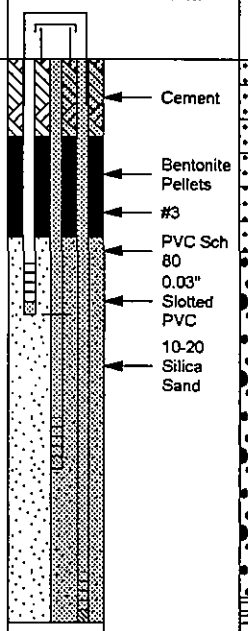
MONITORING WELL COMPLETION LOG NAT01-NAT27-3

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587776.30	DATE DRILLED	07/05/1999
LOCATION	, CO	EAST COORD. (FT)	1107200.51	SURFACE ELEV. (FT NGVD)	5294.56
SITE	NATURITA	HOLE DEPTH (FT)	7.33	TOP OF CASING (FT)	5297.51
WELL NUMBER	NAT27-3	WELL DEPTH (FT)	3.33	MEAS. PT. ELEV. (FT)	5297.51
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.95	to	2.66
WELL SCREEN:	0.5 in. Slotted PVC	2.66	to	3.16
SUMP/END CAP:	0.5 in. PVC Sch 80	3.16	to	3.33
SURFACE SEAL:	Cement	0.0	to	1.0
GROUT:				
SEAL:	Bentonite Pellets	1.0	to	2.33
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	2.33	to	7.33

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings: NAT27-3 casing and screen depths provided; NAT27-1 casing is from 0 to 6.66 ft. and screened to 7.16 ft.; and NAT27-2 casing is from 0 to 4.66 ft. and screened to 5.16 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-2.5 ft. SILTY SAND (SM), light brown in color.
							2.5-7 ft. GRAVEL (GW), some cobbles with coarse sand, light brown in color.
							7-7.33 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE
							Total Depth 7.33 ft.
5	5290						
10	5285						



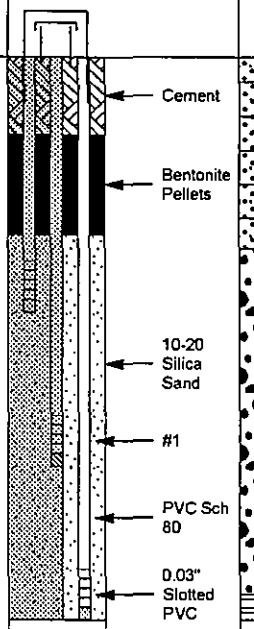
MONITORING WELL COMPLETION LOG NAT01-NAT28-1

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587770.69	DATE DRILLED	07/06/1999
LOCATION	, CO	EAST COORD. (FT)	1107204.15	SURFACE ELEV. (FT NGVD)	5294.66
SITE	NATURITA	HOLE DEPTH (FT)	7.33	TOP OF CASING (FT)	5297.37
WELL NUMBER	NAT28-1	WELL DEPTH (FT)	7.33	MEAS. PT. ELEV. (FT)	5297.37
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.71	to	6.66
WELL SCREEN:	0.5 in. Slotted PVC	6.66	to	7.16
SUMP/END CAP:	0.5 in. PVC Sch 80	7.16	to	7.33
SURFACE SEAL:	Cement	0.0	to	1.0
GROUT:				
SEAL:	Bentonite Pellets	1.0	to	2.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	2.0	to	7.33

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings: NAT28-1 casing and screen depths provided; NAT28-2 casing is from 0 to 4.66 ft. and screened to 5.16 ft.; and NAT28-3 casing is from 0 to 2.66 ft. and screened to 3.16 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-2.5 ft. SILTY SAND (SM).
							2.5-7 ft. GRAVEL (GW), some cobbles.
5	5290						
							7-7.33 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; bedrock
							Total Depth 7.33 ft.
10	5285						



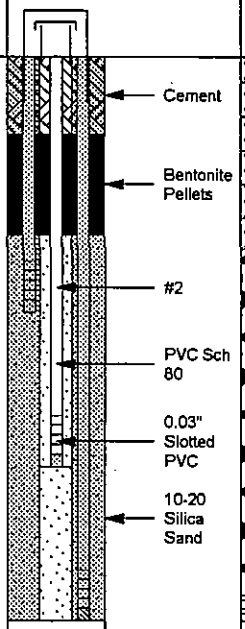
MONITORING WELL COMPLETION LOG NAT01-NAT28-2

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587770.69	DATE DRILLED	07/06/1999
LOCATION	, CO	EAST COORD. (FT)	1107204.15	SURFACE ELEV. (FT NGVD)	5294.66
SITE	NATURITA	HOLE DEPTH (FT)	7.33	TOP OF CASING (FT)	5297.37
WELL NUMBER	NAT28-2	WELL DEPTH (FT)	5.33	MEAS. PT. ELEV. (FT)	5297.37
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.71	to	4.66
WELL SCREEN:	0.5 in. Slotted PVC	4.66	to	5.16
SUMP/END CAP:	0.5 in. PVC Sch 80	5.16	to	5.33
SURFACE SEAL:	Cement	0.0	to	1.0
GROUT:				
SEAL:	Bentonite Pellets	1.0	to	2.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	2.0	to	7.33

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings: NAT28-2 casing and screen depths provided; NAT28-1 casing is from 0 to 6.66 ft. and screened to 7.16 ft.; and NAT28-3 casing is from 0 to 2.66 ft. and screened to 3.16 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-2.5 ft. SILTY SAND (SM).
							2.5-7 ft. GRAVEL (GW), some cobbles.
5	5290						
							7-7.33 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; bedrock
							Total Depth 7.33 ft.
10	5285						



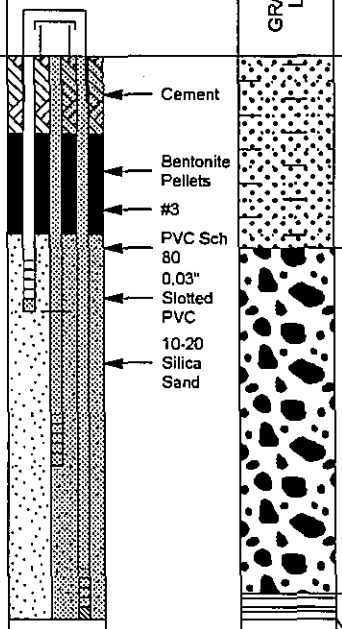
MONITORING WELL COMPLETION LOG NAT01-NAT28-3

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587770.69	DATE DRILLED	07/06/1999
LOCATION	, CO	EAST COORD. (FT)	1107204.15	SURFACE ELEV. (FT NGVD)	5294.66
SITE	NATURITA	HOLE DEPTH (FT)	7.33	TOP OF CASING (FT)	5297.36
WELL NUMBER	NAT28-3	WELL DEPTH (FT)	3.33	MEAS. PT. ELEV. (FT)	5297.36
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.7	to	2.66
WELL SCREEN:	0.5 in. Slotted PVC	2.66	to	3.16
SUMP/END CAP:	0.5 in. PVC Sch 80	3.16	to	3.33
SURFACE SEAL:	Cement	0.0	to	1.0
GROUT:				
SEAL:	Bentonite Pellets	1.0	to	2.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	2.0	to	7.33

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings: NAT28-1 casing and screen depths provided; NAT28-2 casing is from 0 to 4.66 ft. and screened to 5.16 ft.; and NAT28-3 casing is from 0 to 2.66 ft. and screened to 3.16 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-2.5 ft. SILTY SAND (SM).
							2.5-7 ft. GRAVEL (GW), some cobbles.
							7-7.33 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE; bedrock
							Total Depth 7.33 ft.
5	5290						
10	5285						



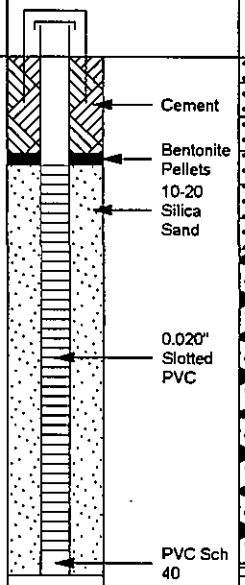
MONITORING WELL COMPLETION LOG NAT01-NAT29

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	587764.89	DATE DRILLED	07/06/1999
LOCATION	, CO	EAST COORD. (FT)	1107208.58	SURFACE ELEV. (FT NGVD)	5294.80
SITE	NATURITA	HOLE DEPTH (FT)	6.75	TOP OF CASING (FT)	5297.65
WELL NUMBER	NAT29	WELL DEPTH (FT)	6.75	MEAS. PT. ELEV. (FT)	5297.65
				SLOT SIZE (IN)	0.020
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	-2.85	to	1.42
WELL SCREEN:	2 in. Slotted PVC	1.42	to	6.42
SUMP/END CAP:	2 in. PVC Sch 80	6.42	to	6.75
SURFACE SEAL:	Cement	0.0	to	1.25
GROUT:				
SEAL:	Bentonite Pellets	1.25	to	1.42
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	1.42	to	6.75

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-2.5 ft. SILTY SAND (SM).
							2.5-6.58 ft. GRAVEL (GW), some cobbles.
5	5290						
							6.58-6.75 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE, bedrock.
							Total Depth 6.75 ft.
10	5285						



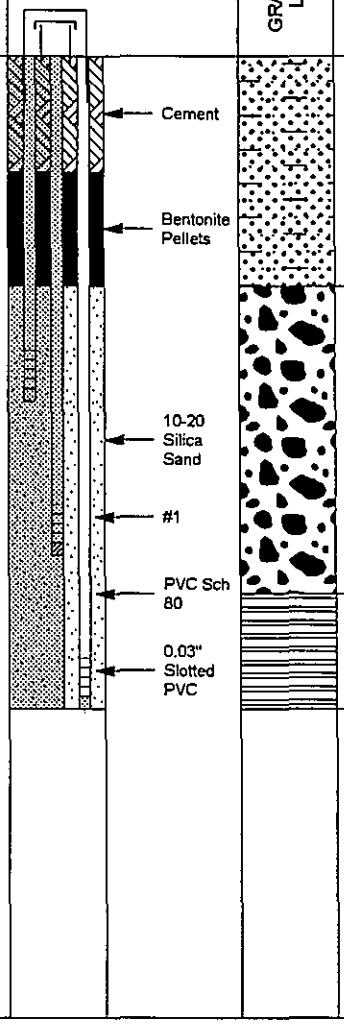
MONITORING WELL COMPLETION LOG NAT01-NAT30-1

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	586838.30	DATE DRILLED	07/06/1999
LOCATION	, CO	EAST COORD. (FT)	1107476.19	SURFACE ELEV. (FT NGVD)	5302.05
SITE	NATURITA	HOLE DEPTH (FT)	8.50	TOP OF CASING (FT)	5304.91
WELL NUMBER	NAT30-1	WELL DEPTH (FT)	8.50	MEAS. PT. ELEV. (FT)	5304.91
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.86	to	7.83
WELL SCREEN:	0.5 in. Slotted PVC	7.83	to	8.33
SUMP/END CAP:	0.5 in. PVC Sch 80	8.33	to	8.5
SURFACE SEAL:	Cement	0.0	to	1.5
GROUT:				
SEAL:	Bentonite Pellets	1.5	to	3.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	3.0	to	8.5

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings: NAT30-1 casing and screen depths provided; NAT30-2 casing is from 0 to 5.83 ft. and screened to 6.33 ft.; and NAT30-3 casing is from 0 to 3.83 ft. and screened to 4.33 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
	5300				Cement; Bentonite Pellets		0-3 ft. SILTY SAND (SM), light brown.
5					10-20 Silica Sand; #1		3-7 ft. GRAVEL (GW), some cobbles and dark brown in color.
	5295				PVC Sch 80; 0.03" Slotted PVC		7-8.5 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE, weathered bedrock from 7.0 to 8.0 ft.
10							Total Depth 8.5 ft.
	5290						



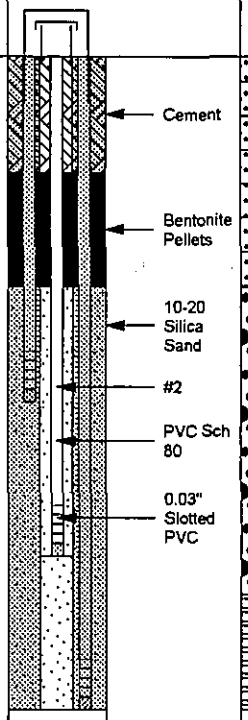
MONITORING WELL COMPLETION LOG NAT01-NAT30-2

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	586838.30	DATE DRILLED	07/06/1999
LOCATION	, CO	EAST COORD. (FT)	1107476.19	SURFACE ELEV. (FT NGVD)	5302.05
SITE	NATURITA	HOLE DEPTH (FT)	8.50	TOP OF CASING (FT)	5304.87
WELL NUMBER	NAT30-2	WELL DEPTH (FT)	6.50	MEAS. PT. ELEV. (FT)	5304.87
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.82	to	5.83
WELL SCREEN:	0.5 in. Slotted PVC	5.83	to	6.33
SUMP/END CAP:	0.5 in. PVC Sch 80	6.33	to	6.5
SURFACE SEAL:	Cement	0.0	to	1.5
GROUT:				
SEAL:	Bentonite Pellets	1.5	to	3.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	3.0	to	8.5

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings: NAT30-2 casing and screen depths provided; NAT30-1 casing is from 0 to 7.83 ft. and screened to 8.33 ft.; and NAT30-3 casing is from 0 to 3.83 ft. and screened to 4.33 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-3 ft. SILTY SAND (SM), light brown.
	5300						
							3-7 ft. GRAVEL (GW), some cobbles and dark brown in color.
5							
	5295						7-8.5 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE, weathered bedrock from 7.0 to 8.0 ft.
							Total Depth 8.5 ft.
10							
	5290						



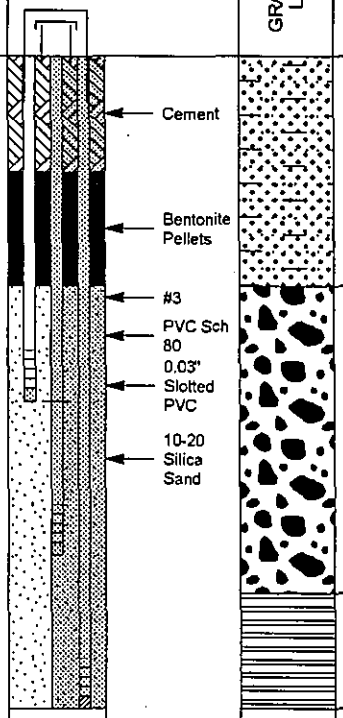
MONITORING WELL COMPLETION LOG NAT01-NAT30-3

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	586838.30	DATE DRILLED	07/06/1999
LOCATION	, CO	EAST COORD. (FT)	1107476.19	SURFACE ELEV. (FT NGVD)	5302.05
SITE	NATURITA	HOLE DEPTH (FT)	8.50	TOP OF CASING (FT)	5304.87
WELL NUMBER	NAT30-3	WELL DEPTH (FT)	4.50	MEAS. PT. ELEV. (FT)	5304.87
				SLOT SIZE (IN)	0.030
				BIT SIZE(S) (IN)	4.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	0.5 in. PVC Sch 80	-2.82	to	3.83
WELL SCREEN:	0.5 in. Slotted PVC	3.83	to	4.33
SUMP/END CAP:	0.5 in. PVC Sch 80	4.33	to	4.5
SURFACE SEAL:	Cement	0.0	to	1.5
GROUT:				
SEAL:	Bentonite Pellets	1.5	to	3.0
UPPER PACK:				
LOWER PACK:	10-20 Silica Sand	3.0	to	8.5

DRILLING METHOD HAMMER CASING ADVANCE
SAMPLING METHOD
DATE DEVELOPED
WATER LEVEL (FT BGS)
LOGGED BY Holmes/Rowland
REMARKS Cluster of 3 casings: NAT30-3 casing and screen depths provided; NAT30-1 casing is from 0 to 7.83 ft. and screened to 8.33 ft.; and NAT30-2 casing is from 0 to 5.83 ft. and screened to 6.33 ft.

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
							0-3 ft. SILTY SAND (SM), light brown.
	5300						
							3-7 ft. GRAVEL (GW), some cobbles and dark brown in color.
5							
	5295						7-8.5 ft. BRUSHY BASIN MEMBER OF MORRISON FORMATION: SHALE, weathered bedrock from 7.0 to 8.0 ft.
							Total Depth 8.5 ft.
10							
	5290						



MONITORING WELL COMPLETION LOG NAT01-0700

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	588165.55	DATE DRILLED	05/22/2001
LOCATION	, CO	EAST COORD. (FT)	1106280.20	SURFACE ELEV. (FT NGVD)	5292.16
SITE	NATURITA	HOLE DEPTH (FT)	10.50	TOP OF CASING (FT)	5292.09
WELL NUMBER	0700	WELL DEPTH (FT)	8.33	MEAS. PT. ELEV. (FT)	5292.09
				SLOT SIZE (IN)	0.010
				BIT SIZE(S) (IN)	3.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	2 in. PVC Sch 40	0.07	to	3.0
WELL SCREEN:	2 in. Slotted PVC	3.0	to	8.0
SUMP/END CAP:	2 in. PVC Sch 40	8.0	to	8.33
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Pellets	0.0	to	1.5
UPPER PACK:	20-40 Silica Sand	1.5	to	2.0
LOWER PACK:	10-20 Silica Sand	2.0	to	8.33

DRILLING METHOD GEOPROBE
SAMPLING METHOD CORE BARREL
DATE DEVELOPED
WATER LEVEL (FT BGS) 5.5 on 05/22/2001
LOGGED BY Hopping, B.
REMARKS Did not acquire water level (~5.0-6.0 ft).

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
			0-2.0 ft.		Bentonite Pellets; 20-40 Silica Sand		0-2.0 ft. SILTY SAND (SM); reddish brown, some pebbles, dry. From 8" to 2.0 ft. layer is grayish tan iron stained mud, claystone, rounded pebbles and gravel.
	5290		2.0-4.0 ft.		PVC Sch; 10-20 Silica Sand		2.0-5.0 ft. CLAYSTONE; igneous cobble present followed by gray/yellowish tan mud silt and carbonaceous shale, iron staining. Color changes to gray at depth, moist.
5			4.0-6.0 ft.		Slotted PVC		5.0-9.0 ft. SANDY GRAVEL (GW-SW); igneous cobbles and pebbles, reddish brown to pinkish fine sand, caliche (white), wet at 6.0 ft.
	5285		6.0-8.0 ft.				@7.0 ft. color changes to brown/tan, and medium to fine grained sand mixed with pebbles. @8.0 ft. wet/saturated.
			8.0-10.0 ft.		Slough		9.0-10.0 ft. GRAVELLY SAND (SW-GW); gray brown medium to fine sand mixed with primarily rounded pebbles and gravel, 60-70% sand, 30-40% pebbles and gravels. Saturated-wet.
10			10.0-12.0 ft.				10.0-10.5 ft. BUSHY BASIN MEMBER OF THE MORRISON FORMATION: SANDSTONE; brown to tan weathered fine sand bedrock surface, abundant iron staining poorly cemented. (moist to dry). Total Depth 10.5 ft.
	5280						

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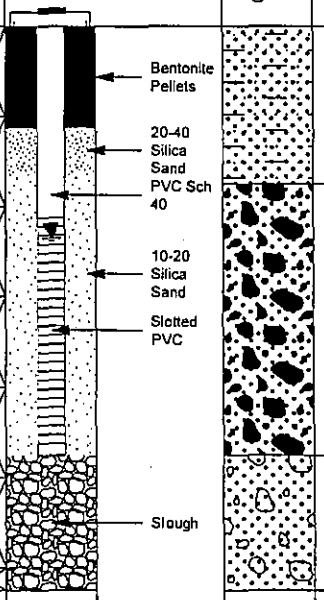
MONITORING WELL COMPLETION LOG NAT01-0701

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	589525.02	DATE DRILLED	05/21/2001
LOCATION	, CO	EAST COORD. (FT)	1106672.35	SURFACE ELEV. (FT NGVD)	5284.73
SITE	NATURITA	HOLE DEPTH (FT)	12.50	TOP OF CASING (FT)	5284.47
WELL NUMBER	0701	WELL DEPTH (FT)	9.50	MEAS. PT. ELEV. (FT)	5284.47
				SLOT SIZE (IN)	0.010
				BIT SIZE(S) (IN)	2.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	1 in. PVC Sch 40	0.26	to	4.25
WELL SCREEN:	1 in. Slotted PVC	4.25	to	9.25
SUMP/END CAP:	1 in. PVC Sch 40	9.25	to	9.5
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Pellets	0.0	to	2.25
UPPER PACK:	20-40 Silica Sand	2.25	to	3.25
LOWER PACK:	10-20 Silica Sand	3.25	to	9.5

DRILLING METHOD GEOPROBE
SAMPLING METHOD CORE BARREL
DATE DEVELOPED
WATER LEVEL (FT BGS) 4.71 on 05/21/2001
LOGGED BY Hopping, B.
REMARKS

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
			0-2.0 ft.		Bentonite Pellets		0-3.5 ft. SILTY SAND (SM);
			2.0-4.0 ft.		20-40 Silica Sand; PVC Sch 40		
5	5280		4.0-6.0 ft.		10-20 Silica Sand		3.5-6.5 ft. GRAVELLY SAND (SW-GW); brown/tan, fine to medium grained sand, rounded pebbles and cobbles (igneous and sandstone), wet @5.5 ft.
			6.0-8.0 ft.		Slotted PVC		
			8.0-10.0 ft.				
10	5275		10.0-12.0 ft.		Slough		9.5-12.5 ft. SANDY GRAVEL (GW-SW); brown sand mixed with primarily gravel, rounded to angular.
			12.0-12.5 ft.				
							Total Depth 12.5 ft.
15	5270						
	5265						



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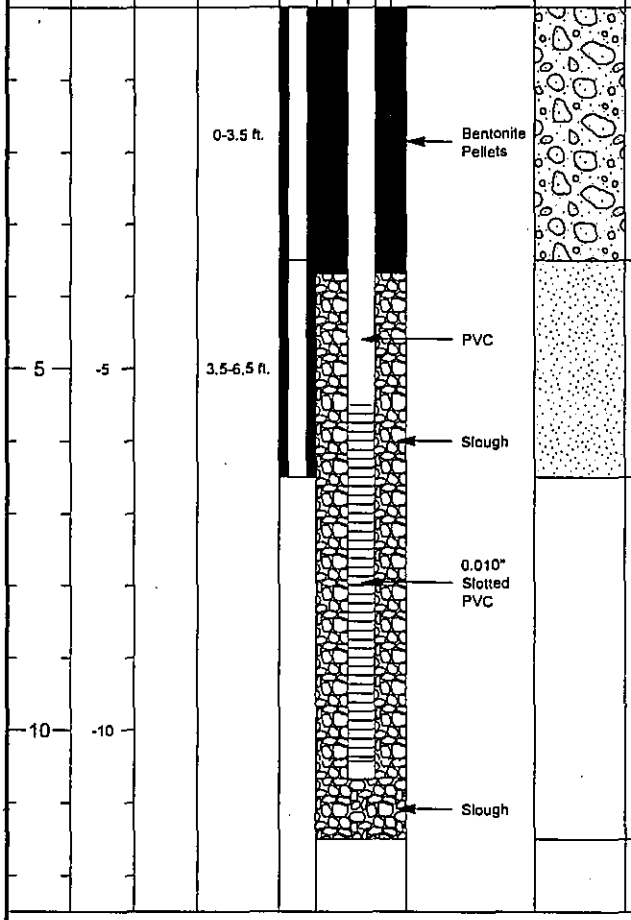
MONITORING WELL COMPLETION LOG NAT01-0715

PROJECT	UMTRA GROUND WATER	NORTH COORD. (FT)	590702.23	DATE DRILLED	04/08/2002
LOCATION	, CO	EAST COORD. (FT)	1106484.09	SURFACE ELEV. (FT NGVD)	
SITE	NATURITA	HOLE DEPTH (FT)	11.50	TOP OF CASING (FT)	
WELL NUMBER	0715	WELL DEPTH (FT)	10.67	MEAS. PT. ELEV. (FT)	
				SLOT SIZE (IN)	0.010
				BIT SIZE(S) (IN)	2.0

	WELL INSTALLATION	INTERVAL (FT)		
SURFACE CASING:				
BLANK CASING:	1 in. PVC		to	5.49
WELL SCREEN:	1 in. Slotted PVC	5.49	to	10.42
SUMP/END CAP:	1 in. PVC	10.42	to	10.67
SURFACE SEAL:				
GROUT:				
SEAL:	Bentonite Pellets	0.0	to	3.7
UPPER PACK:				
LOWER PACK:	Slough	3.7	to	10.67

DRILLING METHOD GEOPROBE
SAMPLING METHOD CORE
DATE DEVELOPED
WATER LEVEL (FT BTOC) 6.53 on 04/08/2002
LOGGED BY Hopping, B.
REMARKS

DEPTH (FT BGL)	ELEV. (FT NGVD)	BLOW COUNTS	SAMPLE ID.	EXTENT	WELL DIAGRAM	GRAPHIC LOG	LITHOLOGIC DESCRIPTION
			0-3.5 ft.		Bentonite Pellets		0-3.5 ft. SANDY GRAVEL (GP-SP); brown to tan, fine sand grading to medium grained mixed with abundant gravel and cobble (rounded, well sorted, dry to moist).
5	-5		3.5-6.5 ft.		PVC; Slough		3.5-6.5 ft. SAND (SP); brown to light tan fine to coarse grained misxed with cobble to pebble size aggregate, medium sorting, moist to wet.
10	-10				0.010" Slotted PVC; Slough		6.5-11.5 ft. No Samples taken. Well began to collapse @ 6.0 ft. so casing was driven to depth with no futher sampling.
							Total Depth 11.5 ft.



Appendix E

USGS Distribution Coefficient Analysis

1.0 Introduction

1.1 Distribution Coefficient (K_d) Analysis

The K_d is a bulk parameter that has been used with some success to describe the retardation of contaminant movement in an aquifer system. Laboratory measurements to determine the K_d for selected analytes were performed on alluvial material to support computer-modeling efforts in characterizing subsurface contaminant transport at the Naturita site.

1.1.1 Method of Solution

Laboratory analyses of the K_d were performed according to American Society for Testing and Materials (ASTM) procedure D 4646–87 (ASTM 1987), with slight modifications as detailed below, for two site-related contaminants of potential concern (COPCs): uranium and vanadium. Essentially, the procedure involves placing a sample representative of a location (e.g., soil, sediments, cuttings, core) into a solution of simulated contaminated ground water with which the material is likely to come in contact. The simulated ground water solution is agitated for 96 hours (uranium) or 24 hours (vanadium) and then centrifuged. The supernatant solution is analyzed and compared to the contaminant concentrations of the original solution. The difference between the two is assumed to be adsorbed to the sample. The linear adsorption isotherm distribution coefficient is generally defined as

$$C_{soil} = K_d \times C_{water}, \text{ which can be rearranged to } K_d = C_{soil}/C_{water},$$

or the ratio of the concentration of the contaminant in soil (or other material of interest) to the concentration of the contaminant in water at equilibrium. Therefore, the higher the K_d, the greater the retardation of contaminant movement in ground water.

The procedure requires analysis of only the solutions (and no actual soil samples) used in the experiments. Site samples collected from background areas or uncontaminated site samples are generally used, and all contaminant loss in the final solution is attributed to sample adsorption. However, for this study, uranium-contaminated alluvial samples were also collected, and uranium(VI) adsorption on these samples was determined by desorption in alkaline solutions and by uranium isotopic exchange in artificial ground water solution.

1.1.1.1 Sample Selection

A large sample of background alluvial material was collected by backhoe from the saturated zone of the aquifer at a location upgradient of the site on July 16 and 17, 1998. The sample was considered uncontaminated because concentrations of dissolved uranium at well 0547 (and decommissioned DOE wells nearby) were always very low, near the background uranium concentrations in the San Miguel River. The background sample of alluvium was screened in the field to remove cobbles larger than about 65 mm, and it was estimated visually that about 50 percent of the material scooped by the backhoe did not pass the 65-mm screen.

1.1.1.2 Preparation of the Sample of Background Alluvium

The sample was air dried at room temperature and sieved to separate the <3 mm fraction. Alluvial material totaling 190 kg passed a 3-mm screen and was mixed into a single composite

sample, representing 30 percent (by weight) of the material that had been sieved in the field through a 65-mm screen. The <3 mm sample represented approximately 15 percent of the total material sampled by backhoe in the field.

Synthetic solutions were prepared that simulated ground water at the Naturita site. Based on ground water analyses for several wells sampled in November 1998 and on preliminary batch experiments, a composition of synthetic ground water (AGW–3) was prepared for experiments equilibrated with air as follows (in mg/L): Na = 55.5, K = 2.5, Ca = 189, Mg = 36.8, SO_4 = 459, Cl = 171, C (inorganic) = 6.46, with pH adjusted to 7.9. The concentrations of C (inorganic) and Ca were expected to change somewhat during the batch experiments, because of the presence of calcite in the alluvial material. The AGW–3 solution equilibrated in the batch experiments with alluvial material and air without a significant change in pH (about 7.9) or alkalinity (37.5 mg/L as $CaCO_3$).

For uranium(VI), because of its tendency to form aqueous carbonate complexes, other synthetic solutions were prepared for experiments equilibrated with gas mixtures containing 0.5 percent CO_2/99.5 percent N_2 (AGW–7) and 2.0 percent CO_2/98 percent N_2 (AGW–5). The composition of AGW–7 was Na = 55.5, K = 2.5, Ca = 98.2, Mg = 36.8, SO_4 = 368.5, Cl = 8.2, and C (inorganic) = 30. This solution yielded a final pH of about 7.58 and an alkalinity of 152 mg/L as $CaCO_3$ after equilibration with the alluvial material and the gas mixture containing 0.5 percent CO_2. This alkalinity corresponds to a C (inorganic) concentration of 36.5 mg/L.

The composition of AGW–5 was Na = 55.5, K = 2.5, Ca = 257, Mg = 36.8, SO_4 = 459, Cl = 193, and C (inorganic) = 40. This solution yielded a final pH of about 7.18 and an alkalinity of 202 mg/L as $CaCO_3$, after equilibration with the alluvial material and the gas mixture containing 2.0 percent CO_2. This alkalinity corresponds to a C (inorganic) concentration of 48.4 mg/L. This latter solution was closer to the observed ground water pH and C (inorganic) concentrations observed in the alluvial aquifer than could be obtained by equilibrating experiments in the presence of air. Alkalinity in the alluvial aquifer ranges from 200 to 500 mg/L (as $CaCO_3$).

After equilibration of the synthetic solution with the alluvial material for 12 hours, either uranium or vanadium was then added from acidified nitrate stock solutions to study a range of target concentrations: 0.006 to 1.9 mg/L uranium or 1 to 16 mg/L vanadium.

1.1.1.3 Sample Analysis

The synthetic ground water solutions were analyzed to determine that the target concentrations were achieved by additions from the uranium(VI) and vanadium(V) stock solutions. These results are reported in Table 1.

Table 1. Laboratory Analytical Results for Synthetic Ground Water Solutions

Sample ID	Sample Description	Solution Volume (mL)	Target Concentration (mg/L)		Analyzed Concentration (mg/L)	
			U	V	U	V
AGW3–1	Synthetic ground water	30	0.0255	1.75	0.0267	1.73
AGW3–2	Synthetic ground water	30	0.241	5.25	0.0254	5.35
AGW3–3	Synthetic ground water	30	2.40	8.75	2.62	8.95

Aliquots of the synthetic ground water were first preequilibrated with each sample at a concentration of 25 g/L prior to use in the actual sample analyses, to preequilibrate the synthetic ground water with the sample surface. The preequilibrated synthetic ground water was filtered through a 0.45 micrometer (µm) filter prior to use in the sample analyses. For analysis with the ground water AGW–3, approximately 0.5 or 0.75 g of each sample was measured and placed in 50-milliliter (mL) polycarbonate centrifuge tubes with 20 or 30 mL of the filtered, preequilibrated synthetic ground water, resulting in sample suspension of 25 g/L. For analysis with the ground water AGW–7, approximately 3.75 g of each sample was measured and placed in 50-mL polycarbonate centrifuge tubes with 30 mL of the filtered, preequilibrated synthetic ground water, resulting in a sample suspension of 125 g/L. For analysis with the ground water AGW–5, approximately 7.5 g of each sample was measured and placed in 50 mL polycarbonate centrifuge tubes with 30 mL of the filtered, preequilibrated synthetic ground water, resulting in a sample suspension of 250 g/L.

Samples were rotated end over end at 14 revolutions per minute (rpm) for 24 hours, after which an aliquot of uranium(VI) or vanadium(V) stock solution was added to achieve the target contaminant concentration in the analysis. Samples were then rotated end-over-end at 14 rpm for 24 hours (V analysis) or 96 hours (U analysis). They were then centrifuged at 23,500 rpm for 30 minutes. The 5 mL aliquots of the resulting leachate samples were preserved with 50 µL concentrated HNO_3 in glass scintillation vials for analysis of U(VI) or vanadium. Analytical results are reported in Tables 2 through 4. Blank centrifuge tubes (with no solid sample) were included for each analysis to check for adsorption onto container walls; no adsorption on the container walls was observed. U(VI) was analyzed by kinetic phosphoresence analysis (KPA), and vanadium was analyzed by inductively coupled plasma optical emission spectrometry (ICP-OES).

