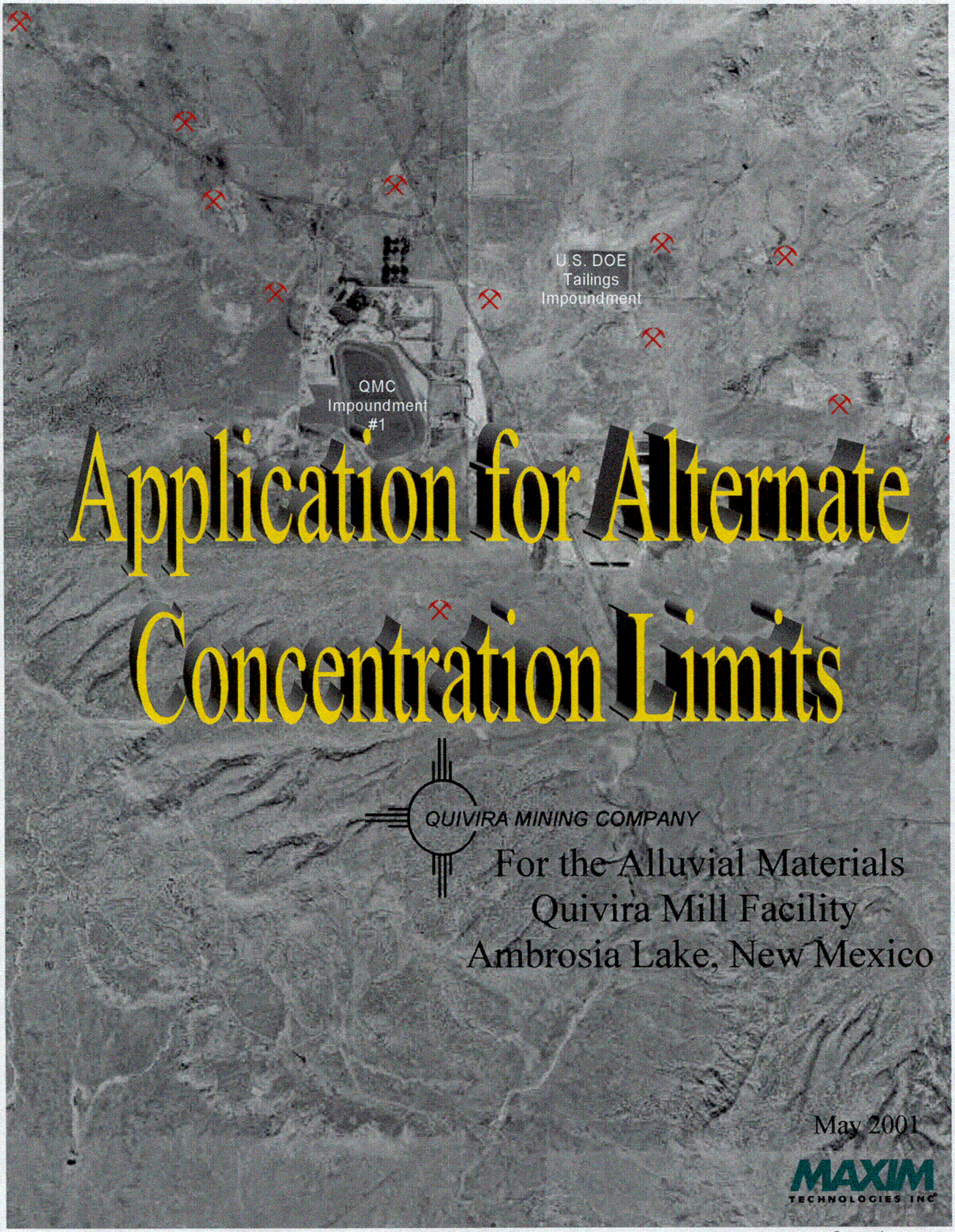

Application for Alternate Concentration Limits

QUIVIRA MINING COMPANY

For the Alluvial Materials
Quivira Mill Facility
Ambrosia Lake, New Mexico

May 2001

MAXIM TECHNOLOGIES INC

C01

APPLICATION FOR ALTERNATE CONCENTRATION LIMITS IN THE ALLUVIAL MATERIALS AT THE QUIVIRA MILL FACILITY AMBROSIA LAKE, NEW MEXICO

Prepared for
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MAY 2001

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ACRONYM/ ABBREVIATION	DEFINITION
10E-09 uCi/ml	10^{-9} microCuries per Milliliter
ACL	Alternate Concentration Limits
ALARA	As Low As Reasonably Achievable
CAP	Corrective Action Program
DOE	U.S. Department of Energy
ft/d	Feet per Day
ft^2/d	Square Feet per Day
ft^3/d	Cubic Feet per Day
g/L	Grams per Liter
gpm	Gallons per Minute
mg/L	Milligrams per Liter
NRC	Nuclear Regulatory Commission
pCi/L	picoCuries per Liter
POC	Point of Compliance
POE	Point of Exposure
TDS	Total Dissolved Solids
UMTRA	Uranium Mill Tailings Remedial Action
UTL	Upper Tolerance Limit
U-nat	Natural Uranium
EPA	U.S. Environmental Protection Agency
ppm	Parts per Million
ppb	Parts per Billion
NOAEL	No Observed Adverse Effects Level
MCL	Maximum Contamination Level
GPS	Groundwater Protection Standard
TRC	Tres Hermanos Sandstone Unit C
TRB	Tres Hermanos Sandstone Unit B
TRA	Tres Hermanos Sandstone Unit A

ACRONYM/ ABBREVIATION	DEFINITION
GA	Gross Alpha
NPDES	National Pollution Discharge Elimination System

1 INTRODUCTION

Rio Algom Mining Corporation/Quivira Mining Corporation (QMC) submits this application for Alternate Concentration Limits (ACLs) that are protective of human health and the environment to replace the current cleanup standards used for the corrective action program (CAP) for groundwater in the Alluvium at QMC's uranium mill in Ambrosia Lake, New Mexico. This CAP, conducted in compliance with U.S. Nuclear Regulatory Commission (NRC) Source Materials License SUA-1473 and implemented in 1989, was designed to abate milling-related impacts to groundwater by reducing concentrations of constituents of concern at point of compliance (POC) wells to groundwater protection standards (GPS) set forth in the license. The current CAP has reduced constituent concentrations, however GPS have not been met. This document will demonstrate that these standards are impractical and unattainable because of ambient groundwater conditions.

This document addresses groundwater in the Alluvium of the Arroyo del Puerto (Alluvium) at the facility. An ACL Application for groundwater in the upper bedrock units has already been submitted to the NRC by letter in February 2000 (AVM 2000). The Alluvium is a 0-100 foot thick unit consisting of fine, clay-rich sand or sandy clay that overlies bedrock units in the Ambrosia Lake Valley.

A number of sources, including mine pumping and discharge, seepage from the nearby U.S. Department of Energy (DOE) Facility and runoff/erosion from abandoned mine spoils and ore piles, have contributed constituents to the alluvial groundwater. These sources have resulted in widespread ambient groundwater contamination that is unrelated to but inseparable from milling impacts. An estimation of the constituent concentrations in areas not impacted by QMC milling is presented in Appendix A. The current GPS, based on water quality from a single monitor well completed in the Alluvium, are unrealistic due to high ambient concentrations of constituents in the vicinity. It is not technically feasible to reduce constituent concentrations at the POC wells to the GPS due to the ambient conditions in the Alluvium. However, naturally occurring geochemical and hydrologic processes do reduce constituent concentrations by removing constituents from groundwater along its flowpath, resulting in acceptable health based risks at the point of exposure (POE).

Saturated conditions within the Alluvium are a result of mine water discharge to the surface during the 40 years of uranium mining throughout the Ambrosia Lake district. The Alluvium was dry when mining began and never was and never will be a groundwater resource. Once the discharge of treated mine water to the Arroyo del Puerto is halted, the Alluvium will dewater, and naturally occurring, geochemical processes will reduce constituent concentrations within the QMC restricted area boundary, resulting in the protection of human health and the environment at the POE. This specific approach for groundwater corrective action has been accepted and approved by the NRC at the DOE Ambrosia Lake Uranium Mill Tailings Remedial Action (UMTRA) facility located one mile east of the QMC Facility.

This application for ACLs is submitted in accordance with 10 CFR 40, Appendix A (Criteria 5B(5) and 5B(6)), and follows the ACL application guidance the *Standard Format and Content Guide for Alternate Concentration Limit Applications* (NRC 1996). The application includes a characterization of ambient conditions at the facility, a hazard assessment, a corrective action assessment, and proposed ACLs.

1.1 Physical Setting and Facility Background

1.1.1 Location

Ambrosia Lake Valley is located in McKinley County, New Mexico, approximately 20 miles due north of Grants in a remote part of central New Mexico (Figure 1.1). The QMC Facility is within the Ambrosia Lake Uranium District, in portions of Sections 30, 31, and 32, Township 14 North, Range 9 West, Sections 5 and 6, Township 13 North, Range 9 West, and Section 1, Township 13 North, Range 10 West (Figure 1.2).

1.1.2 Facility History

Activities at the facility started in 1957. A water storage reservoir was constructed to contain mine water for mill use and unlined evaporation Ponds 4, 5, and 6 were constructed in 1957 for evaporative treatment of mine water and mill effluents. Tailings Impoundments 1 and 2 and Pond 3, located at the eastern toe of Tailings Impoundment 1 for decant of the tailings impoundments, were built in late 1958. The tailings were first produced in November 1958. The solid portions of the process were disposed through a slurry transfer system to the tailings impoundments, while the liquid fraction was transferred to evaporation ponds. Evaporation pond residues from Ponds 3, 4, 5, 6, 7, and 8 were placed in Tailings Impoundments 1, 2, and 3 when closure activities were started.

The previously dry portions of the Alluvium have been recharged by the following: seepage and discharges at other uranium mining and milling operations in the vicinity, discharge of treated mine water from the facility, and seepage from the tailings impoundments and from evaporation Ponds 3 through 6.

The unlined evaporation Ponds 7 and 8, built in 1961, and Tailings Impoundments 1 and 2 overlie bedrock, while unlined Ponds 3, 4, 5, and 6 are within the Alluvium. The unlined evaporation Ponds 4, 5, and 6 were not used during the years 1960 to 1975. Instead, the water was diverted to ponds atop Tailings Impoundments 1 and 2 and to the unlined evaporation Ponds 7 and 8. During the 15-year time span when unlined evaporation Ponds 4, 5, and 6 were not used, the channel and Alluvium continued to receive water from solutions seeping from Tailings Impoundments 1 and 2 and Pond 3 and from the continued discharge of treated mine water. The infiltration and percolation of this water created an area of saturation along the stream channel, slowly saturating the Alluvium.

In 1976, the natural stream course of the Arroyo del Puerto, which carries National Pollution Discharge Elimination System (NPDES) permitted mine water discharge, was diverted from its natural course just east of Pond 3 to its current location along the northern and eastern restricted area boundary. This placed the Arroyo del Puerto channel to the east of the unlined Ponds 4, 5, and 6, and also east of the lined Ponds 9 and 10 which were constructed in 1976. Following the channel relocation, unlined Ponds 4, 5, and 6 were placed back into service to hold and evaporate excess process solutions.

In 1983, QMC entered into an assurance of discontinuance (AOD) with the State of New Mexico to minimize the future impact of mill tailings solutions seeping into the Alluvium. The approved AOD remedial action plan required the construction and maintenance of an Interceptor Trench and discontinuing the use of all unlined evaporation Ponds, including Ponds 4, 5, 6, 7 and 8. These ponds were taken out of service in 1983 and all solutions were removed.

Construction of the trench was initiated in 1984. The interceptor trench was intended to prevent tailings seepage from entering the Alluvium and to create a local hydrologic gradient towards the trench. This gradient caused the solutions in the Alluvium to the east of the interceptor trench to flow towards the trench for recovery and removal from the unit. Alluvial material in the area of the trench was removed down to the underlying Mancos shale or sandstone contact. The completed trench extends approximately 6,200 feet on the down gradient side of Tailings Impoundment 1 along the northern, eastern, and southern toe of the pile (Figure1.2).

Completed to a maximum excavation depth of 36 feet, the trench has effectively captured seepage from the tailings impoundment, thereby preventing further migration of seepage to the Alluvium. Due to the depth of excavation, the hydrologic gradient east of the interceptor trench has been reversed from its normal easterly direction to a westerly gradient. The reversed gradient created by the interceptor trench combined with the recharge of the fresh water from the re-aligned channel of the Arroyo del Puerto has been effective in flushing the Alluvium in the vicinity of the former Ponds 4, 5 and 6.

1.1.3 Groundwater Protection Program

On June 1, 1986, the State of New Mexico relinquished its licensing authority over uranium milling activities. The NRC reasserted its regulatory jurisdiction over New Mexico uranium processing facilities. As a result of the new regulatory jurisdiction, QMC submitted a detection monitoring plan to the NRC on January 29, 1988 for the hydrogeologic units that could potentially be impacted by processing of uranium ore and disposal of by-product material at the facility. The hydrogeologic units addressed by the groundwater protection program were the Tres Hermanos A Sandstone Unit (TRA), the Tres Hermanos B Sandstone Unit (TRB), the Dakota Sandstone Unit (Dakota) and the Alluvium. The Detection Monitoring Plan was submitted pursuant to the NRC's newly adopted 10 CFR 40, Appendix A, Criteria 7 regulations that had became effective on December 14, 1987. Upon plan approval, the NRC established its groundwater protection program for the facility.

Following the review of data from the groundwater detection monitoring program sampling events, the NRC established GPSs for hazardous constituents in groundwater at the POC wells for the TRA, TRB, Dakota and the Alluvium. The GPS for all hazardous constituents, except combined radium, were set at "background" concentrations determined from sampling events in October 1988 from one background well in each of the aquifers.

1.1.3.1 Alluvial Groundwater Corrective Action Program

The Alluvium within the Ambrosia Lake valley was dry prior to mining. With the commencement of mining activities in the area during the 1950s, dewatering of the mines resulted in the following two actions: 1) development of a cone of depression within the underlying geologic units (Tres Hermanos, Dakota and Westwater) and 2) recharge into the Alluvium.

QMC initiated the following corrective actions to mitigate water migration: 1) re-alignment of the Arroyo del Puerto in 1976 to divert surface water flows around the evaporation ponds; 2) discontinued use and removal of ponded solutions from all unlined evaporation ponds; and 3) construction of an interceptor trench adjacent to Tailings Impoundment 1. As a result of the interceptor trench forming a reverse hydraulic gradient within the Alluvium in the vicinity of the trench, the NPDES discharge water from the Arroyo del Puerto infiltrates and flushes the Alluvium from the NPDES creek towards the interceptor trench. This has resulted in improved water quality within the impacted Alluvium. These corrective actions are still in operation.

In excess of 82 million gallons of water consisting of impacted water and the groundwater sweep program (described in Section 1.3.2.1) were recovered and removed from the Alluvium via the interceptor trench and disposed within lined evaporation ponds during the period of July 1998 through June 1999. This volume also included storm water runoff that accumulated within the trench.

In addition to the flushing action, geochemical processes act upon the water present within the Alluvium. These processes result in neutralization of groundwater and reduced solubility of many inorganic constituents.

1.1.4 Surrounding Land and Water Use

Utilization of groundwater in the Ambrosia Lake area can be divided into two categories: 1) irrigation, and 2) domestic/stock watering. Neither irrigation nor domestic/stock watering wells are completed in the Alluvium in the vicinity of the tailings impoundments. The Alluvium is not capable of providing sufficient water for use because it is not saturated anywhere except within the vicinity of the facility and the DOE tailings impoundment. Groundwater corrective action compliance and license termination were obtained by the DOE at their facility through the application of Supplemental Standards, demonstrating that the Alluvium is not, and never was, an aquifer because of limited groundwater yield.

A listing provided by the US Geological Survey (USGS 1998) shows approximately 65 groundwater wells within a 25-mile radius of the facility. The closest groundwater supply well is completed in the Westwater Canyon Sandstone Member of the Morrison formation at a location approximately 1.5 miles west of the QMC Facility.

There has been a large reduction in water use and groundwater withdrawals in the area over the past 10 to 15 years because of poor economic conditions associated with the decline of the uranium industry. The current economic base in the Ambrosia Lake area is reclamation at the Facility and ranching. A socioeconomic study (Dames and Moore 1989) of the Grants-Milan area indicates that the area is already very sparsely populated and the population is declining. Projecting into the future, with facility reclamation nearing completion, any increased use of groundwater in the Ambrosia Lake area in the vicinity of the tailings impoundment is highly unlikely.

1.2 Geology

QMC's mill and tailings facility is located north of the Zuni Uplift portion within the San Juan Basin. The basin is characterized by broad areas of relatively flat lying sedimentary rocks, dipping to the northeast, with portions of the basin covered with Alluvium and basalt flows. The QMC mill is within the Ambrosia Lake Valley that extends from the western side of Mount Taylor.

Tectonic activity since the time of sedimentary deposition has resulted in many northward trending faults and fractures in the Ambrosia Lake Valley. The QMC facility is located on a horst bounded by the Ambrosia and San Mateo faults. Faults and fractures affect the vertical transport of groundwater and hydraulic communication between different hydrostratigraphic units.

The stratigraphic sequence of hydrologic significance in the valley consists, in descending order, of the Alluvium (the subject of this evaluation), the Mancos shale and Tres Hermanos C, B and A sandstones (TRC, TRB, TRA), the Dakota Sandstone, the Brushy Basin and the Westwater Canyon members of the Morrison Formation. The ore-bearing unit in the vicinity is the Westwater Canyon. The units that have been affected by milling activities at QMC are the Alluvium, Tres Hermanos B sandstone, and the Dakota sandstone.

The QMC mill site and Tailings Impoundments 1 and 2 are located on the weathered Mancos Formation (saprolite) or on Alluvium overlying the Mancos section. The bedrock units that have been impacted by tailings seepage include the Dakota Sandstone and the TRB.

1.3 Hydrogeology

This section discusses the general hydrogeology of the site. A detailed hydrogeologic assessment of the alluvial groundwater system is presented in Section 2.3.1

1.3.1 Hydrostratigraphic Units

Figure 1.3 is a generalized hydrogeologic cross section through the Ambrosia Lake Valley. Principal near-surface bedrock hydrogeologic units beneath the valley include the TRC, TRB, TRA and the Dakota Sandstones. Mancos shale serves as aquitards that separate these water-bearing units.

1.3.1.1 Groundwater Flow

Groundwater flow within bedrock units is generally down-dip, toward the north-northeast. One exception to this is a small portion of TRB in the southwest portion of the study area. Trenches IT-2 and IT-3 intercept water flowing in the TRB to the east from beneath Tailings Impoundment 1 (Figure 1.2). Groundwater flow in the Alluvium is generally southeast parallel to the Arroyo del Puerto and is discussed in greater detail in Section 2.2.1.

Bedrock units are recharged where they crop out or where they are covered by Alluvium. Seepage from Pond 8 has entered the Dakota locally. In the past, however, this pond has dried up while out of service. Most of the seepage from Tailings Impoundments 1 and 2 migrates laterally through the Alluvium and shallow saprolite in the direction of the surface slope to the Alluvium of Arroyo del Puerto where it enters the interception trench. The seepage that enters the unweathered bedrock beneath Tailings Impoundment 1 and 2 slowly migrates through the TRB to the north and northeast of the Facility in the general direction of the dip. The dewatering trench located between Pond 7 and Pond 2 (Figure 1.2) has minimized any tailings seepage to the TRA, which underlies the Alluvium in the general vicinity of Pond 7.

A regional cone of depression has formed within bedrock units beneath the site resulting from the presence of vent holes and mine shafts and the dewatering of mines north and east of the facility (QMC 1986). The bedrock formations above the Westwater Canyon Member of the Morrison Formation have essentially been dewatered within this cone of depression.

1.4 Current Groundwater Protection Standards

GPS established in Source Materials License SUA-1473 are based on short-term monitoring of water quality data conducted approximately twelve years ago from NRC-designated background well 5-03 (Figure 1.2). The GPS listed in Table 1.1 are currently applied to three POC wells (31-61, 32-59, and MW24). QMC does not consider these standards representative of ambient groundwater quality because they do not account for the variability exhibited in wells that are unimpacted by former milling operations.

Table 1.1. NRC Groundwater Protection Standards (GPS) for the Alluvium at the QMC site, Ambrosia Lake, New Mexico.	
	GPS
Molybdenum (mg/L)	0.06
Nickel (mg/L)	0.06
Lead-210 (pCi/L)	4.9
Radium-226+228 (pCi/L)	5.0
Selenium (mg/L)	0.05
Thorium-230 (pCi/L)	3.1
Natural Uranium (mg/L)	0.06

According to the NRC (1998), background water quality is defined as follows:

"...the chemical quality of water that would be expected at a site if contamination had not occurred from the uranium milling operation. Ambient contamination from uranium mineral bodies, mining operations, or other human activities are considered as part of the background water quality."

The GPS currently prescribed in the license do not account for the widespread ambient groundwater contamination present in the Alluvium resulting from mine pumping and discharge, seepage from the nearby DOE Facility and runoff/erosion from abandoned mine spoils and ore piles. An evaluation was conducted of water quality in areas not impacted by mill operations. The results of the widespread ambient groundwater contamination characterization study are presented in Appendix A: Background Water Quality in the Alluvial Materials at the QMC Facility, Ambrosia Lake, New Mexico.

1.5 Proposed Alternate Concentration Limits

Based on the results of the hazard assessment and statistical analysis of current data associated with the POC wells, QMC has developed site-specific ACLs that are protective of human health and the environment and meet "as low as reasonably achievable" (ALARA). The proposed ACLs are presented in Table 1.2.

Table 1.2. Proposed Alternate Concentration Limits (ACLs) for the Alluvium at the QMC Facility, Ambrosia Lake, New Mexico.

	Background (UTL_{95}) Concentration	Highest Observed Concentration in MW 31-63*	ACL
Mo (mg/L)	83	0.20	83
Ni (mg/L)	0.14	0.20	0.14
Se (mg/L)	3.1	0.05	3.1
Gross Alpha (pCi/L)	16726	No Data	16726
Ra-226 (pCi/L)	190	35	
Ra-228 (pCi/L)	6.1	No Data	
Ra-226 + Ra-228 (pCi/L)	196.1	No Data	196.1
Th-230 (pCi/L)	5	10	10
U (mg/L)	11.1	2.92	11.1
Pb-210 (pCi/L)	36	58	58

*Highest observed concentration in Monitor Well 31-63 (currently considered to be the most impacted well at the site) during the period from 1994 to the present.
UTL_{95}= 95 percent Upper Tolerance Limit

The hazard assessment indicates that natural geochemical conditions result in the attenuation of constituent concentrations within short distances from the potential mill-related sources, regardless of whether those constituents are derived from QMC milling activities, mine pumping and discharge, seepage from the nearby DOE Facility, or runoff/erosion from mine spoils and ore piles. Results of geochemical and groundwater flow modeling indicate attenuation of constituent concentrations to levels well below risk-based thresholds before reaching the proposed POE. The proposed POE will be the southeastern edge of the QMC Land Withdrawal Area where the Alluvium is present adjacent to Arroyo del Puerto (Figure 1.2). ACLs were selected from the 95 percent Upper Tolerance Limit (UTL) on background groundwater concentrations or from the highest observed concentration in Monitor Well 31-63 (currently considered to be the most impacted well at the facility) during the period from 1994 to the present, whichever is higher.

Additional description of the geochemical and groundwater modeling is provided in Section 2.0. Appendix A contains the results of the geochemical model and the groundwater flow model is presented in Appendix B. Additional information regarding the proposed ACLs is provided in Section 4.0.

2 HAZARD ASSESSMENT

2.1 Source and Contaminant Characterization

This section delineates the areas where contamination exists, documents the individual chemical constituents that contribute to the contamination, and estimates the amount of contamination that exists in groundwater as a result of uranium processing at the QMC facility. This information is used in the development of a conceptual model of the QMC facility.

This section will identify and discuss the following:

- Background groundwater quality in the Alluvium
- Uranium processing and process solutions
- Milling-related constituents that are of concern to human health and the environment (listed GPS)
- The extent and magnitude of contamination of groundwater contributed by QMC milling-related activities
- Attenuation or fate and transport characteristics of contaminants of the listed GPS.

2.1.1 Background Evaluation

Data on background groundwater quality as established by the Uranium Recovery Field Office in License Condition 34 is limited to one monitor well in each geologic unit at the facility. According to NRC Materials License SUA-1473, alluvial background groundwater quality for this facility is recognized in Monitor Well 5-03. It is theorized that this well was chosen as background because it had the lowest concentrations of mill derived constituents.

Spatial variability in groundwater quality in groundwater is commonly much greater than temporal variability noted in one monitor well. Therefore, it is unlikely that this one background monitor well in the Alluvium adequately represents the true variability of alluvial groundwater at the QMC Facility. Concentrations of constituents reported in

Monitor Well 5-03 do not reflect all of the sources of constituents in the vicinity of Ambrosia Lake (Figure 2.1). Additional sources of molybdenum, nickel, lead, selenium, radium thorium and uranium, which are unrelated to milling impacts, include the following:

- Mine Pumping and Discharge
- Seepage from the Nearby UMTRA Title I Tailings Site (DOE Facility)
- Runoff and Erosion from Abandoned Mine Spoils and Ore Piles

The influence of these and any other sources of constituents must be evaluated to determine realistic cleanup standards that consider the range of background conditions as defined by the NRC (1998).

The current GPS for the QMC mill facility, based on water quality from the single Monitor Well 5-03, are not achievable due to high ambient concentrations of constituents at the facility. The wide variety of sources and hydrogeochemical processes that are known to have operated in the Ambrosia Lake Valley have resulted in higher levels of uranium ore-related constituents in groundwater than are observed in Well 5-03

2.1.1.1 Mine Pumping and Discharge

As discussed earlier, the alluvial materials were unsaturated before mining began in the Ambrosia Lake Valley (Bostick 1985). Mine-dewatering discharges from underlying geologic units created saturated conditions within the Alluvium during the development of numerous mines in the vicinity. The quality of mine discharge water is dependent on site-specific mine conditions and mining processes. Mine discharge has not, historically, been regulated by the NRC and has been considered unrelated to regulated milling activities.

Historically, discharge water from the mines located in Ambrosia Lake Valley exceeds alluvial GPS for uranium, molybdenum, and selenium. It is important to note that while mine discharge water is the primary source of groundwater in Monitor Well 5-03, low concentrations of constituents measured in groundwater at that location are likely due to the natural attenuation capacity of the alluvial materials as mine water infiltrates and travels through the Alluvium. The natural attenuation capacity of the alluvial materials removes constituents from groundwater along its flowpath, resulting in low concentrations of constituents in alluvial groundwater in areas away from constituent sources.

2.1.1.2 Seepage from the DOE Facility

Seepage from the nearby DOE Facility (Figure 2.2) is unrelated to milling activity at the QMC Facility, although it does contribute to saturation and constituent mass in the Alluvium within the confines of QMC's proposed Land Withdrawal Area. Figure 2.2 shows contours of uranium concentrations using 1986 DOE data from the DOE Facility. The 1986 groundwater data were used as they represent the most complete sampling event in the DOE database. QMC uranium data are also contoured at the same contour interval and for the same time period. These contour plots strongly suggest that, at least until 1986, the DOE Facility seepage was the primary contributor to uranium concentrations in alluvial groundwater on the east side of Highway 509.

Flow directions in the Alluvium are toward and along a paleochannel incised into older bedrock units. The axis of the paleochannel is roughly parallel to the current axis of the Arroyo del Puerto (Figure 2.3) but is east of that feature, near the current location of Highway 509. Any flow from the QMC Facility (which has employed a hydrologic barrier using flow in Arroyo del Puerto between tailings seepage and the paleochannel since mining began in 1957, and a seepage collection system since 1983) is first east toward the paleochannel and then south along the axis of the paleochannel. Flow from the DOE Facility (which has never employed a barrier or seepage collection system) is west toward the paleochannel, where it joins with flow from the QMC Facility and moves south into the QMC Land Withdrawal Area.

The effect of seepage from the DOE Facility can be clearly identified in the analyses of groundwater collected from monitor wells on the eastern side of the QMC Facility. Figure 2.4 shows contours of Total Dissolved Solids (TDS)/chloride ratios in groundwater from monitor wells completed in the Alluvium between Tailings Impoundment 1 and the DOE Facility Tailings Impoundment. The TDS/chloride ratio found in seepage from a uranium mill tailings impoundment is related to the milling process, and can serve to fingerprint the source of the seepage. The milling at the QMC Facility was an acid leach process that used sodium chlorate as an oxidizer, resulting in higher chloride concentrations, while milling at the DOE Facility was an alkaline leach process (DOE 1985) that did not use sodium chlorate.

Groundwater collected near the tailings impoundment at the QMC Facility has a TDS/chloride ratio between 5 and 15 (Figure 2.4). As seepage from Tailings Impoundment 1 moves along its flowpath, the natural geochemical attenuation capacity of alluvial materials removes various constituents from solution, thus lowering the TDS of resulting groundwater. In contrast, chloride is a conservative constituent that typically does not react with alluvial material and its concentration in groundwater is expected to remain constant along a flowpath.

If groundwater TDS/chloride ratios in the alluvial material were only affected by seepage from Tailings Impoundment 1, the ratio could be expected to decrease from the 5-15 range as groundwater moves away from the impoundment. This is because the numerator (TDS) would be constantly getting smaller through natural geochemical processes, while the denominator (chloride) remains the same. Mine discharge water would have little effect on the ratio because it has both low TDS and low chloride relative to tailings seepage, so that it would dilute both equally. However, analytical data from groundwater indicate that TDS/chloride ratios *increase* dramatically to the east away from Tailings Impoundment 1 (Figure 2.4), indicating another source of water for the samples characterized by the elevated TDS/chloride ratios in the eastern portion of the facility. The TDS/chloride ratios seen in groundwater in the eastern portion of the site are consistent with alkaline leach milling processes such as those employed at the DOE Facility (DOE, 1985).