Table 2. Analytical Results for Sample Leachate Solutions Using the Uncontaminated Alluvial Deposit Sample and Synthetic Ground Water AGW–3 (equilibrated with the partial pressure of CO_2 in air)

Sample ID	Sample Description	Solution Volume (mL)	Synthetic Solution Type	Sample Mass (g)	Concentration (mg/L)	
					U	V
Ex6S7	Alluvium composite leachate	30	AGW–3	0.75	0.00635	
Ex6S8	Duplicate	30	AGW–3	0.75	0.00584	
Ex6S9	Alluvium composite leachate	30	AGW–3	0.75	0.0167	
Ex6S10	Duplicate	30	AGW–3	0.75	0.0180	
Ex6S11	Alluvium composite leachate	30	AGW–3	0.75	0.0530	
Ex6S12	Duplicate	30	AGW–3	0.75	0.0514	
Ex6S13	Alluvium composite leachate	30	AGW–3	0.75	0.196	
Ex6S14	Duplicate	30	AGW–3	0.75	0.192	
Ex6S15	Alluvium composite leachate	30	AGW–3	0.75	0.412	
Ex6S16	Duplicate	30	AGW–3	0.75	0.420	
Ex6S17	Alluvium composite leachate	30	AGW–3	0.75	2.24	
Ex6S18	Duplicate	30	AGW–3	0.75	2.13	
ExVS5	Alluvium composite leachate	20	AGW–3	0.5		1.16
ExVS6	Duplicate	20	AGW–3	0.5		1.17
ExVS8	Alluvium composite leachate	20	AGW–3	0.5		4.34
ExVS9	Duplicate	20	AGW–3	0.5		4.32
ExVS11	Alluvium composite leachate	20	AGW–3	0.5		7.75
ExVS12	Duplicate	20	AGW–3	0.5		7.83
ExVS14	Alluvium composite leachate	20	AGW–3	0.5		11.8
ExVS15	Duplicate	20	AGW–3	0.5		12.0
ExVS17	Alluvium composite leachate	20	AGW–3	0.5		16.2
ExVS18	Duplicate	20	AGW–3	0.5		16.1

Table 3. Analytical Results for Sample Leachate Solutions Using the Uncontaminated Alluvial Deposit Sample and Synthetic Ground Water AGW–7 (equilibrated with 0.5 percent CO_2)

Sample ID	Sample Description	Solution Volume (mL)	Synthetic Solution Type	Sample Mass (g)	Concentration (mg/L)
					U
Ex11S107	Alluvium composite leachate	30	AGW–7	3.75	0.0178
Ex11S108	Duplicate	30	AGW–7	3.75	0.0182
Ex11S109	Alluvium composite leachate	30	AGW–7	3.75	0.0305
Ex11S110	Duplicate	30	AGW–7	3.75	0.0304
Ex11S111	Alluvium composite leachate	30	AGW–7	3.75	0.0644
Ex11S112	Duplicate	30	AGW–7	3.75	0.0657
Ex11S113	Alluvium composite leachate	30	AGW–7	3.75	0.188
Ex11S114	Duplicate	30	AGW–7	3.75	0.200
Ex11S115	Alluvium composite leachate	30	AGW–7	3.75	0.589
Ex11S116	Duplicate	30	AGW–7	3.75	0.574
Ex11S117	Alluvium composite leachate	30	AGW–7	3.75	1.95
Ex11S118	Duplicate	30	AGW–7	3.75	1.96

Table 4. Analytical Results for Sample Leachate Solutions Using the Uncontaminated Alluvial Deposit Sample and Synthetic Ground Water AGW–5 (equilibrated with 2.0 percent CO_2)

Sample ID	Sample Description	Solution Volume (mL)	Synthetic Solution Type	Sample Mass (g)	Concentration (mg/L)
					U
Ex10S7	Alluvium composite leachate	30	AGW–5	7.5	0.0252
Ex10S8	Duplicate	30	AGW–5	7.5	0.0225
Ex10S9	Alluvium composite leachate	30	AGW–5	7.5	0.0308
Ex10S10	Duplicate	30	AGW–5	7.5	0.0307
Ex10S11	Alluvium composite leachate	30	AGW–5	7.5	0.0566
Ex10S12	Duplicate	30	AGW–5	7.5	0.0621
Ex10S13	Alluvium composite leachate	30	AGW–5	7.5	0.180
Ex10S14	Duplicate	30	AGW–5	7.5	0.187
Ex10S15	Alluvium composite leachate	30	AGW–5	7.5	0.529
Ex10S16	Duplicate	30	AGW–5	7.5	0.535
Ex10S17	Alluvium composite leachate	30	AGW–5	7.5	1.87
Ex10S18	Duplicate	30	AGW–5	7.5	1.83

1.1.1.4 K_d Calculation

K_ds are calculated using the analytical data summarized in Table 5 through Table 7 and the following equation:

$$K_d = \frac{(A - B)V}{(M_S)B}$$

where
A = total initial concentration (mg/L) of the COPCs in the synthetic ground water,
B = final concentration of the COPCs in the leachate after 96 hours (uranium) or 24 hours (vanadium) in contact with the sediment sample (mg/L),
V = volume of solution (mL),
M_s = mass of sediment sample (grams), and
K_d = distribution coefficient (milliliters per gram [mL/g]).

Results of the calculations are presented in Table 5 through Table 7. The K_d values are consistent with R_d values in the ASTM procedure; this value only represents a true K_d if equilibrium conditions were attained during the test period.

Table 5. Measured K_d Values for the Uncontaminated Alluvial Deposit Sample and Synthetic Ground Water AGW–3 (equilibrated with the partial pressure of CO_2 in air)

Sample ID	Sample Description	Initial Concentration (mg/L)		Final Concentration (mg/L)		K_d (mL/g)	
		U	V	U	V	U	V
Ex6S7	Alluvium composite leachate	0.0108		0.00635		28.1	
Ex6S8	Duplicate	0.0107		0.00584		33.9	
Ex6S9	Alluvium composite leachate	0.0279		0.0167		27.1	
Ex6S10	Duplicate	0.0280		0.0180		22.5	
Ex6S11	Alluvium composite leachate	0.0791		0.0530		19.8	
Ex6S12	Duplicate	0.0794		0.0514		21.9	
Ex6S13	Alluvium composite leachate	0.255		0.196		12.2	
Ex6S14	Duplicate	0.256		0.192		13.2	
Ex6S15	Alluvium composite leachate	0.533		0.412		11.7	
Ex6S16	Duplicate	0.534		0.420		10.8	
Ex6S17	Alluvium composite leachate	2.59		2.24		6.1	
Ex6S18	Duplicate	2.59		2.13		8.6	
ExVS5	Alluvium composite leachate		1.73		1.16		20.0
ExVS6	Duplicate		1.73		1.17		19.5
ExVS8	Alluvium composite leachate		5.35		4.34		9.3
ExVS9	Duplicate		5.35		4.32		9.5
ExVS11	Alluvium composite leachate		8.95		7.75		6.2
ExVS12	Duplicate		8.95		7.83		5.7
ExVS14	Alluvium composite leachate		13.3		11.8		5.2
ExVS15	Duplicate		13.3		12.0		4.5
ExVS17	Alluvium composite leachate		17.8		16.2		4.0
ExVS18	Duplicate		17.8		16.1		4.3

Table 6. Measured Uranium K_d Values for the Uncontaminated Alluvial Deposit Sample and Synthetic Ground Water AGW–7 (equilibrated with 0.5 percent CO_2)

Sample ID	Sample Description	Initial Concentration (mg/L)	Final Concentration (mg/L)	K_d (mL/g)
		U	U	U
Ex11S107	Alluvium composite leachate	0.0304	0.0178	5.8
Ex11S108	Duplicate	0.0304	0.0182	5.4
Ex11S109	Alluvium composite leachate	0.0466	0.0305	4.3
Ex11S110	Duplicate	0.0454	0.0304	4.2
Ex11S111	Alluvium composite leachate	0.0904	0.0644	3.5
Ex11S112	Duplicate	0.0940	0.0657	3.6
Ex11S113	Alluvium composite leachate	0.273	0.188	3.7
Ex11S114	Duplicate	0.274	0.200	3.0
Ex11S115	Alluvium composite leachate	0.756	0.589	2.3
Ex11S116	Duplicate	0.756	0.574	2.6
Ex11S117	Alluvium composite leachate	2.42	1.95	2.0
Ex11S118	Duplicate	2.40	1.96	1.8

Table 7. Measured Uranium K_d Values for the Uncontaminated Alluvial Deposit Sample and Synthetic Ground Water AGW–5 (equilibrated with 2.0 percent CO_2)

Sample ID	Sample Description	Initial Concentration (mg/L)	Final Concentration (mg/L)	K_d (mL/g)
		U	U	U
Ex10S7	Alluvium composite leachate	0.0430	0.0252	3.0
Ex10S8	Duplicate	0.0429	0.0225	3.8
Ex10S9	Alluvium composite leachate	0.0570	0.0308	3.6
Ex10S10	Duplicate	0.0570	0.0307	3.6
Ex10S11	Alluvium composite leachate	0.0974	0.0566	3.1
Ex10S12	Duplicate	0.0979	0.0621	2.5
Ex10S13	Alluvium composite leachate	0.283	0.180	2.4
Ex10S14	Duplicate	0.282	0.187	2.2
Ex10S15	Alluvium composite leachate	0.772	0.529	2.0
Ex10S16	Duplicate	0.777	0.535	1.9
Ex10S17	Alluvium composite leachate	2.55	1.87	1.5
Ex10S18	Duplicate	2.54	1.83	1.6

Measured K_d values obtained for the alluvial aquifer samples were adjusted on the basis of aquifer grain size analysis. It was found in collecting the uncontaminated alluvial material that only 15 percent of the aquifer material was in the <3 mm fraction and that most of the material was gravel to cobble size. Therefore, the measured K_d values for the alluvial aquifer, which were

performed on the <3 mm fraction, were adjusted by multiplying by 0.15. This assumes that the gravel- and cobble-sized materials are insignificant in terms of contaminant adsorption. The adjusted values are reported in Table 8 through Table 10.

Table 8. Results for K_d Values Adjusted for Grain-Size Distribution for the Uncontaminated Alluvial Deposit Sample and Synthetic Ground Water AGW–3 (equilibrated with the partial pressure of CO_2 in air)

Sample ID	Sample Description	K_d (mL/g)	
		U	V
Ex6S7	Alluvium composite leachate	4.2	
Ex6S8	Duplicate	5.1	
Ex6S9	Alluvium composite leachate	4.1	
Ex6S10	Duplicate	3.4	
Ex6S11	Alluvium composite leachate	3.0	
Ex6S12	Duplicate	3.3	
Ex6S13	Alluvium composite leachate	1.8	
Ex6S14	Duplicate	2.0	
Ex6S15	Alluvium composite leachate	1.8	
Ex6S16	Duplicate	1.6	
Ex6S17	Alluvium composite leachate	0.92	
Ex6S18	Duplicate	1.3	
ExVS5	Alluvium composite leachate		3.0
ExVS6	Duplicate		2.9
ExVS8	Alluvium composite leachate		1.4
ExVS9	Duplicate		1.4
ExVS11	Alluvium composite leachate		0.93
ExVS12	Duplicate		0.86
ExVS14	Alluvium composite leachate		0.77
ExVS15	Duplicate		0.67
ExVS17	Alluvium composite leachate		0.59
ExVS18	Duplicate		0.64

Table 9. Results for K_d Values Adjusted for Grain-Size Distribution for the Uncontaminated Alluvial Deposit Sample and Synthetic Ground Water AGW–7 (equilibrated with 0.5 percent CO_2)

Sample ID	Sample Description	K_d (mL/g) U
Ex11S107	Alluvium composite leachate	0.87
Ex11S108	Duplicate	0.81
Ex11S109	Alluvium composite leachate	0.65
Ex11S110	Duplicate	0.63
Ex11S111	Alluvium composite leachate	0.52
Ex11S112	Duplicate	0.54
Ex11S113	Alluvium composite leachate	0.56
Ex11S114	Duplicate	0.45
Ex11S115	Alluvium composite leachate	0.35
Ex11S116	Duplicate	0.39
Ex11S117	Alluvium composite leachate	0.30
Ex11S118	Duplicate	0.27

Table 10. Results for K_d Values Adjusted for Grain-Size Distribution for the Uncontaminated Alluvial Deposit Sample and Synthetic Ground Water AGW–5 (equilibrated with 2.0 percent CO_2)

Sample ID	Sample Description	K_d (mL/g) U
Ex10S7	Alluvium composite leachate	0.45
Ex10S8	Duplicate	0.58
Ex10S9	Alluvium composite leachate	0.54
Ex10S10	Duplicate	0.54
Ex10S11	Alluvium composite leachate	0.46
Ex10S12	Duplicate	0.37
Ex10S13	Alluvium composite leachate	0.36
Ex10S14	Duplicate	0.32
Ex10S15	Alluvium composite leachate	0.29
Ex10S16	Duplicate	0.28
Ex10S17	Alluvium composite leachate	0.23
Ex10S18	Duplicate	0.25

The data show that the K_d values are somewhat dependent on the concentration of the COPC, under otherwise constant chemical conditions (Figure 1 through Figure 3). In addition, the data show that the uranium K_d values are greatly decreased by increasing alkalinity (or partial pressure of carbon dioxide gas), due to the formation of weakly adsorbing, aqueous uranyl-carbonate complexes (Figure 4).

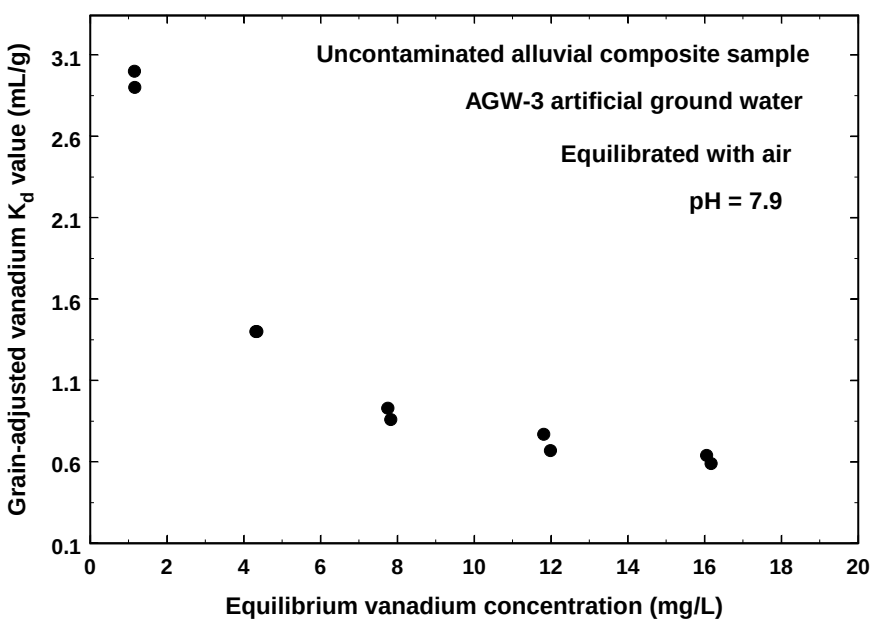


Figure 1. Grain-Adjusted K_d Values for Vanadium as a Function of Vanadium Concentration Vanadium Concentrations in the Alluvial Aquifer Vary from Below Detection to 7 mg/L

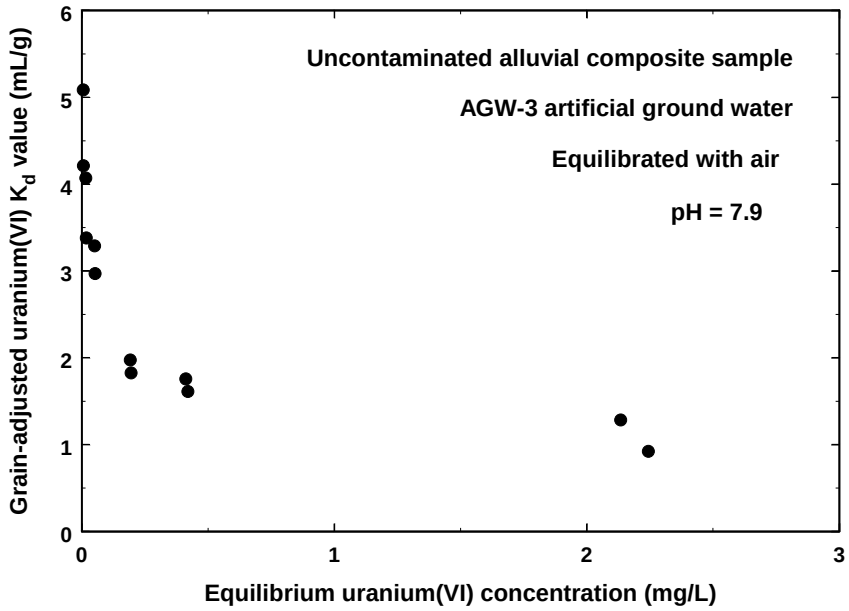


Figure 2. Grain-Adjusted K_d Values for Uranium as a Function of Uranium Concentration
Uranium Concentrations in the Alluvial Aquifer Vary from 0.005 to 2.6 mg/L

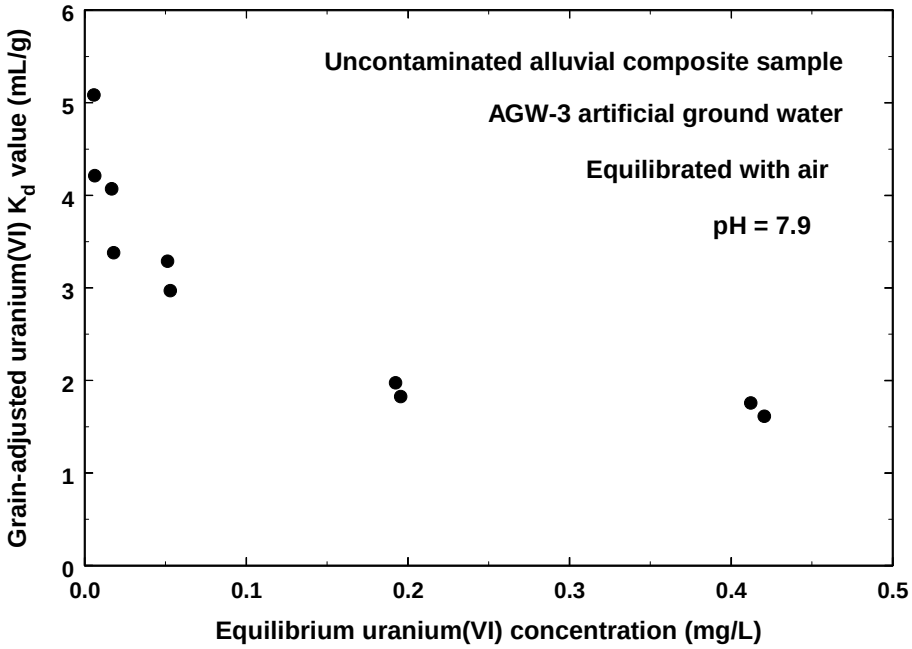


Figure 3. Grain-Adjusted K_d Values for Uranium as a Function of Uranium Concentration at Low Uranium Concentrations
Uranium Concentrations in the Alluvial Aquifer Vary from 0.005 to 2.6 mg/L

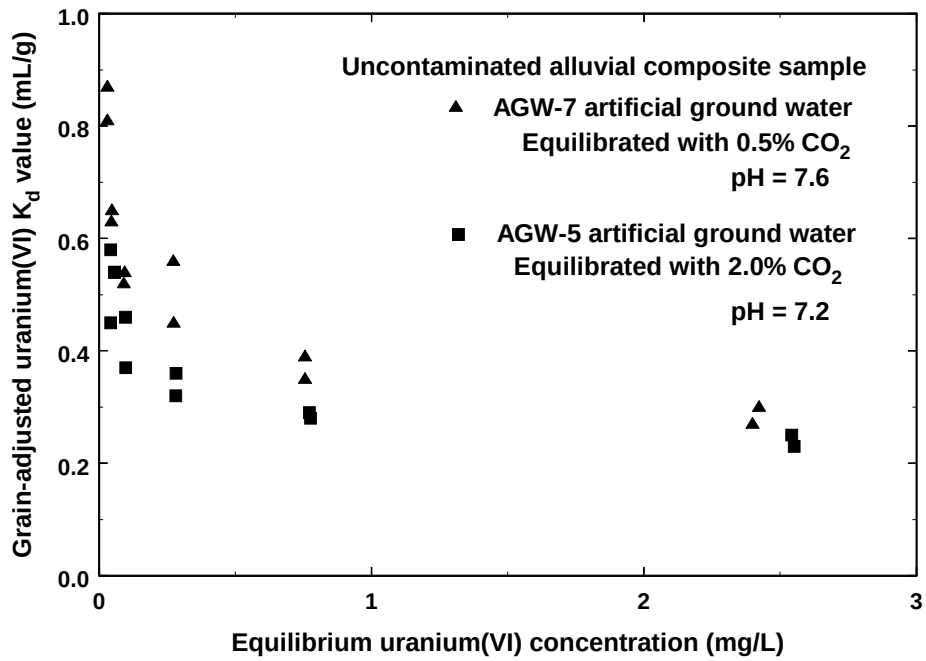


Figure 4. Grain-Adjusted K_d values for Uranium as a Function of Uranium Concentration in Waters Equilibrated with 0.5 or 2 percent CO_2
Each System Reaches a Different Equilibrium pH Value Due to Equilibration with Carbonate Minerals in the Alluvial Sediments. Partial Pressures of CO_2 in the Alluvial Aquifer Range from 1 to 10 percent CO_2

If left undisturbed, the trailing edge of the contaminant plume will probably leave the site with low uranium concentrations and an alkalinity closer to background conditions. This would be near the conditions represented by the sample analysis with 0.5 percent CO_2, although alluvial ground water usually has a lower pH (7.0 to 7.2). Based on the range of K_d values indicated by the sample analysis, it is recommended that K_d values in the range of 1–3 mL/g be used for both uranium and vanadium in the contaminant transport modeling of alluvial ground water.

End of current text

Appendix F

Contaminant Transport Modeling

1.0 Introduction

1.1 General Setting

The Naturita site is located in Montrose County in the southwestern portion of Colorado, about 2 miles northwest of the town of Naturita along Colorado State Highway 141 (Figure 1). Most of the site is on the west bank of the San Miguel River, between the river and the highway. The former ore storage area is west of the highway. The site (Figure 2) covers 53 acres which includes the former tailings pile area (27 acres), the former mill yard and former ore-buying station (14 acres), and the adjacent former ore storage area (12 acres). A brief operating history of the site can be found in page 2-1 through 2-4 of the BLRA (DOE 1995). A gravel mining operation upgradient of the former site is not considered in the U.S. Geological Survey (USGS) flow model. The future expansion of this operation could significantly impact the ground water flow and the transport of contaminants.

1.2 Study Objective

1.2.1 Natural Flushing

As part of the compliance strategy for the cleanup of contaminated ground water at the Naturita UMTRA Project site it is necessary to develop a computer ground water flow model and a subsequent contaminant transport model to assist in forecasting whether natural flushing of the contaminants of potential concern (COPC) is a viable remediation alternative.

This document presents the use of the steady state deterministic flow model, developed by the USGS, the steady state stochastic flow model, and the development of the contaminant transport models (deterministic and stochastic) to predict future COPC concentrations. The various flow and transport parameters that affect the hydraulic head and contaminant distribution for the steady state deterministic and steady state stochastic models are described below.

The steps used for obtaining a calibrated flow and transport model for the site follow the ASTM Standard Guides D5447–93 and D5718–95. The specific steps are to: (1) evaluate the hydrogeologic setting and develop a conceptual model, (2) select the codes to be used in the analysis, (3) establish the relationship between the conceptual and numerical models, and (4) perform calibration and sensitivity analysis on the flow model parameters and sensitivity analysis on transport parameters.

Stochastic simulations for uranium were performed for both the flow or transport models even though the deterministic model indicated that neither uranium or vanadium come close to achieving the clean-up standard by natural flushing within 100 years.

1.2.2 Pumping Followed by Natural Flushing

The purpose of this modeling was to determine if pumping specified wells (unknown) at specified rates (unknown) for a specified number of years (unknown) followed by natural flushing for 100 years would result in achieving the clean-up standard for uranium and vanadium. This is a classical optimization problem and could probably be formulated as such. However, a much simpler approach is taken here.

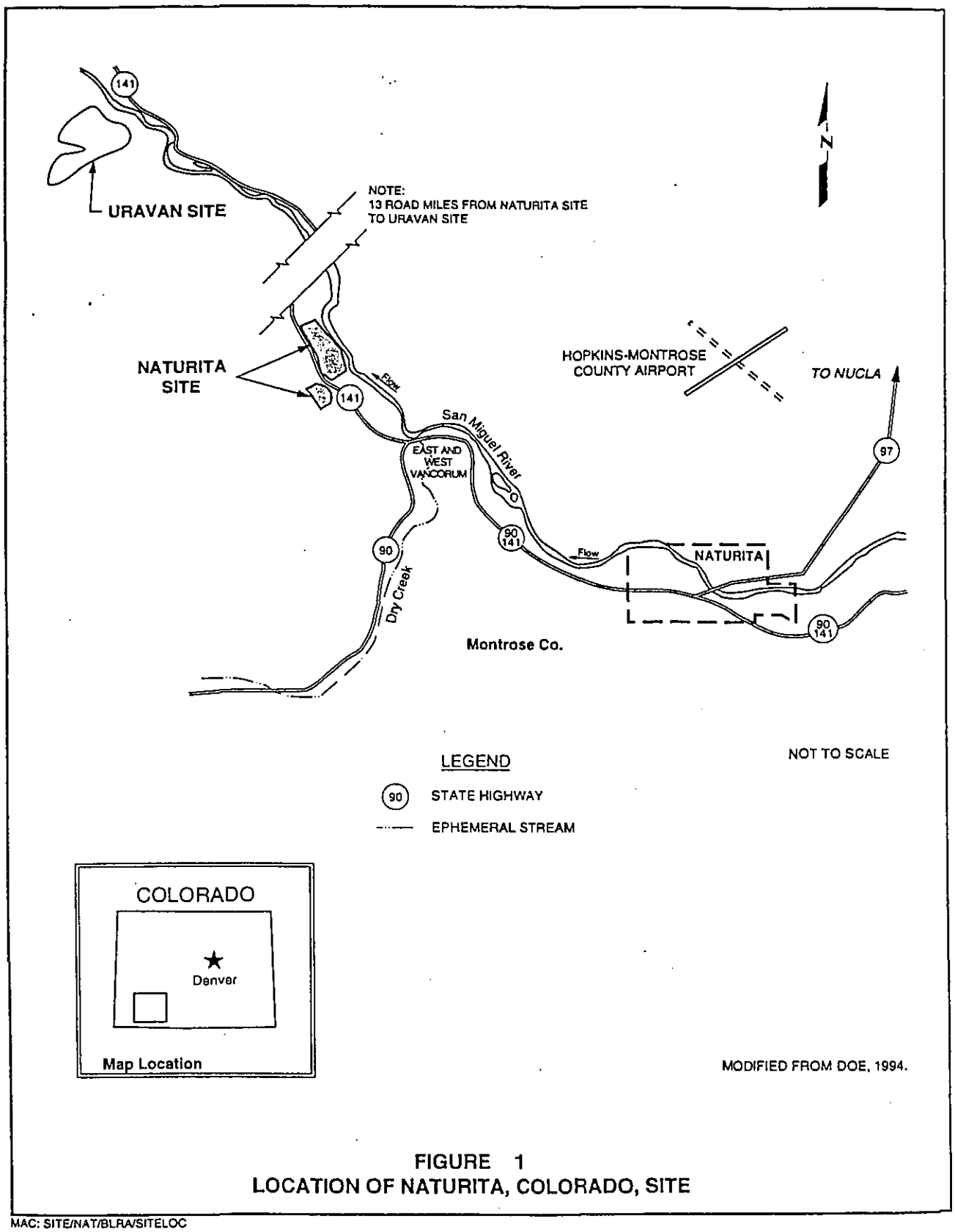


FIGURE 1
LOCATION OF NATURITA, COLORADO, SITE

MAC: SITE/NAT/BLRA/SITELOC

Figure 1. Location of the Naturita Site

2.6 Sources and Sinks

The San Miguel River is a source of water to the aquifer. Areal recharge over the area is an annual source of water to the site. The San Miguel River is considered to be both a sink and a source (i.e., the alluvial aquifer discharges water to the river along some reaches and the river recharges the alluvial aquifer along other reaches). Discharge and recharge are seasonal in nature.

2.6.1 Sources

Two sources of recharge to the alluvial aquifer have been identified: precipitation and recharge from the San Miguel River.

The model surface area is represented by one recharge zone, with recharge being solely from precipitation. The calibrated USGS model uses a recharge value of 0.0 inches per year (in/yr). Site-specific meteorological data indicate there is approximately 13 inches of annual precipitation (0.00297 ft per day [ft/day]) in the Naturita area. However, the estimated amount available for recharge based on the Thornthwaite equation (Thornthwaite and Mather 1957) is 1.99 to 2.79 in/yr (0.00045 to 0.00064 ft/day).

2.6.2 Sinks

Several sources of discharge from the alluvial aquifer have been identified. These include evapotranspiration and ground water discharge from the alluvial aquifer into the San Miguel River. Evapotranspiration is accounted for by the use of a net recharge estimate (which includes the loss due to evapotranspiration).

3.0 Computer Code

3.1 Code Selection

MODFLOW (McDonald and Harbaugh 1988), a modular three-dimensional finite-difference ground water flow model published by the USGS was selected as the flow code for this project. MT3DMS (Zheng and Wang 1999), a modular three-dimensional transport model for simulation of advection, dispersion, and chemical reaction of contaminants in ground water systems was selected as the transport code for this project. Each of these codes is divided into a main program and a group of independent subroutines called modules. Each module is made up of packages that deal with a single aspect of the simulation. The user of either MODFLOW or MT3DMS need only use those modules that simulate the stresses placed upon the flow and transport systems. This version of MT3DMS contains a new transport solver that is very efficient and makes multiple long simulation runs feasible.

The USGS was tasked with developing a steady state deterministic flow model for the Naturita site. The USGS uses the Argus Open Numerical Environments (Argus ONE) family of product for the pre- and post-processing for MODFLOW. The calibrated MODFLOW files created by the Argus ONE products were then converted to a format compatible with the version of MODFLOW in GWVistas. The output from MODFLOW is used as input to MT3DMS.

GWVistas (Environmental Simulations, Inc. 1997) is a Windows-driven, graphical, pre- and post- processor for MODFLOW and MT3DMS. It is used in conjunction with the site model to facilitate data entry, data-file modification, program execution, and analysis of modeling results. GWVistas was used to complete additional flow model simulations for sensitivity analysis of flow parameters and for all the transport modeling using MT3DMS.

3.2 Code Description

These codes are fully described in the references cited. They have been verified, benchmarked, and approved for use by most government and regulatory agencies.

4.0 Steady State Deterministic Flow Model

The USGS was contracted with and tasked to develop a steady state deterministic flow model for the Naturita site. This effort is described and documented in a separate document.

4.1 Model Grid and Model Boundary Conditions

The San Miguel River flows in a north-northwest direction in the vicinity of the Naturita site, therefore the model grid was rotated 30 degrees counterclockwise so that the y-axis of the model is oriented along the length of the site. An orthogonal grid, consisting of 263 rows and 69 columns, was designed to encompass the site and an extensive area surrounding the site. The grid size is approximately 25 ft by 25 ft. The alluvial aquifer is bounded to the west by the rocks of the Brushy Basin Member which forms the lower canyon wall (which is approximately the location of Highway 141) and is considered a no-flow boundary. To the east, south, and north of the site the San Miguel River dissects the valley alluvium and constitutes a hydrologic boundary for the alluvial aquifer. This boundary is represented as a river boundary. Many of these hydrological/geological features are visible in Figure 2. Figure 3 shows the model extent and some natural physical features.

4.2 Hydraulic Parameters

Aquifer tests were conducted by the USGS and are described in a separate document.

4.3 Sources and Sinks

The model surface area is represented by a single recharge zone. The steady state recharge value assigned to this zone is 0.0 ft/day as recommended by the USGS.

Discharge from the ground water system consists of subsurface flow from alluvial aquifer into some sections of the San Miguel River on a seasonal basis. Discharge also occurs at the north end of the site where the San Miguel River crosses from the east side to the west side of the valley.

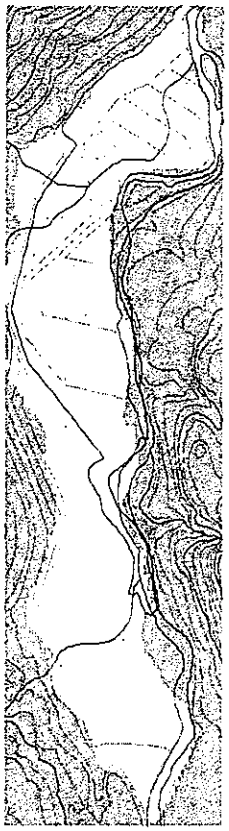


Figure 3. Model Extent and Site Features

4.4 Boundary Conditions

The west side of the model is represented as a no-flow boundary where the Brushy Basin Member geological unit forms the lower canyon wall and rises above the alluvium. The east, south, and north of the model is defined by the San Miguel River and is represented as a river boundary. The southeast part of the model is represented by a head-dependent flux boundary (GHB source) to account for upgradient subsurface flow into the alluvial aquifer.