2.1.1.3 Runoff and Erosion from Mine Spoils and Ore Piles

Figure 2.1 shows numerous mine sites that drain to Arroyo del Puerto in the Ambrosia Lake Valley. QMC has documented one incident in 1997 when storm water mobilized stockpiled uranium ore and spoils at the Coppin Mine, directly south of the QMC Facility (QMC 1997). Storm runoff transported this material to the vicinity of stock ponds north of the QMC NPDES Outfall, resulting in a discharge with elevated levels of uranium and selenium at the NPDES Outfall.

While this is the only documented incident, it is likely that mining related sediments have been transported from similar sources to Arroyo Del Puerto in the past. Such sources undoubtedly contribute constituents to surface water during storm events and to groundwater through infiltration. There is also a potential to concentrate mining related constituents through the evaporation of standing water in the wake of storm events. These residual ponds would be an extended source of infiltration to groundwater.

2.1.1.4 Background Values

Background values for the QMC Facility were determined by the calculation of a UTL for constituent data sets that were either Normally or Lognormally distributed, or in data sets that were not Normally or Lognormally distributed, the highest observed value was assigned as the UTL.

Background concentrations established for constituents in the Alluvium near the QMC Facility are shown in Table 2.1. The current GPS set forth in License SUA-1473 are also presented in Table 2.1, along with risk-based standards calculated for the groundwater at the QMC Facility (AVM 2000).

The following points support the contention that seepage from the DOE Facility, mine pumping and discharge, and the runoff and erosion from mine spoils and ore piles have caused widespread ambient groundwater contamination that is unrelated to, but inseparable from impacts related to milling at the QMC Facility:

- Statistical analysis of DOE natural background data suggests that levels of some constituents (e.g. uranium and molybdenum) occur naturally at levels that are an order of magnitude higher than current GPS.

- EPA Method 1312 Synthetic Precipitation Leaching Procedure (SPLP) leaching results for mine spoil and ore pile soil samples indicates that there is a potential for these sources to contribute concentrations of ore related constituents to groundwater.

- Seepage from tailings at the DOE Title I Facility has contributed solutions with high constituent concentrations to alluvial materials. While natural attenuation will reduce concentrations in transport, these solutions will ultimately arrive at the QMC POE.

- QMC has no control over the sources of constituents other than those they have contributed to groundwater. Constituents from the DOE Facility are just as likely to arrive at the QMC POE as constituents from the QMC Facility.

Table 2.1. Background 95 Percent Upper Tolerance Limits (UTLs) values.

	Background (UTL_{95}) Concentration	NRC GPS	Risk-Based Protection Value
Mo (mg/L)	83	0.1	0.2
Ni (mg/L)	0.14	0.06	0.1
Se (mg/L)	3.1	0.1	0.1
GA (pCi/L)	16726	57	
Ra-226 (pCi/L)	190		
Ra-228 (pCi/L)	6.1		
Ra-226 + Ra-228 (pCi/L)		5*	41**
Th-230 (pCi/L)	5	3	139
U (mg/L)	11.1	0.1	0.2
Pb-210 (pCi/L)	36	5	13
* NRC GPS for Radium is Ra-226+Ra-228 = 5 pCi/L.			
** Risk Based Protection Value for Radium is Ra-226+Ra-228 = 41 pCi/L.			

A number of sources, specifically mine pumping and discharge, seepage from the nearby DOE Facility and runoff/erosion from abandoned mine spoils and ore piles, have contributed constituents to the alluvial groundwater. As a result, background groundwater in the alluvial materials is of low quality and, therefore, of limited use. The current GPS, based on water quality from a single monitor well completed in the Alluvium, are unrealistic due to high ambient concentrations of constituents present in groundwater at the facility.

2.1.2 Uranium Recovery Processes and Reagents Used

Merritt (1971) indicates that acid leaching of sandstone uranium ores contributed sulfuric acid (H_2SO_4) to the tailings piles, and, thus, to the groundwater at the QMC Facility. Sodium chlorate ($NaClO_3$) was added to the acid process as an oxidizer to bring the solution to an Eh of between 0.400 and 0.425 volts. Additionally, ammonia gas (NH_3) was used as a neutralizer and sodium chloride (NaCl) was used in the stripping process. Thus, major indicators of contamination expected in wells downgradient are the sulfate (SO_4^{2-}), and chloride (Cl^-) ions. Secondary indicators of contamination are ammonium (NH_4^+), and nitrate (NO_3^-) (mostly from oxidation of ammonium). Constituents that can be expected in association with the uranium ores themselves are iron, lead, molybdenum, nickel, radium, selenium, thorium, and uranium (DeVoto 1978).

2.1.3 Historical and Current Waste Management

Historical and current waste management activities are described in Section 1.1.2. Past corrective actions, including minimizing the amount of free water, use of lined ponds, removal of standing tailings solution, construction and operation of the interceptor trench, and construction of the tailings cover, have reduced seepage of tailings fluid to groundwater. Reduced seepage has, in turn, resulted in reduced concentrations of constituents in groundwater at the POC monitor wells.

2.1.4 Constituent Concentration Trends

Concentrations of constituents in process liquids, tailings liquids and in Monitor Well 31-63 are shown in Table 2.2. A major reduction in constituent concentrations takes place when seepage from the tailings impoundment is neutralized on contact with carbonate material in the alluvial material. The concentrations of most constituents are much lower in alluvial monitor wells than they are in tailings solutions.

Table 2.2. Concentrations of constituents in process liquids, tailings liquids and in monitor well 31-63 (currently considered to be the most contaminated well at the site).

	Process Liquids	Tailings Liquids (1987)	MW 31-63 (Highest)	MW 31-63 (Current)
pH (s.u.)	1.1	3.95	3.7 (lowest)	5.4
Chloride (mg/L)	1,540	2,300	5800	3130
Molybdenum (mg/L)	14	0.46	1.07	0.004
Nickel (mg/L)	1.0	1.0	2.66	0.009
Lead-210 (pCi/L)	-	4.5	58	58
Radium-226+228 (pCi/L)	336	62	35.91	2.8
Selenium (mg/L)	6	< 1.2	0.32	0.026
Sulfate (mg/L)	34,600	16,000	44300	9380
TDS (mg/L)	40,800	28,090	76200	17400
Thorium-230 (pCi/L)	-	11	12.9	6.2
Natural Uranium (mg/L)	11.2	8.4	13.8	0.282

In addition, concentrations of most constituents in monitor wells that are near Tailings Impoundment 1 have shown declining trends during the past 20 years. Figure 2.5 shows time series plots of chloride and constituents of concern in groundwater samples from Monitor Wells 31-63 and 31-61 (the most upgradient POC well)(Figure 1.2). Chloride, considered the best tracer of overall trends in these wells, shows marked declines in both wells. Chloride has declined in Monitor Well 31-63 from near 6,000 mg/L in the early 1980s to current levels of near 4,000 mg/L. During the same period, chloride concentrations in Monitor Well 31-61 have declined from 4,000 mg/L to less than 1,000 mg/L. Uranium shows similar declining concentration trends. Concentration trends for other constituents are more erratic but overall constituent concentrations are declining. All constituent concentrations are currently low with the possible exception of Lead-210.

Time series plots of concentrations of chloride and other constituents of concern in groundwater samples from background Monitor Well 5-03 are shown in Figure 2.6. Chloride concentrations in this well show the influence of increasing chloride concentrations in pumped mine water from the nearby Arroyo de Puerto. However, among other constituents (molybdenum, nickel, selenium and uranium), early higher concentrations have disappeared and most have been at or near the detection limit for the last eight to ten years. Radionuclides show no trends at all, indicating little or no transport.

2.1.5 Distribution of Constituents and Attenuation Properties

Figure 2.7 shows chloride concentration contours from the most recent sampling round at the facility (April 1999). Chloride is the primary indicator of facility related constituents in groundwater because levels of this constituent were high in milling processes and relatively low in mine discharge water. Figure 2.7 displays locally high concentrations of chloride just downgradient of Tailings Impoundment 1, and adjacent to a series of unlined evaporation ponds that have since undergone remediation. Local chloride highs confirm the intuitive assumption that Tailings Impoundment 1 and the unlined evaporation ponds are the primary sources of constituents in this part of the Alluvium. Locally elevated chloride near Monitor Well 32-57 (230 mg/L) is suggestive of the influence of seepage from the Title I Facility to the east.

TDS/chloride ratios in groundwater from monitor wells completed in the Alluvium (Figure 2.4) define the extent of groundwater that has been impacted by seepage from Tailings Impoundment 1 and the former unlined evaporation ponds. Tailings Impoundment 1 has now been covered to minimize infiltration, thereby restricting future seepage from that source. Former evaporation ponds, taken out of service in 1983, are in the final phases of reclamation. By these actions QMC has removed the primary sources of mill related constituents to groundwater and constituent mass in groundwater can be expected to diminish with time and natural attenuation.

Contaminants are transported at the facility by groundwater flow in the Alluvium. Mobility and/or potential for attenuation depend on the species of ions in the aqueous environment. The types of ion species and complexes in groundwater depend on anion and cation availability and on pH and Eh conditions. If conditions are oxidizing, attenuation of metallic constituents will be primarily by adsorption. If reducing conditions are present, many metallic constituents may be removed from solution by precipitation as metallic sulfides. The pH conditions measured in most alluvial monitor wells are in the range of 6.5 to 9.4, but pH values are much lower near the sources of contamination (in some cases pH readings are near 3.5).

2.1.5.1 Lead-210

Lead-210 is a product of the uranium-238 decay chain, but once it is in solution its behavior is the same as any other lead isotope. Lead-210 concentrations in near-source Monitor Well 32-60 have been as high as 98 pCi/L (October 1989). However, the lead-210 concentrations in this well have shown a strong downward trend since that time. Lead-210 concentrations during the most recent sampling round were 8.1 pCi/L (April 1999). Figure 2-8 indicates that lead-210 concentrations have not moved far from source areas, and appear to be naturally attenuated at the QMC facility.

2.1.5.2 Molybdenum

Under oxidizing conditions, the dominant molybdenum species above a pH of 5 is molybdate ion (MoO_4^{2-}). Many of the metallic elements have molybdates of low solubility. The sulfide mineral molybdenite, also with a low solubility, forms under reducing conditions. Figure 2.9 demonstrates that molybdenum concentrations in the Alluvium are tightly restricted to near source areas. Molybdenum is primarily present in the Alluvium in monitor wells that are adjacent to the Arroyo del Puerto carrying mine discharge water averaging 0.23 mg/L molybdenum. Table 2.2 shows that while alluvial groundwater has historically had molybdenum concentrations as high as 1.07 mg/L, current concentrations in the Alluvium are near 0.004 mg/L. Consistent with the low solubility of molybdenum there has been minimal transport of molybdenum from sources.

2.1.5.3 Nickel

Dissolved nickel is present in oxidizing, acidic, near-source environments as the cation Ni^{2+}. This species is mobile under acidic, oxidizing conditions. However, it is strongly adsorbed by Fe/Mn oxides and hydroxides (Rai 1984) that are likely present in abundance in near-source environments at the QMC facility. Figure 2.10 shows the current distribution of nickel in the Alluvium and Table 2.2 presents the historical high concentrations of nickel in samples from near source Monitor Well 31-63 and current nickel concentrations. Monitor Well 31-63 typically has the highest constituent concentrations at the facility, yet concentrations of nickel in this well have decreased by at least two orders of magnitude since 1986. Data indicate that nickel in groundwater is naturally attenuated in the vicinity of the QMC facility.

2.1.5.4 Selenium

Selenium occurs in solution as selenate or selenite species under oxidizing Eh conditions. These anionic species should be adsorbed under acid conditions and desorb as conditions become more neutral. As conditions become reducing, selenides become more stable and selenium precipitates as ferroselite or substitutes for sulfur in pyrite. Currently selenium is primarily present in the Alluvium in monitor wells that are adjacent to the Arroyo del Puerto (Figure 2.11) carrying mine discharge water that averages 1.4 mg/L selenium. Table 2.2 shows that while alluvial groundwater has historically had selenium concentrations as high as 0.32 mg/L, current concentrations in the Alluvium are at least an order of magnitude lower. This is evidence that selenium is being naturally attenuated in the Alluvium.

2.1.5.5 Radium-226+228

Radium-226 and radium-228 are products of the uranium-238 and thorium-232 decay chains, respectively. However, once in solution, these isotopes display the same geochemical behavior as all other radium ions. Radium, present in solution almost exclusively as Ra^{2+} ion, soluble only under acid conditions and is generally immobile in natural waters due to the extreme insolubility of radium sulfate (Brookins 1988). Radium-226 typically comprises more than 90 percent of total radium. Figure 2.12 shows the Radium-226 distribution in the Alluvium. Radium-226 is present above 5 pCi/L in three highly localized areas in the Alluvium. The two areas in the northern portion of the facility are directly adjacent to sources and the third, at the southern end of the facility is completely isolated from the other two. This isolation and the very low solubility of radium sulfate suggest a local source for the third area that is unrelated to other sources at the QMC facility. Data indicate that radium has been naturally attenuated in the Alluvium.

2.1.5.6 Thorium-230

Thorium-230 is part of the uranium-238 decay chain but is geochemically identical to other isotopes of thorium in aqueous solution. Thorium is soluble only at low pH values, and, at pH values above about 3 precipitates as thorium oxide (Brookins 1988). Figure 2.13 displays the thorium-230 distribution in the Alluvium; and this constituent appears to be somewhat mobile. However, note that the distribution of thorium closely mimics the distribution of uranium (Figure 2.14). Thorium-230 is a product of the uranium-238 decay chain and is produced continuously wherever natural uranium is present. When uranium is removed from a region thorium^{230} typically falls to low levels (Brookins 1984).

2.1.5.7 Uranium

Uranium is mobile in acidic, oxidized water, primarily as uranyl sulfate and carbonate complexes. Under reducing conditions uranium is removed from solution as a uranium oxide. The current uranium distribution in the Alluvium (Figure 2.14) indicates that the highest concentrations are adjacent to the Arroyo del Puerto carrying mine discharge water. Treated mine discharge water has consistently had uranium concentrations in the 1-2 mg/L range. Despite these levels of uranium and the high volume of mine discharge water relative to tailings and pond seepage, most monitor wells currently show uranium concentrations lower than 0.5 mg/L. This is evidence of natural attenuation of uranium in the Alluvium.

2.1.5.8 Gross Alpha

Gross alpha has also been identified as a possible constituent of concern. However, it was reported in the ACL petition for the uppermost bedrock units (AVM 2000) that the laboratory performing the groundwater analyses stated that the gross alpha concentration results includes alpha activity from U-nat and all other alpha emitters. Normally, alpha activity from uranium will contribute most of the gross alpha activity in neutralized groundwater impacted with uranium mill tailings liquids from sulfuric acid leach process. Figure 2.15 shows that the distribution of gross alpha in groundwater closely mimics the distribution of uranium.

2.2 Transport Assessment

This section contains a description of geochemical modeling that concludes that abundant reductive and neutralization capacity in the alluvial material will act to limit the migration of constituents from any of the multiple sources in the Ambrosia Lake area. The geochemical modeling section is followed by a description of hydrogeologic modeling that concludes that the Alluvium will return to its premining unsaturated condition in less than 100 years after mine dewatering ceases.

2.2.1 Geochemical Assessment

2.2.1.1 Geochemical Conditions in the Alluvium

The alluvial materials were unsaturated before mining began in the Ambrosia Lake Valley (Bostick 1985). Mine-dewatering discharges from underlying geologic units created saturated conditions in the Alluvium during the development of numerous mines in the Ambrosia Lake area. The quality of mine discharge water is dependent on site-specific mine conditions, and mining processes.

A number of sources, specifically mine pumping and discharge, seepage from the nearby DOE Facility, and runoff/erosion from abandoned mine spoils and ore piles, have contributed constituents to the alluvial groundwater. As a result, ambient groundwater in the alluvial materials is of low quality and, therefore, of limited use.

Geochemical modeling examines the interaction between aquifer matrix materials and groundwater. The composition of matrix materials affects attenuation capacity. A thin section study of samples of alluvial materials from the QMC Facility (Gold Hill Geologic Research 2000) indicates they contain abundant clay, quartz, and chalcedony in limonite (amorphous iron oxyhydroxide) and calcite ($CaCO_3$) cement. Chalcedony (SiO_2) is a slightly more reactive form of SiO_2 than quartz and is typically present in samples at close to 20 percent by volume. Both limonite and calcite typically exceed 10 percent of each sample by volume. Gypsum ($CaSO_4$) is present in each sample (1-2 percent by volume) and very fine-grained magnetite was present in trace amounts.

2.2.1.2 Observed Transport

High concentrations of $CaCO_3$ in the alluvial materials have caused neutralization of tailings solutions within a few hundred feet of the tailings pile, attenuating many constituents of concern in the solution. In areas that are farther downgradient, $CaCO_3$ has not reacted with low pH solutions. Thus, neutralization capacity in the rest of the alluvial materials remains high.

In general, Eh conditions are oxidizing in a narrow band along the flowing portion of Arroyo del Puerto, and immediately downgradient of Tailing Impoundment 1. Conditions become more reducing in areas away from these features (Figure 2.16). The Arroyo del Puerto stream flow is a source of oxidized water to the alluvial materials, accounting for the narrow band of oxidizing groundwater adjacent to this feature. Merritt (1971) indicates that $NaClO_3$, was typically added to the milling process as an oxidizer to bring the solution to an Eh of between 0.400 and 0.425 volts. These values are consistent with Eh values measured in groundwater immediately downgradient of Tailings Impoundment 1.

The sparse distribution of oxidizing conditions at the facility, after more than 40 years of oxidizing flow in Arroyo del Puerto and seepage from Tailings Impoundment 1, is testament to the reductive capacity of the alluvial materials. Monitor Well 5-03 (Figure 2.16), is approximately 450 feet from Arroyo del Puerto by the shortest possible pathway, has a measured Eh value of –0.082 millivolts (reducing). A quick calculation (450 feet/40 years = 11.25 feet/year) reveals that the oxidizing front, from the infiltration of Arroyo del Puerto surface water into alluvial materials, can be traveling at a *maximum* rate of less than 12 feet per year. This indicates that a high reductive capacity still exists in alluvial materials a short distance from features that supply oxidizing waters.

There is no evidence that constituents of concern have reached Monitor Well 5-03. However, there is evidence that the redox front in the vicinity of Monitor Well 5-03 is moving at less than 12 feet per year. Monitor Well 5-03 is more than 3,200 feet upgradient of the QMC Land Withdrawal Area boundary or POE. The above observations suggest that it would take at least 260 years for the redox front (the depletion in redox capacity) to reach the Land Withdrawal Area boundary from Monitor Well 5-03 ((3200feet/year)/12 feet = 267 years).

2.2.1.3 Geochemical Modeling of the Alluvium

It is necessary to be able to predict changes in constituent speciation and changes in mineral solubility as groundwater moves from one environment to another because groundwater in the Alluvium occurs in a variety of geochemical environments. Accordingly, it was necessary that the computer code selected for geochemical modeling of the Alluvium be capable of chemical speciation and mass transfer (i.e., dissolution/precipitation, ion exchange/adsorption, etc.). The computer code PHREEQC (Parkhurst 1995) was chosen for this study because it has these capabilities, it is based on the long established and well accepted PHREEQE model (Parkhurst et al 1980), and thermodynamic data from a variety of sources can easily be incorporated into the model. The model takes a solution that comes out of the toe of Tailings Impoundment 1 and equilibrates it with the composition of alluvial materials. Geochemical modeling is described in more detail in Appendix B.

2.2.1.3.1 Initial Solution

The majority of the attenuation capacity of the alluvial materials is used up by neutralization of the low pH that characterizes acid tailings solutions and reaction of the aquifer matrix materials with major constituents of tailings solutions (sodium, sulfate, iron, and magnesium). Chemical interaction between the aquifer matrix and minor and trace constituents (molybdenum, nickel, selenium, radium, thorium, uranium, and lead) use little of the attenuation capacity. Therefore, to obtain conservative results, the initial model solution incorporates major element and pH data from a 1980 sampling of Monitor Well D-4 located immediately downgradient of Impoundment 1. Sampling occurred before the 1983 installation of the interceptor trench that collects tailings seepage.

Minor and trace element concentrations for the initial model solution are taken from the highest observed concentrations in groundwater from Monitor Well 31-63 during the period from 1994 to the present. This well is immediately downgradient of Tailings Impoundment 1 and is currently considered to be the most contaminated well at the facility.

2.2.1.3.2 Reactive Minerals

The model assumes the presence of the minerals calcite, chalcedony, and gypsum in the aquifer matrix that are available to react with constituents in groundwater. The amount of each of these minerals present initially is consistent with their abundance in the matrix and their solubility in water. For example, chalcedony is the most abundant of the reactive minerals in the aquifer matrix but is the least soluble; therefore the model assumes that 0.001 moles of chalcedony are available to react with the initial solution. By contrast, calcite is only half as abundant as chalcedony but is many times more soluble. Therefore, the model assumes that 0.05 moles of calcite are available to react with the initial solution.

Magnetite is present in the aquifer matrix in trace amounts and may be an authugenic phase. Therefore it was allowed to precipitate if it came to saturation. Pyrite was also allowed to precipitate to keep the system from becoming unrealistically reducing. In addition, the following minerals were allowed to precipitate if they came to saturation: molybdenite, RaSO4, Th(OH)4(am), uraninite, and NiSe.

2.2.1.3.3 Adsorption Surface

The model assumes that amorphous iron oxyhydroxides comprise ten percent of the alluvial material by weight and that only 0.1 percent of that amount is available as a sorbant surface. Therefore, each cell of the model contains 0.1 percent ferrihydrite, by weight, as an adsorption surface.

2.2.1.3.4 Model Assumptions and Limitations

Primary model assumptions and limitations that need to be understood before drawing conclusions based on geochemical modeling are:

- Only equilibrium precipitation and adsorption are modeled. Mixing with other sources of water in the Alluvium and dilution and dispersion effects would result in lowering the concentrations of most, if not all, constituents of concern. Mixing and dilution and dispersion are not taken into account in this model.

- Data for major elements were from data collected in 1980. Concentrations of all constituents in tailings seepage have declined for the last 20 years. This feature of the model allows a high confidence in predictions that risks to human health and the environment at the POE will not increase over time.

- Minor and trace element data were taken from the highest observed concentration in groundwater during the period between 1994-2000. A more realistic approach would be to model the mean concentration but using the higher concentration is more conservative.

- Gross alpha could not be included explicitly in the model because it is not an elemental parameter.

2.2.1.3.5 Model Results

Model results are shown in Table 2.3.

Table 2.3. Concentrations of constituents at the downgradient edge of tailings impoundment #1(model input) and at the point of exposure (model output).

	Input	Output
Bicarbonate (mg/L)	0	51.0
Calcium (mg/L)	1005	1061
Chloride (mg/L)	2574	2574
Iron (mg/L)	44	0.018
Potassium (mg/L)	8.6	8.6
Magnesium (mg/L)	342	342
Molybdenum (mg/L)	0.201	0.00001
Sodium (mg/L)	191	191
Nickel (mg/L)	0.2	0.0004
Lead (pCi/L)	58	0.00001
Radium (pCi/L)	35	17
Sulfate (mg/L)	781	785
Selenium (mg/L)	0.05	7.4E-12
Thorium (pCi/L)	10	8.6E-14

2.2.2 Conclusions of Geochemical Assessment

The presence of more than ten percent calcite in aquifer materials and observations concerning the distribution of redox conditions in the Alluvium indicate the presence of abundant reductive and neutralization capacity in the alluvial material, which will act to limit the migration of constituents from any of the multiple sources in the Ambrosia Lake area. Groundwater modeling supports the postulated reduction in constituent concentrations in groundwater over time and over distance from the source. Under the current flow regime, it would take at least 260 years for the redox front (the depletion in redox capacity) to reach the Land Withdrawal Area boundary from Monitor Well 5-03. In the mean time, dilution, dispersion and mixing processes would be acting to reduce concentrations of constituents of concern along the flowpath. Hence, it would be considerably more than 260 years before the modeled concentrations in Table 2.3 were exceeded at the Point of Exposure.

2.2.3 Hydrogeologic Assessment

The hydrogeology and water quality of the alluvial groundwater flow system at the site have been discussed in QMC (1986 and 1996), Cooper and John (1968) and Craven and Hammock (1958).

During the recent geological past erosional forces have cut a canyon up to 100-foot deep into bedrock surface. Wind and water filled the canyon with sediment forming the current alluvial valley (Figure 1.3). Near surface sediments are described in monitoring well lithologic logs as ranging from fine-grained sand with clay up to gravel. Recently weathered shale (saprolite) is present in many locations.

2.2.3.1 Groundwater Flow

Figure 2.17 is the groundwater elevation map for the Alluvium in the valley. Currently, groundwater in the alluvial system flows to the southeast with a gradient of approximately 0.006. A groundwater mound has formed in the northern portion of the study area, caused by infiltration from the Arroyo del Puerto bypass channel. North of this mound, groundwater flows north toward mine shafts and vent holes located in Section 30. South of the mound groundwater flows toward the northern half of trench IT-1, creating the "groundwater sweep". Groundwater seeping from Tailings Impoundment 1 flows east toward trench IT-1. Some of the water in the Alluvium beneath Tailings Impoundments 1 and 2 leaks into TRB beneath it and flows eastward where is its intercepted by IT-2, IT3, and IT-4. East of the facility groundwater flow from the DOE Tailings pile and the highlands east of it is to the southwest with a gradient of approximately 0.01.

Groundwater exits the alluvial system where vent holes and mine shafts intersect the water table at the northern and eastern margins of the study area. Alluvial groundwater also exits the southern end of study area as underflow beneath the Arroyo del Puerto through a narrow gap in bedrock.

Prior to mining in the area, natural sources of recharge to the alluvial system were insufficient to establish saturated conditions within the Alluvium QMC (1986). Any water infiltrating beyond the root zone probably drained into sandstone units below the alluvial system. Two principal sources of recharge to the alluvial system are currently maintaining the saturated condition near the facility:

- Infiltration of water from the Arroyo del Puerto bypass channel, and
- Seepage from Tailings Impoundments 1 and 2.

Hydraulic gradients between the alluvial system and subcropping Tres Hermanos units are generally downward (Figure 1.3) indicating some groundwater is probably leaking from the alluvial system into subjacent sandstone units. This idea is supported by the water budget analysis discussed below.

Hydrographs for alluvial monitoring wells (Figure 2.18) provide some insight regarding recharge to the system. Groundwater elevations measured in alluvial monitoring well in northern portion of the site (Wells 30-47 and 30-49) increased approximately 15 to 20 feet between 1984 and 1999 showing that the alluvial system is still filling in response to influx from the Arroyo bypass. Increases in groundwater elevation in these wells during the late 1990s are in-part related to irrigation during that period. In 1984 interception trench IT-1 was constructed, and in 1985 the facility ceased adding water to Tailings Impoundments 1 and 2. As a consequence water table elevations measured in wells 31-61 and 31-63 between 1984 and 1987 dropped 10 to 15 feet. Interception Trench 1 has been responsible for the capture of groundwater northeast of IT-1 as well as capturing flow coming from Tailings Impoundments 1 and 2. Groundwater levels in well 32-57, which is located in the center of the alluvial valley near the convergence of groundwater flows from the DOE and QMC facilities (Figure 1.1), increased approximately three feet between 1984 and 1993. Between 1993 and 1999, water levels in well 32-57 fell less than one foot.

Monitoring well MW-29 is screened across the contact between the Alluvium and underlying TRC. The hydrograph for well MW-29 indicates the Alluvium near there was draining between 1988 and 1996 and that that the water table dropped into the TRC in about 1996. In other words, the Alluvium near MW-29 has been dry since 1996. The hydrograph for well MW-30 indicates that the Alluvium south of the DOE tailings pile is also draining and the Alluvium will probably dry up in the near future. The hydrograph for well 5-04 indicates that water table elevations have exhibited a relatively high degree of variability since 1995. This is related to variability in the quantity of treated mine water present in the Arroyo Del Puerto. The hydrograph for well 5-08 indicates that groundwater elevations away from the Arroyo del Puerto near the POE have remained fairly steady, fluctuating approximately five feet between 1984 and 1999.

2.2.3.2 Flow System Characteristics

Estimates of hydraulic conductivity for the Alluvium range from 0.6 feet per day (ft/d) based on pumping tests performed in wells AW-1 and AW-2 (QMC 1986), to 30 ft/d based on lithologic descriptions in monitoring well logs. The groundwater model developed for the site (Appendix C) was calibrated using a hydraulic conductivity of 18 ft/d. Based on the lithology of the Alluvium, porosity is estimated to range from 0.15 to 0.25 (Fetter 1989). Specific yield estimates range from 0.10 to 0.20. Estimates of average linear groundwater velocity for the site based on these parameters and a gradient of 0.006 range from 0.014 to 1.2 feet per day.

2.2.3.3 Surface Water

Prior to mining activity, the Arroyo del Puerto was an ephemeral drainage. Flow in the creek occurred only in response to large rainfall or snowmelt events. Currently, the creek is dry until it reaches the B-3 discharge point. An average of 337,000 ft^3/d was discharged to the Arroyo del Puerto channel at the B-3 discharge during 1999. Water may be removed from the creek for mine injection and irrigation. Most of the remaining water in the channel is pumped into Pond 9 at the Puertocito Creek weir. Between the B-3 discharge point and the Puertocito Creek weir water leaks from the creek. This leakage is the primary source of recharge to the alluvial groundwater system in the site.