4.5 Calibration Objectives and Results

Although the steady state deterministic flow model was developed and calibrated by the USGS, it is important to determine if the model meets the acceptance criteria that would be considered realistic for this site. The acceptance criteria chosen for this project are:

1) The model must be able to simulate the general flow directions observed at the site. Measured ground water elevations in February 2000 are represented as a potentiometric surface in Figure 4. Simulated steady state ground water elevations are presented in Figures 5 and 6.

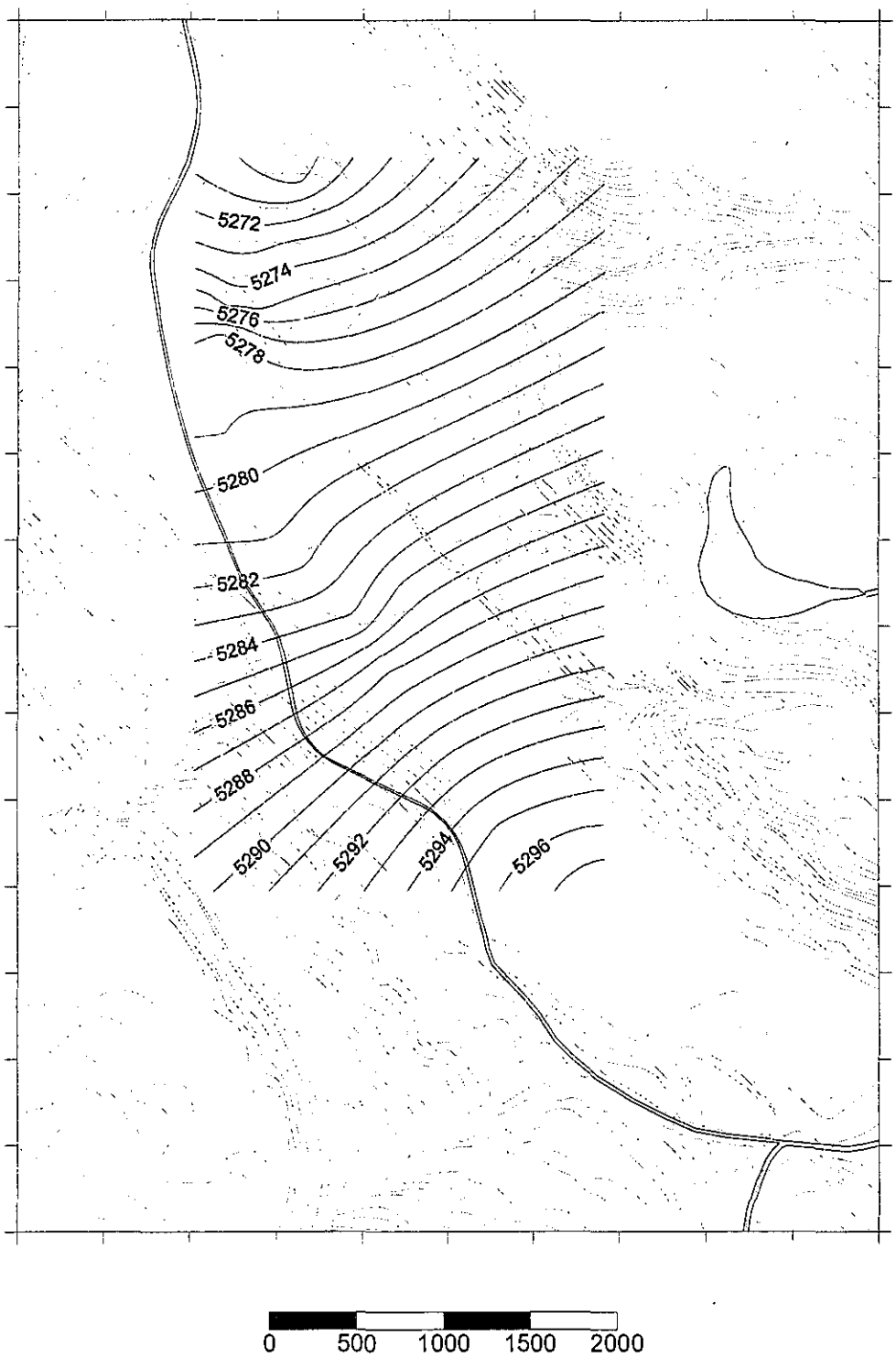


Figure 4. Potentiometric Surface (in feet above MSL)—February 2000

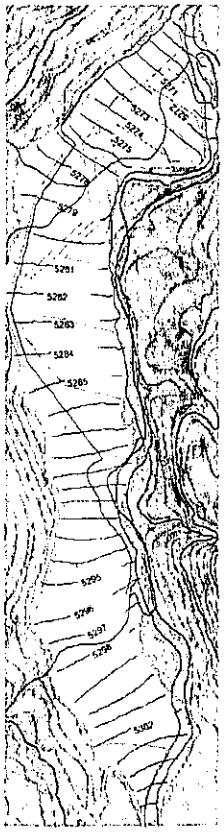


Figure 5. Simulated Steady State Ground Water Elevations (in feet above MSL)

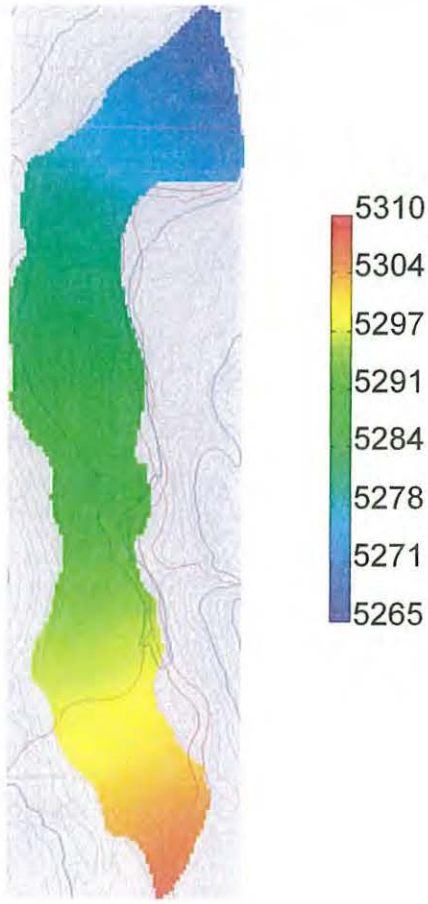


Figure 6. Simulated Steady State Ground Water Elevations (in feet above MSL)

2) The numerical model should not have any inherent bias. In other words, since the model will either over or under predict the measured hydraulic heads, the arithmetic mean of the residuals should be as close to 0.0 as possible and fairly evenly distributed above and below 0.0. Figure 7 displays the observed hydraulic heads versus residuals for the steady state model. The plot shows a slight bias of underestimating water levels at the higher elevations.

3) Forty-one calibration targets were selected for the steady state model based on the February 2000 water level measurements. Several flow model calibration objectives were set prior to receiving the calibrated model from the USGS. The objectives and the calibrated model results for the steady state model are shown in Table 1. Although some of the criteria are not met, none of the criteria is exceeded by a significant amount.

4) The mass balance error must be less than 1 percent. The mass balance error for the steady state model is -0.27443 percent.

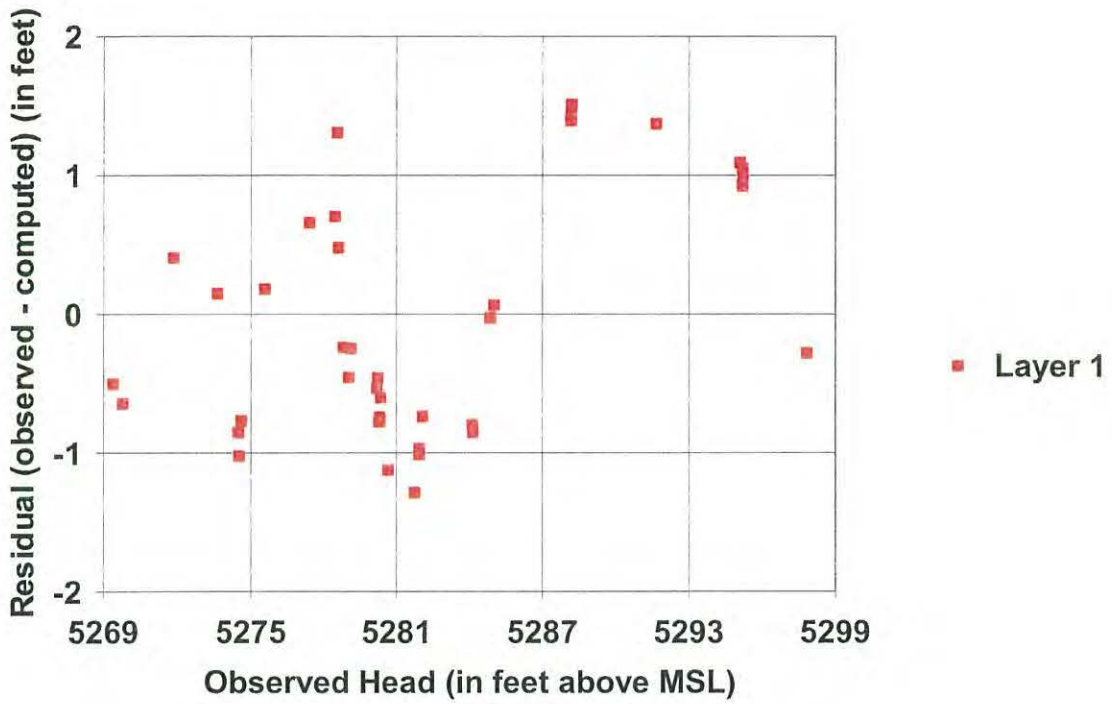


Figure 7. Comparison of Residual versus Observed Head

Table 1. Calibration Objectives and Results

	Residual Mean (ft)	Absolute Residual Mean (ft)	Sum of Squares (ft^2)	Minimum Residual (ft)	Maximum Residual (ft)	Standard Deviation/Range (%)
Objective	0	< 1.	< 30.75	> -2.0	< 2.0	< 5.0
Actual	-0.067	0.737	28.878	-1.284	1.511	2.940

4.6 Calibration and Residual Analysis

The steady state deterministic calibrated model results and the residual at each target are shown in Table 2. The results satisfy the specified criteria. A plot of predicted (computed) hydraulic head versus observed hydraulic head demonstrates that the model accurately predicts field measurements (Figure 8).

Table 2. Calibration Target Residuals

Well ID	Observed Head (ft)	Predicted Head (ft)	Residual (observed – predicted)
NAT01-1	5279.10	5279.34	-0.24
NAT02	5282.06	5282.80	-0.74
NAT03	5280.27	5281.04	-0.77
NAT04-1	5281.92	5282.93	-1.01
NAT05	5280.17	5280.70	-0.53
NAT06-1	5281.73	5283.01	-1.28
NAT07-1	5280.32	5280.92	-0.60
NAT08	5280.30	5281.06	-0.76
NAT09	5280.28	5281.02	-0.74
NAT10	5280.64	5281.76	-1.12
NAT11	5284.12	5284.97	-0.85
NAT12-1	5279.01	5279.46	-0.45
NAT13-1	5284.12	5284.94	-0.82
NAT14-1	5284.11	5284.90	-0.79
NAT15-1	5280.21	5280.67	-0.46
NAT16-1	5281.93	5282.90	-0.97
NAT17-1	5288.16	5286.65	1.51
NAT18-1	5288.14	5286.69	1.45
NAT19	5288.13	5286.74	1.39
NAT20	5295.18	5294.25	0.93
NAT21-1	5295.20	5294.20	1.00
NAT22-1	5295.19	5294.14	1.05
NAT23	5277.38	5276.72	0.66
NAT24	5278.53	5277.22	1.31
NAT25	5278.44	5277.73	0.71
NAT26	5278.79	5279.03	-0.24
NAT27-1	5284.84	5284.86	-0.02
NAT28-1	5284.87	5284.89	-0.02
NAT29	5285.00	5284.93	0.07
NAT30-1	5291.64	5290.27	1.37
MAU01	5274.59	5275.36	-0.77
MAU02-1	5274.50	5275.52	-1.02
MAU03	5271.82	5271.41	0.41
MAU04	5269.77	5270.41	-0.64
MAU05	5274.47	5275.32	-0.85
MAT06	5273.60	5273.45	0.15
MAU07	5269.37	5269.87	-0.50
MAU08	5275.56	5275.38	0.18
547	5295.08	5293.99	1.09
548	5278.58	5278.10	0.48
DM-1	5297.83	5298.11	-0.28
n	41		
Mean	-0.067		
Absolute Mean	0.737		
Sum of Squares	28.878		
Standard Deviation	0.837		
Minimum	-1.284		
Maximum	1.511		

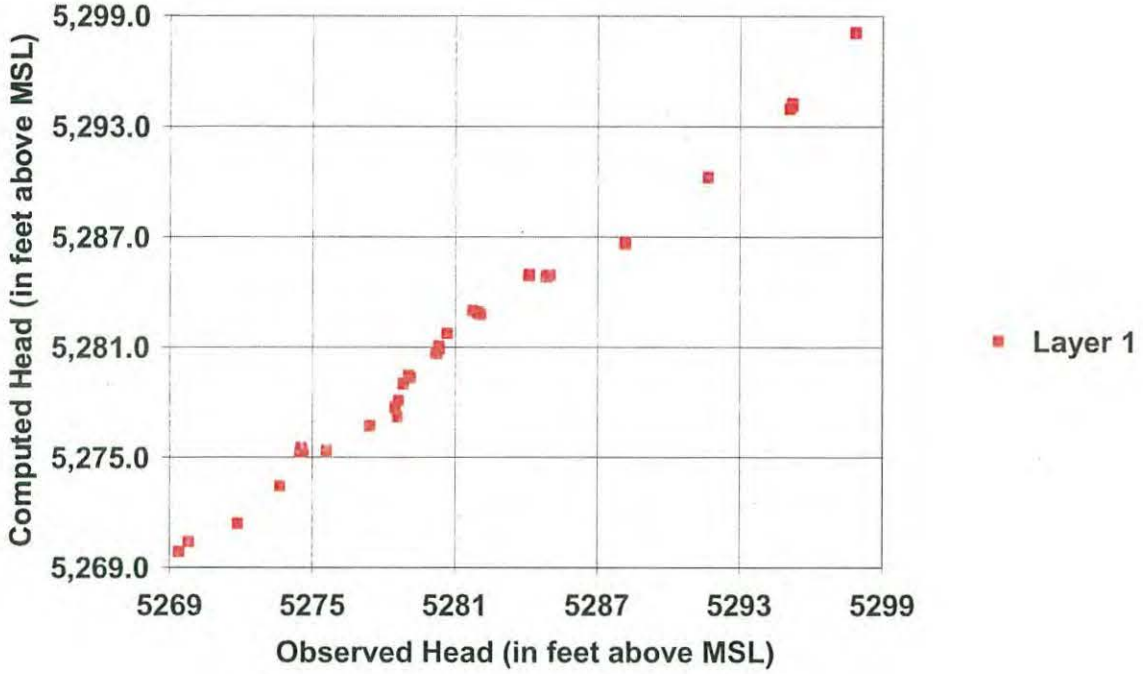


Figure 8. Comparison of Computed Head versus Observed Head

4.7 Flow Model Sensitivity Analysis

A sensitivity analysis is useful to evaluate the effects that variations in flow and transport parameters have on the final predicted contaminant concentration results. Highly sensitive parameters can be treated as uncertain for stochastic simulations. The flow parameters selected for the sensitivity analysis are hydraulic conductivity, recharge, river bed conductance, GHB conductance, river stage, and GHB head. The criteria used for sensitivity analysis of the flow model to these flow parameters is the residual sum of squares, (i.e., the difference between the computed head and observed head at the 41 target wells). The results of the sensitivity analysis for these six parameters are shown in Figures 9 through 14. Visually, this qualitative (subjective) analysis indicates that the flow model is not sensitive to hydraulic conductivity, river bed conductance, GHB conductance, or GHB head. The model does appear to be sensitive to recharge and river stage.

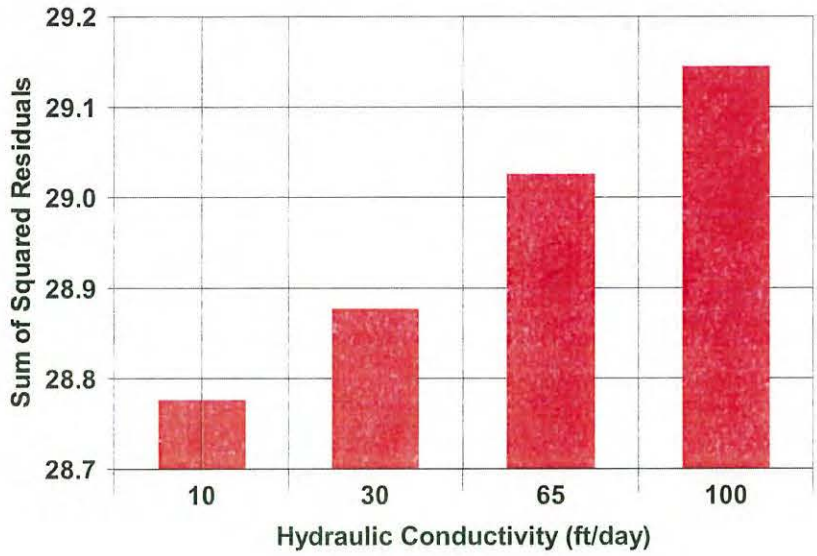


Figure 9. Hydraulic Conductivity Sensitivity Analysis Results

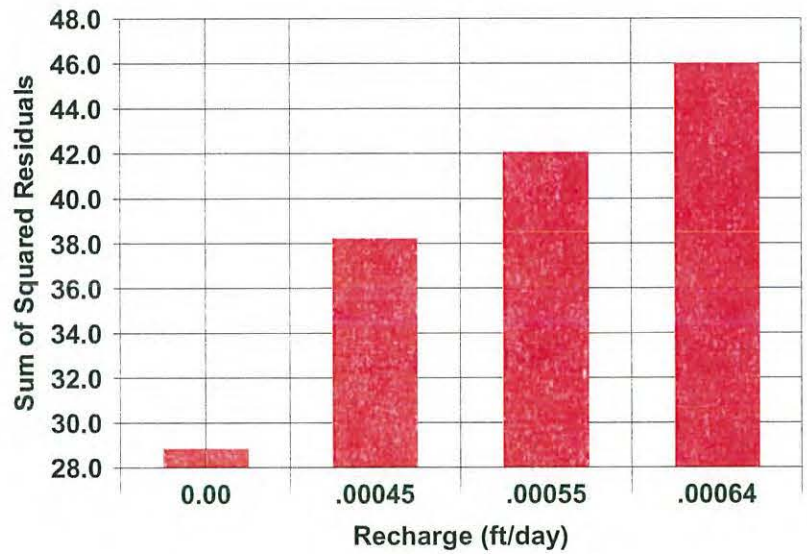


Figure 10. Recharge Sensitivity Analysis Results

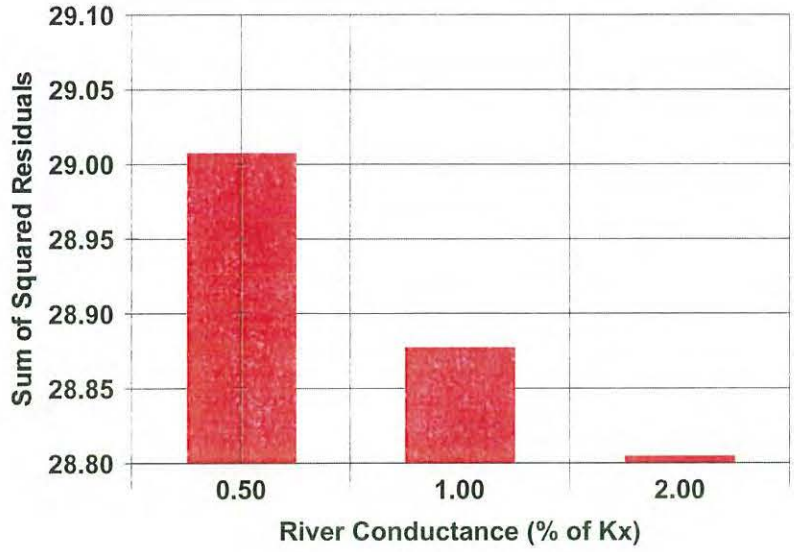


Figure 11. River Conductance Sensitivity Analysis Results

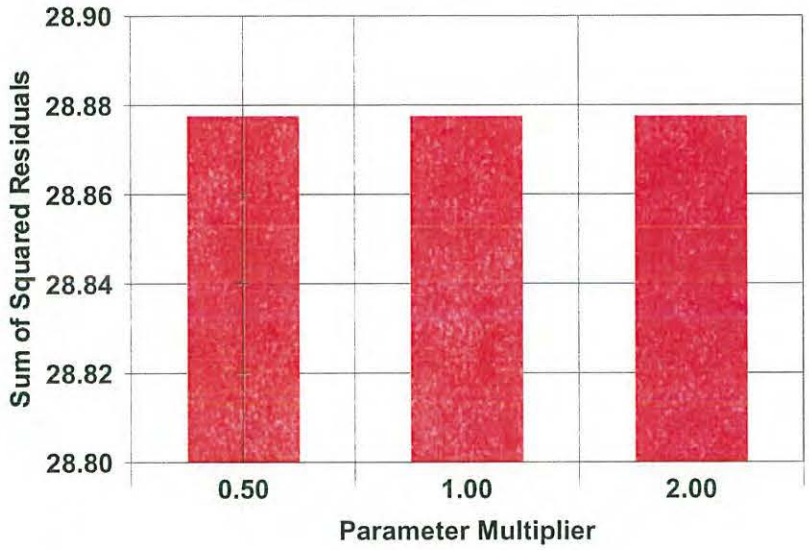


Figure 12. GHB Conductance Sensitivity Analysis Results

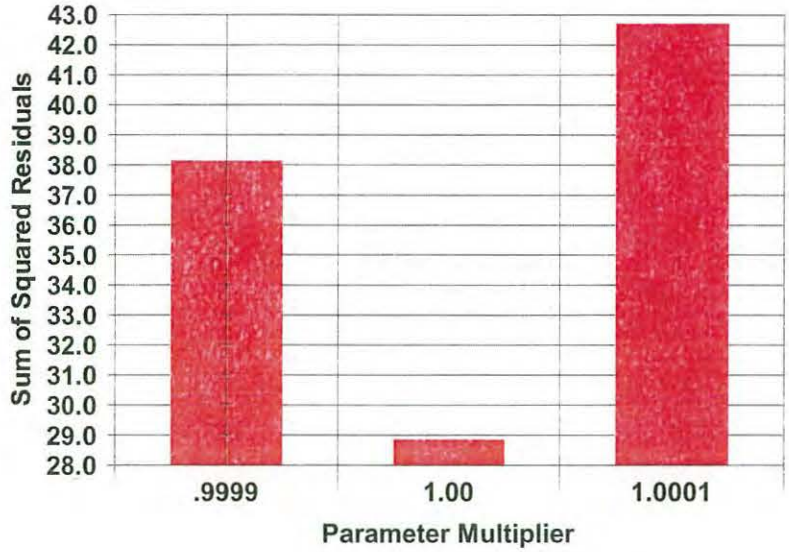


Figure 13. River Stage Sensitivity Analysis Results

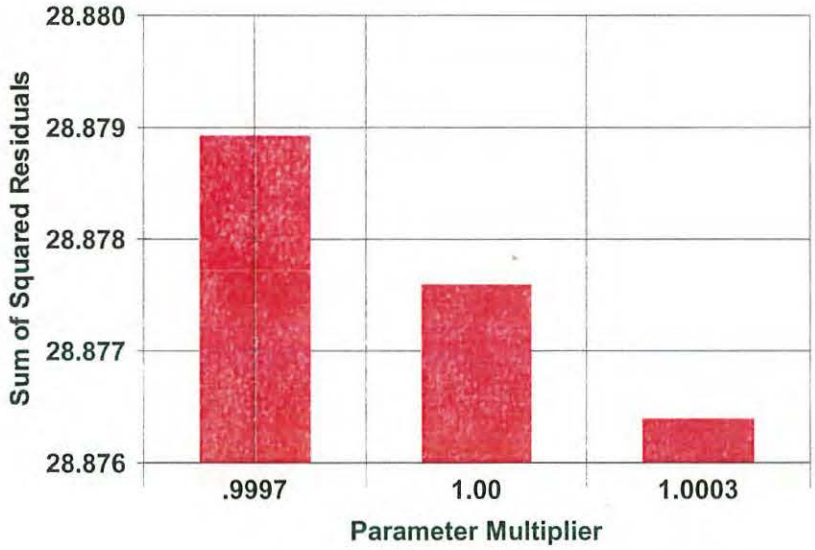


Figure 14. GHB Head Sensitivity Analysis Results

As an additional quantitative (objective) check, the coefficient of variation (CV) of the residual sum of squares can be calculated for each of these flow parameters. The residual sum of squares for GHB conductance does not vary for different parameter values, therefore the CV cannot be calculated for this parameter. The CV was calculated for hydraulic conductivity, recharge, river bed conductance, river stage, and GHB head. The CV is defined as the standard deviation (σ) divided by the mean ($\bar{x}$). Flow parameters resulting in a CV greater than 1 percent between the predicted residual sum of squares for different parameter values can be considered sensitive. The CV has been calculated using an unbiased estimate of the standard deviation (σ) adjusted for

sample size (Dixon and Massey 1957). The results of the CV analysis are shown in Table 3. These results indicate recharge and river stage appear to be sensitive, and are in agreement with qualitative visual residual sum of squares sensitivity analysis.

Table 3. Flow Parameter Coefficient of Variation Analysis

Flow Parameter	Mean	Standard Deviation	Adjusted Standard Deviation	Coefficient of Variation
Hydraulic Conductivity	28.95643	0.16221	0.17590	0.00607
Recharge	38.79988	7.34060	7.96014	0.20516[a]
River Conductance	28.89681	0.10245	0.11557	0.00400
River Stage	36.58345	7.05642	7.95964	0.21757[a]
GHB Head	28.87764	0.00127	0.00143	0.00005

[a]indicates parameter is sensitive per this criteria

The criteria used for sensitivity analysis of the transport model to these flow parameters is the CV. This quantitative (objective) check was made on each of the flow parameters in Table 3. For this sensitivity analysis, each of these flow parameters was simulated at three or four different parameter values. These values are shown in Table 4. The approach taken here is to calculate the coefficient of variation (CV) of the difference in predicted concentration at each selected time interval (5, 10, 15, 25, 50, 60, 70, 80, 90, and 100 years). Any parameter resulting in a CV greater than 15 percent between the predicted concentration at any time interval is considered sensitive and will be treated as stochastic.

Table 4. Flow Model Sensitivity Parameter Values

Parameter	Low Value and Low Stochastic Value	Mid-Range Value		High Value and High Stochastic Value
Hydraulic Conductivity (ft/day)	10	30[a]	65	100
Recharge (in/yr)	0.[a]	1.99	2.39	2.79
Recharge (ft/day)	0.[a]	.00045	.00055	.00064
Parameter	**Low Value**	**Mid-point Value**	**High Value**	
River Bed Conductance	5% of Kx = 30	10% of Kx = 30	20% of Kx = 30	
Parameter	**Low Multiplier**	**Multiplier**	**High Multiplier**	
River Stage	.9999 (~ -0.5 ft)	1.0000[a]	1.0001(~ +0.5 ft)	
GHB Head	.9997(~ -1.5 ft)	1.0000[a]	1.0003(~ +1.5ft)	

[a]USGS recommended value

The results of this analysis are presented in Table 5. This analysis shows that the flow model is sensitive to hydraulic conductivity at 10, 15, 25, 50, 60, 70, 80, 90, and 100 years. Recharge is sensitive at 10, 15, 25, 50, 60, 70, 80, 90, and 100 years. The model is not sensitive to river bed conductance, river stage, or GHB head. Because the primary concern is to determine which parameters have an effect on the results of the transport simulations, both hydraulic conductivity and recharge are treated as stochastic in the flow model.

Table 5. Flow Model Coefficient of Variation Analysis Results at Specific Times (Years)

Flow Parameter	Year	Mean	Standard Deviation	Adjusted Standard Deviation	Coefficient of Variation
Hydraulic Conductivity					
	5	2.37900	0.10600	0.11494	0.04832
	10	2.17518	0.31611	0.34279	0.15759[a]
	15	1.95590	0.51102	0.55415	0.28332[a]
	25	1.53273	0.83991	0.91080	0.59424[a]
	50	0.93843	1.06031	1.14980	1.22523[a]
	60	0.82181	1.02828	1.11507	1.35684[a]
	70	0.72194	0.97968	1.06237	1.47154[a]
	80	0.63412	0.93164	1.01027	1.59317[a]
	90	0.55950	0.88796	0.96291	1.72101[a]
	100	0.49854	0.84654	0.91799	1.84136[a]
Recharge					
	5	2.12215	0.20761	0.22513	0.10609
	10	1.79180	0.39132	0.42434	0.23682[a]
	15	1.53165	0.51960	0.56345	0.36787[a]
	25	1.36029	0.71144	0.77149	0.56715[a]
	50	0.56471	0.49696	0.53890	0.95430[a]
	60	0.41401	0.42247	0.45813	1.10657[a]
	70	0.29102	0.33167	0.35966	1.23587[a]
	80	0.19514	0.24164	0.26203	1.34278[a]
	90	0.12487	0.16488	0.17879	1.43185[a]
	100	0.07676	0.10682	0.11584	1.50909[a]
River Bed Conductance					
	5	2.42667	0.00012	0.00013	0.00005
	10	2.36820	0.00017	0.00020	0.00008
	15	2.29923	0.00060	0.00068	0.00030
	25	2.02543	0.00201	0.00227	0.00112
	50	1.30473	0.00275	0.00310	0.00238
	60	1.04387	0.00215	0.00243	0.00232
	70	0.78606	0.00190	0.00214	0.00272
	80	0.55615	0.00145	0.00164	0.00294
	90	0.37135	0.00089	0.00100	0.00270
	100	0.23655	0.00051	0.00058	0.00243
River Stage					
	5	2.42710	0.00161	0.00182	0.00075
	10	2.36733	0.00433	0.00489	0.00206
	15	2.29927	0.01035	0.01167	0.00508
	25	2.02740	0.02519	0.02842	0.01402
	50	1.30627	0.01412	0.01592	0.01219
	60	1.04597	0.01600	0.01805	0.01726
	70	0.78872	0.01508	0.01701	0.02157
	80	0.55830	0.01356	0.01530	0.02740
	90	0.37308	0.01137	0.01282	0.03436
	100	0.23794	0.00876	0.00988	0.04153

Table 5 (continued). Flow Model Coefficient of Variation Analysis Results at Specific Times (Years)

Flow Parameter	Year	Mean	Standard Deviation	Adjusted Standard Deviation	Coefficient of Variation
GHB Head					
	5	2.42660	0.00000	0.00000	0.00000
	10	2.36830	0.00000	0.00000	0.00000
	15	2.29930	0.00000	0.00000	0.00000
	25	2.02570	0.00000	0.00000	0.00000
	50	1.30470	0.00000	0.00000	0.00000
	60	1.04390	0.00000	0.00000	0.00000
	70	0.78606	0.00001	0.00001	0.00001
	80	0.55613	0.00002	0.00002	0.00004
	90	0.37135	0.00001	0.00001	0.00004
	100	0.23655	0.00001	0.00001	0.00003

[a]indicates parameter is sensitive at this time (year) per this criteria

5.0 Steady State Deterministic Contaminant Transport Model

5.1 Transport Parameters

The contaminant transport parameters of interest are longitudinal and transverse dispersivity, effective porosity, bulk density, K_d (distribution coefficient), and the initial concentration distribution for each of the COPC.

The K_d typically has the greatest impact on the amount of time required for natural flushing to reduce the contamination level below the required standard. For uranium the estimated range of values for this site is from 0.3975 to 1.1225 milliliters per gram (mL/g). An average value of 0.6078 mL/g was used as the K_d value for uranium. For vanadium the estimated range of values for this site is from 4.445 to 20.6575 milliliters per gram (mL/g). An average value of 12.46 mL/g was used as the K_d value for vanadium. A site specific arsenic K_d value is not available for the Naturita site, therefore a K_d value of 5.45 mL/g (from another UMTRA site with an alluvial aquifer) was used. Since this value is higher than the literature values, the results are considered conservative.

The literature on dispersivity as it relates to large-scale models is vague and often contradictory, with longitudinal values ranging from 2 percent to 30 percent of the length of the plume or maximum flow path length. In addition, dispersivity is almost impossible to measure in the field for large sites. Commonly a value of 10 percent of the length of the plume is used for longitudinal dispersivity. With a maximum flow path length of approximately 2,500 ft, the longitudinal dispersivity could be as much as 250 ft. However, this is considered unrealistic for this site because the width of the site (transverse distance) is small relative to the length of the site (longitudinal distance), consequently a value of 100 ft was used. This value is approximately 4 percent of the length and considered a conservative estimate. For this transport model transverse dispersivity is 10 percent (10 ft) of longitudinal dispersivity (100 ft).

Bulk density was set at 1.55 g/mL (approximately 97 lbs/ft^3). The effective porosity was set to 25 percent.