2.2.3.4 Groundwater Modeling

Maxim developed a numerical model of groundwater flow and contaminant transport to serve as an interpretive tool to test the conceptual model and to help assess the possible affects of future actions at the facility. Numerical model development is summarized below. Appendix C contains detailed description of numerical model development, calibration and results.

Maxim developed a water balance for the alluvial groundwater system as one of the first steps in developing the numerical groundwater model discussed below and in Appendix C to help estimate flux inputs for the model. The following is a summary of the resulting flux estimates.

	Low (ft^3/d)	High (ft^3/d)	Estimated Flux(ft^3/d)
IN			
Arroyo and Irrigation Infiltration	81,620	163,423	119,850
Influx from Tailings Impoundment 1	3,000	12,000	5,000
Influx from highlands to the DOE pile	109	8,500	5,000
Total In:	84,729	183,923	**129,850**
OUT			
Underflow to South	504	25,200	18,000
Trench IT-1	4,000	19,250	8,000
Trench IT-2	96	231	149
Trench IT-3	1,020	2,312	1,328
Trench IT-4	424	2349	543
Infiltration to mineshafts & vents	26,044	109,342	48,000
Total Out:	26,044	109,342	**76,020**
Infiltration to Bedrock Units:			**53,830**

The water balance analysis suggests that an appreciable amount of groundwater from the alluvial system is draining into mine shafts and vents and subcropping sandstone units.

The groundwater model was developed using MODLFOW and MODPATH. Figure 2-19 shows the model grid and steady state boundary conditions. The single layer model consists of 147 rows and 172 columns with 100-foot grid spacing. The model includes the alluvial groundwater system near the QMC and DOE facilities and the Section 4 ponds. Boundary conditions include:

- Constant flux cells representing recharge from the Arroyo del Puerto.
- Constant flux cells representing recharge from the Tailings Impoundments 1 and 2
- Constant head/flux representing drainage from DOE tailings pile and northeast highlands.
- Drain cells representing leakage to TRA, TRB and TRC beneath the alluvium.
- Drain cells representing water removed from the system by interception trenches IT-1, IT-2, IT-3, and IT-4.
- Drain cells representing drainage to mine shafts and vent holes.

The model was calibrated to steady state conditions by the "trial-and-error" method to late 1997 groundwater elevation data from alluvial monitoring wells.

Figure 2-20 shows calibrated water table elevation contours and model residuals for each target well (residual is the difference between the target value and the modeled value). A comparison of modeled contours (Figure 2-20) to contours based on field measured values (Figure 2-17) shows a reasonably good qualitative fit. Appendix C contains a discussion of quantitative calibration results.

Particle tracking techniques were then used under steady state conditions to help interpret contaminant fate and transport times and directions. The modeled advective groundwater velocity was approximately 0.5 feet per day. Steady state particle tracking indicates that much of the contaminant mass is captured by drainage to mine shafts and vents.

In order to assess the effectiveness of the CAP and to estimate the time required to capture contaminant plumes, the calibrated flow model was run in transient mode under two scenarios. The first scenario maintained the fluxes used in the steady state calibration for the Arroyo del Puerto. To assess the affects of discontinuing the current CAP, constant flux boundaries representing the Arroyo del Puerto infiltration and drain cell boundaries representing interception trenches were removed from the model. Inputs representing declining flux from Tailings Impoundments 1 and 2 and the DOE tailings impoundment were simulated as described in Appendix C. Under both scenarios, the model was then run for a period of 1,000 years.

The 1,000 year transient run simulating operation of the current CAP resulted in a water table that is very similar to steady state conditions, with the exception that water table elevations southeast of Tailings Impoundment 1 were slightly lower. This indicates that if the current CAP is continued, the alluvial groundwater system will remain saturated indefinitely.

Figure 2-21 shows results of the discontinued CAP transient scenario after 65 years. Figure 2-21 indicates that after 65 years most of the alluvial system is dewatered. At 100 years, only 4 feet of saturation remains at the southern model boundary and relatively little water is discharging as underflow in the Alluvium.

Results of particle tracking for the current CAP scenario indicate that approximately 40 years were required for all the particles representing the current plume in the alluvial system to be captured or removed from the system. More than 100 years were required to capture particles within the TRB included in the southwest portion of the model domain. This assumes advective transport velocities, which would be representative of the least retarded species (chloride). Other more retarded species would require more time. In addition, due to heterogeneities and preferential flow paths present in real systems, practical experience indicates that approximately 4 to10 pore volumes would be required to remove 100 percent of contaminant mass from the system. A small quantity of contaminated water drains from Tailings Impoundment 1 at 1,000 years. However, after about 100 years this quantity becomes negligible.

It is difficult to assess the time required for complete capture of particles under the discontinued CAP scenario due to numerical problems with the model after 200 years caused by model cells going dry. MODPATH results show that particles remain in TRB portion of the model domain after 1,000 years. However, this water is stagnant and trapped by dry cells within the model.

2.2.4 Conclusions Of Transport Assessment

Geochemical modeling indicates that there will be a reduction in constituent concentrations in groundwater over time and over distance from the source due to natural attenuation by alluvial material. Under the current flow regime, it would take at least 260 years for the redox front (the depletion in redox capacity) to reach the withdrawal area boundary from Monitor Well 5-03. In the mean time, dilution, dispersion and mixing processes would be acting to reduce concentrations of constituents of concern along the flowpath. Hence, it would be considerably more than 260 years before the modeled concentrations in Table 2.3 were exceeded at the Point of Exposure.

Hydrogeologic modeling indicates that the alluvium will return to its premining unsaturated state in less than half that time if mine dewatering ends and flow in the Arroyo del Puerto ceases to provide current levels of recharge. The bulk of the Alluvium will be dewatered within 65 years. Therefore, all constituents that are derived from QMC milling processes will be contained within the withdrawal area as a result of geochemical and hydrogeologic processes.

2.3 Exposure Assessment

In accordance with the Standard Format and Content Guide for Alternate Concentration Limits Application (NRC 1996), this exposure assessment provides the following:

- Identification of existing and potential future uses of water resources (potentially complete exposure pathways to alluvial groundwater) that may be affected by the QMC Mill Facility

- Evaluation of potential human and environmental exposures to hazardous constituents at the proposed POEs for the Alluvium

- Site-specific maximum permissible levels of constituents, applicable at the identified POE, that are considered protective of human health and the environment

- A demonstration that the proposed ACLs do not pose any threat or potential future hazards to human health or the environment

ACLs are being proposed for the following parameters: Molybdenum, Nickel, Selenium, Lead 210, Natural uranium, Thorium 230, Radium 266, and Radium 228. For the human health hazard evaluation, potential exposures to these parameters are assessed quantitatively by comparing site-specific risk-based concentrations with the modeled values at the proposed POEs.

The four major components of an exposure pathway are as follows:

- a source and mechanism of constituent release to the environment

- an environmental transport medium for the released constituents (e.g., air, water, soil)

- a point of potential human contact with the affected medium (the exposure point)

- a human exposure route (e.g., inhalation, ingestion or dermal contact) and receptor at the exposure point

The absence of even one of these elements renders an exposure pathway incomplete. Without exposure, there is no potential risk; therefore, the exposure assessment is a critical component of a risk assessment.

2.3.1 Resource Classification and Water Uses

The Facility lies within the Bluewater Underground Water Basin. The New Mexico State Engineer is responsible for administering the groundwater and surface water rights in the basin. All water users must file and obtain an approval before diverting waters to beneficial use; permits are required before drilling a well to extract water. The basin is considered fully appropriated and any major new water rights must be purchased from existing rights-holders.

Utilization of groundwater in the Ambrosia Lake area can be divided into two categories: 1) irrigation and 2) domestic/stock watering. Neither irrigation nor domestic/stock watering wells in the vicinity of the tailings impoundments are completed in the Alluvium. The Alluvium is not capable of providing sufficient water for use because it is not saturated anywhere except within the vicinity of the QMC facility and the US DOE tailings impoundment. Groundwater corrective action compliance and license termination was obtained by the DOE at their facility through the application of Supplemental Standards, demonstrating that the Alluvium is not, and never was, an aquifer because of limited yield.

A listing provided by the US Geological Survey (USGS 1998) shows approximately 65 groundwater wells within a 25-mile radius of the facility. The closest groundwater supply well is completed in the Westwater Canyon Sandstone Member of the Morrison formation at a location approximately 1.5 miles west of the tailings impoundments. There has been a large reduction in water use and groundwater withdrawals in the area of the Facility over the past 10 to 15 years because of poor economic conditions associated with the decline of the uranium industry. The current economic base in the Ambrosia Lake area is reclamation at the Facility and ranching. The area is very sparsely populated and the population is declining. Projecting into the future, with facility reclamation nearing completion, any increased use of groundwater in the Ambrosia Lake area in the vicinity of the tailings impoundment is highly unlikely.

A socioeconomic study (Dames & Moore 1989) of the Grants-Milan area was performed by ARCO to support the Bluewater Uranium Mill Site ACL petition. The study area consisted of approximately 50 square miles around the Bluewater Mill Site. The objective of the study was to characterize current land uses and project future land and water use within the study area around the Bluewater Mill Site. The study reported that most of the area is undeveloped range land and industrial property, and that the already sparse population in the area is declining. The study concluded that, given the poor economy and high vacancy rates in Grants and Milan, future development is not expected within the study area. Similar conclusions can be drawn for the Facility, which is at a more remote location approximately 20 miles from the Bluewater Mill Site.

2.3.2 Existing and Potential Future Uses of Water Resources

2.3.2.1 Potential Future Groundwater Uses

In defining potential future groundwater uses, the following three factors must be acknowledged. Groundwater in the alluvial aquifer is not used as a potable source nor is groundwater expected to be used as one in the foreseeable future for the following reasons:

- Tests indicate that the alluvial aquifer could not long sustain a 150-gallon/day pumping rate. The DOE demonstrated at their facility that the Alluvium is not, and never has been, an aquifer due to limited yield (DOE 1995).

- There are few people living in the area of the Facility, and the sparse population that characterizes the Grants-Milan area is expected to decline even further. No residents within five miles have wells in the Alluvium, and it is not expected that any wells will be installed downgradient of the Facility. The proposed institutional control area for the Facility includes some land beyond the current operational restricted area land so that all POC wells and any Facility reclamation designed feature would be within the boundary of the land subject to institutional control and long-term surveillance. This prevents people from installing wells in this area or contacting potential surface hazards. In addition, data collected in the 1989 socioeconomic study (Dames & Moore 1989) indicate that the poor economy is causing the population in the area to decline, further reducing the potential of someone using groundwater for potable purposes.

- Ambient background quality of the water has been demonstrated to be poor, making this groundwater unattractive as a potable water source. Groundwater in the vicinity of the Facility has been adversely impacted by mine pumping and discharge, infiltration of seepage from the nearby DOE Title I Facility, and runoff from abandoned mine spoils and ore piles. All these sources have contributed constituents to the alluvial groundwater, affecting groundwater quality and limiting the usefulness of the Alluvium as a potable water source. This was discussed in greater detail in Section 2.1.1.

None of the factors identified above are expected to change in the future. There are currently no complete exposure pathways to groundwater and none are expected to be complete in the foreseeable future. However, consistent with QMC's ACL petition for the uppermost bedrock units, it was conservatively assumed that groundwater at the POE could be used as a drinking water source for purposes of developing health risk-based concentrations.

In reality, consumption of drinking water from impacted groundwater sources is an incomplete exposure pathway primarily for two reasons. The aquifer has a very limited yield and could not support sustained domestic supply use. The ambient background quality of the water in the Alluvium is poor, making it an undesirable source of drinking water.

The milk ingestion pathway was considered an incomplete exposure pathway because there are no existing dairy herds within 50 miles of the Facility nor are there likely to be any dairy farms in the future and the alluvium could not provide a sustained supply for such use. Typical practice is to co-mingle milk from several individual dairy herds. Therefore, in the unlikely event dairy cows were to be raised near the Facility, the potential impact of groundwater obtained at the POE and used to water the dairy cows would be small due to dilution from other milk sources during processing for distribution.

Beef cattle do exist in the vicinity of the Facility but it is highly unlikely that groundwater is used for watering of these cattle. Surface water is typically used for stock watering and irrigation purposes. Currently, there are two stock ponds in the vicinity of the downgradient edge of the land being transferred (i.e., the POE). Current practice is to fill the stock ponds with treated mine water and runoff from the facility. However, once dewatering is discontinued, the source of water for the stock ponds will be eliminated, making this an incomplete exposure pathway. As discussed above, no dairy cattle live or graze in the area so human ingestion of milk was not considered a complete exposure pathway. Treated mine water may have been used to irrigate alfalfa but this will no longer be possible when mine dewatering ends. Therefore, for the reasons detailed, ingestion of beef from cattle consuming treated mine water and forage irrigated with treated mine water and/or ingestion of vegetation irrigated with treated mine water are not considered complete exposure pathways.

Ingestion of meat from wild game grazing on irrigated land and consuming minewater is a possible complete exposure pathway but a highly unlikely one. Hunting does occur on a seasonal basis, but direct or indirect exposure of wild game that might be hunted to affected groundwater is not likely. Alluvial groundwater is not now used, nor is it expected to be used, to irrigate crops that wild game could eat. Additionally, there are no surface expression points for groundwater within 100 miles of the tailings area so direct contact with groundwater is not possible. Ingestion of produce irrigated with groundwater is also considered to be an incomplete exposure pathway because groundwater is not used for irrigation (with the exception of alfalfa which humans do not eat) in this area.

Public water supplies would not be affected by groundwater from the Facility since groundwater in the alluvial aquifer is not being used by any municipal water system within 100 miles of the tailings area. The nearest three municipal water systems, approximately 20 miles from the Facility, are the City of Grants, Village of Milan, and Village of Bluewater. Wells supplying water to these systems are completed either in the San Andres aquifer or the alluvial aquifer of the Rio San Jose and Rio San Mateo.

2.3.2.2 Potential Future Surface Water Uses

The potential for contamination of naturally occurring surface water is negligible because groundwater does not naturally discharge to surface water within 100 miles of the tailings area. The only surface water that exists in the vicinity of the Facility is water that is pumped out of the mines to the land surface during dewatering of the mines. This water source will disappear when dewatering ceases. Without natural discharge to surface water, there are no exposure point concentrations and exposure to surface water is considered an incomplete pathway.

2.3.2.3 Exposure Pathways Excluded from Quantitative Evaluation

As mentioned earlier, without exposure there is no risk. Pathways considered in this assessment but not quantitatively evaluated due to the lack of a complete exposure pathway and/or low probability of exposure include the following:

- ingestion of milk from dairy cows provided with forage irrigated with groundwater or impacted water,
- ingestion of meat from animals directly consuming groundwater and forage irrigated with groundwater,
- ingestion of produce irrigated with groundwater,
- dermal contact with groundwater, and
- direct or indirect exposure routes associated with hydraulically connected surface water.

The rationales for excluding these exposure pathways from the quantitative evaluation were provided earlier.