Initial concentration plumes were developed in Surfer® for each of the COPC. The set of data for each COPC was kriged in Surfer® and interpolated to approximately a 25 ft grid spacing which corresponds to the model grid size. Each resulting surface was then interpolated to all active model grid cell centers and imported as the initial concentration plume. The plots presented in Figures 15, 16, and 17 show the initial concentration plumes for each of the COPCs. The range of concentration is shown on the color bar in each figure.

5.2 Transport Calibration and Parameter Sensitivity Analysis

The calibration and sensitivity analysis of the transport model is not as straightforward as the flow model. The calibration and sensitivity analysis of the flow parameters to the flow model is based on the residual sum of squares of observed head minus computed head. Similarly, the calibration and sensitivity analysis of the transport parameters to the transport model could be based on the residual sum of squares of observed concentration minus computed concentration. Since GWVistas does not yet have the capability to calibrate on concentration, only sensitivity analysis was used.

The transport parameters selected for sensitivity analysis are porosity, bulk density, K_d (for uranium and vanadium), longitudinal dispersivity, and transverse dispersivity. For the sensitivity analysis, each of the transport parameters (except transverse dispersivity) were simulated at three parameter values that correspond to the lowest expected value, the most likely value, and the highest expected value. Transverse dispersivity was simulated at three parameter values that are a percentage of the longitudinal dispersivity. These values are shown in Table 6. The approach taken here is to calculate the coefficient of variation (CV) of the difference in predicted concentration at each selected time interval (5, 10, 15, 25, 50, 60, 70, 80, 90, and 100 years). Any parameter resulting in a CV greater than 15 percent between the predicted concentration at any time interval is considered sensitive, and will be treated at stochastic if possible. GWVistas does not allow some transport parameters to be stochastic.

Table 6. Transport Model Sensitivity Parameter Values

Parameter	Lowest Expected	Most Likely (unless otherwise noted)	Highest Expected
Porosity	0.25[a]	0.30	0.40
Bulk Density (g/mL)	1.13	1.55	1.99
Uranium K_d (mL/g)	0.3975	0.6078	1.1225
Vanadium K_d (mL/g)	4.445	12.46	20.6575
Long. Disp. (ft)	50	100	200
Parameter	**% of Long. Disp.**	**% of Long. Disp.**	**% of Long. Disp.**
Trans. Disp.	10[a]	20	50
Parameter	**Low Value**	**Mid Value**	**High Value**
Trans. Disp. (ft)	10[a]	20	50

[a]Most Likely

The results are shown in Table 7. This analysis shows that the transport model is sensitive to porosity, bulk density, uranium K_d, longitudinal dispersivity, and transverse dispersivity. Porosity, uranium K_d, and longitudinal dispersivity are treated as stochastic. GWVistas does not allow bulk density and transverse dispersivity to be stochastic. Transverse dispersivity will show some variability because it is a percent of longitudinal dispersivity, which is stochastic.

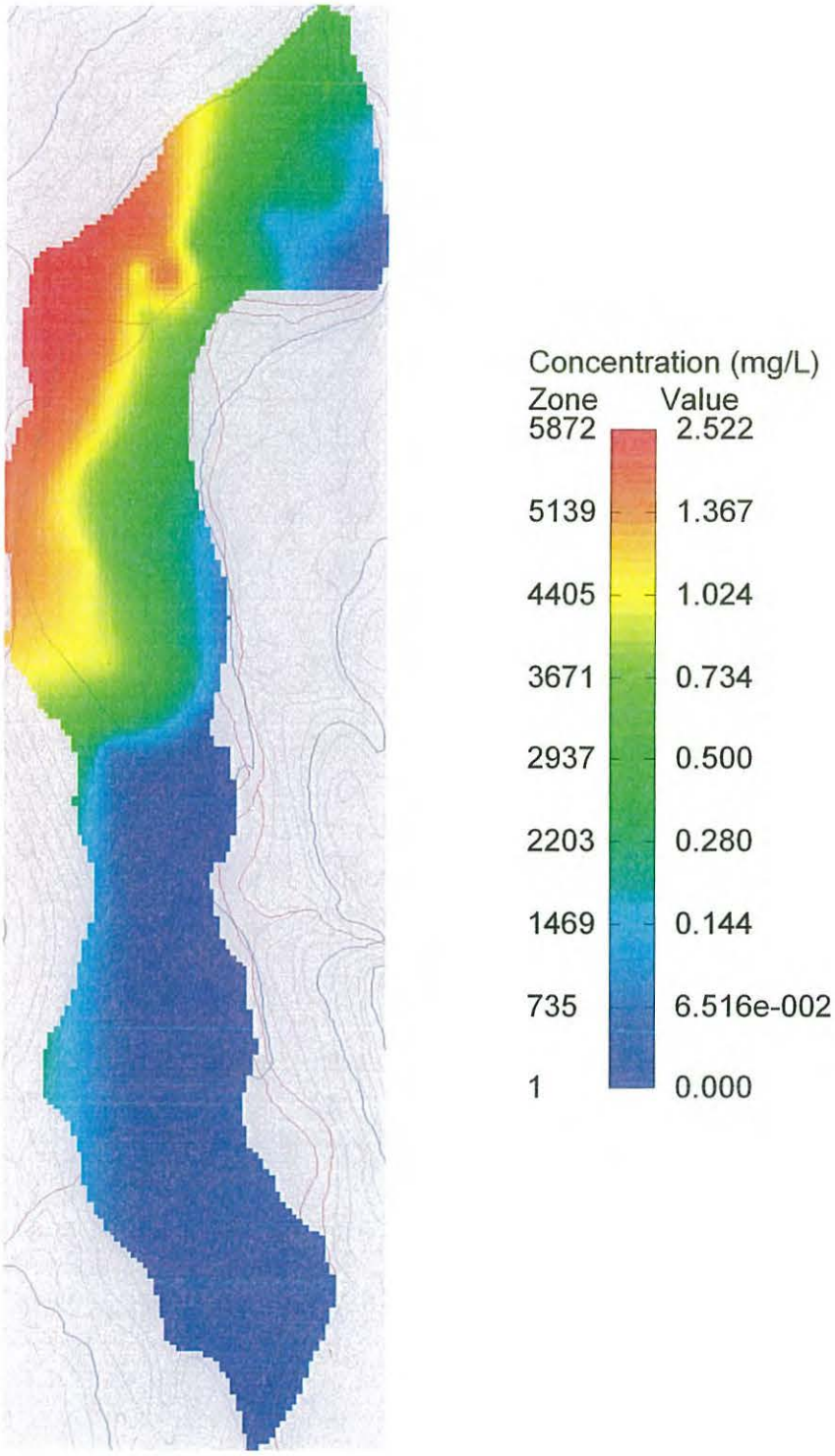


Figure 15. Initial Uranium Concentration

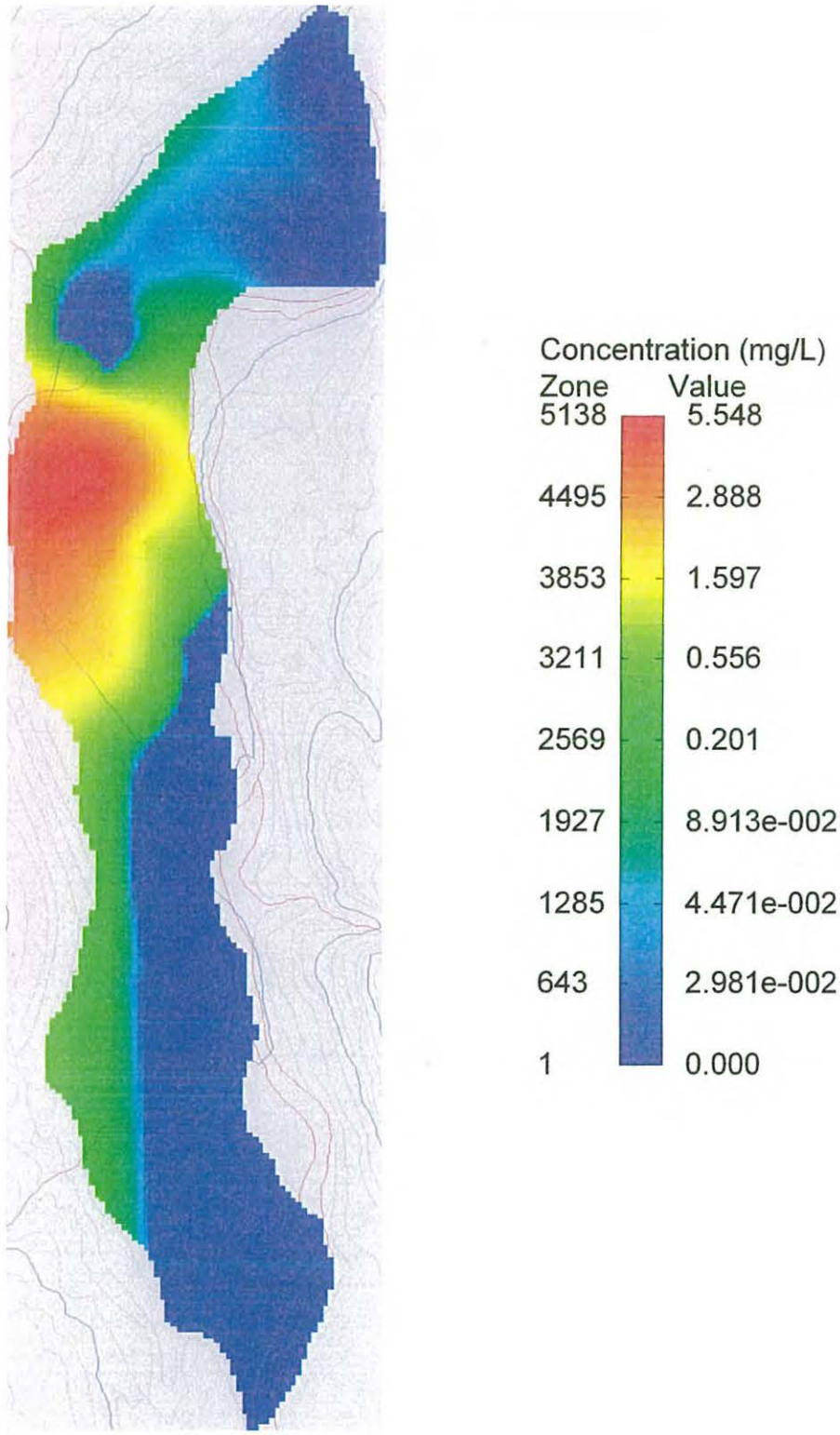


Figure 16. Initial Vanadium Concentration

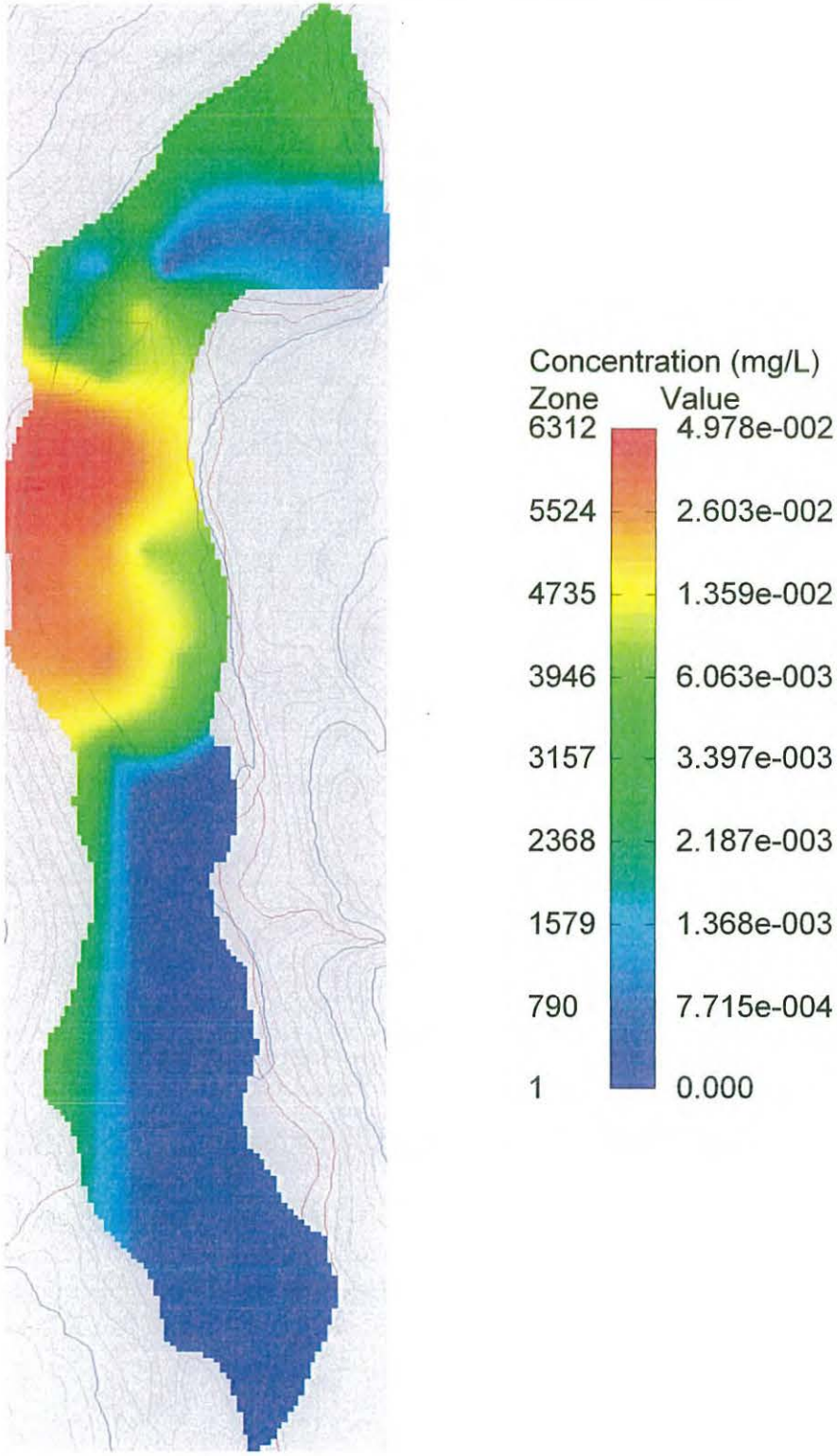


Figure 17. Initial Arsenic Concentration

Table 7. Transport Model Coefficient of Variation Analysis Results at Specific Times (Years)

Flow Parameter	Year	Mean	Standard Deviation	Adjusted Standard Deviation	Coefficient of Variation
Porosity					
	5	2.43020	0.00412	0.00465	0.00191
	10	2.37330	0.00538	0.00607	0.00256
	15	2.31230	0.01411	0.01591	0.00688
	25	2.06630	0.04513	0.05091	0.02464
	50	1.36847	0.07095	0.08004	0.05849
	60	1.12363	0.08897	0.10036	0.08931
	70	0.87625	0.10144	0.11442	0.13058
	80	0.64690	0.10319	0.11640	0.17993[a]
	90	0.45318	0.09423	0.10629	0.23455[a]
	100	0.30344	0.07805	0.08804	0.29013[a]
Bulk Density					
	5	2.42543	0.01518	0.01713	0.00706
	10	2.36177	0.02739	0.03090	0.01308
	15	2.28133	0.07127	0.08039	0.03524
	25	1.99947	0.18396	0.20750	0.10378
	50	1.26196	0.29326	0.33079	0.26213[a]
	60	1.00384	0.34752	0.39200	0.39050[a]
	70	0.76447	0.36471	0.41139	0.53814[a]
	80	0.55966	0.34156	0.38528	0.68841[a]
	90	0.39607	0.29176	0.32911	0.83093[a]
	100	0.27218	0.23178	0.26145	0.96056[a]
K_d – Uranium					
	5	2.43187	0.03222	0.03635	0.01495
	10	2.36727	0.04996	0.05635	0.02380
	15	2.27933	0.11209	0.12644	0.05547
	25	2.01690	0.29130	0.32859	0.16292[a]
	50	1.32897	0.52352	0.59053	0.44435[a]
	60	1.07465	0.58288	0.65749	0.61182[a]
	70	0.85851	0.61359	0.69213	0.80620[a]
	80	0.68685	0.61510	0.69383	1.01017[a]
	90	0.54906	0.58576	0.66074	1.20340[a]
	100	0.43888	0.53506	0.60355	1.37522[a]
K_d – Vanadium					
	5	5.31613	0.11290	0.12735	0.02396
	10	5.18977	0.19229	0.21690	0.04179
	15	5.08167	0.24534	0.27675	0.05446
	25	4.90573	0.32142	0.36257	0.07391
	50	4.59133	0.41699	0.47036	0.10245
	60	4.51227	0.41008	0.46257	0.10251
	70	4.43793	0.41200	0.46474	0.10472
	80	4.35900	0.42313	0.47730	0.10950
	90	4.28047	0.45270	0.51064	0.11930
	100	4.20683	0.47929	0.54064	0.12852

Table 7 (continued). Transport Model Coefficient of Variation Analysis Results at Specific Times (Years)

Flow Parameter	Year	Mean	Standard Deviation	Adjusted Standard Deviation	Coefficient of Variation
Longitudinal Dispersivity					
	5	2.41797	0.05348	0.06032	0.02495
	10	2.34723	0.09163	0.10336	0.04404
	15	2.26457	0.15054	0.16980	0.07498
	25	1.99683	0.22181	0.25021	0.12530
	50	1.29265	0.29686	0.33486	0.25905[a]
	60	1.02913	0.28894	0.32592	0.31670[a]
	70	0.77957	0.25304	0.28543	0.36614[a]
	80	0.55403	0.19039	0.21476	0.38764[a]
	90	0.36997	0.12134	0.13687	0.36994[a]
	100	0.23652	0.06955	0.07845	0.33168[a]
Transverse Dispersivity					
	5	2.40037	0.03229	0.03643	0.01518
	10	2.31553	0.06763	0.07628	0.03294
	15	2.19827	0.12686	0.14309	0.06509
	25	1.84983	0.20988	0.23674	0.12798
	50	1.06217	0.25712	0.29003	0.27305[a]
	60	0.79107	0.25576	0.28850	0.36470[a]
	70	0.55676	0.22893	0.25823	0.46381[a]
	80	0.37173	0.18380	0.20733	0.55774[a]
	90	0.23550	0.13429	0.15148	0.64322[a]
	100	0.14318	0.09131	0.10299	0.71935[a]

[a]indicates parameter is sensitive at this time (year) per this criteria

5.3 Predictive Results for Uranium

A contaminant transport model using MT3DMS, based on the calibrated steady state deterministic flow model, was used for predictive simulations. Simulation results were extracted for selected times up to 100 years into the future. Predicted uranium concentrations above the UMTRA Project maximum concentration level (MCL) of 0.044 milligrams per liter (mg/L) at 5, 10, 25, 50 and 100 years into the future are presented in Figures 18 through 22, respectively. The areas of the model in the figures that do not have color (are white) are below the MCL. For this scenario the maximum predicted concentration at 5, 10, 25, 50, and 100 years is 2.4266, 2.3683, 2.0257, 1.3047, and 0.23654 mg/L, respectively.

While these plots give a general aerial view of the remaining contamination area, they do not provide a clear picture of the contaminant change with time. The plots in Figures 23, 24, and 25 show the change in concentration versus time for monitor well locations MAU08, MAU07, and 548, respectively.

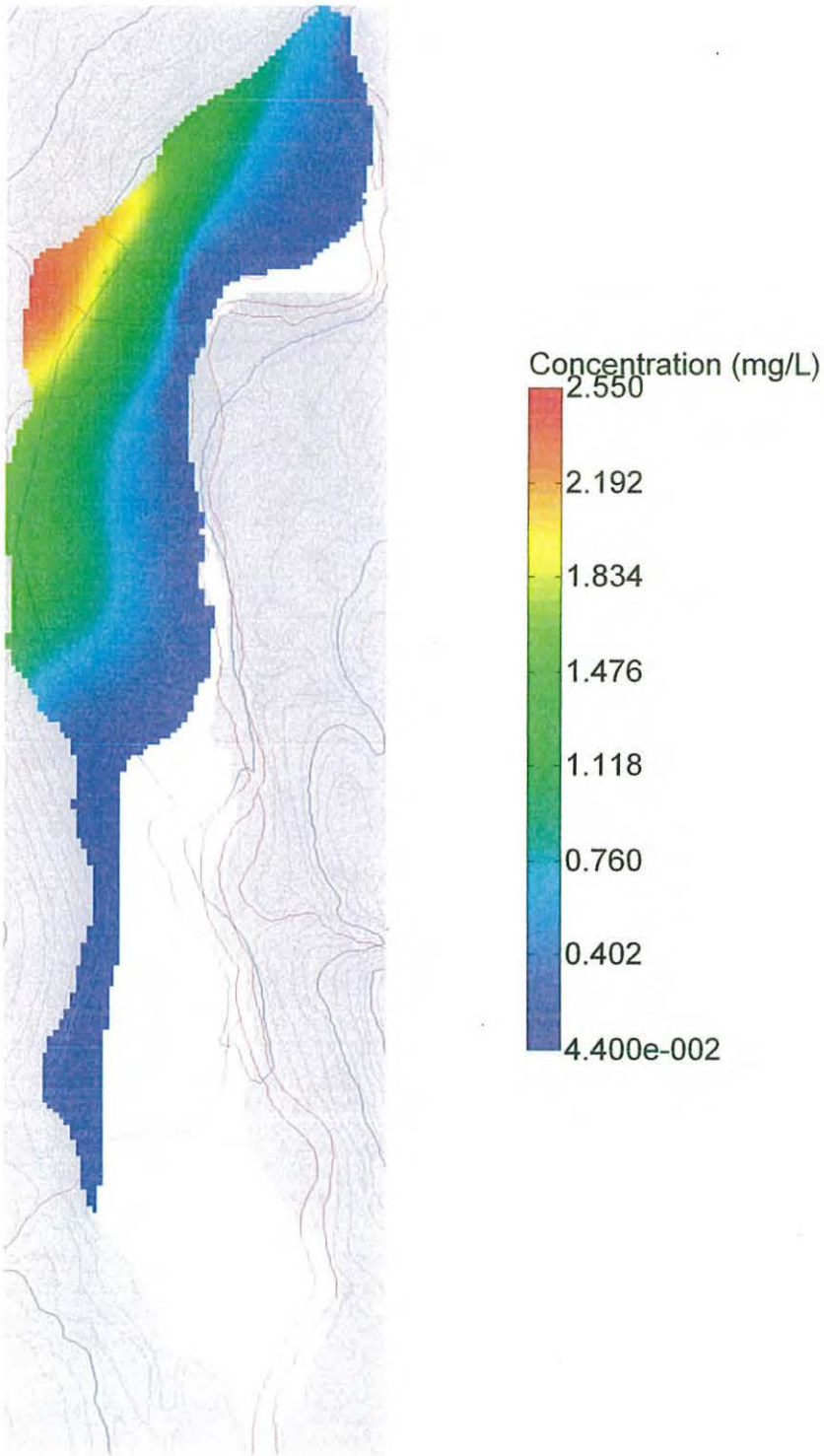


Figure 18. Predicted Steady State Uranium Concentration at 5 Years

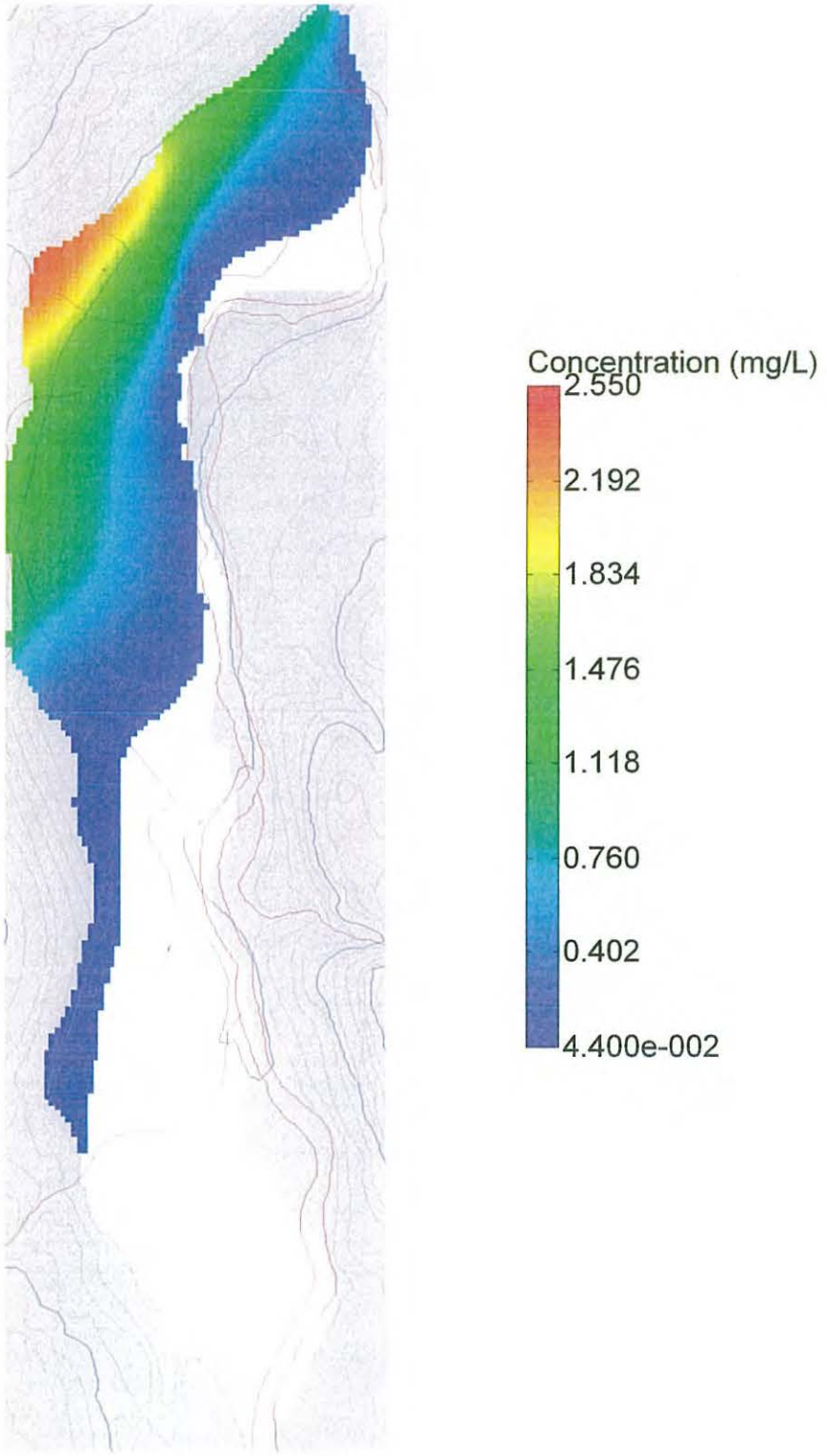


Figure 19. Predicted Steady State Uranium Concentration at 10 Years

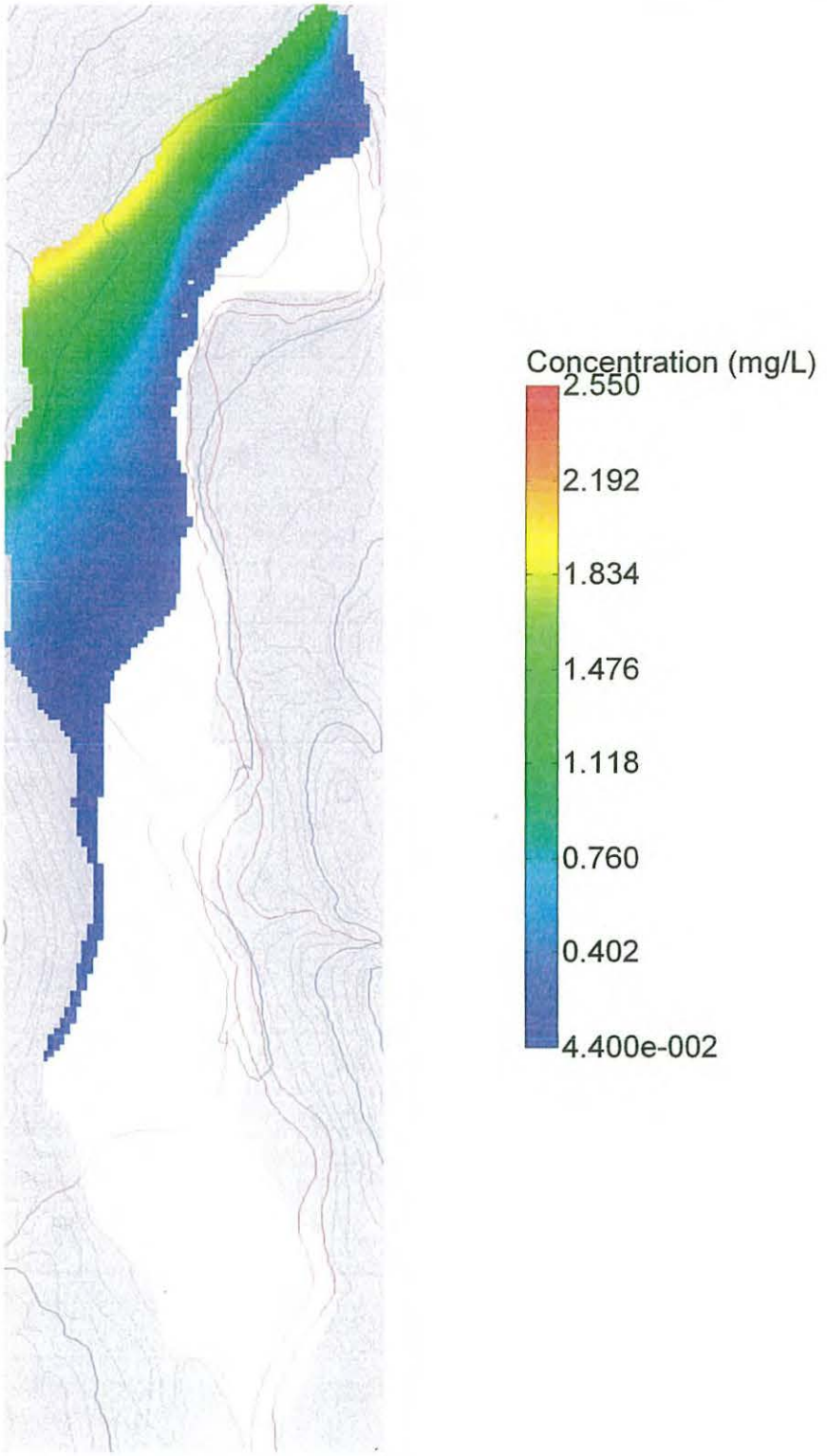


Figure 20. Predicted Steady State Uranium Concentration at 25 Years

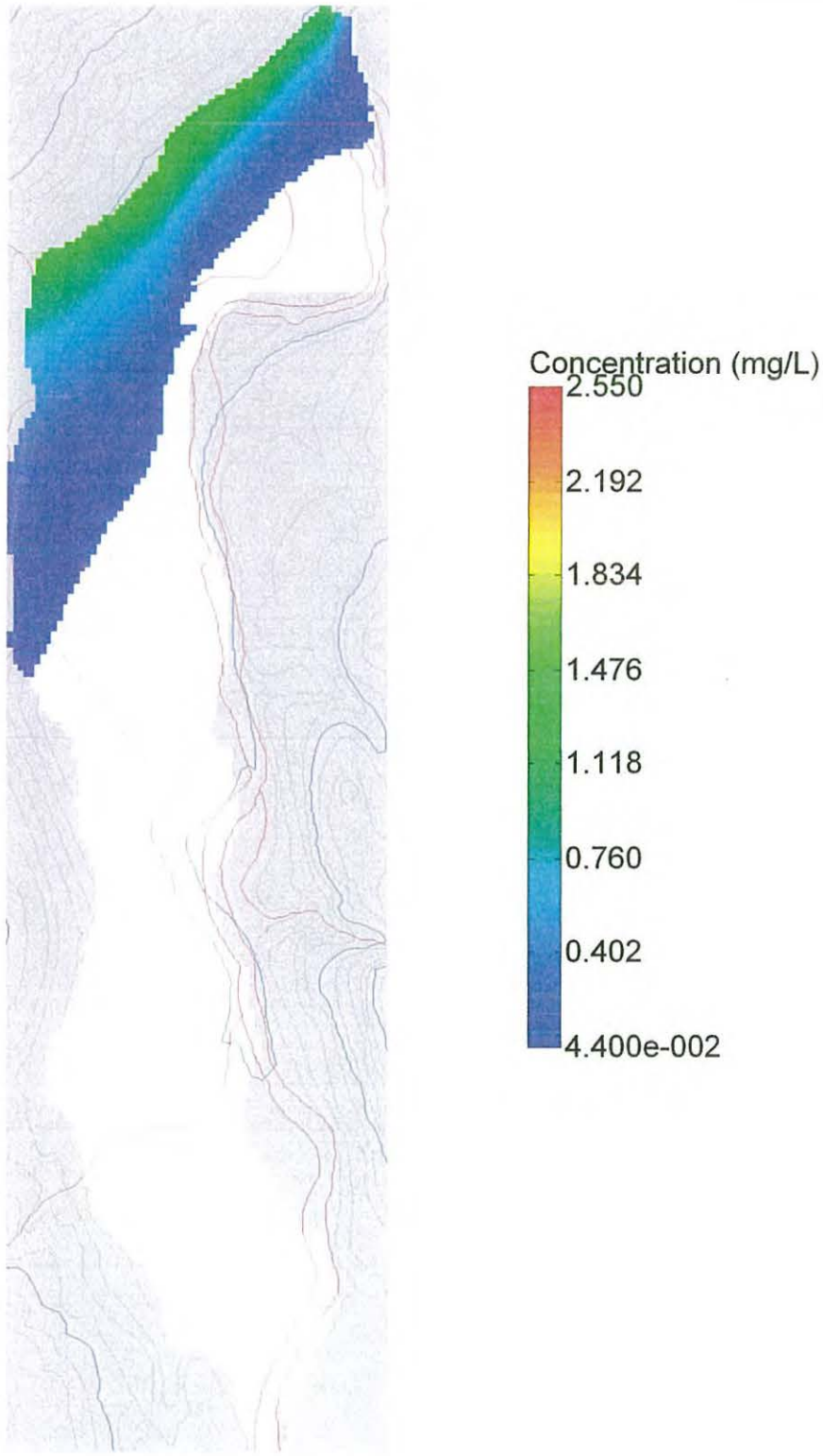


Figure 21. Predicted Steady State Uranium Concentration at 50 Years

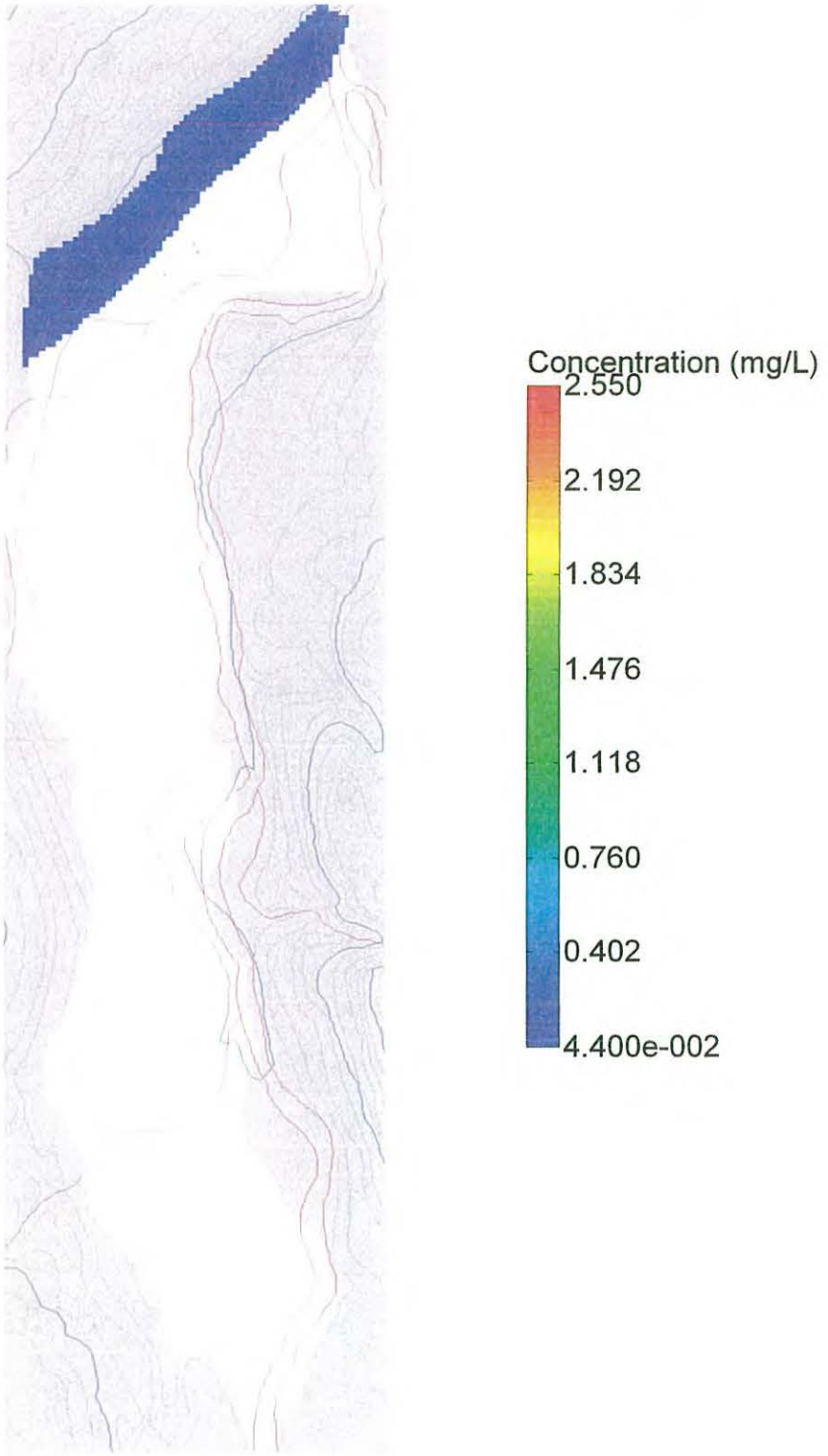


Figure 22. Predicted Steady State Uranium Concentration at 100 Years

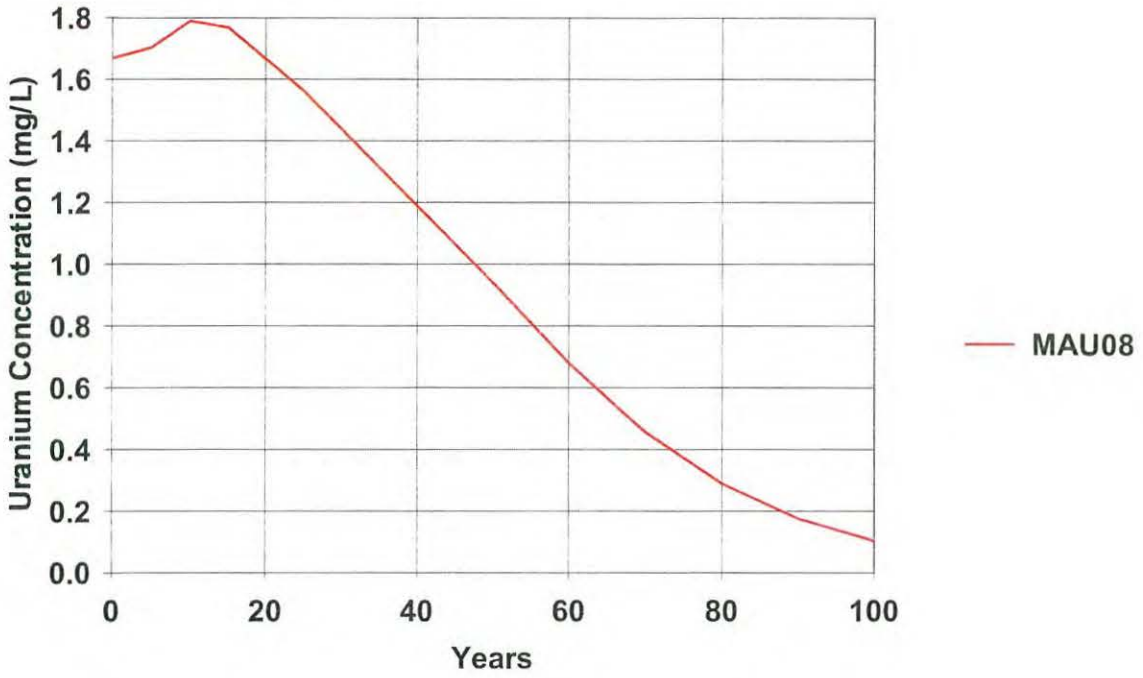


Figure 23. Uranium Concentration versus Time for Monitor Well MAU08

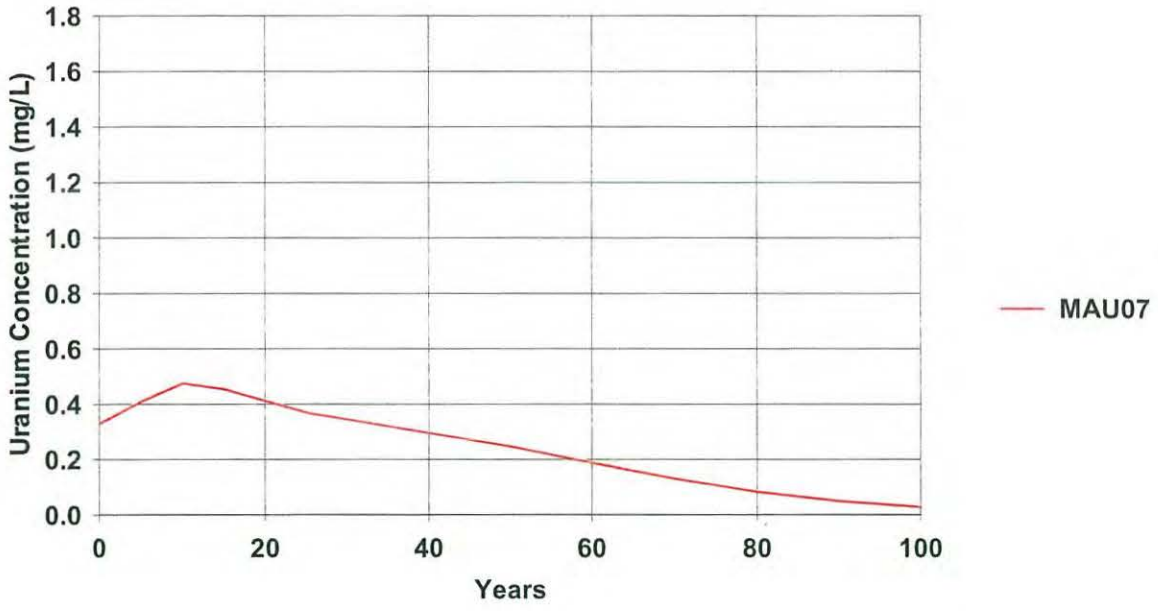


Figure 24. Uranium Concentration versus Time for Monitor Well MAU07

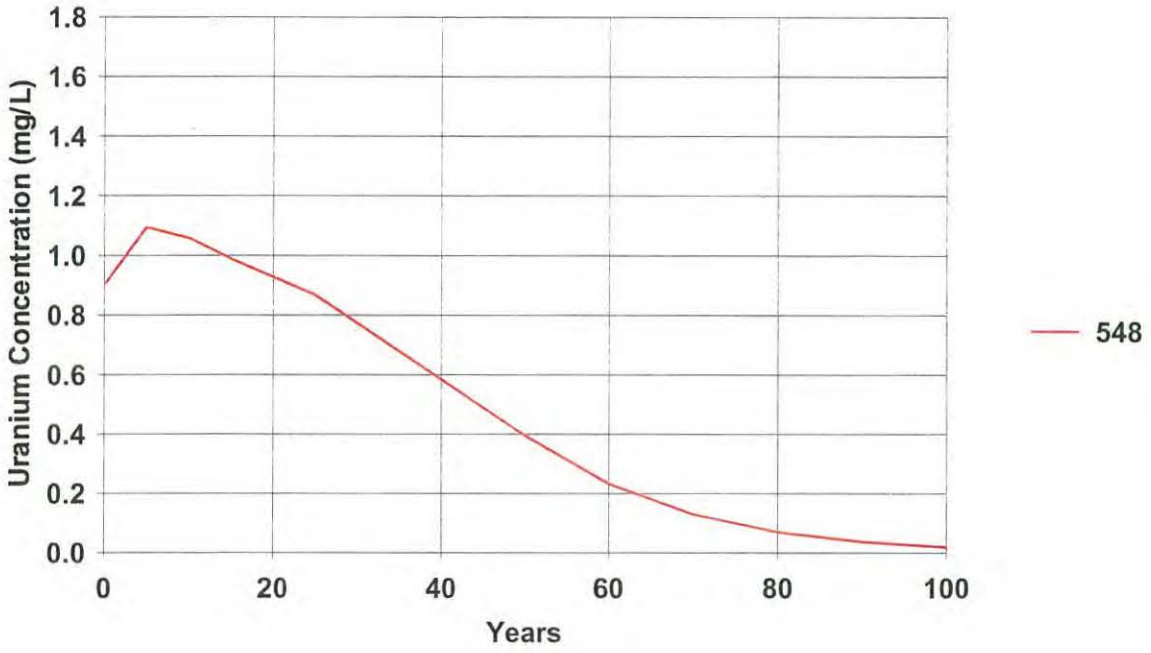


Figure 25. Uranium Concentration versus Time for Monitor Well 548

5.4 Predictive Results for Vanadium

Predicted vanadium concentrations above the risk-based concentration of 0.33 mg/L at 5, 10, 25, 50 and 100 years into the future are presented in Figures 26 through 30, respectively. The areas of the model in the figures that do not have color (are white) are below the risk-based concentration. For this scenario the maximum predicted concentration at 5, 10, 25, 50, and 100 years is 5.3589, 5.2583, 5.0065, 4.7099, and 4.3286 mg/L, respectively.

5.5 Predictive Results for Arsenic

Simulation results show that at 10 years the maximum remaining arsenic concentration is 0.045368 mg/L, which is below the UMTRA Project MCL of 0.05 mg/L. A concern regarding the arsenic plume was to ensure the maximum concentration does not exceed 0.05 mg/L as the plume migrates downgradient off site. The plots in Figures 31 and 32 show the concentration change with time at monitor wells MAU08 and MAU07, respectively. Both wells are off site and downgradient of the former millsite. Monitor well MAU08 is near the northern boundary of the site while MAU07 is close to where the alluvial aquifer discharges into the San Miguel River. Both plots indicate that the UMTRA Project MCL of 0.05 mg/L is not exceeded.

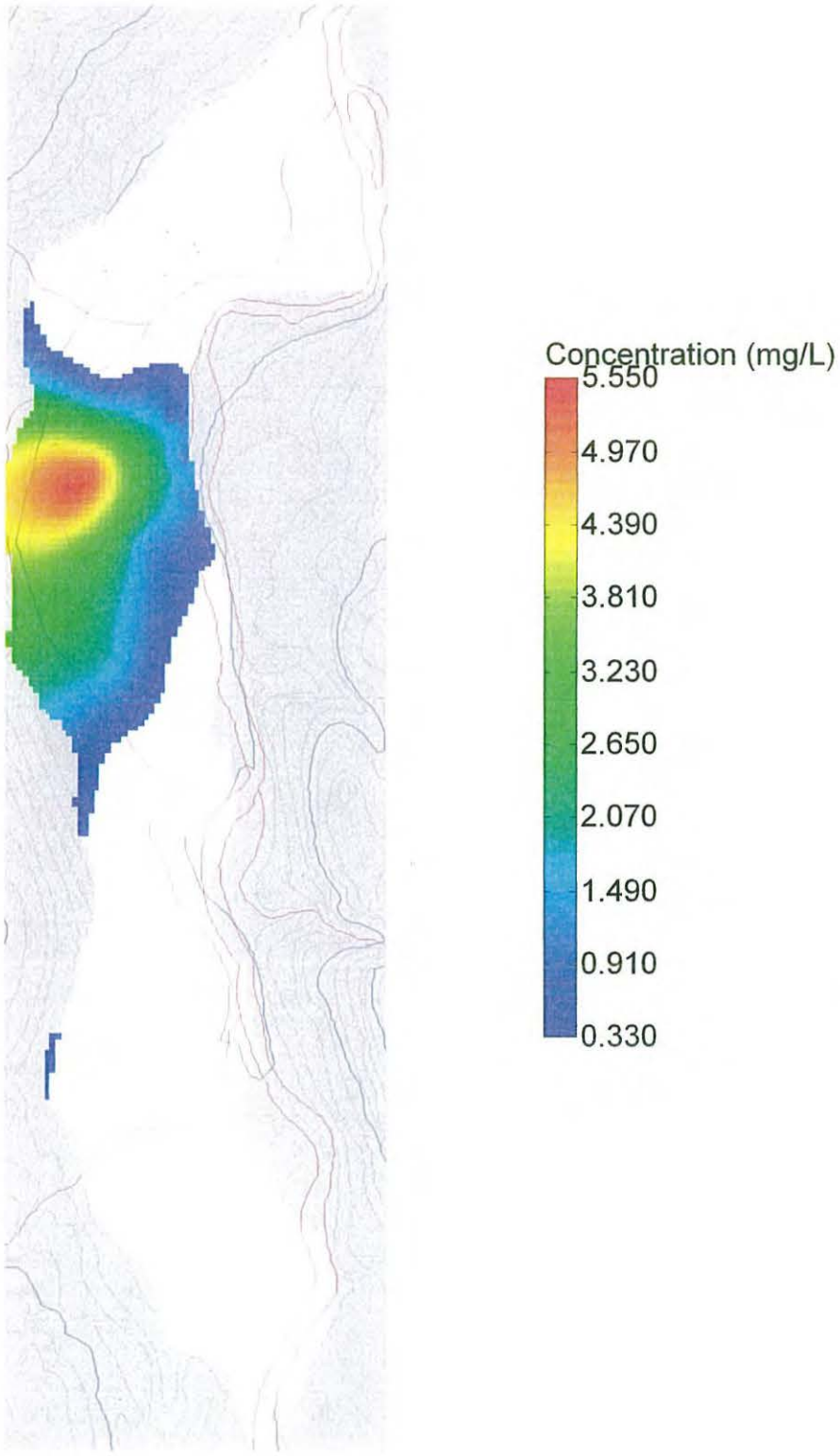


Figure 26. Predicted Steady State Vanadium Concentration at 5 Years

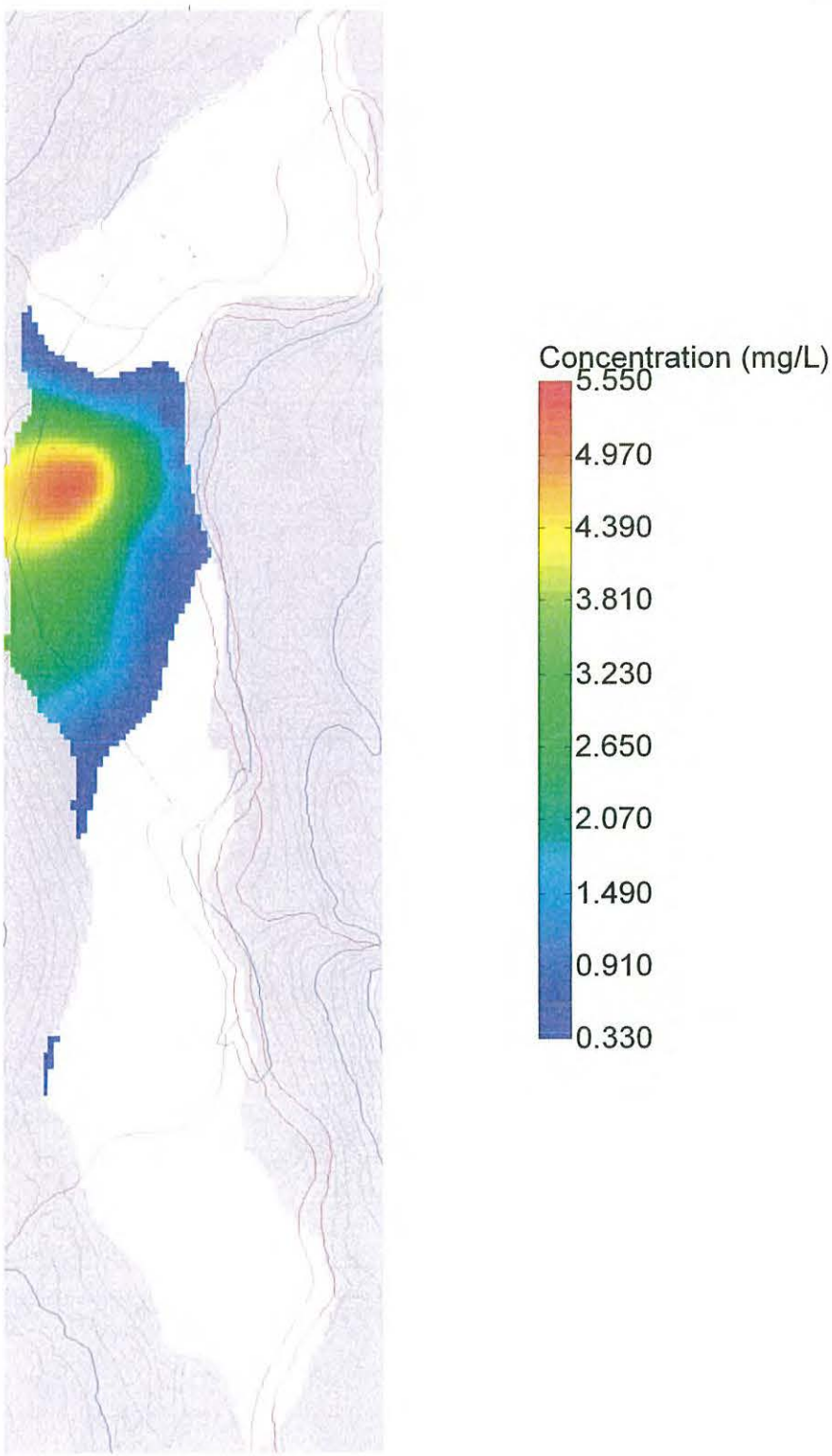


Figure 27. Predicted Steady State Vanadium Concentration at 10 Years

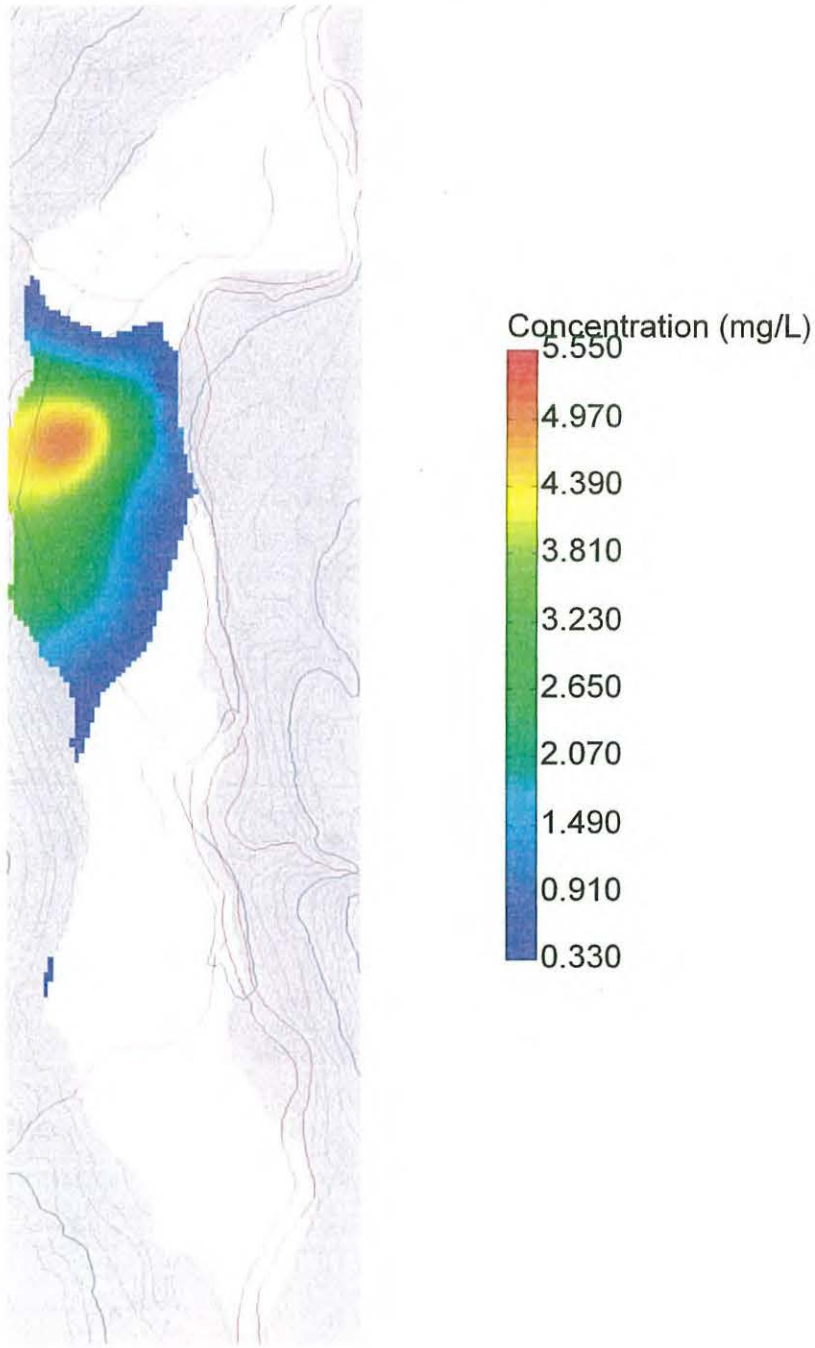


Figure 28. Predicted Steady State Vanadium Concentration at 25 Years

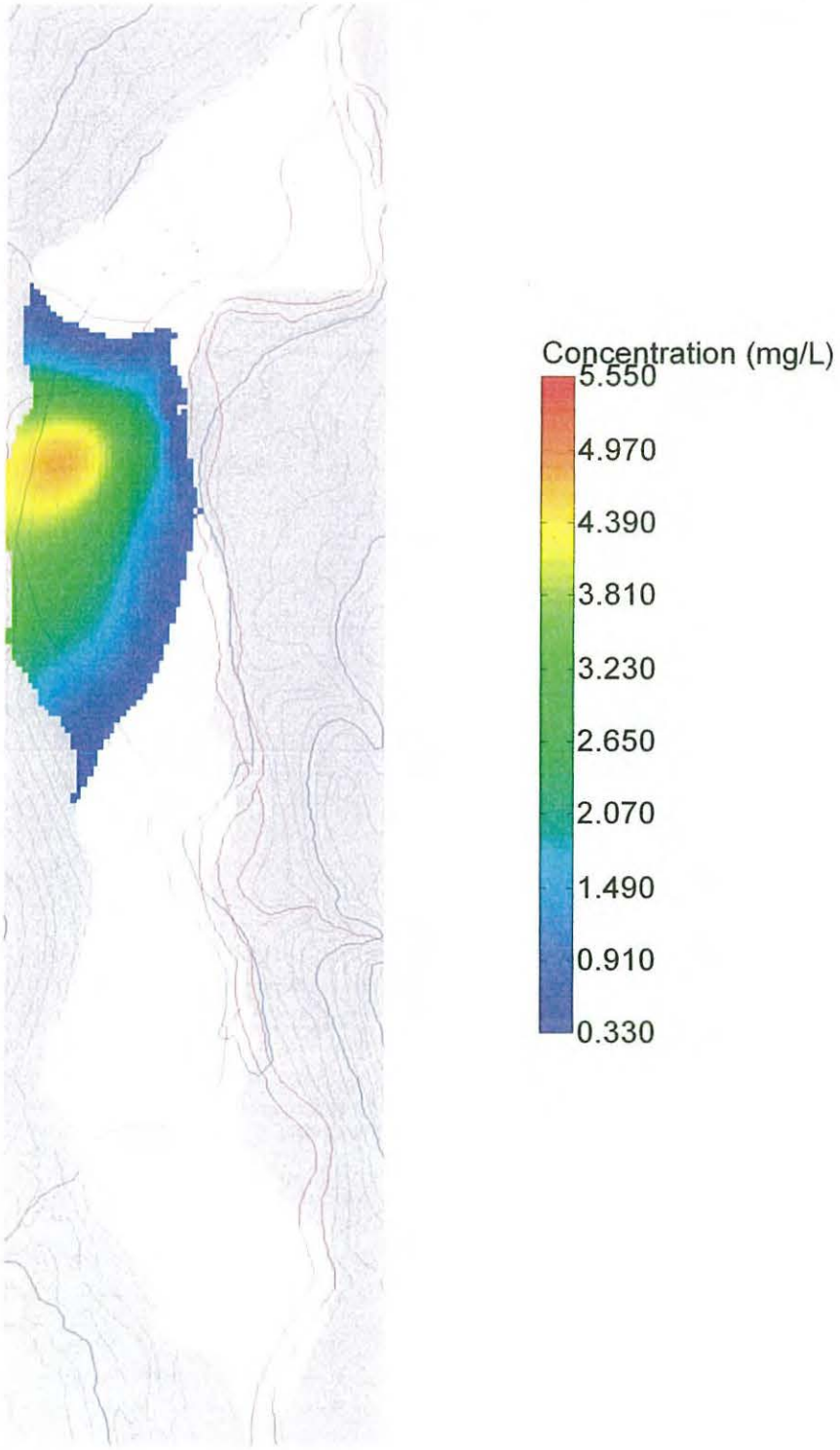


Figure 29. Predicted Steady State Vanadium Concentration at 50 Years

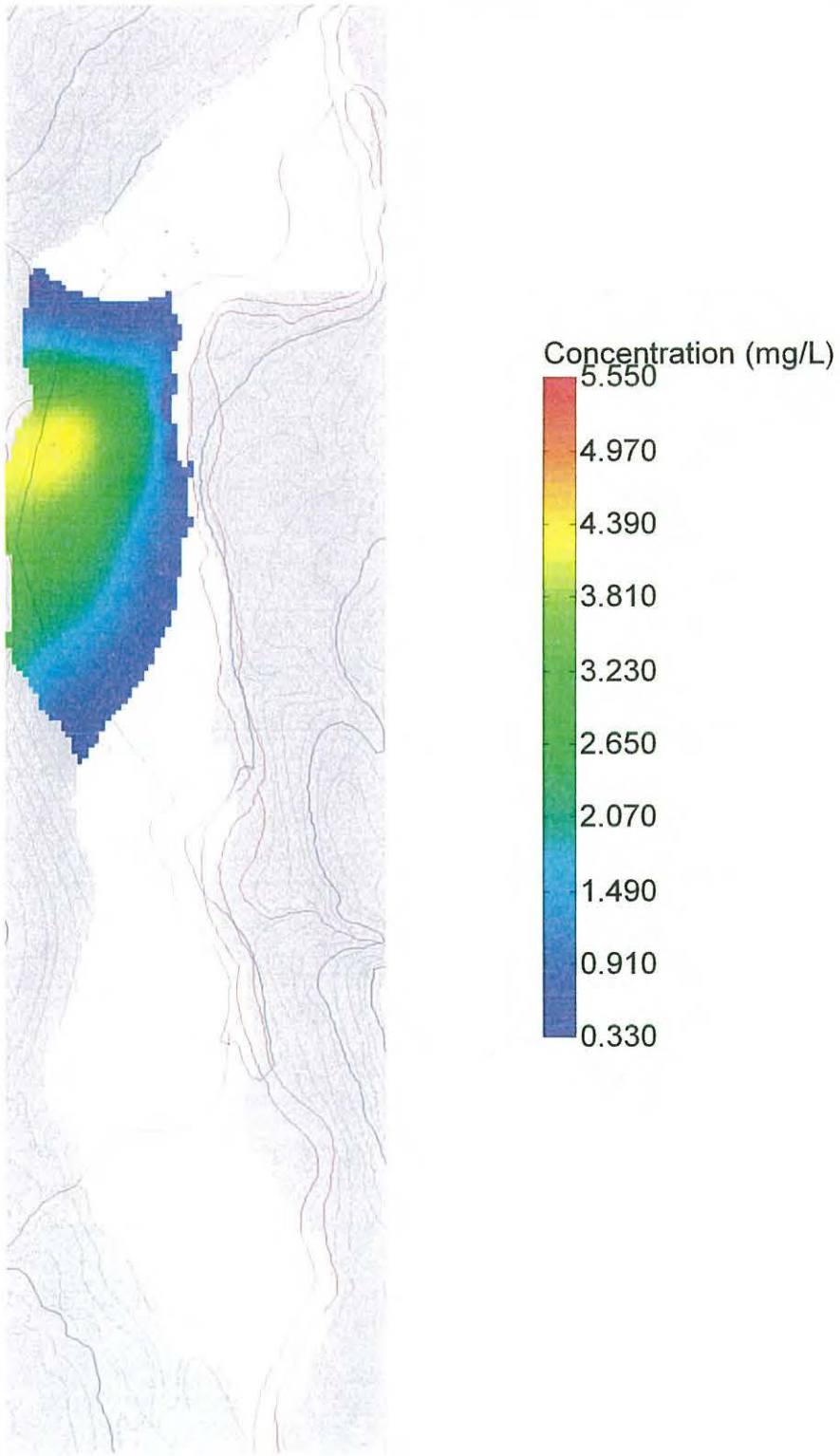


Figure 30. Predicted Steady State Vanadium Concentration at 100 Years

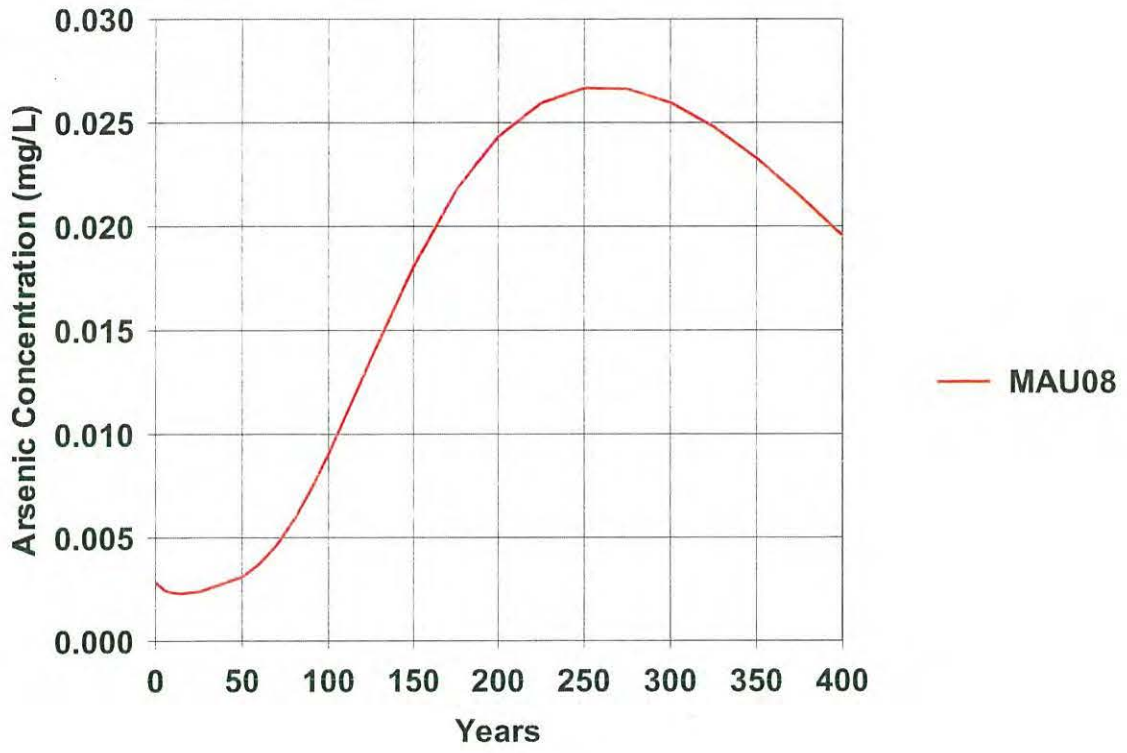


Figure 31. Arsenic Concentration versus Time for Monitor Well MAU08

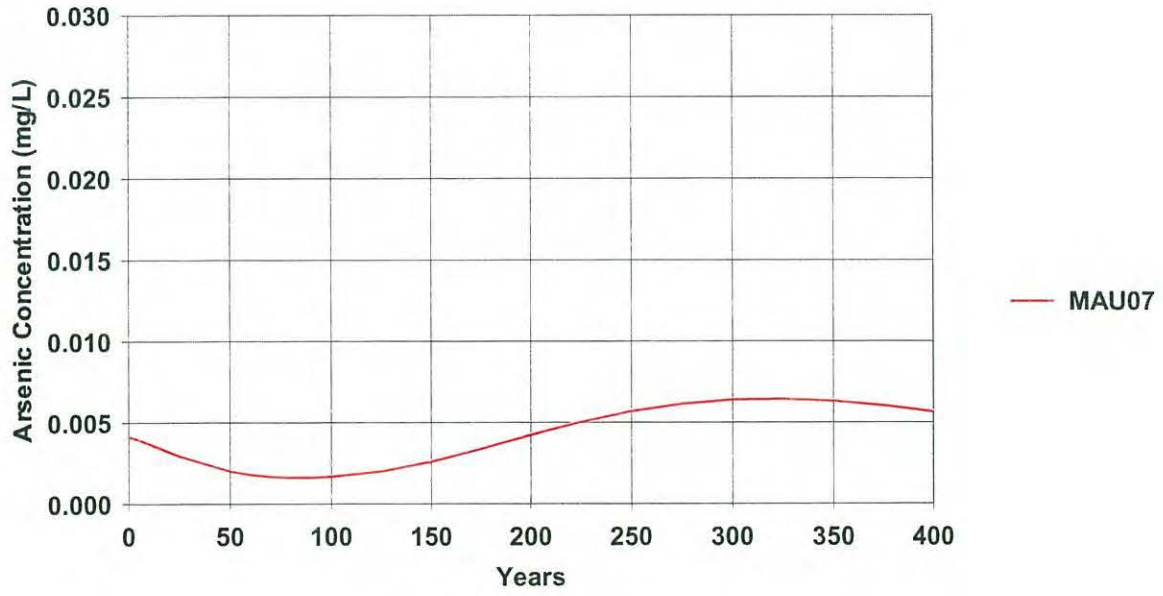


Figure 32. Arsenic Concentration versus Time for Monitor Well MAU07

6.0 Stochastic Simulations

6.1 Stochastic Parameters

Stochastic flow and transport simulations were run for only uranium. The flow and transport parameters that are treated as uncertain parameters are shown in Table 8. The distribution type and distribution parameters assigned to each of the stochastic parameters are specified.