2.3.3 Constituents of Concern in Groundwater

The hazardous constituents of concern include the following: molybdenum, nickel selenium, lead-210, natural uranium, thorium-230, radium-226, and radium 228. Gross alpha has also been identified as a possible constituent of concern. However, the ACL petition for the uppermost bedrock units reported that the laboratory that performs the groundwater analyses stated that the gross alpha concentration results includes alpha activity from natural uranium and all other alpha emitters. Normally, alpha activity from uranium will contribute most of the gross alpha activity in neutralized groundwater impacted with uranium mill tailings liquids from a sulfuric acid leach process. Proposed health risk-based concentrations will be developed for all the potential alpha emitters (natural uranium, Th-230, Ra-226 and -228, and Pb-210) in neutralized groundwater impacted with uranium mill tailings liquids. Therefore, development of a health risk-based concentration or an ACL for gross alpha was not deemed necessary.

A hazard evaluation was completed for the constituents identified above to demonstrate that the proposed ACLs for the Alluvium will not pose substantial risk to human health and the environment in the event exposure were to occur. A health risk-based concentration limiting the lifetime risk to 1 x 10^{-4} for groundwater consumption at a potential POE location was calculated for each constituent. ACLs were established for the POC wells based on either the health risk-based concentration or a higher concentration which would insure that the health risk-based concentrations are maintained at the POE locations due to attenuation in the constituent concentrations during groundwater transport between the POC wells and the POE locations. If the groundwater concentrations of each constituent in the alluvial aquifer wells that are at the downgradient edge of the Land Withdrawal Area (wells 5-08 and 5-04) are below the calculated health risk-based concentrations presented here, the constituent concentrations in the alluvial aquifer unit do not pose a substantial risk to the human health or the environment.

The hazard evaluation from exposure to radionuclides in groundwater was performed primarily using risk coefficients from the following documents:

- USEPA's Federal Guidance Report (FGR) No. 13, Part 1 (EPA 402-R-97-014) "Health Risk from Low Level Environmental Exposure to Radionuclides" (EPA 1988)
- The Final Generic Environmental Impact Statement on Uranium Milling NUREG-0706 (NRC 1980)

- The National Council on Radiation Protection and Measurements Report I231 "Screening Models for Releases of Radionuclides to Atmosphere, Surface Water, and Ground (NCRP 1996)

2.3.4 Evaluation of Human Health Hazards

This section documents the assumptions, equations, and input parameters used to develop health risk-based concentrations assuming use of groundwater at the POE as a potable water source. Potential human exposure pathways have been identified based on current and anticipated future land and water uses. While ingestion of impacted groundwater is not currently occurring nor is it expected to occur, in an effort to be conservative, complete, and consistent with the ACL petition for the uppermost bedrock units, this exposure pathway was considered to be complete.

The evaluation of potential hazards involves the identification of health risk-based concentrations in groundwater for the anticipated complete exposure scenario. Then, the calculated concentrations are compared to modeled values at the proposed POE wells to assess the potential hazard should groundwater in the vicinity of the POE wells be used as a potable source.

2.3.4.1 Health Risk-based Concentrations

Proposed health risk-based concentrations for the constituents of potential concern in groundwater will be Maximum Contaminant Levels (MCLs), when available and applicable, or calculated values assuming a 1×10^{-4} target risk. MCLs protective of humans using water as a drinking source have been used because there is no control of groundwater directly downgradient of the POE. While highly unlikely considering the poor ambient background quality of the water and the sparse regional population, groundwater could be used as a drinking water source. The application of MCLs or values calculated assuming household use of the groundwater at the POE is therefore a conservative and health protective approach.

2.3.4.1.1 Health Risk-based Concentrations for Nickel, Selenium, and Molybdenum

MCLs have been established by the USEPA for nickel and selenium. MCLs are generally health-based concentrations that may have been adjusted to account for technological limitations. The MCLs for nickel and selenium are 0.1 mg/L and 0.05 mg/L, respectively. Note though that the MCL for nickel has been remanded so there is no enforceable federal MCL for nickel at this time. The chronic effects associated with the ingestion of nickel at concentrations above 0.1 mg/L following long term exposures include heart and liver damage, dermatitis, and decreased body weight.

While there is no enforceable MCL for molybdenum, USEPA has identified 0.18 mg/L in drinking water as a health protective concentration. While the conservative nature inherent in the development of MCLs is recognized, these values (0.18 mg/L, 0.1 mg/L, and 0.05 mg/L) are proposed as the health risk-based concentrations for molybdenum, nickel and selenium, respectively, in groundwater.

2.3.4.1.2 Calculated Health Risk-based Concentrations

Health risk-based concentrations that will limit the lifetime risk to 1×10^{-4} assuming groundwater consumption at the POE location are necessary for natural uranium, lead-210, thorium-230, radium-226, and radium-228. Review of the potential groundwater exposures that might be associated with the alluvial aquifer indicate that the health risk-based concentrations calculated for these constituents in the ACL petition developed for the uppermost bedrock units are also applicable to the alluvial aquifer.

The health risk-based concentrations which limit the lifetime cancer mortality risk associated with ingestion of a radionuclide in water to less than 1×10^{-4} are determined using an USEPA (1998) risk coefficient. The lifetime acceptable radionuclide intake (I [Bq]) is calculated as:

$$I\ (Bq) = R/r$$

where R = acceptable lifetime risk of 1×10^{-4} and r = USEPA (1998) risk coefficient expressed as probability of radiogenic cancer mortality rate per unit (Bq) intake of a particular radionuclide in tap water averaged over all ages and genders.

Next, the acceptable intake is used in the following equation to calculate the health risk-based concentration (C_{hb}) targeted to achieve a lifetime risk of 1×10^{-4}:

$$C_{hb} = [(I)(CF)]/[(y)(d)(Q)]$$

Where I = lifetime radionuclide intake, CF = unit conversion factor of 27 pCi/Bq, y = exposure duration for groundwater of 30 years, d = exposure frequency of 350 days per year (USEPA, 2000), and Q = 1.11 liters per day lifetime combined average intake of tap water (USEPA, 1998). Using a 30 year exposure duration to calculate the health risk-based concentration is considered very conservative because of the very low probability that any individual would move near the facility and use the alluvial aquifer as their primary potable water source for 30 years.

2.3.4.1.3 Health Risk-based Concentration for Natural Uranium

The toxicology of uranium has been extensively studied in both humans and animal models and the results of these studies have been summarized in journals, government documents, and meeting proceedings. Natural uranium can cause both chemotoxic and radiotoxic effects. The chemotoxic effects of uranium have been observed in humans exposed under both accidental and experimental conditions and have been quantified using animal models. Soluble uranium oxide ions complex with serum proteins and bicarbonate. The bicarbonate complex is filterable at the renal glomerulus. The uranium oxide ion dissociates within the tubular filtrate and recombines with cell surface ligands (Durbin, 1984). At low doses, it appears that renal injury is indicated by urinary biochemical changes rather than overt illness; the association between the biochemical indicators and clinically observable injury is not well defined.

The New Mexico Water Quality Control Commission has established a groundwater protection standard for natural uranium of 5 mg/L (equivalent to 3,400 pCi/L) based on its chemotoxicity. Recently, a concentration limit for natural uranium of 0.43 mg/L based on chemotoxicity in drinking water was established in the Bluewater Uranium Mill Site, Grants, NM Alternate Concentration Limits Petition (ARCO 1995). This 0.43 mg/L (equivalent to 300 pCi/L) health risk-based concentration was derived for threshold for human kidney injury, and is much more restrictive than NM's 5 mg/L groundwater protection standard. The NRC agreed with the chemotoxicity health risk-based concentration of 0.43 mg/L and approved the groundwater ACLs.

Natural uranium has not been demonstrated to be a human carcinogen. There is no direct evidence that ingestion of uranium induces cancer in humans (Mays et al. 1985) and EPA (1985) reports that ingestion of natural uranium has not been shown to cause cancer or bone marrow damage in laboratory animals. High specific activity uranium isotopes, U-232 and U-233, have induced bone sarcomas in mice (National Research Council 1988). The designation of natural uranium as a Class A carcinogen appears to be based on the qualitative and quantitative similarity in the results of animal studies involving U-232/U-233 and Ra-226, in combination with the fact that the USEPA considers all radionuclides to be Class A carcinogens.

The NRC effluent limit for natural uranium in water specified in Appendix B of 10 CFR 20 to control dose to an individual member of the general public is 300 pCi/L. This effluent limit is based on identifying a concentration in drinking water that will limit radiation dose to the NRC's 0.1 rem acceptable dose limit for individual members of the general public. The health risk-based concentration for radiotoxicity associated with natural uranium for this petition was developed using risk coefficients from FGR 13 (USEPA 1998) for ingestion of tap water.

FGR 13 identifies risk coefficients for ingestion of uranium isotopes in tap water that are expressed as the probability of radiogenic cancer mortality per unit intake where the intake is averaged over all ages and genders. However, while FGR 13 does not specify a risk coefficient for natural uranium, the mortality risk coefficients for U-234, U-235, and U-238 are 1.24E-09 Bq^{-1}, 1.21E-09 Bq^{-1}, and 1.13E-09 Bq^{-1}, respectively. As was used in the QMC's ACL petition for the uppermost bedrock units, a risk coefficient for natural uranium of 1.19E-09 Bq^{-1} was calculated based on activity fractions of U-234, U-235, and

U-238 in natural uranium at 0.4889, 0.02218, and 0.4889, respectively. Then the risk coefficient for Th-234, a short-lived decay product of U-238, was added to the U-238 risk coefficient because Th-234 activity will build in to equilibrium within a few months. The final risk coefficient for natural uranium used to develop the health risk-based concentration was 1.36E-09 Bq^{-1}.

Using the calculated risk coefficient, the health risk-based concentration for natural uranium was calculated as follows:

I(Bq) = R/r where

R = 1E-04

r = 1.36E-09 Bq-1

I = 1E-04/1.36E-09 = 7.4E+04 Bq

The health risk-based concentration for natural uranium, calculated using the parameters identified above, that will limit the lifetime risk associated with exposure in tap water to 1 x 10^{-4} is:

C_{hb} = I/(ED)(EF)(IW)

Chb = [(7.4E+04 Bq)(27 pCi/Bq)]/[(30 yr)(350 day/year)(1.11 L/day)] = 164 pCi/L

The 164 pCi/L, the limiting concentration due to radiotoxicity calculated for this ACL petition, is equivalent to 0.24 mg/L. This value is more restrictive than NM's 5 mg/L groundwater protection standard (3300 pCi/L), the 0.43 mg/L (300 pCi/L) limit established in ARCO's 1995 ACL petition, and the NRC's 300 pCi/L effluent limit for licensed facilities. This groundwater concentration, 164 pCi/L or 0.24 mg/L, at the POE well would be protective of human health and the environment, and would ensure a lifetime risk below the 10^{-4} target level.

2.3.4.1.4 Health Risk-based Concentration for Lead 210

The health risk-based concentration for Pb-210 was calculated using the 1.75E-08 mortality risk coefficient specified in FGR 13 for ingestion of tap water containing Pb-210. The health risk-based concentration, targeted to achieve a 10^{-4} risk due to radiotoxic hazard associated with ingestion of lead 210 in tap water, was calculated in the same manner as the value for natural uranium.

$I = (1.0E\text{-}04)/(1.75E\text{-}08\ Bq^{-1})$

$= 5.7E{+}03\ Bq$

Therefore, the health risk-based concentration of Pb-210 that will limit the lifetime risk to 1×10^{-4} is:

$C_{hb} = [(5.7E{+}03\ Bq)(27\ pCi/Bq)]/[(30\ years)(350\ days/year)(1.11\ l/day)$

$= 13\ pCi/L$

2.3.4.1.5 Health Risk-based Concentration for Thorium 230

The health risk-based concentration for Thorium-230 was calculated using the 1.67E-09 mortality risk coefficient specified in FGR 13 for ingestion of tap water containing Thorium 230. The health risk-based concentration was targeted as follows to achieve a 10^{-4} risk:

$I = (1.0E\text{-}04)/(1.67E\text{-}09\ Bq^{-1})$

$= 6.0E{+}04\ Bq$

$C_{hb} = [(6.0E{+}04\ Bq)(27\ pCi/Bq)]/[(30\ years)(350\ days/year)(1.11\ l/day)$

$= 139\ pCi/L$

2.3.4.1.6 Health Risk-based Concentration for Radium-226 and 228

There are currently three standards for Ra-226/228 in groundwater. The USEPA has identified 5 pCi/L as the MCL for Ra-226/228. The NRC uses 5 pCi/L as a groundwater protection standard (10 CFR 40, Appendix A) for Ra-226 and Ra–228 combined, and the New Mexico Water Quality Control Commission regulations, subpart III, identify a groundwater protection standard of 30 pCi/L. These standards were established for large and diverse populations and include an ample margin of safety. However, it is highly unlikely the alluvial aquifer groundwater will be used as a drinking water source, especially considering that the area surrounding the Facility is a remote area with a very low probability that ground water will be used as a potable source.

In addition, the radiological characteristics of Ra-226 and -228 indicate that a combined value for the two isotopes may not be the best approach to developing a protective value. Ra-226 is an alpha emitter while Ra-228 is a beta emitter. Based on the risk coefficients, Ra-228 poses a 3.8 times higher cancer mortality risk per unit intake than Ra-226. Therefore, the MCL is not proposed as the health risk-based concentration. Instead, a health risk-based concentration will be calculated for each radium isotope using risk coefficients presented in FGR 13. Then, a combined health risk-based concentration that ensures a lifetime risk of mortality due to ingestion of Ra-226/228 in groundwater of 1 x 10^{-4} will be developed. The combined value will be based on the fractions of Ra-226 and Ra-228 in the source area, and the resulting value will be proposed as the ACL.

The health risk-based concentration for Ra-226 was calculated using the 5.32E-09 mortality risk coefficient specified in FGR 13 for ingestion of tap water containing Ra-226. The health risk-based concentration was targeted to achieve a 10^{-4} risk as follows:

$I = (1.0E\text{-}04)/(5.32E\text{-}09\ Bq^{-1})$

$= 1.9E{+}04\ Bq$

$C_{hb} = [(1.9E{+}04\ Bq)(27\ pCi/Bq)]/[(30\ years)(350\ days/year)(1.11\ l/day)$

$= 44\ pCi/L$

The health risk-based concentration for Ra-228 was calculated using the 2.0E-08 mortality risk coefficient specified in FGR 13 for ingestion of tap water containing Ra-228. The health risk-based concentration was targeted as follows to achieve a 10^{-4} risk:

$I = (1.0E\text{-}04)/(2.0E\text{-}08\ Bq^{-1})$

$= 5.0E+03\ Bq$

$C_{hb} = [(5.0E+03\ Bq)(27\ pCi/Bq)]/[(30\ years)(350\ days/year)(1.11\ l/day)$

$= 12\ pCi/L$

As shown above, the health risk-based concentrations for Ra 226 and Ra 228 in groundwater were calculated to be 44 pCi/L and 12 pCi/L, respectively. Separate health risk-based concentrations were developed to account for the different radiological characteristics; specifically, Ra-226 is an alpha emitter while Ra-228 is a beta-emitter.