Non-stochastic flow and transport parameters are listed in Table 9.

Table 8. Stochastic Flow and Transport Parameters

Parameter	Distribution			
	Type	Standard Deviation	Minimum	Maximum
Hydraulic Conductivity (ft/day)				
Longitudinal	Triangular	N/A	10	100
Transverse	Triangular	N/A	100% Longitudinal	
Dispersivity (ft)				
Longitudinal	Triangular	N/A	50	200
Transverse	Triangular	N/A	10% Longitudinal	
K_d				
Uranium (mL/g)	Triangular	N/A	0.3975	1.1225
(ft^3/lb)	Triangular	N/A	.006367	.01798
Recharge (ft/day)	Triangular	N/A	0	.00064
Recharge (in/yr)	Triangular	N/A	0	2.79
Porosity	Triangular	N/A	0.25	.40

Table 9. Non-Stochastic Flow and Transport Parameters

Parameter
River Stage (ft)
River Bed Conductance (ft^2/day)
River Concentration (mg/L)
GBH Head (ft)
GHB Conductance (ft^2/day)
GHB Concentration (mg/L)
Bulk Density (g/mL)

One of the problems associated with stochastic simulations is to determine how many realizations (individual simulations) are sufficient. From a strict mathematical standpoint, hundreds or even thousands of realizations may be necessary to truly represent the uncertainty when random samples are drawn from distributions for a number of parameters. A qualitative or subjective justification to determine if enough realizations were simulated can be obtained by looking at a plot of cumulative average residual sum of squares versus realization number. If there is limited change in the cumulative average as the number of realizations increases, then it

there is limited change in the cumulative average as the number of realizations increases, then it can be safely concluded that enough simulations have been run. The plot in Figure 33 indicates that the cumulative average residual sum of squares becomes relatively stable at about 31.8 ft^2 after 160 realizations. Therefore, 200 realizations should be adequate to account for the uncertainty in the stochastic parameters.

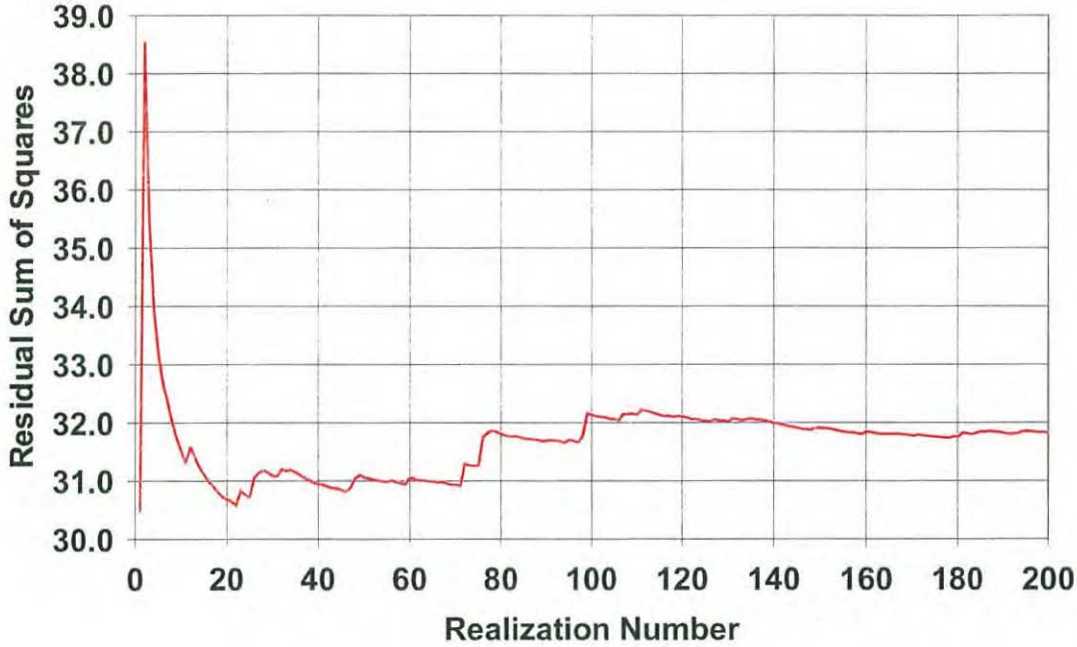


Figure 33. Cumulative Average Residual Sum of Squares versus Realization Number

Another useful evaluation tool is to look at how the individual realizations compare to the calibrated flow model results. The plot in Figure 34 shows the residual sum of squares for each of the 200 realizations. Few if any of the realizations are below the calibrated model residual sum of squares value of 28.878 ft^2, which is plotted on the figure. This indicates that the calibrated flow model is close to an optimum minimum. Note that at about realization 75 and 78 and again at about realization 99 the residual sum of squares is relatively high compared to the other realizations. These high values account for the jump at the same locations in Figure 33.

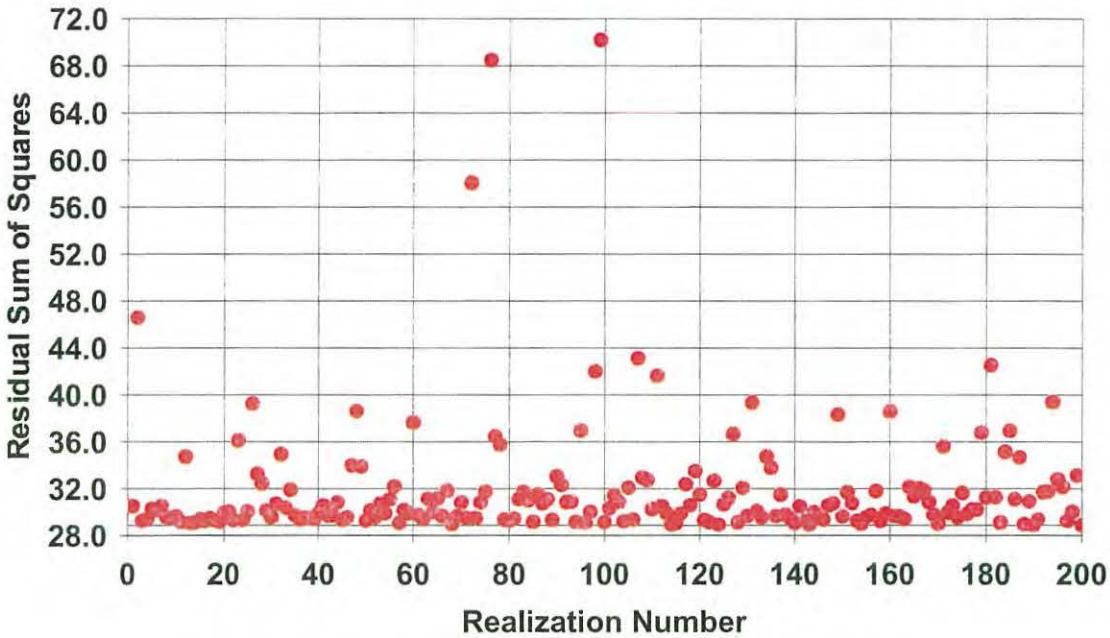


Figure 34. Residual Sum of Squares versus Realization Number

Based on the type of distribution associated with the uncertain parameters, the average remaining concentration from the results of the stochastic realizations will be lower than the deterministic results. Although this is not apparent, consider Table 10 which shows the mid-point of the triangular distributions used for each of the uncertain parameters (hydraulic conductivity, recharge, porosity, K_d, and longitudinal dispersivity). The mid-point stochastic values are higher than the deterministic values. For three of the five parameters (hydraulic conductivity, recharge, and longitudinal dispersivity) the mid-point stochastic value will result in a faster clean-up time. For the other two parameters (porosity and K_d) the higher mid-point stochastic value will result in a longer clean-up time. Table 5 indicates that both hydraulic conductivity and recharge are sensitive as early as 10 years while Table 7 indicates that porosity is not sensitive until 80 years and K_d is not sensitive until 50 years. While this is only a qualitative (subjective) analysis, it supports the notion that the remaining concentration at any time will be lower for the average stochastic results than for the deterministic results.

Table 10. Comparison of Deterministic vs. Mid-point Stochastic Parameter Values

Parameter	Deterministic Value	Mid-point Stochastic Value
Hydraulic Conductivity (ft/day)	30.	43.875
Recharge(ft/day)	0.	0.00019
Recharge (in/yr)	0.	0.7884
Porosity	0.25	0.29393
Kd (mL/g)	0.6078	0.69055
Longitudinal Dispersivity (ft)	100	113.397

If the mid-point stochastic parameter values are used in the deterministic model the maximum predicted concentration for uranium at 5, 10, 25, 50, and 100 years is 2.2380, 2.0111, 1.3038, 0.55829, and 0.030455 mg/L, respectively. These values are all lower than the deterministic

values reported in Section 5.3 and compare favorably with the average stochastic results in Section 6.2.

Figures 35 and 36 are plots of the average or mean head field of the 200 realizations. A visual comparison of Figures 35 and 36 with the steady state deterministic results in Figures 5 and 6 shows that they are almost identical. Figure 37, which presents the variability in head, represents the standard deviation in the heads of the 200 realizations. Although this plot is difficult to interpret, according to basic statistics about 68 percent of the heads in the simulation can be expected to fall within one standard deviation of the mean and about 95 percent can be expected to fall within two standard deviations. For these 200 realizations, the standard deviation in heads ranges from 0.0 to +0.3662. This indicates that there is very little variation in the results of the 200 realizations and essentially all of the results fall within one standard deviation of the mean.

6.2 Predictive Results for Uranium

Contaminant transport simulation results for uranium were extracted for selected times up to 100 years into the future. Average concentrations and the associated uncertainty at each time period of interest are based on 200 computer simulations. Figure 15 shows the initial concentration plume. Predicted uranium concentrations above the UMTRA Project MCL of 0.044 mg/L at 5, 10, 25, 50, and 100 years into the future are presented in Figures 38 through 42, respectively. The areas of the model in the figures that do not have color (are white) are below the MCL. The maximum average remaining concentration at 5, 10, 25, 50, and 100 years are 2.2156, 1.9671, 1.2854, 0.57426, and 0.12087 mg/L, respectively.

By varying the value of the uncertain or stochastic parameters during each of the 200 simulations, the variance associated with the mean predicted concentration was used to calculate the probability that the mean uranium concentration will exceed the uranium standard. Probability contour maps showing areas within the alluvial aquifer that exceed the uranium ground water standard at 5, 10, 25, 50 and 100 years into the future are illustrated in Figures 43 through 47, respectively. At 5, 10, and 25 years there is 100 percent probability that the standard will be exceeded over a significant part of the former millsite and downgradient. At 100 years there is still a 49 percent probability that the standard will be exceeded.

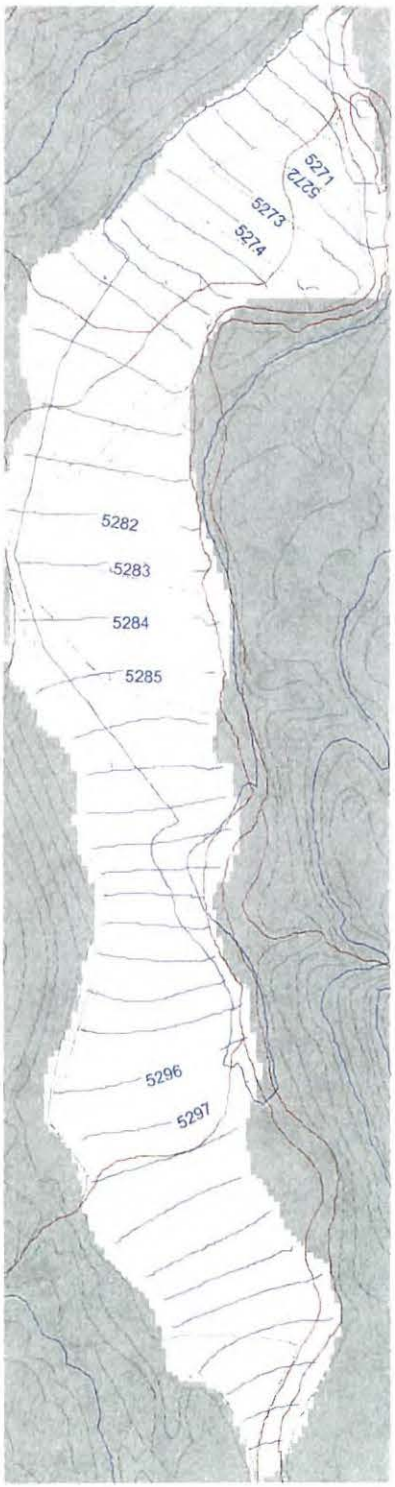


Figure 35. Average Simulated Steady State Stochastic Ground Water Elevations (in feet above MSL)

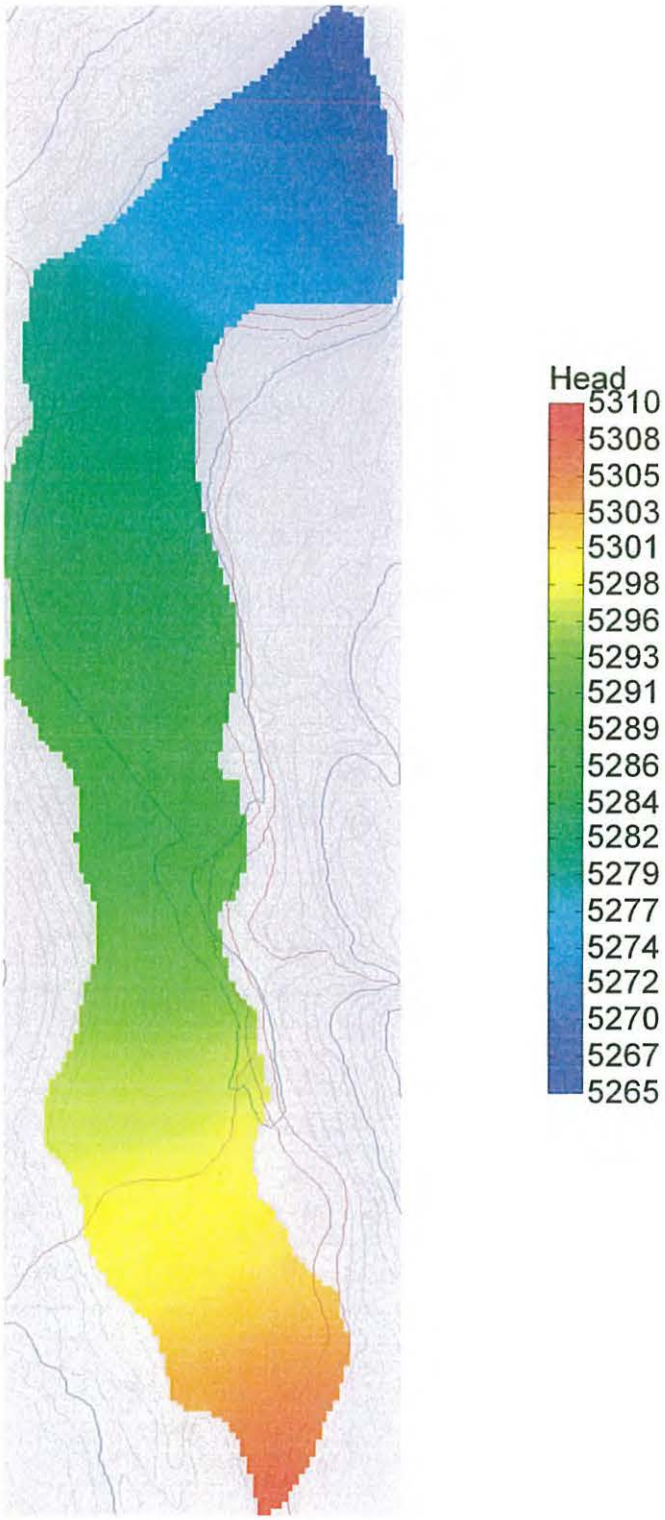


Figure 36. Average Simulated Steady State Stochastic Ground Water Elevations (in feet above MSL)

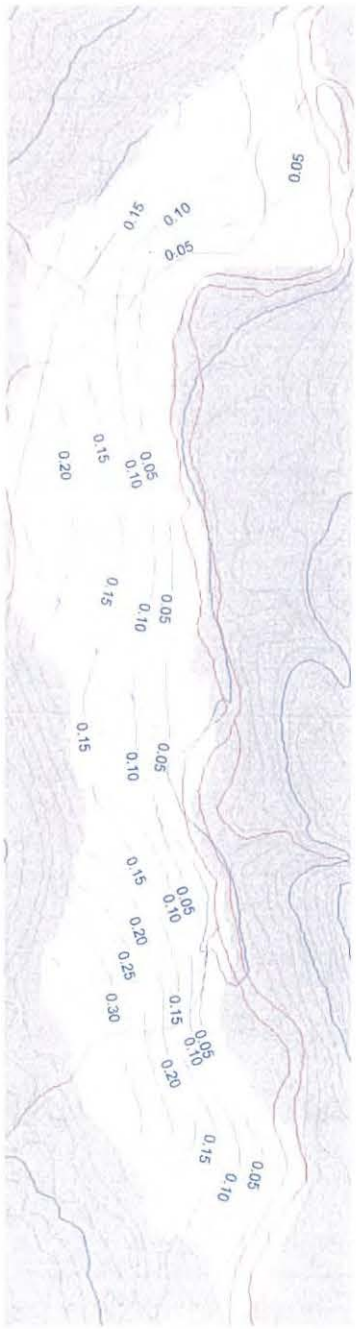


Figure 37. Standard Deviation of Head Field

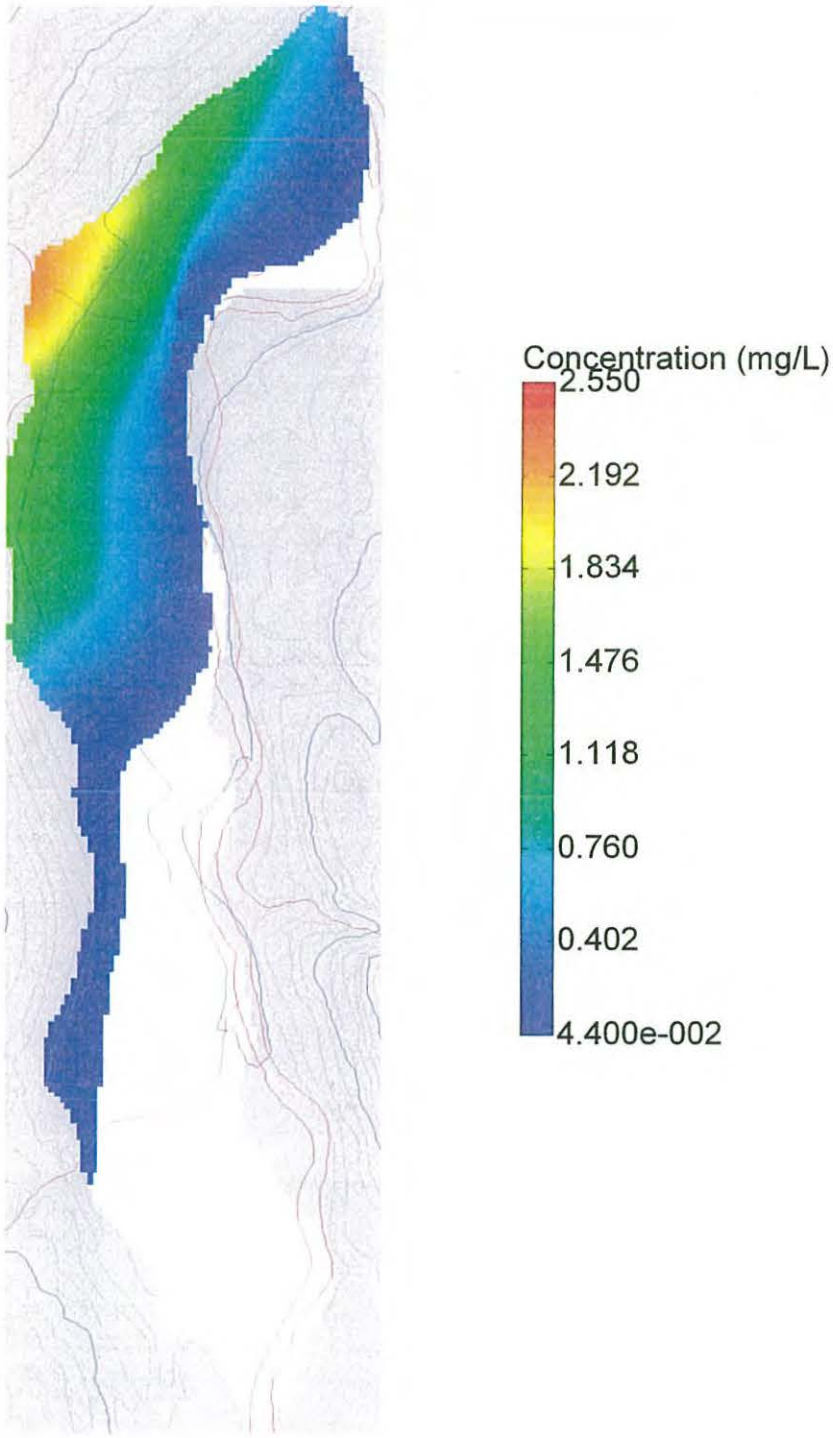


Figure 38. Predicted Steady State Stochastic Uranium Concentration at 5 Years

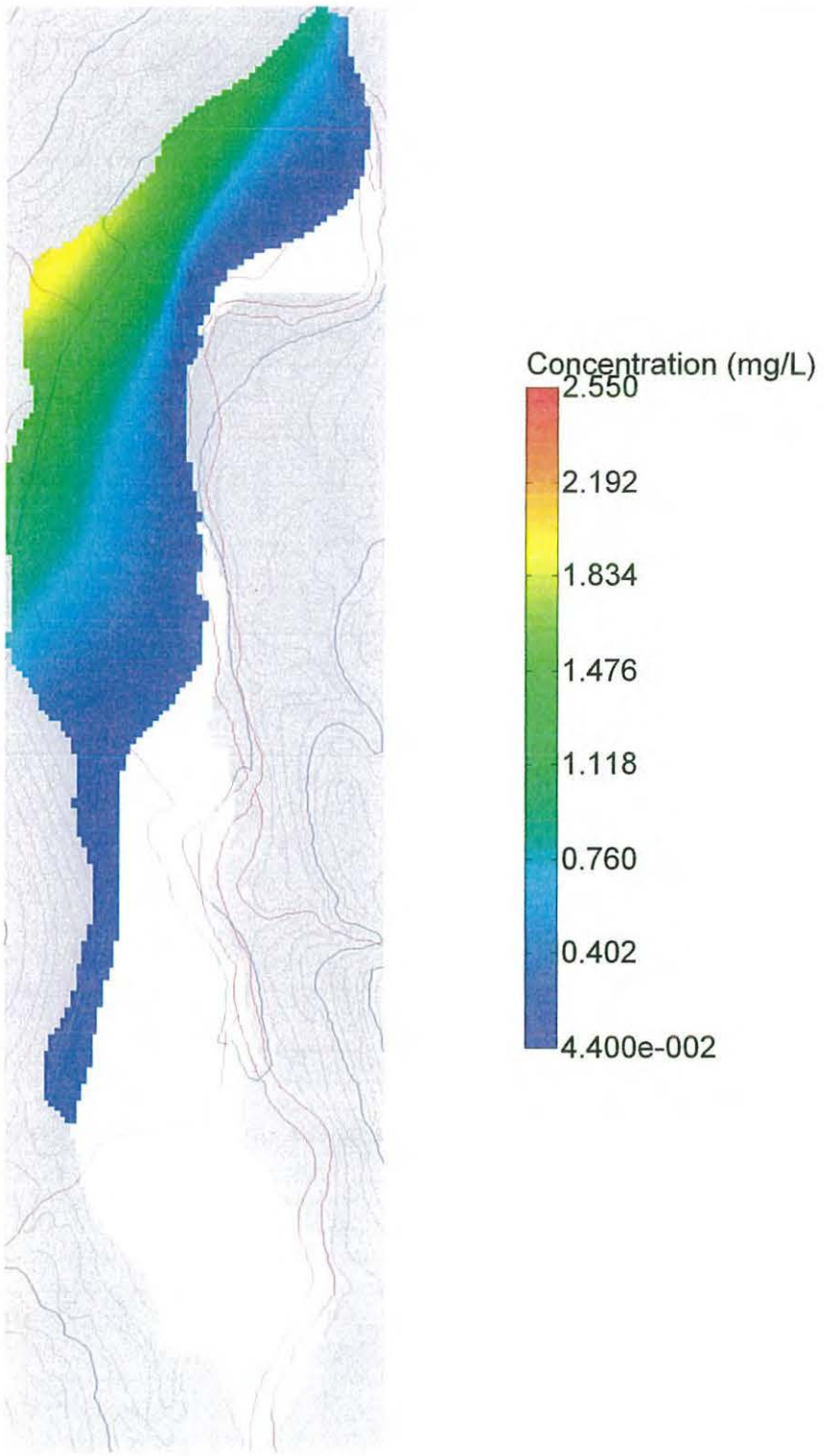


Figure 39. Predicted Steady State Stochastic Uranium Concentration at 10 Years

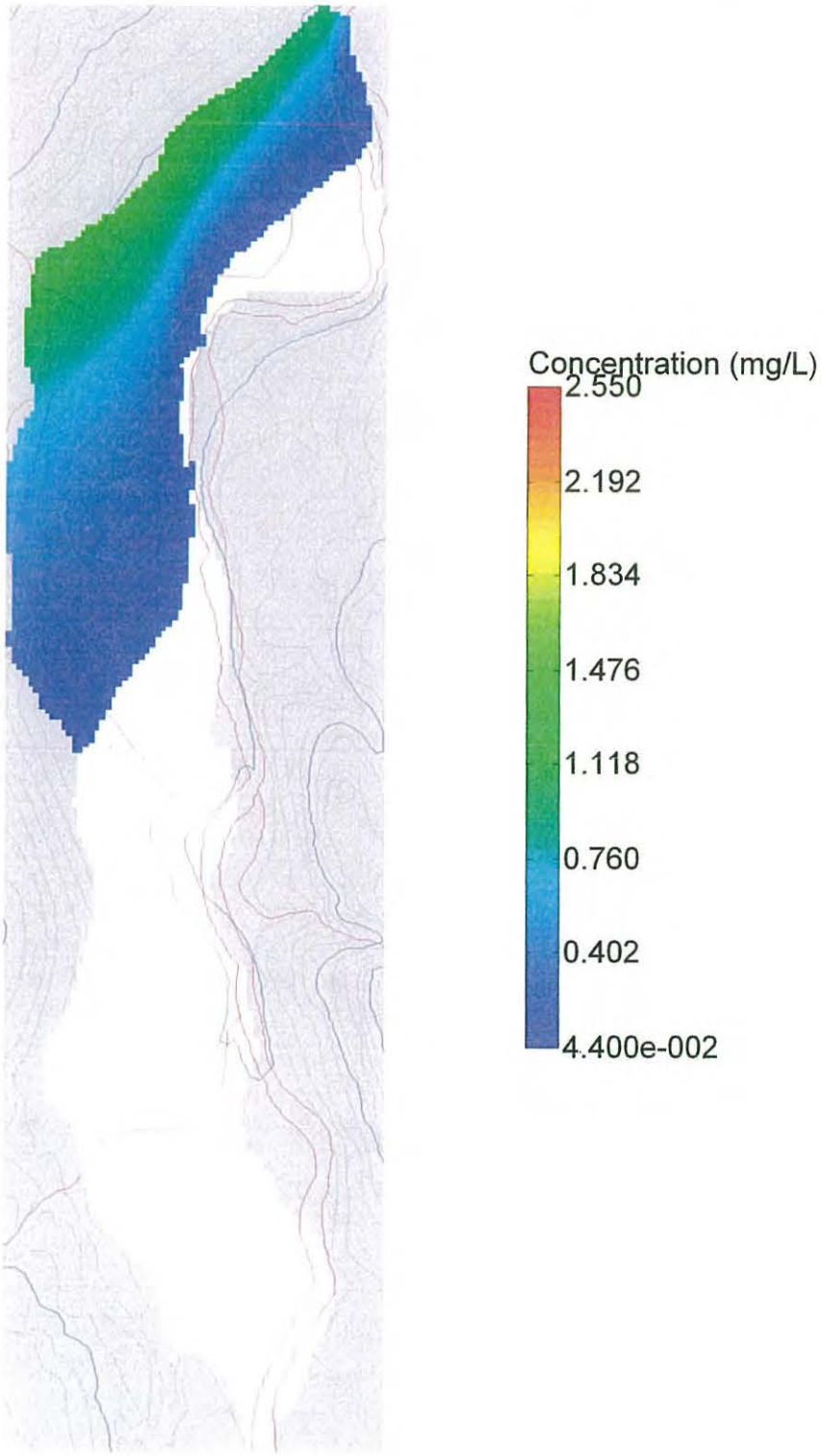


Figure 40. Predicted Steady State Stochastic Uranium Concentration at 25 Years

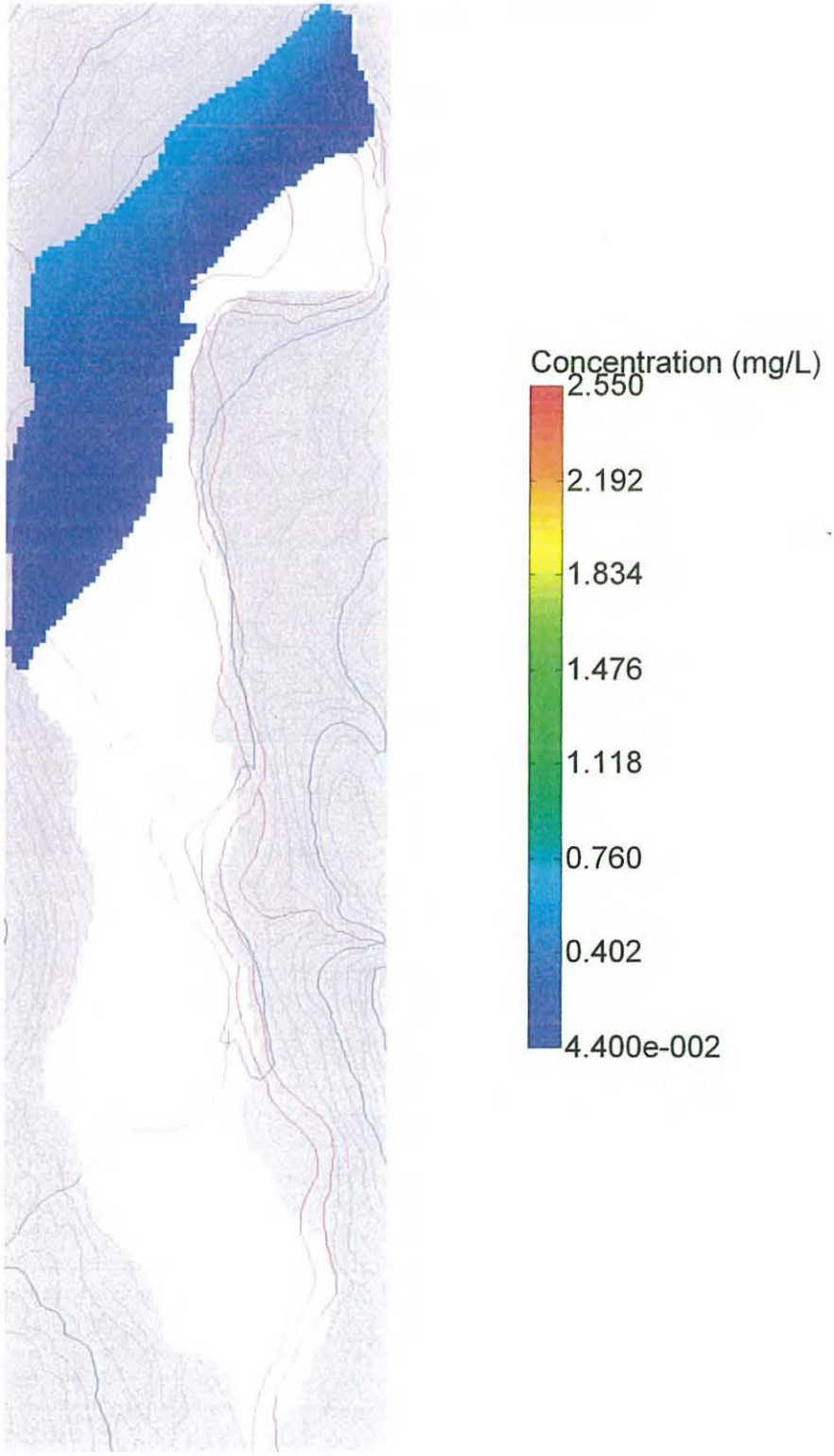


Figure 41. Predicted Steady State Stochastic Uranium Concentration at 50 Years

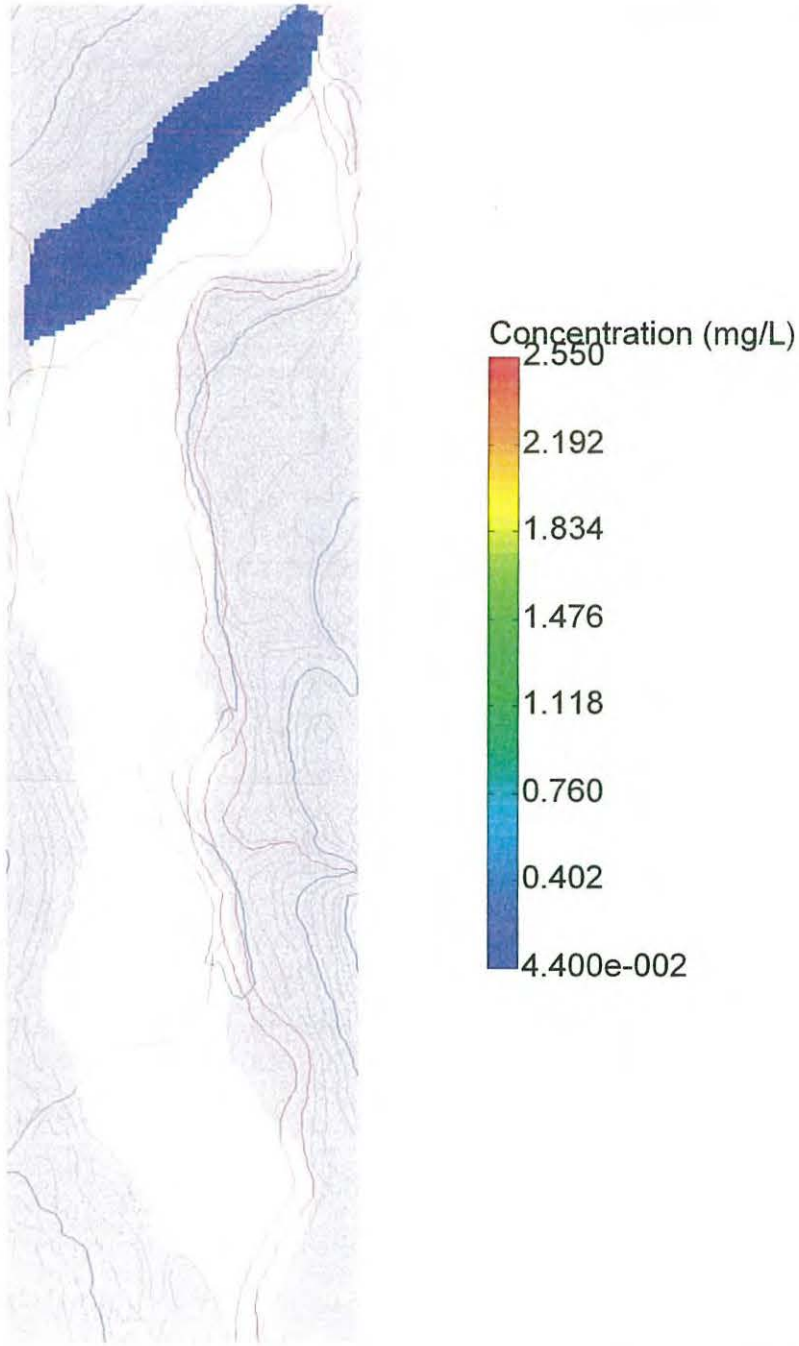


Figure 42. Predicted Steady State Stochastic Uranium Concentration at 100 Years

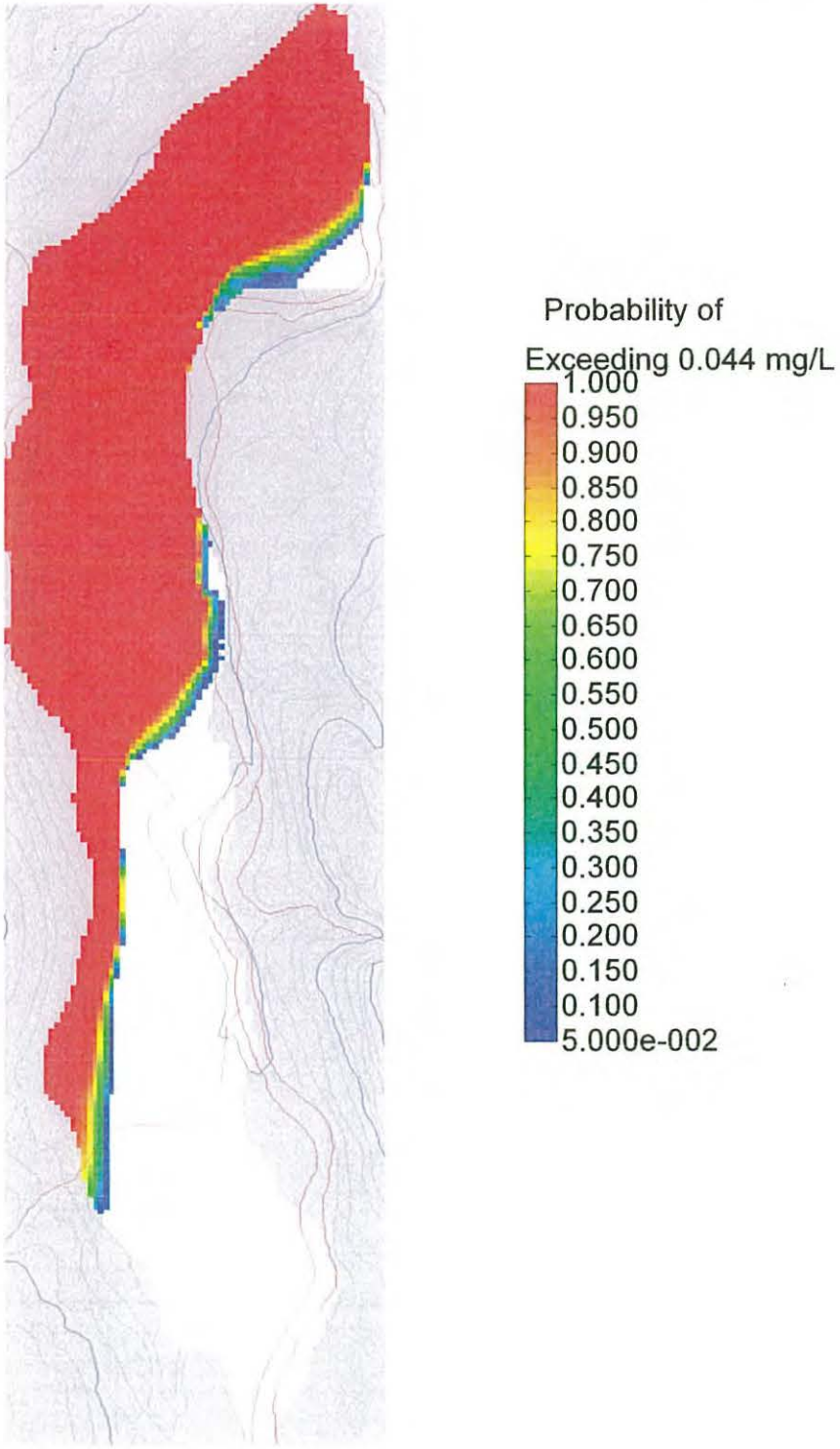


Figure 43. Probability of Uranium Concentration Exceeding the Standard at 5 Years

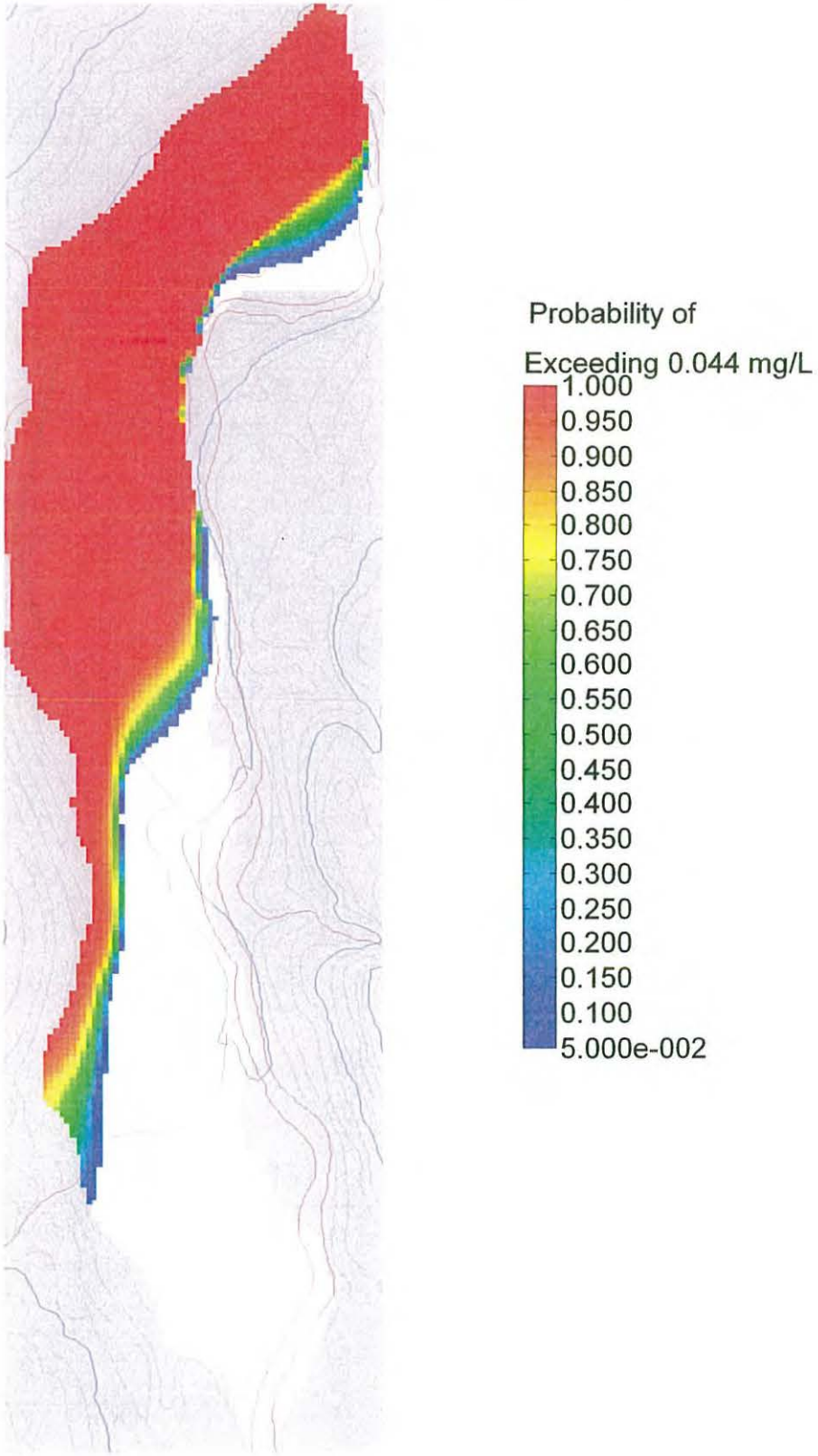


Figure 44. Probability of Uranium Concentration Exceeding the Standard at 10 Years

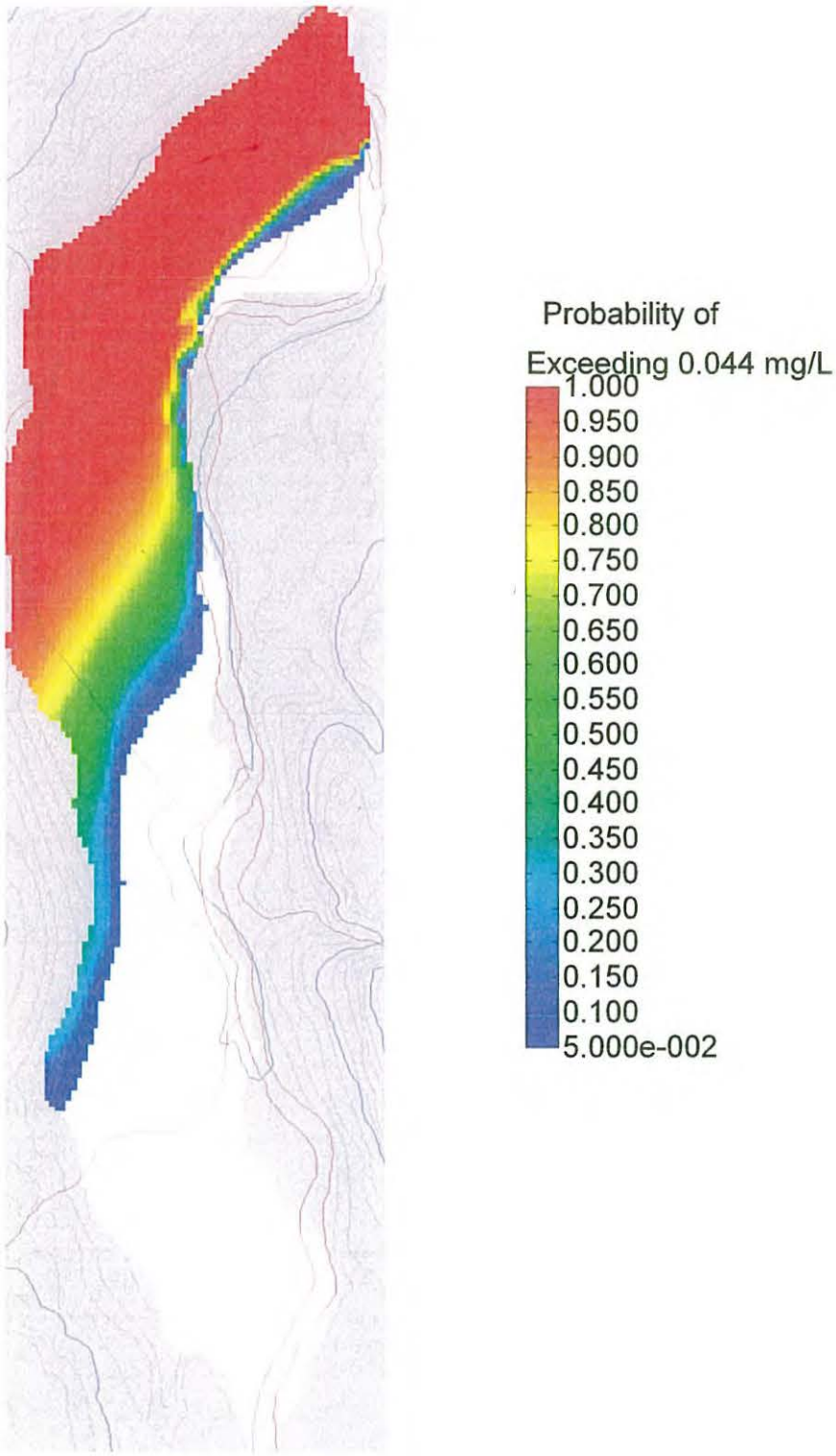


Figure 45. Probability of Uranium Concentration Exceeding the Standard at 25 Years

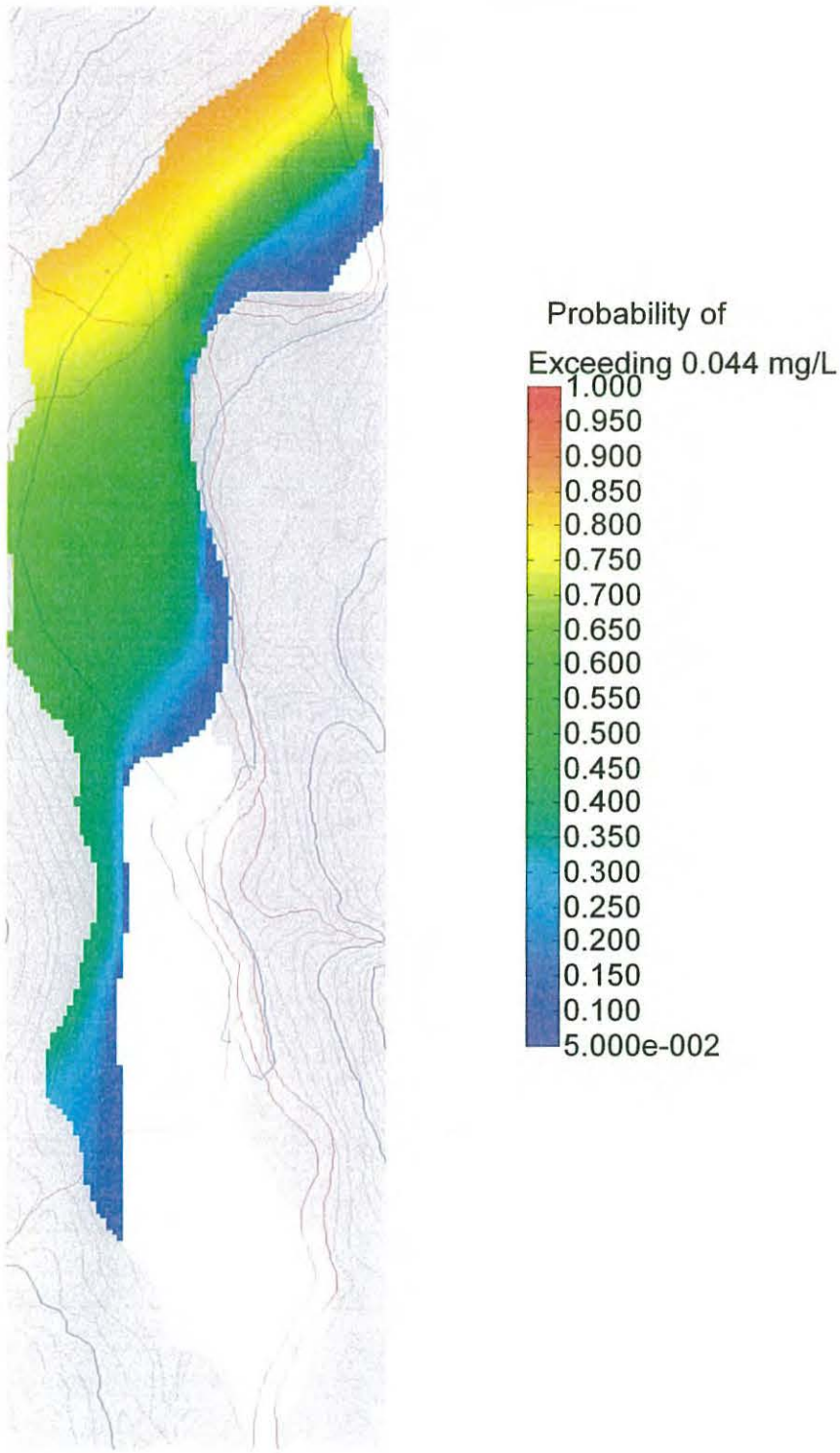


Figure 46. Probability of Uranium Concentration Exceeding the Standard at 50 Years

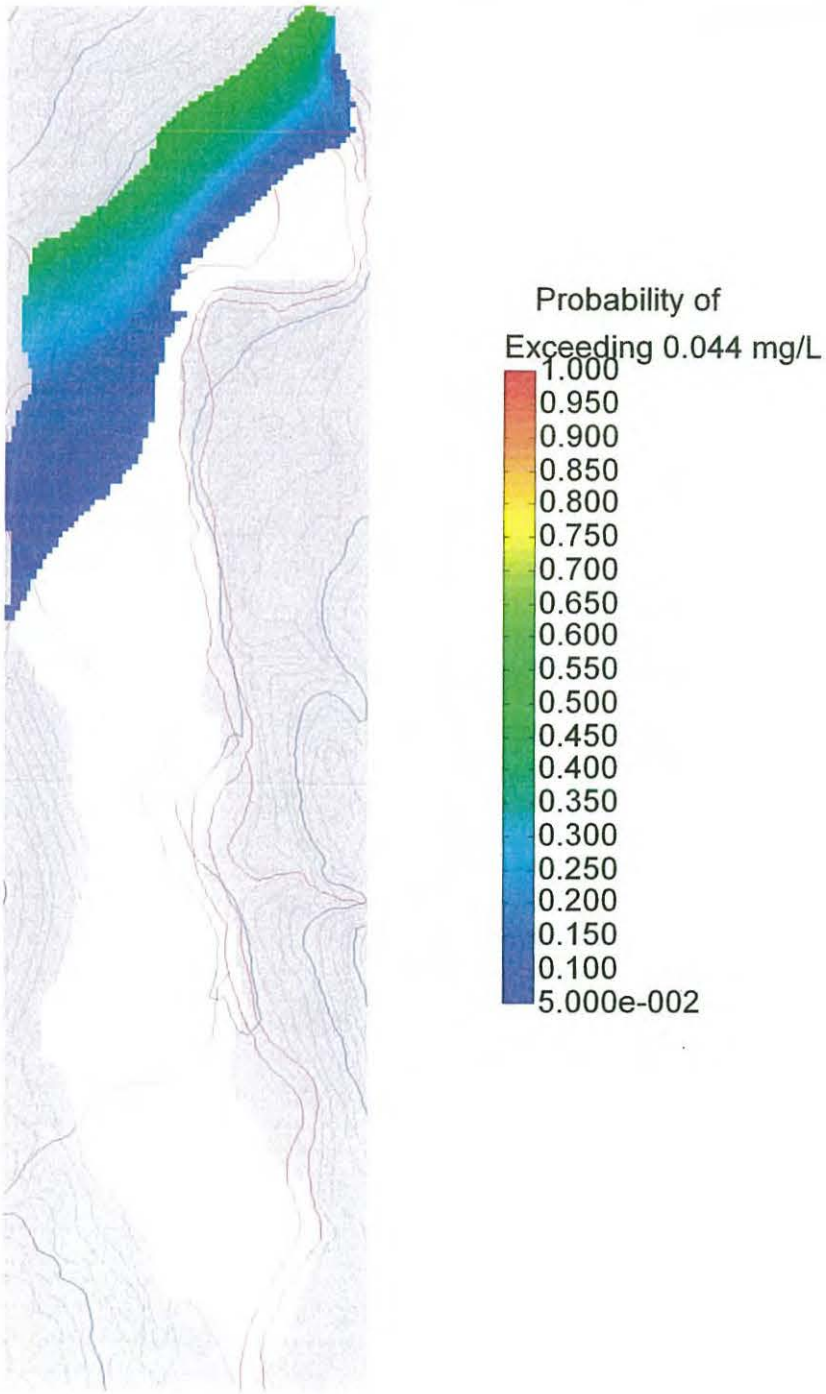


Figure 47. Probability of Uranium Concentration Exceeding the Standard at 100 Years

7.0 Pumping Followed by Natural Flushing

This modeling task could be formulated as a classical optimization problem. Optimization modeling problems inherently require considerable time and effort. Therefore, before the time and effort were committed to developing an optimization model a much simpler approach was taken to determine if there was any reasonable possibility that this strategy would succeed.

7.1 Step/Task 1

The first task is to determine to what levels will uranium and vanadium need to be reduced, by pumping, such that each will meet the required standard within 100 years of naturally flushing? To do this it was determined how long it would take uranium and vanadium to naturally flush. Modeling indicates that it would take approximately 135 years for uranium to flush and more than 1000 years for vanadium to flush to the required standards. The maximum remaining concentration of vanadium at 1,000 years is approximately 2.31 mg/L. Vanadium is not considered further in this analysis because of the extreme time required to naturally flush.

This task can now be stated differently, i.e., what is the concentration of uranium at 35 years?

The maximum remaining concentration of uranium at 35 years is approximately 1.70 mg/L. Therefore, any pumping scenario would need to reduce the contamination level for uranium to this value in order for natural flushing to reduce contamination to the required standard within 100 years of natural flushing.

7.2 Step/Task 2

The next task is to determine which wells or location should be used for pumping and what pump rates should be used? The rationale used, although obviously not optimal locations, was to select existing wells that show high concentration of either uranium or vanadium. These wells would be pumped at the highest possible rate such that the aquifer would not dry up. Four existing wells that show high concentration of either uranium or vanadium were selected as potential pumping locations. These wells are MAU08, NAT01-1, NAT03, and NAT06-1.

Initially it was decided to try pumping each well at 10 gallons per minute (gpm) or 1,925 ft^3/day. However, because of the limited saturated thickness (approximately 2 to 6 ft) and the low hydraulic conductivity, it is not possible to pump this amount of water from any of the wells.

Modeling determined the maximum pump rate that could be sustained at each of these wells, pumped individually, without drying up the area in the vicinity of the well. These values are shown in Table 11.

Table 11. Maximum Individual Pump Rates

Well	Pump Rate	
	gpm	ft^3/day
MAU08	1	192.5
NAT01-1	6	1,155.
NAT03	3	577.5
NAT06-1	3	577.5

Additional modeling determined the maximum pump rate that can be sustained, with all wells pumped simultaneously, without drying up the area in the vicinity of any of the wells. These values are shown in Table 12.

Table 12. Maximum Simultaneous Pump Rates

Well	Pump Rate	
	gpm	ft^3/day
MAU08	.5	96.25
NAT01-1	5	962.5
NAT03	2	385
NAT06-1	3	577.5

Three scenarios were modeled to determine if pumping could reduce the contamination to levels required for natural flushing to complete the cleanup. Pump scenarios were done only for uranium since the cleanup time for uranium is considerable less than for vanadium. Table 13 specifies the pump rates used in each scenario.

Table 13. Pump Rates for each Scenario

Well	Pump Rate (gpm)		
	Run 1	Run 2	Run 3
MAU08	1	1	0.5
NAT01-1	1	2	5
NAT03	1	1	2
NAT06-1	1	2	3
Total	4	6	10.5

Table 14 below shows the maximum remaining concentration at selected years for the natural flushing case (i.e., no pumping) and the three pumping scenarios.

Table 14. Maximum Remaining Concentration for each Scenario

Years	Maximum Remaining Concentration (mg/L)			
	Natural Flushing	Run 1	Run 2	Run3
0	2.5220	2.5220	2.5220	2.5220
5	2.4266	2.4358	2.4476	2.5043
10	2.3683	2.3797	2.3954	2.4873
15	2.2993	2.3285	2.3519	2.4594
25	2.0257	2.1147	2.1884	2.4077
50	1.3047	1.3527	1.4707	2.0998
60	1.0439	1.0400	1.1552	1.9028
70	0.78606	0.75038	0.85610	1.6842
80	0.55612	0.51044	0.60078	1.4563
90	0.37134	0.33101	0.40296	1.2332
100	0.23654	0.20698	0.26095	1.0258

The results, particularly for Runs 2 and 3, seem contradictory. Intuitively, it seems that if an aquifer is pumped the maximum remaining concentration at any time would be less than without

any pumping. However, the results show just the opposite. In fact, as more water is extracted from the aquifer, the higher the maximum remaining concentration. Why is this?

Two factors contribute to and cause the unexpected results. These are the saturated thickness and the low hydraulic conductivity. If the pump rate is such that the aquifer water level is drawn down to the point that the aquifer in the vicinity of a well is almost dry, there is no water moving through the soil matrix. All the water that flows toward the well is extracted from the well. The cone of depression that develops around each well will leave much of the soil matrix dry, i.e., no water flows through the soil. With no water moving through the soil, the contamination adsorbed (attached to) the soil does not dissolve into the water. Figure 50 which shows the maximum remaining concentration at 100 years for Run 3 does indeed indicate that some of the alluvial aquifer has begun to dry up.

If these results are accurate, and there appears to be a logical explanation, then pumping does not appear to be a viable alternative for reducing the concentration of uranium and vanadium to the required levels such that 100 years of natural flushing would complete the cleanup. These results indicate that it is highly unlikely that an optimization model would yield significantly different results. Therefore, the money, time, and effort to develop such a model were not expended.

Plots of the remaining uranium concentration above the MCL at 100 years for each of the three scenarios are shown in Figures 48, 49, and 50. The areas of the model in the figures that do not have color (are white) are below the MCL.

8.0 Summary and Conclusions

A ground water flow and transport model was developed to evaluate if natural processes will reduce site-related COPC concentrations to regulatory levels in the alluvial aquifer within 100 years. Several different versions of the model were developed and employed to address conditions in the vicinity of the site. A steady state deterministic flow and transport model was used as the basis for the stochastic model. A steady state stochastic flow and transport model was used to quantify the uncertainty in flow and transport parameters. Based on modeling results, natural flushing does not appear to be an acceptable compliance strategy that allows natural processes to reduce uranium and vanadium concentrations in the ground water below the standards within 100 years. Arsenic concentration level will be reduced below the standard within 10 years. A steady state deterministic flow and transport model with pumping well was used to evaluate the feasibility of pumping for a period of time followed by natural flushing. This option does not appear to be a viable alternative.

The gravel mining operation upgradient of the former site has recently expanded and it is likely that there will be future expansions. This operation was not considered in the USGS flow model and subsequently not considered in the transport modeling. The recent and future expansion of this operation could significantly impact the ground water flow and the transport of contaminants. Without modeling the impacts from the gravel mining operation, the predicted concentrations of the COPC in this report are most likely underestimated.