Evaluation of the groundwater data collected from the source area for the Alluvium indicate that the radium composition is 99 percent Ra-226 and only one percent Ra-228. The source does not contain significant concentrations of Ra-228, probably because Ra-228 is a thorium series (Th-232) radionuclide, and the facility processed uranium ore containing uranium (U-238) and actinium (U-235) series radionuclides. Ra-228 is not part of either of these decay series. These data are consistent with that reported in the ACL petition for the uppermost bedrock units. Toxicological data indicate that Ra-228 presents a higher cancer risk per unit intake than Ra-226. As was done in the ACL petition for the uppermost bedrock units, it was conservatively assumed that the average Ra-228 was not one percent, but three percent.

Considering the individual health risk-based concentrations of 44 pCi/L for Ra-226 and 12 pCi/L for Ra-228 calculated above, and the assumption that the groundwater contains 97 percent Ra-226 and 3 percent Ra-228, the combined health risk-based concentration designed to limit the lifetime mortality risk to 1×10^{-4} was calculated as follows:

$[C_{Ra\text{-}228}/C_{hb\ Ra\text{-}228}] + [C_{Ra\text{-}226}/C_{hb\ Ra\text{-}226}] = 1.0$

Where:

$C_{Ra\text{-}228}$ = limiting Ra-228 concentration in pCi/L (3.1 percent or 0.31 of the Ra-226 limiting concentration based on fraction in the source)

$C_{hb\ Ra\text{-}228}$ = Ra-228 health risk-based concentration of 12 pCi/L

$C_{Ra\text{-}226}$ = limiting Ra-226 concentration in pCi/L

$C_{hb\ Ra\text{-}226}$ = Ra-226 health risk-based concentration of 44 pCi/L

$[(C_{Ra\text{-}226} * 0.031)/12] + [C_{Ra\text{-}226}/44] = 1.0$

$C_{Ra226} = 39.5$ pCi/L

$C_{Ra\text{-}228} = 0.031 * 39.5$ pCi/L

$C_{Ra\text{-}228} = 1.2$ pCi/L

Using these data, the combined Ra-226 and Ra-228 health risk-based concentration that limits the lifetime cancer risk to 10^{-4} was calculated as follows:

is 39.5 pCi/L + 1.2 pCi/L = 41 pCi/L.

In summary, the health risk-based concentrations applicable at the POE for the constituents of potential concern are as follows:

- Molybdenum: 0.18 mg/L
- Nickel: 0.1 mg/L
- Selenium: 0.05 mg/L
- Lead 210: 13 pCi/L
- Natural uranium: 164 pCi/L
- Thorium 230: 139 pCi/L
- Radium 266 and Radium 228 combined: 41 pCi/L

2.3.4.1.7 Comparison of Health Risk-based Concentrations to Other Potentially Applicable Standards

The health risk-based concentrations presented for the alluvial groundwater were compared to some State of New Mexico surface water standards (NM Water Quality Control Commission, 2000) to ensure that the proposed risk-based concentrations were protective. Specifically, the health risk-based concentrations were compared to the available New Mexico standards for domestic water supply, irrigation, and livestock watering because, while these exposure pathways are incomplete, these are the only potentially complete exposure pathways for the alluvial groundwater. All of the health risk-based concentrations proposed here were equivalent to or below the domestic water supply, irrigation, and livestock watering standards with one exception. The exception is the Ra-226/Ra-228 standard for livestock watering of 30 pCi/L. This standard is lower than the proposed health risk-based concentration of 41 pCi/L. It is likely that the New Mexico standard was calculated assuming the water contained a greater percentage of Ra-228 than the data for the alluvial aquifer has demonstrated here, and is more conservative than required for a water source containing one percent Ra-228.

2.3.4.1.8 Comparison of Health Risk-based Concentrations to Modeled Values at the Proposed POE Wells

Validated geochemical modeling was performed to estimate concentrations of constituents in groundwater at the POE after equilibration of tailings seepage with alluvial materials (Geochemical Modeling Report, Appendix B). Table 2.4 compares health risk-based concentrations of constituents in groundwater to modeled concentrations at the proposed POE wells. In all cases, modeled concentrations at the POE wells are well below risk-based concentrations, typically by several orders of magnitude.

Table 2.4. Comparison of health risk-based concentrations to modeled values at the proposed POE wells, QMC Facility, Ambrosia Lake, New Mexico.

Constituent	Modeled Concentrations	Risk-based Concentrations
Molybdenum (mg/L)	0.00001	0.18
Nickel (mg/L)	0.0004	0.1
Lead-210 (pCi/L)	0.00001	13
Radium-226 (pCi/L)	17	41
Selenium (mg/L)	7.4E-12	0.05
Thorium-230 (pCi/L)	8.6E-14	139
Uranium (mg/L)	5.0E-06	0.24*

*Uranium converted from mg/L to pCi/L assuming secular equilibrium.

2.3.4.2 Human Health Hazard Assessment Summary

The modeled groundwater concentrations at the POE for all constituents of interest are all below the human health risk-based concentrations. This indicates that the proposed health risk-based concentrations do not pose any present or potential future hazards to human health. Although NRC guidelines (1996) for ACL applications specify that the persistence and permanence of adverse effects must be considered in the human hazard evaluation, this requirement is not relevant to this analysis as no adverse human health impacts are anticipated.

2.3.5 Environmental Hazard Assessment

The potential for environmental exposures to groundwater in the vicinity of the Facility is expected to be limited to non-existent due to the lack of permanent surface-water bodies. No significant environmental or agricultural impacts can be postulated associated with exposure to groundwater containing constituents at the concentrations proposed in this ACL demonstration because the impacted aquifer does not discharge to surface water sources in the vicinity of the Facility. Therefore, this environmental hazard evaluation is semi-qualitative in nature. The health risk-based concentrations protective of human health should be adequate to ensure that the health of livestock and indigenous wildlife is sufficiently protected. Therefore, the proposed health risk-based concentrations were compared to benchmark concentrations expected to cause minimal effects on wildlife populations.

The potential for adverse effects on physical structures was also considered. There are no physical structures in the vicinity of the Facility or in the flow path of the groundwater that could be adversely affected by the proposed health risk-based concentrations.

2.3.5.1 Ecological Benchmark Concentrations for Inorganic Constituents

The toxicological benchmarks for inorganic constituents are based on no observed adverse effects levels (NOAELs) for representative mammalian and avian wildlife species assuming the animal receives 100 percent of its water from one source. The NOAELs, presumed to be non-hazardous to the surrounding biota, were derived for the DOE's Oak Ridge facility and presented by Sample et al. (1996). The collection of benchmark values indicated that white-tailed deer are the most sensitive species for which data are available. The benchmark water concentrations protective of white-tailed deer for the three inorganic constituents of interest are as follows:

Molybdenum (MoO_4)	0.60 mg/L
Nickel (nickel sulfate hexahydrate)	171 mg/L
Selenium (selenate)	0.086 mg/L

The proposed human health risk-based concentrations are all below the NOAEL-based toxicological benchmark values listed above. Therefore, the proposed human health risk-based concentrations for groundwater are considered protective of the environment.

2.3.5.2 Ecological Benchmark Concentrations for Radionuclide Parameters

The health risk-based concentrations were compared to benchmarks for radionuclides established for the Rocky Flats Environmental Technology Site (Higley, 1995). The water concentrations are based on a maximum radiation dose to wildlife of 100 mrad per day. This dose rate represents a NOAEL for chronic radiation exposure to terrestrial and aquatic animals. Per Higley (1995), this maximum dose rate was derived based on the findings of an International Atomic Energy Agency technical report. The report stated that "There is no convincing evidence from the scientific literature that chronic radiation dose rates of 1 mGy/day or 100 mrad/day will harm animal or plant populations".

The benchmark radionuclide concentrations used here were calculated considering the allowable dose rate, daily intake, fraction of the nuclide assimilated, and the body mass of the animal. The benchmark concentrations for water for terrestrial species are as follows:

Lead 210	170 pCi/L [a]
Natural uranium	7 mg/L
Thorium 230	170 pCi/L [a]
Ra-226	250 pCi/L
Ra-228	170 pCi/L

[a] No benchmark values are provided for Lead 210 and Thorium 230. Therefore, the benchmark concentration presented for Ra-228, the lowest of the applicable values presented in Higley (1995), was used as a surrogate in the comparison for Lead 210 and Thorium 230.

The calculated health risk-based concentrations for the radionuclide parameters are below the ecological benchmarks, indicating that the health risk-based concentrations are protective of the environment.

2.3.5.3 Environmental Hazard Assessment Summary

The health risk-based concentrations calculated for the constituents of interest are all below the environmental benchmarks protective of wildlife. This demonstrates that the proposed health risk-based concentrations do not pose any present or potential future hazards to the environment. NRC guidelines (1996) for ACL applications specify that the persistence and permanence of adverse effects must be considered in the environmental hazard evaluation. However, this requirement is not relevant to this analysis as no adverse environmental impacts are anticipated.

2.3.6 Hazard Assessment Summary

Ore milling operations at the Ambrosia Lake Facility and placement of mill tailings ceased in January 1985. The mill tailings reclamation activities were implemented in 1987 and tailings reclamation is scheduled for completion. Cessation of milling operations and implementation of a groundwater corrective action program has resulted in rapidly declining constituent levels in groundwater. This ACL demonstration presents health risk-based concentrations for groundwater based on an acceptable cancer risk of 1×10^{-4} and/or a hazard quotient of 1 for non-carcinogenic constituents considering the protection of human health at present and foreseeable future POE. The health risk-based concentrations are not intended to be drinking water standards for the general public but are site-specific values shown to present no substantial health risk. The risk-based concentrations take into account the very low probability of exposure to groundwater, the limited population that could potentially be exposed, and reasonable estimates of health risk. The poor local ambient background groundwater quality further reduces the possibility that groundwater will be used as a potable water source.

The human health risk-based concentrations were compared to available ecological benchmarks considered protective of wildlife. The human health risk-based concentrations calculated for the constituents are more restrictive than concentrations that might be of concern for ecological receptors, and are therefore also considered protective of the environment. The concentrations modeled for all constituents of interest in groundwater at the POE are all below the human health risk-based concentrations, indicating that the risk-based concentrations do not pose any present or potential future hazards to human health.

3 CORRECTIVE ACTION ASSESSMENT

3.1 Previous Corrective Action

A history of the previous corrective action was presented in Section 1.1.2 of this report.

Past corrective actions, including minimizing the amount of free water, use of lined ponds, removal of standing tailings solution, construction and operation of the interceptor trench, and construction of the tailing cover, have reduced seepage of tailings fluid to groundwater. Reduced seepage has in turn, resulted in reduced concentrations of hazardous constituents in groundwater at the POC (See Section 2.2.3).

3.2 Results of the Groundwater Corrective Action Program

Since GPS for several constituents are exceeded at the POC in the Alluvium, the NRC required QMC to implement a groundwater CAP. The approved groundwater CAP for the Alluvium is briefly described below.

On June 1, 1986, the State of New Mexico relinquished its licensing authority over uranium milling activities. The NRC reasserted its regulatory jurisdiction over New Mexico uranium processing facilities and associated byproduct material. As a result of the new regulatory jurisdiction, QMC submitted a detection monitoring plan to the NRC on January 29, 1988 for the hydrogeologic units that could potentially be impacted by processing of uranium ore and disposal of by-product material at the facility. The hydrogeologic units addressed by the groundwater protection program were the TRA, the TRB, the Dakota Sandstone and the Alluvium. The Detection Monitoring Plan was submitted pursuant to the NRC's newly adopted 10 CFR 40, Appendix A, Criteria 7 regulations that had became effective on December 14, 1987. Upon plan approval, the NRC established its groundwater protection program for the facility.

Following the review of data from the groundwater detection monitoring program sampling events, the NRC established GPSs for hazardous constituents in groundwater at the POC wells for the TRA, TRB, Dakota and the Alluvium. The GPS for all constituents, except combined radium, were set at "background" concentrations determined from sampling events in October 1988 from one background well in each of the aquifers.

Prior to mining, the Alluvium within the Ambrosia Lake valley was dry. With the commencement of mining activities in the area during the 1950s, dewatering of the mines resulted in two actions: 1) development of a cone of depression within the underlying geologic units (Tres Hermanos, Dakota and Westwater); and 2) recharge into the Alluvium. QMC initiated the following corrective actions to mitigate water migration: 1) re-alignment of the Arroyo del Puerto in 1976 to divert surface water flows around the evaporation ponds; 2) discontinued use of all unlined evaporation ponds and removal of ponded solutions; 3) construction of an interceptor trench adjacent to Tailings Impoundment 1. The interceptor trench forms a reverse hydraulic gradient within the Alluvium, so the treated minewater infiltrates and flushes the Alluvium from the realigned channel towards the interceptor trench; resulting in improved water quality within the impacted Alluvium.

A total of 856,000,000 gallons of water consisting of impacted water from Tailings Impoundment 1 and the groundwater sweep program were recovered and removed from the Alluvium via the interceptor trench since 1984. The recovered water, which included storm water runoff that accumulated within the trench, was disposed of within lined evaporation ponds.

In addition to the groundwater sweep/interceptor trench program, geochemical processes also act upon the water present within the Alluvium (Appendix B). This results in neutralization of the water and reduced solubility and migration of constituents. The three corrective actions described above for the Alluvium are currently in operation.

3.3 Feasibility of Alternate Groundwater Corrective Actions for the Alluvium

It is technically impracticable to restore groundwater quality to the licensed standards at the POCs because of the presence of widespread groundwater impacts resulting from other sources containing the same constituents as that from milling, and the fact that the

Alluvium was not and never will be an aquifer. Continued operation of the groundwater CAP will not bring constituent concentrations at the POCs to the GPS listed in the NRC license. Groundwater modeling indicates that once the mine water discharge to the Arroyo de Puerto ceases, saturation levels within the Alluvium will decrease over time, and the Alluvium will be completely dewatered within 65 to 100 years. Modeling also indicates that seepage from Tailings Impoundment 1, as a result of completion of tailings reclamation and construction of the low permeability cover, will continue to decrease. With the closing of the interceptor trench, natural attenuation mechanisms will prohibit incremental degradation of residual (and diminishing) groundwater quality immediately downgradient of Tailings Impoundment 1. Modeling results indicated that the water quality of the Alluvium will be protective of human health and the environment at the proposed POEs.

With final reclamation at the QMC nearing completion, the range of other practical groundwater corrective action alternatives for the Alluvium is limited. With the proposed termination of mine water discharge into Arroyo del Puerto, the Alluvium will eventually (within 65 to 100 years) dewater. Therefore, the consideration of costly alternative corrective action scenarios is inappropriate. However, several alternative technologies were reexamined for potential feasibility and effectiveness as corrective action measures for the Alluvium at the Facility. The potentially feasible alternatives to continuing the current CAP for the Alluvium include the following:

1. Enhanced tailings dewatering
2. Facility reclamation and termination of mine water discharge into Arroyo del Puerto

3.3.1 Enhanced Tailings Dewatering

With the exception of the main Tailings Impoundments 1 and 2, all the remaining unlined evaporation ponds (4, 5, 6, 7, and 8) have been dewatered, and the majority of residues have been removed and consolidated into Impoundment 1 or 3. These ponds will be closed using an NRC approved plan to reduce recharge of water to the Alluvium. The two main Tailings Impoundments will slowly dewater as a result of completion of tailings reclamation and construction of the low permeability cover.