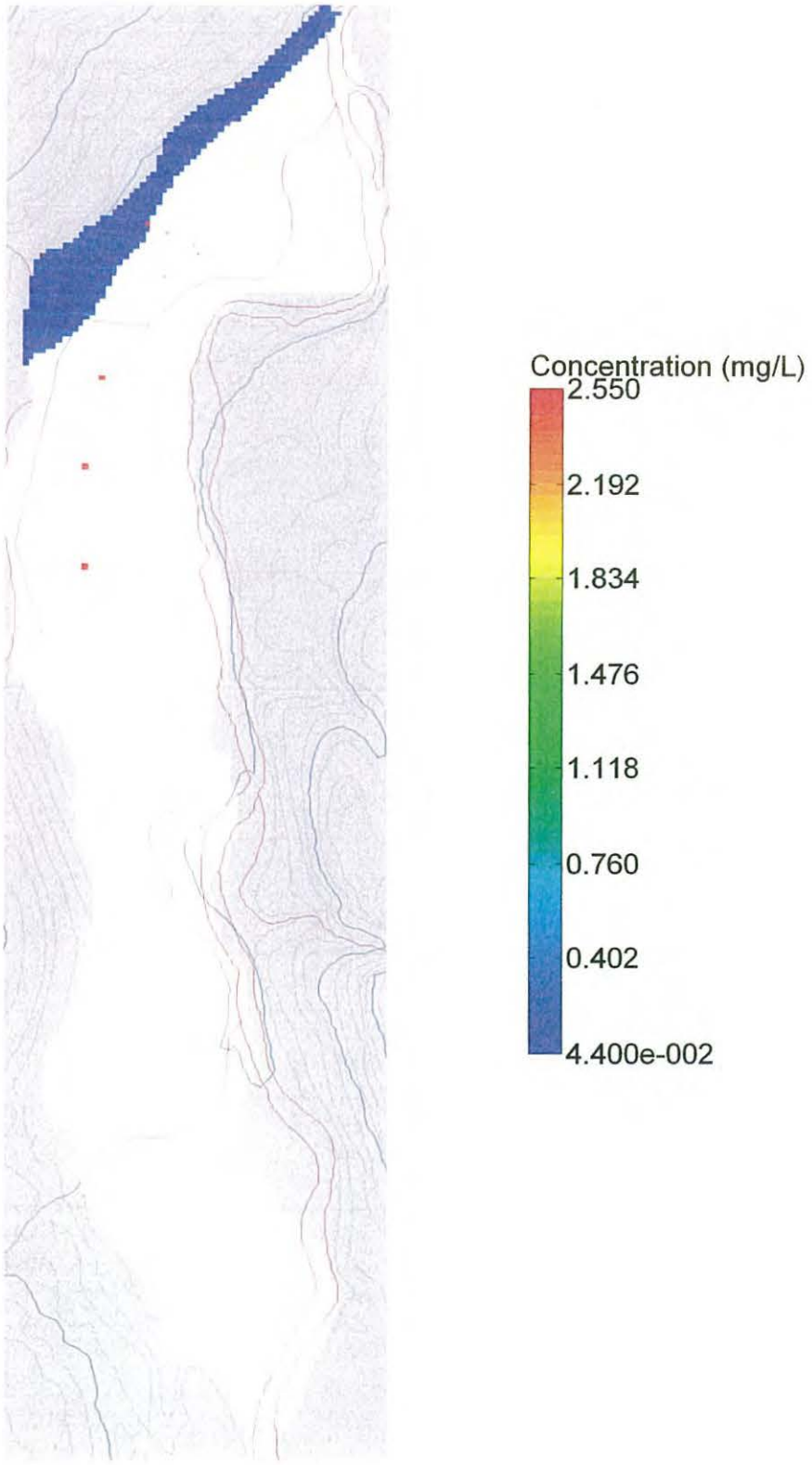


Figure 48. Uranium Concentration at 100 Years – Pump Scenario 1

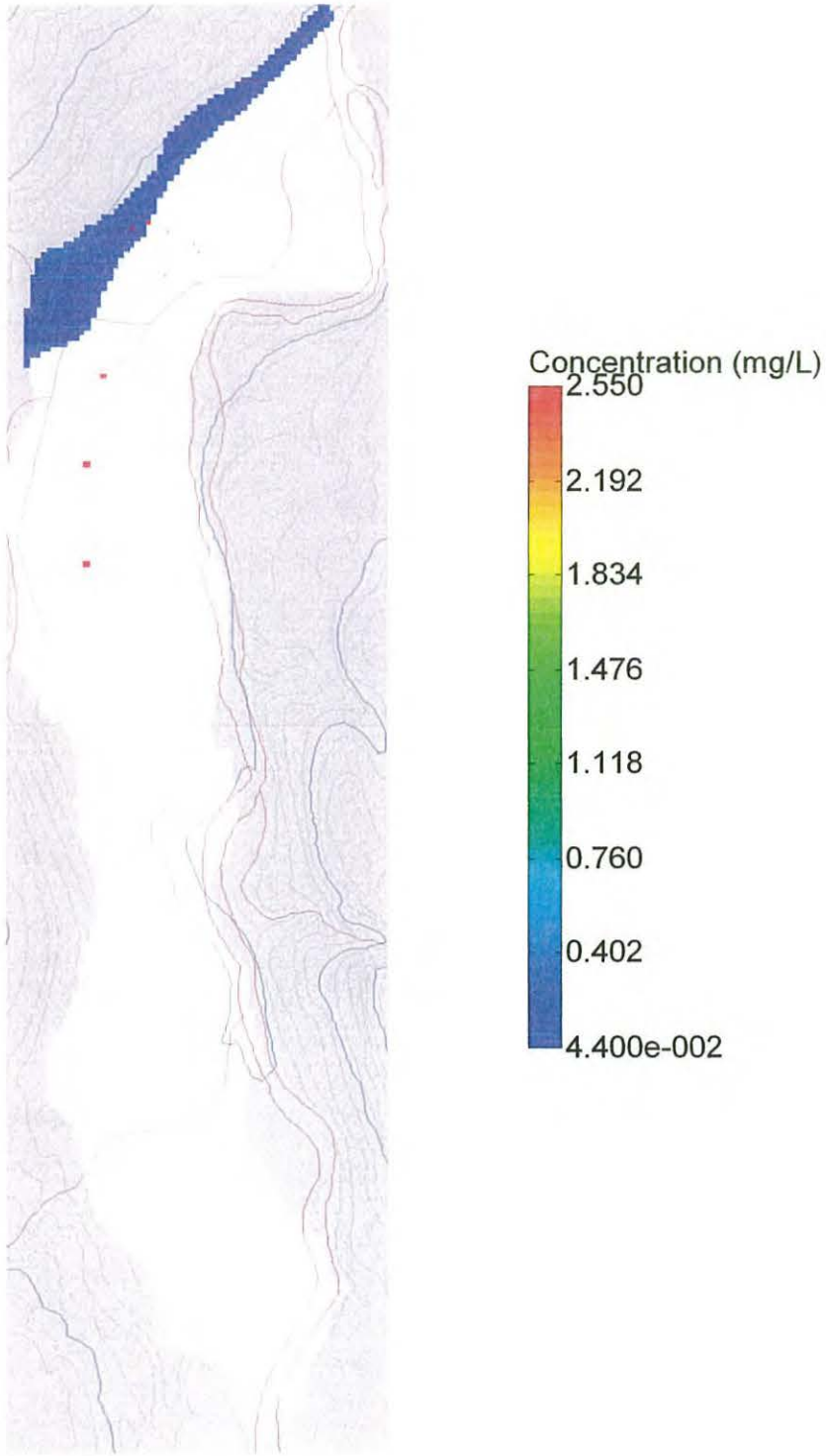


Figure 49. Uranium Concentration at 100 Years – Pump Scenario 2

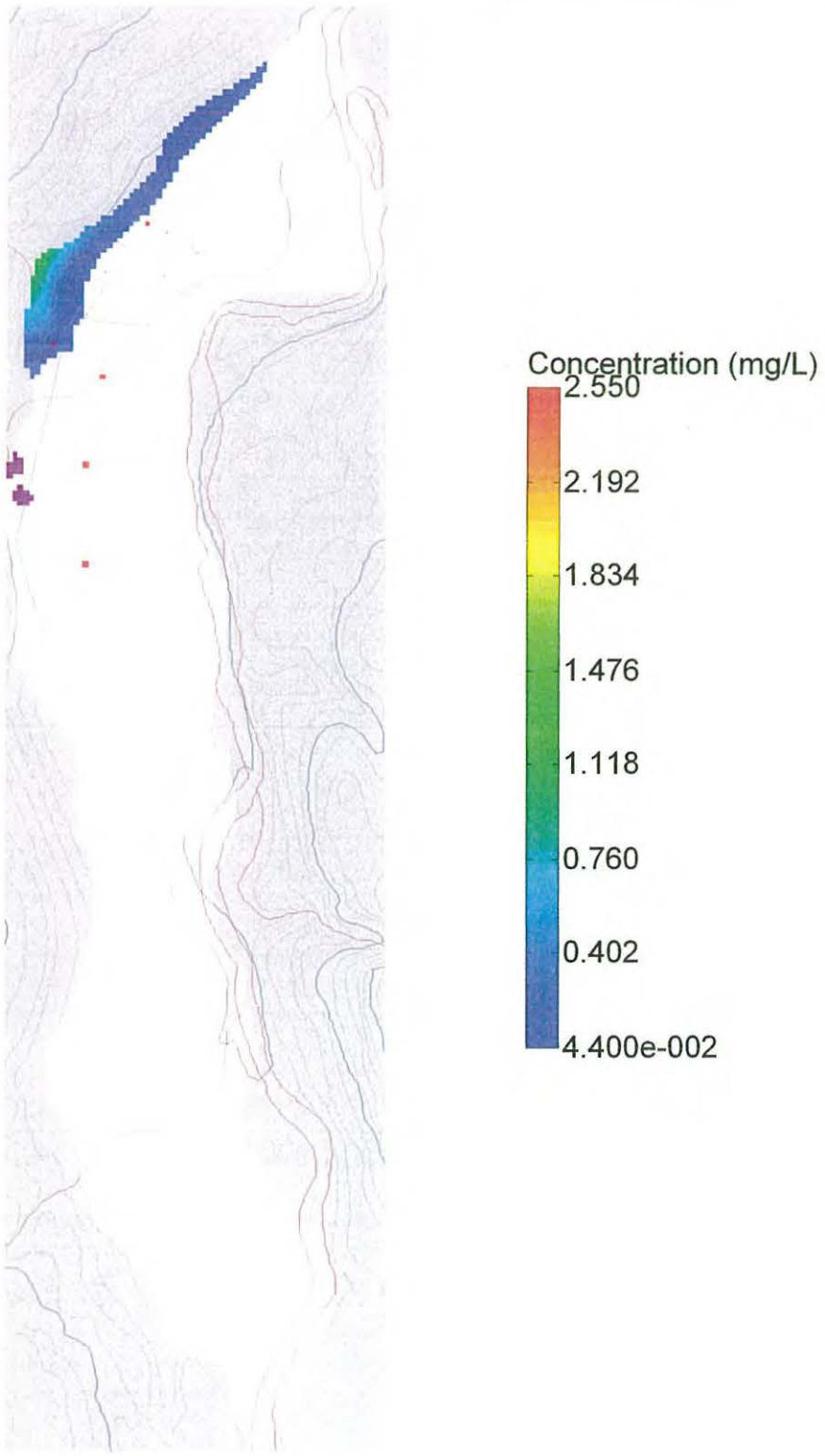


Figure 50. Uranium Concentration at 100 Years - Pump Scenario 3

8.1 Qualitative Analysis

Ground water flow patterns predicted by the steady state deterministic flow model (Figures 5 and 6) and the steady state stochastic flow model (Figures 35 and 36) closely resemble the ground water gradient measured in February 2000. This visual analysis suggests that the calibrated flow model adequately and accurately predicts the observed water level elevations.

8.2 Quantitative Analysis

Data presented in Table 1 and Figures 7 and 8 indicate that the calibrated steady state deterministic flow model satisfies the acceptance criteria and calibration objectives established before modeling. Calibration results presented in Figure 7 demonstrate that the flow model has a slight bias of underestimating water levels at the higher elevations. However, the target residuals are fairly evenly distributed, with 16 above and 25 below 0.0 ft, with a mean residual of –0.067 ft and an absolute mean residual of 0.737 ft. Results presented in Figure 8 demonstrate that the predicted hydraulic heads versus the observed heads fall on a straight line, as expected.

8.3 Model Predictions

Results of the steady state deterministic MT3DMS transport predictive simulations indicate that on average the maximum uranium concentration in the ground water at the Naturita site will not decrease to below the UMTRA Project MCL of 0.044 mg/L in 100 years (Figure 22).

The maximum predicted concentration after 100 years is 0.23654 mg/L. Results of the vanadium simulations show similar results. The maximum vanadium concentration in the ground water at the Naturita site will not decrease to below the risk-based concentration standard of 0.33 mg/L in 100 years (Figure 30). The maximum predicted concentration after 100 years is 4.3286 mg/L.

The maximum arsenic concentration in the ground water at the Naturita site will decrease to below the UMTRA Project MCL of 0.05 mg/L within 10 years. The maximum predicted concentration after 10 years is 0.045468 mg/L.

The steady state stochastic MT3DMS transport predictive simulations show similar results. Average uranium concentrations and the associated uncertainty at each time period of interest are based on 200 computer simulations. Figure 42 indicates that on average the maximum remaining concentration in the ground water (0.12087 mg/L) will not fall below the UMTRA Project MCL of 0.044 mg/L in 100 years. Furthermore, the stochastic simulations predict that at 100 years there is a 49 percent probability that the maximum concentration will be greater than the standard over a significant area of the alluvial aquifer (Figure 47). All these data suggest that there is a high probability that the remaining uranium concentration will exceed the standard, and natural flushing does not appear to be an acceptable compliance strategy.

The pumping followed by natural flushing modeling indicates that pumping water from the alluvial aquifer for a reasonable amount of time would not reduce the uranium and vanadium concentration to the required levels. Even after 25 years of pumping, the remaining uranium concentration is significantly higher than the concentration levels that would naturally flush within 100 years.

9.0 References

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Appendix G

Data Set Used in Pattern Recognition Modeling

Table 1. Chemical, physical, and isotopic data used in pattern recognition modeling at the Naturita study site. Data were collected and analyzed by the U.S. Geological Survey during June 2000.

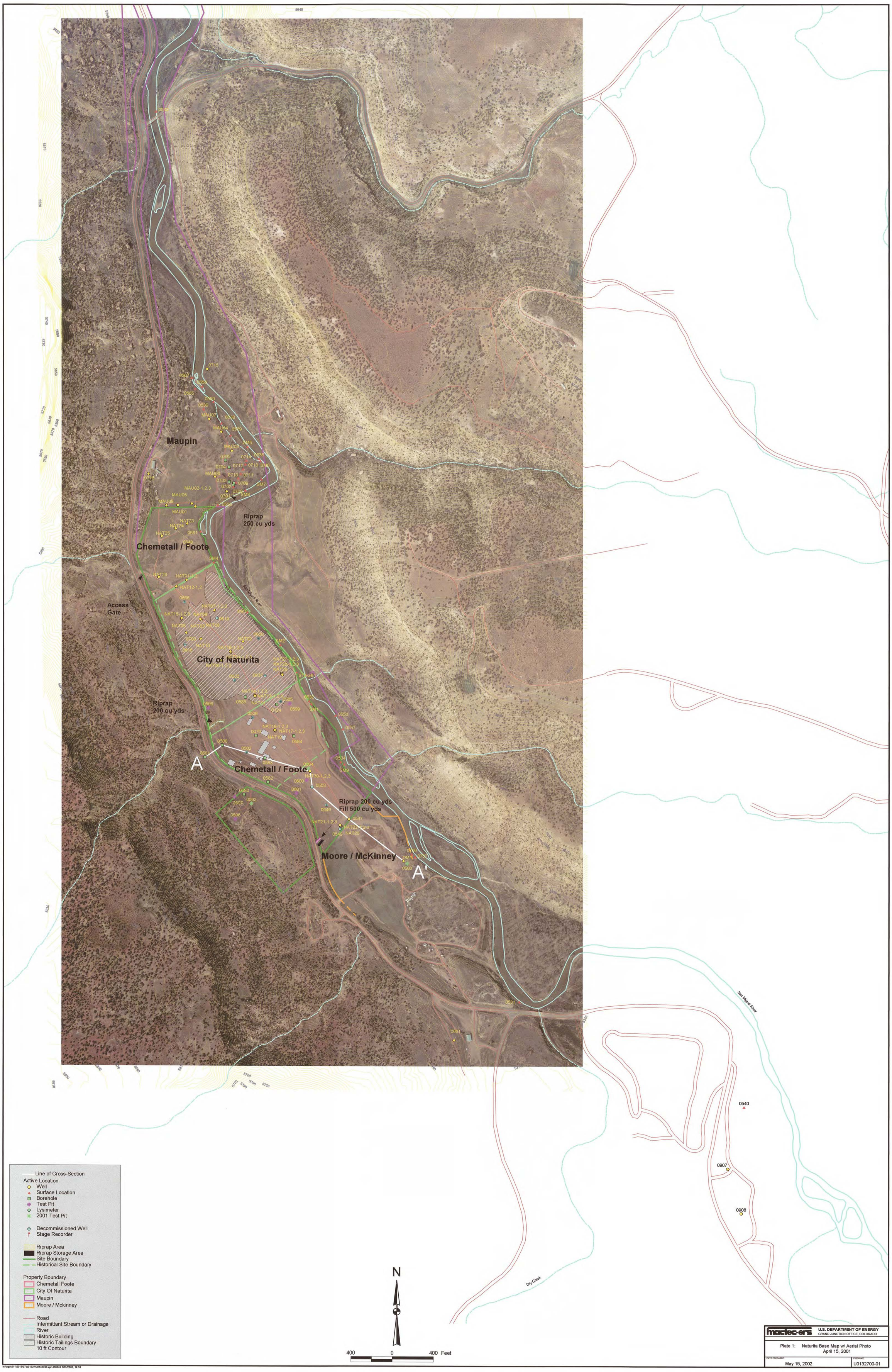
[Al, aluminum; Alk, alkalinity as calcium carbonate; B, boron, Br, bromide; Ca, calcium; Cl, chloride; DO, dissolved oxygen; Fe, iron; K, potassium; Mg, magnesium; Na, sodium; ORP, oxidation reduction potential; Si, silicon; SO4, sulfate; SC, specific conductance; Sr, strontium; T, water temperature; U, uranium; V, vanadium; $\delta^{18}O$, delta oxygen-18; δD, delta deuterium; mg/L, milligrams per liter; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter; mV, millivolts; deg. C, degrees Celsius; permil, parts per thousand]

Sample site	Al, mg/L	Alk, mg/L	B, mg/L	Br, mg/L	Ca, mg/L	Cl, mg/L	DO, mg/L	Fe, mg/L	K, mg/L	Mg, mg/L	Mn, mg/L	Na, mg/L	ORP, mV	pH, units	Si, mg/L	SO_4, mg/L	SC, µS/cm	Sr, mg/L	T, deg. C	U, µg/L	V, µg/L	$\delta^{18}O$, permil	δD, permil
DM1	0.29	227	0.04	0.1	54.1	4.7	0.35	0.29	1.85	20.3	0.32	18.2	-67	7.12	4.64	131	589	0.83	14.2	4.32	0.04	-105.58	-14.71
DOE547	0.28	160	0.04	0.1	64	11.5	0.33	0.07	1.65	28.1	0.26	32.8	120	7.1	4.5	308	864	1.11	15.3	4.66	0.04	-83.36	-9.2
DOE548	0.39	326	0.1	0.24	157	39	0.3	0.18	9.38	47.3	1.57	134	-23	7.21	6.93	566	1660	1.95	13.2	907	0.13	-99.78	-13.71
MAU01	0.41	502	0.12	25.4	224	148	0.6	0.03	21.9	106	0.89	259	221	6.8	8.46	950	2890	4.8	14	710	0.04	-97.46#	-12.82#
MAU02-2	0.32	359	0.08	1.49	180	49	0.27	0.36	8.47	52.6	3.07	127	44	6.9	6.74	597	1820	2.34	13.7	646	0.04	-100.22	-13.52
MAU02-3	0.32	365	0.08	1.57	179	53	0.32	0.44	8.91	56.6	3.93	128	69	6.95	7.09	611	1880	2.48	12.1	535	0.04	-99.8	-13.52
MAU03	0.28	229	0.04	0.07	60.2	8	0.73	0.12	2.15	26.8	1.12	27.3	116	7.12	6.31	210	818	1.1	14.6	106	0.04	-105.0	-14.39
MAU04	0.29	269	0.06	0.14	61.8	15	0.25	1.32	2.62	33.1	1.35	38.4	-76	6.95	7.01	233	945	1.18	15.1	172	0.04	-102.62#	-14.11#
MAU05	0.37	369	0.09	0.55	193	57	0.4	0.75	6.81	55.2	4.84	141	-8	6.99	7.22	639	1900	2.52	*12.9	331	0.04	-100.5	-13.48
MAU06	0.29	221	0.04	0.15	60.7	8.2	1.05	0.25	2.95	29.4	0.42	20.8	95	7.17	6.43	219	807	1.18	11.9	62.3	0.04	-104.96	-14.28
MAU07	0.36	397	0.1	0.36	193	70	0.32	1.88	5.5	65.6	1.59	136	-64	6.83	7.56	614	1910	2.64	14.7	525	0.04	-96.98	-13.26
MAU08	0.41	464	0.11	15.4	273	262	1.64	1.52	40.2	93.8	1.35	374	1	6.9	6.99	1200	3550	4.69	13.1	1660	0.04	-94.4	-12.71
NAT01-1	0.37	359	0.14	0.58	214	80	0.26	1.53	11.4	64.1	2.1	231	-68	7.1	6.93	904	2380	2.59	13.1	1230	0.04	-99.3#	-12.87#
NAT01-2	0.38	346	0.14	0.42	222	82	0.21	2.46	12.2	66.3	2	230	-68	7.11	7.11	924	2400	2.92	19.6	1200	0.04	-99.3#	-12.87#
NAT02	0.28	314	0.08	9.15	131	17	0.86	0.09	36.9	36.6	0.33	63.8	-23	7.25	5.14	376	1290	1.59	15	439	2.25	-100.38	-13.49
NAT03	0.36	365	0.12	11.8	194	50	0.34	0.04	20.7	59.3	0.94	178	-18	7.17	7.92	734	2060	2.29	14.9	1030	4.88	-99.33	-13.43
NAT04-1	0.39	389	0.11	0.4	195	40	0.43	0.03	13.2	55.1	0.81	159	171	7.02	7.36	686	1900	2.2	12.8	697	2.78	-96.57	-13.02
NAT04-2	0.35	361	0.1	0.58	195	40	0.29	0.03	12.1	54.6	0.78	156	143	7.01	7.33	686	1900	2.2	13.3	684	2.9	-96.57#	-13.02#
NAT04-3	0.41	371	0.1	0.4	194	40	0.29	0.03	12.1	54.6	0.78	155	137	7.01	7.35	688	1890	2.18	13.5	678	2.93	-96.57#	-13.02#
NAT05	0.38	405	0.15	0.4	184	140	0.64	0.05	13.4	82.3	1.25	366	22	7.12	8.42	1110	3040	3.3	14.5	1540	4.54	-99.23	-13.17
NAT06-1	0.39	401	0.14	0.46	224	68	0.3	0.14	20.1	66.8	1.03	247	-29	6.95	7.83	970	2510	2.62	13.4	1170	2.57	-100.7#	-13.59#
NAT06-2	0.34	401	0.13	0.46	225	64	0.27	0.03	20.2	65.8	1.1	243	23	6.92	7.81	962	2510	2.61	13.5	1160	3.17	-99.37#	-13.45#
NAT07-1	0.29	330	0.07	1.3	150	22	0.28	0.06	11.2	36.2	0.56	78.8	46	7.11	6.17	403	1330	1.33	13.9	509	1.87	-101.81#	-13.76#
NAT07-2	0.32	326	0.07	0.9	151	21.5	0.28	0.05	10.6	36.1	0.52	77.9	75	7.09	6.12	402	1330	1.33	14.4	493	2.07	-100.65#	-13.69#

NAT07-3	0.31	324	0.08	0.79	152	21.5	0.34	0.03	9.8	36.7	0.48	77	98	7.1	6.2	404	1370	1.36	14.6	493	2.23	101.23#	-13.72#
NAT08	0.29	379	0.11	0.4	189	50	0.26	0.05	16.4	58.7	1	176	-50	7.16	7.75	724	2030	2.24	13.3	1010	5.65	-101.97	-13.57
NAT09	0.33	379	0.11	1.36	195	54	0.54	0.03	16.1	61.3	0.81	182	54	7.13	8.09	750	2080	2.47	14.3	1050	4.54	-100.98	-13.53
NAT10	0.32	389	0.12	1.62	217	60	0.32	0.05	19.9	63.1	0.91	208	-37	7.1	7.77	862	2300	2.49	13.3	1080	5.51	-101.18	-13.44
NAT11	0.37	389	0.14	4.8	227	66	0.31	0.05	17.2	69.5	1.99	248	19	6.96	8.16	992	2560	3.2	13.4	994	1.64	-102.17#	-13.34#
NAT12-1	0.31	407	0.17	1.98	204	126	0.82	0.05	7.72	75.2	2.56	331	115	7.06	6.93	1100	2980	3.32	14.2	1120	0.04	-95.74#	-12.56#
NAT13-1	0.36	415	0.12	0.42	217	62	0.31	0.3	16.4	64.8	1.97	235	-35	7.07	7.93	922	2390	2.91	13.3	983	1.85	-97.3	-13.08
NAT13-2	0.32	409	0.12	0.58	213	58	0.27	0.75	14.9	68	1.92	233	-76	7.06	8.35	934	2400	3.15	13.8	955	1.59	-96.86	-12.95
NAT13-3	0.38	415	0.15	0.64	221	60	0.2	1.15	12.9	71.6	1.88	233	-59	7.07	8.59	958	2410	3.55	14.3	918	1.47	-96.01	-12.89
NAT14-1	0.38	413	0.12	0.44	219	56	0.24	0.27	14.8	67.7	1.93	229	-49	7.05	8.24	930	2390	3.12	13.7	949	2.5	-97.07	-12.86
NAT14-2	0.32	415	0.13	0.54	220	56	0.23	0.34	14	69.4	1.91	228	-52	7.05	8.42	934	2430	3.26	13.9	933	2.36	-96.42	-12.84
NAT14-3	0.28	413	0.15	0.52	223	58	0.23	0.32	13.5	73	1.93	230	-64	7.07	8.73	972	2470	3.37	14.5	908	2.11	-97.22	-12.87
NAT15-1	0.29	452	0.15	0.42	184	132	0.37	0.38	14	81.8	1.32	352	-37	7.12	8.49	1100	3010	3.27	13.8	1510	4.48	-98.48#	-12.97#
NAT15-2	0.31	425	0.14	0.52	183	138	0.3	0.07	14.2	82.2	1.25	362	-88	7.14	8.49	1120	3090	3.32	13.7	1550	5.23	-98.48#	-12.97#
NAT15-3	0.28	407	0.14	0.52	183	136	0.28	0.11	14.2	82	1.25	359	-58	7.14	8.51	1110	3110	3.28	14.4	1560	5.16	-98.48#	-12.97#
NAT16-1	0.3	361	0.09	0.36	191	39	0.27	0.29	12.7	54.7	0.79	152	41	6.98	7.32	686	1900	2.15	13.5	669	3.1	-101.17#	-13.35#
NAT16-2	0.31	365	0.09	0.43	190	38	0.25	0.22	12.5	54.5	0.78	152	-20	6.99	7.34	684	1900	2.17	13.9	675	3.19	-101.17#	-13.35#
NAT16-3	0.28	361	0.09	0.48	195	38	0.27	1.22	12.7	55	0.77	153	-97	6.98	7.35	684	1900	2.18	14.1	685	2.41	-101.17#	-13.35#
NAT17-1	0.3	373	0.05	0.29	210	35	0.25	0.28	5.16	59.1	1.31	146	-15	6.9	6.05	726	1920	2.36	13.6	90.8	0.33	-94.5	-12.67
NAT17-2	0.28	381	0.06	0.45	207	35	0.24	0.64	5.46	58.9	1.27	146	-57	6.92	6.13	723	1910	2.33	13.4	91.9	0.21	-93.16	-12.66
NAT17-3	0.36	369	0.07	0.7	205	41	0.29	0.33	6.6	61.2	1.1	153	-13	6.92	6.25	735	1950	2.55	14.3	102	0.29	-94.98	-12.68
NAT18-1	0.36	385	0.06	0.25	209	41	0.33	0.06	5.8	60.7	1.16	152	85	6.86	6.18	735	1960	2.49	14.6	90.9	0.55	-94.27	-12.63
NAT18-2	0.36	369	0.05	0.3	209	36	0.28	0.17	5.08	59.5	1.28	147	21	6.89	6.05	730	1930	2.38	13.4	86.6	0.37	-95.38	-12.69
NAT18-3	0.36	365	0.06	0.27	211	34	0.26	0.31	4.97	59.1	1.31	147	-14	6.86	6.06	722	1920	2.37	13.4	91	0.3	-94.62	-12.65
NAT19	0.32	353	0.07	0.2	207	36	0.69	0.24	4.72	59.4	1.26	145	20	6.91	6.01	722	1960	2.35	14.1	85.4	0.31	-93.54	-12.63
NAT20	0.28	231	0.05	0.12	64.1	11	0.43	0.17	2.55	30.9	0.04	40.7	79	7.1	5.17	324	963	1.19	14.4	12.9	0.04	-85.4	-9.9
NAT21-1	0.3	274	0.05	0.1	65.6	10.5	0.32	0.43	2.71	31.6	0.04	42.2	-14	6.97	5.32	320	1020	1.23	14.4	13.7	0.04	-90.52	-10.93
NAT21-2	0.28	239	0.05	0.1	64.2	10.5	0.3	0.03	2.65	31.5	0.04	42.1	-34	6.99	5.33	319	1020	1.22	15.5	12.9	0.04	-89.09	-10.72
NAT22-1	0.28	261	0.05	0.1	64.9	10.5	0.28	0.5	3.34	31.5	0.04	42.5	68	6.94	5.43	319	1020	1.22	14.9	14.9	0.04	-90.89	-11.1
NAT22-2	0.28	253	0.05	0.11	64.6	10.5	0.25	0.03	2.7	31.2	0.04	42.8	67	6.96	5.36	318	1020	1.22	15.4	14.6	0.04	-89.57	-11.03
NAT23	0.33	332	0.1	0.34	168	43	0.52	0.11	9.99	45.7	0.12	135	57	6.76	7.26	577	1730	2.03	15.4	710	0.04	-100.99	-13.69
NAT24	0.29	340	0.11	0.48	170	54	0.37	0.33	11.9	51.1	1.47	170	23	6.94	6.94	658	1910	2.04	12.4	945	0.04	-98.51#	-13.28#
NAT25	0.42	515	0.14	0.98	228	292	0.37	0.66	12	73.1	0.34	532	-28	6.88	6.99	1250	3870	3.7	12.5	1840	0.04	-94.03	-12.47
NAT26	0.35	549	0.43	4.8	195	632	0.68	0.03	23.1	91.4	0.35	912	146	7.05	6.02	1690	5720	4.54	13.8	2410	0.04	-91.25#	-11.94#
NAT27-1	0.28	312	0.09	24	137	71	0.23	0.04	9.61	53.1	0.97	74.9	65	7.28	6.38	435	1750	2.57	15.2	237	0.26	-99.27	-13.31
NAT27-2	0.29	300	0.11	26	148	73	2.76	0.03	12.4	59.9	0.62	84.4	122	7.32	6.76	440	1620	3.21	18.3	218	0.13	-99.16	-13.18

NAT28-1	0.3	304	0.08	47	111	47	0.24	0.04	26.8	47.7	1.24	65.9	66	7.3	6.37	446	1570	2.58	15.1	248	0.12	-99.96	-13.38
NAT28-2	0.28	302	0.1	41	128	39	1.57	0.03	26.2	55.5	1.36	70.3	112	7.32	6.86	425	1570	3.27	18.4	245	0.05	-100.39	-13.34
NAT29	0.37	300	0.15	11.5	183	42	4	0.04	8.9	68.5	0.85	81.4	176	7.17	8.38	580	1650	5.22	*16.75	258	0.04	-98.46	-13.35
NAT30-1	0.3	292	0.05	0.1	116	11	0.36	0.19	2.85	32.7	0.87	45	28	6.97	6.36	324	1080	1.4	15.3	15	0.04	-89.41	-12.11
NAT30-2	0.28	308	0.05	0.1	120	11	0.6	0.17	2.94	33	0.83	45.2	26	6.94	6.46	327	1110	1.4	15.7	16.2	0.04	-90.13	-12.02
SM1	0.29	71	0.04	0.08	35.6	1.72	7.64	0.03	0.93	6.77	0.04	4.96	78	8.54	2.66	64.8	241	0.4	16.6	0.84	0.04	-106.89#	-14.29#

* Actual data missing, value estimated from adjacent wells during June 2000 sampling period.
# Actual data missing, value substituted from March 2000 data or set equal to value at the adjacent sample point in each multi-completion well cluster.


Maupin
Chemetall / Foote
City of Naturita
Riprap
250 cu yds
Access
Gate
Riprap
200 cu yds
A
Chemetall / Foote
Riprap 200 cu yds
Fill 500 cu yds
Moore / McKinney
A'
San Miguel River
Dry Creek
Line of Cross-Section
Active Location
Well
Surface Location
Borehole
Test Pit
Lysimeter
2001 Test Pit
Decommissioned Well
Stage Recorder
Riprap Area
Riprap Storage Area
Site Boundary
Historical Site Boundary
Property Boundary
Chemetall Foote
City Of Naturita
Maupin
Moore / Mckinney
Road
Intermittant Stream or Drainage
River
Historic Building
Historic Tailings Boundary
10 ft Contour
N
400 0 400 Feet
U.S. DEPARTMENT OF ENERGY
GRAND JUNCTION OFFICE, COLORADO
Plate 1: Naturita Base Map w/ Aerial Photo
April 15, 2001
May 15, 2002
U0132700-01