Enhanced dewatering of the main Tailings Impoundments 1 and 2 would require numerous pumping wells installed through the cap. Furthermore, extraction of fluids from the tailings slimes would not be feasible. Based on experience, it is estimated that approximately 50 dewatering wells would be needed to dewater tailing sands and that pumping would have to be sustained for at least four years. However, since a radon barrier and reclamation cover have been placed on Tailings Impoundment 1 and 2, and some of the tailings have been compressed and fluids drained from the tailings, further tailings liquids extraction could be reduced and the pumping period to dewater tailings sands may be considerably shorter than four years. Any tailings liquids recovered by this process would need to be treated at the mill to recover uranium and the treated liquid would be disposed of in the existing ponds. Construction of additional ponds for these liquids was not included in the cost estimation for this alternative.

Penetration of the cap for the installation of wells would increase the potential rate of infiltration through the cap and could increase the radon flux from the covered tailings. Also, the bulk of the tailings solution that could seep from the main Tailings Impoundment has already been captured and removed by the interceptor trench, a key component of the groundwater CAP for the Alluvium. Modeling indicates that seepage from the Tailings Impoundment will be negligible within 100 years.

3.3.2 Facility Reclamation and Termination of Mine Water Discharge into Arroyo del Puerto

The Reclamation Plan with termination of mine dewatering discharge to the Arroyo del Puerto is considered the Base Case, the alternative against which other corrective action measures are compared. Decommissioning and reclamation of the Facility is being completed in accordance with NRC standards. Installation of the radon barrier and low permeability cover on Tailings Impoundments 1 and 2, will effectively eliminate the facility as a future active source of groundwater contamination.

Termination of the mine dewatering and discharge to the Arroyo del Puerto is included in the Base Case because discharge to the Arroyo del Puerto to enhance groundwater capture between the arroyo and interceptor trench is no longer effective and necessary to flush constituents of concern towards the interceptor trench. The NRC Staff has recently interpreted mine discharge water that has been used for licensed activities to be regulated processing byproduct, making continued mine pumping untenable at this time. Groundwater modeling indicates that once discharge to Arroyo del Puerto is terminated, the saturated interval within the Alluvium will dry up. Also, as discussed in Section 2.0, the natural attenuation capacity of the Alluvium will effectively mitigate constituents of concern.

3.4 Corrective Action Costs

This section summarizes and compares the costs of alternative corrective actions. Present values of the feasible corrective action were calculated to facilitate an equitable evaluation of total costs in comparison with benefits. Cost estimates for the additional corrective actions were prepared to a feasibility level of accuracy, i.e. +/- 25 percent. Present values were calculated assuming a net discount rate of 2% (interest rate minus operation cost inflation rate). All capital costs are assumed to be incurred in the first year. The estimates in the present value calculation are in 2001 dollars.

3.4.1 Cost of Current Alluvial CAP

The current cost for maintaining the CAP for the Alluvium unit is budgeted by QMC at $830,000 per year. For long-term operation, the cost would increase due to the need for pump replacements, maintenance of the interceptor trench and French drains, mine water pumping, maintenance of lined evaporation cells, and treatment components. Therefore, a total cost of about $900,000 per year is a reasonable estimate for the annual operation and maintenance of the Alluvium CAP. As of December 31, 2000, 856 million gallons have been pumped from the alluvial interceptor system at a total cost of $5 million.

Modeling estimates indicate that an additional 100 years would be required to reach the point where continued seepage from Tailings Impoundment 1 would be minimal. At this point QMC could eliminate the groundwater sweep (discharge of treated mine water to the arroyo) and related interceptor system. The present net value of continuing the alluvial CAP for an additional 100 years at an annual operating and maintenance cost of $900,000 per year is approximately $61.2 million.

3.4.2 Cost for Enhanced Tailings Dewatering

Brief summaries of the major capital and operating cost components for enhanced tailings dewatering are summarized in Table 3.1. In the present value calculations, it is assumed that dewatering would occur over a four-year period. The actual time period could be longer because tailings slimes will generally dewater over a very long period of time.

Table 3.1. Potential future corrective action capital and operating costs for enhanced tailings dewatering.

Corrective Action Component	Capital Cost	Annual Operating Cost	Present Value (Year 2000)
Installation of 50 wells to depth of 55 ft	$143,000		$143,000
Installation electrical supply & 50 pumps	$306,000		$306,000
Installation of headers & piping (10,000 ft)	$306,000		$306,000
Water treatment system upgrade	$153,000		$153,000
O&M of pumps & piping (4 years)		$306,000	$1,163,000
Water treatment O&M (4 years)		$510,000	$1,938,000
Net Present Value			**$4,009,000**

3.4.3 Facility Reclamation and Termination of Mine Water Discharge into Arroyo del Puerto

Since this is the Base Case, a cost estimate for this alternative was not developed. Instead, costs were developed for the other corrective action alternative, which would be an addition to the Base Case.

3.5 Corrective Action Benefits

3.5.1 Benefit of Continuation of Current Alluvial CAP

The approved CAP for the Alluvium serves to prevent possible exposure to groundwater impacted by milling related constituents seeping from the tailings impoundments and unlined evaporation ponds 4, 5, and 6. The primary components of the CAP consist of the following: 1) re-alignment of the Arroyo del Puerto to divert surface water flows around the evaporation ponds, 2) discontinued use of all unlined evaporation ponds and removal of ponded solution, and 3) construction of an interceptor trench adjacent to Tailings Impoundment 1. The intercept trench has created a reverse hydraulic gradient with the Alluvium, so the treated mine discharge water infiltrates and flushes the Alluvium from the realigned channel towards the intercept trench. The flushing has resulted in improved water quality in the impacted Alluvium.

As previously demonstrated, the discharge of treated mine waters to the Arroyo del Puerto only serves to keep the Alluvium saturated, and provides a pathway for constituents of concern to enter the Alluvium. The NRC has recently ruled that mine discharge water that has been used for licensed activities is a regulated processing byproduct, making continued mine pumping and continued operation of the CAP untenable at this time.

The license-mandated GPS associated with the current CAP were derived from one monitor well and therefore do not account for the widespread ambient background contamination resulting from former ore stockpiles and DOE-related contamination impacting the Alluvium within the QMC restricted boundary. Some of GPS are already being met at the POC wells for the Alluvium. Where the GPS are not currently being met at an alluvial POC well, attenuation of the constituent concentrations between the POC and any potential POE location beyond the long-term institutional control boundary will ensure that health risk-based concentrations will be met for any groundwater migration to potential POE locations. The demonstrated attenuation capacity of the Alluvium is such that effects from constituents of concern in seepage from the tailings impoundments will be effectively mitigated prior to reaching any Alluvium POE.

Therefore, the continuation of the groundwater CAP for the Alluvium provides no additional protection of public health and the environment, especially since discontinuing the CAP will effectively dewater the Alluvium over time completely eliminating any points of exposure. The Alluvium is not (and never was) a groundwater resource. Since the hydrogeologic conditions are the same, this approach is parallel to the groundwater corrective action program approved by the NRC for the DOE Ambrosia Lake UMTRA facility.

3.5.2 Benefit of Enhanced Tailings Dewatering

Enhanced dewatering of Tailings Impoundments 1 and 2 using approximately 50 pumping wells would extract liquids from the tailings sands but would not recover fluids from the tailings slimes. The primary benefit of implementing this alternative would be to shorten the time period required to operate the interceptor trench. This conclusion is based on the 856,000,000 gallons of water containing elevated concentrations of U-nat, Ra-226, Pb-210 and Th-230 recovered by the interceptor trench since 1984 compared to the relatively minor increase in these constituents observed in the Alluvium downgradient of the main Tailings Impoundments. Even with enhanced tailings dewatering the tailings solution would continue to slowly seep from the tailings slimes and from the residual fluid in the tailings sands that cannot be effectively recovered by pumping.

While enhanced tailings dewatering may provide minor reduction in tailings seepage reaching the Alluvium, it would at best, result in only marginal changes in the concentration of constituents in groundwater in the Alluvium downgradient of the

Facility. Enhanced dewatering of the main Tailings Impoundment would not be a cost-effective corrective action for the Alluvium at the Facility. As discussed earlier, the natural attenuation capacity of the Alluvium is such that it would effectively mitigate any constituents of concern prior to reaching the proposed POEs, and make a more significant effect on constituent concentrations at the POEs than enhanced tailings dewatering. The penetration of the tailings reclamation cover for well installation and the handling of tailings water and treatment residuals associated with enhanced tailings dewatering would pose far greater risk and potential environmental concern than any minor change in hazardous constituent concentrations in the Alluvium which already meet GPS at the POC.

3.5.3 Benefits of Facility Reclamation and Termination of Mine Water Discharge into Arroyo del Puerto

The reclamation activities already performed at the Facility, including capping the tailings and continued closure of all unlined evaporation ponds, have significantly reduced seepage impacts to the Alluvium. Dewatering of the Alluvium will be initiated if the flow of treated groundwater into the Arroyo del Puerto is eliminated, coupled with the filling in of the existing interceptor trenches and French drains. Current modeling indicates that the saturation levels at the proposed POE will decrease to approximately four feet within 100 years of eliminating discharge of treated mine water into the Arroyo del Puerto and removal of the interceptor trenches. This time interval of 100 years includes a conservative estimate of decreasing tailings impoundment seepage. It was demonstrated in the modeling effort and through the evaluation of analytical data that the attenuation capacity of the Alluvium is such that constituents in seepage from the Tailings Impoundments will be mitigated prior to reaching the proposed POE. Termination of the active groundwater CAP at the QMC Facility is consistent with and parallel to the Supplemental Standards approach (based on the Alluvium not being a resource) approved by the NRC as a corrective action at the DOE Ambrosia Lake UMTRA facility.

The designation of ACLs for the Alluvium and the establishment of the long-term institutional control area boundary proposed in this ACL Petition provides protection of human health and the environment and ensures that the residual groundwater in the Alluvium downgradient of the institutional control boundary will continue to be protective of human health and the environment.

As discussed previously, discharge of treated mine water into the Arroyo del Puerto continues to keep the Alluvium saturated and provides a pathway of introduction of constituents of concern into the Alluvium. Also, alluvial groundwater within the QMC restricted area boundary is impacted by offsite abandoned mine sites as well as by groundwater impacts derived from the DOE Ambrosia Lake facility. Therefore, the continuation of the groundwater CAP for the Alluvium provides no additional benefit.

3.6 Demonstration of ALARA Principles

3.6.1 ALARA Requirements

Radiation protection regulations mandate that doses be "as low as is reasonably achievable" (ALARA), taking into account the following factors:

- the state of technology
- the economics of improvement in relation to benefits to public health and safety
- various societal and socioeconomic considerations
- the utilization of atomic energy in the public interest

License termination, or termination of a CAP, requires that the licensee demonstrate that the applicable dose criteria have been met and that doses are ALARA. Restoration of groundwater potentially impacted by licensed activities requires that hazardous constituent concentration limits be met at a specified POC. These concentration limits are either background concentrations, drinking water concentration limits, or site-specific ACLs which, if met, will not result in an unacceptable risk to humans or the environment at the nearest downgradient proposed POE.

This ALARA analysis determines whether the proposed ACL values that are protective of human health and the environment are ALARA "after considering practicable corrective actions" (NRC 1996). The NRC Draft Regulatory Guide DG-4006 describes methodology for demonstrating compliance with the radiological criteria license termination, and assumes a value of $2,000 for one person-rem averted (NRC 1998). The ALARA compares the total dose averted by specific corrective action programs and the economic value of averting that dose. If the cost per person-rem averted is greater than $2,000, ACLs are considered to be ALARA (NRC 1998).

3.6.2 ALARA Demonstration for the Alluvium

Past corrective actions, including minimizing the amount of free water, using lined ponds, removal of standing tailings solution, construction and operation of the interceptor trench, and construction of the tailings cover, have reduced seepage of tailings fluid to groundwater. Reduced seepage has in turn, resulted in reduced concentrations of hazardous constituents in groundwater at the POC. It is technically impracticable to restore alluvial groundwater quality to the licensed standards at the POCs because of the presence of widespread groundwater impacts contributed by sources other than the Facility. The range of practical groundwater corrective action alternatives for addressing the Alluvium is limited. In addition, with the proposed termination of mine water discharge into Arroyo del Puerto, the Alluvium will eventually dewater.

Alternative technologies were evaluated for potential feasibility and effectiveness as corrective action measures for the Alluvium. The two alternative corrective actions (enhanced tailings dewatering and continued current CAP) were assessed along with the base case of Facility reclamation and termination of mine water discharge into Arroyo del Puerto. Typically, benefits are summarized, using available data, in terms of the estimated reduction in U-nat concentrations at the POC or the potential dose averted. Estimated costs of each corrective action alternative and the cost per unit U-nat concentration reduction at the POC are typically used as a measure of the cost effectiveness of the alternative.

Anticipated changes in the Alluvium associated with the alternative corrective actions and the base case complicate an ALARA demonstration. Data demonstrate that constituent concentrations as measured in alluvial wells have shown some decline over the last ten years. Any marginal changes in the concentrations of constituents of concern at POC wells in the Alluvium resulting from either enhanced tailings dewatering or continued operation of the current CAP are expected to be minor compared to the changes that have resulted from the corrective action alternatives already implemented. Therefore, the possible U-nat concentration reduction at the POC associated with either implementation of enhanced tailings dewatering or continued operation of the current CAP is insignificant compared to the costs associated with these two actions. Enhanced dewatering is expected to cost $4,009,000 and maintaining the CAP is expected to cost $61.2 million over 100 years. As demonstrated in a decrease in constituent concentrations in alluvial wells, the effectiveness of corrective action activities already implemented at the Facility have significantly reduced seepage impacts. Continuation of the dewatering program (the current CAP) for the Alluvium and bedrock units, at a cost of approximately $830,000 per year, will not further reduce groundwater concentrations in the Alluvium. Thus, expending any further resources towards the alluvial CAP will provide no appreciable benefit or reduction in the potential hazards to human health or the environment.

As discussed earlier, groundwater modeling indicates that once the reclamation activities are completed, saturation levels in the Alluvium will decrease over time and the Alluvium will be completely dewatered within 65 to 100 years. Natural attenuation mechanisms will act to further reduce constituent concentrations in the Alluvium. When the Alluvium is dry there is no exposure to impacted groundwater, thus there are no risks to human health and the environment, and the alluvial groundwater concentrations will be zero and ALARA.

Nevertheless, Table 3.2 summarizes the costs and benefits of alternative corrective actions relative to the base case of tailings reclamation and termination of mine dewatering. Benefits are summarized in terms of the estimated reduction in U-nat concentrations at the POC. Estimated cost of each alternative corrective action and the cost per unit U-nat concentration reduction at the POC are used as a measure of the cost effectiveness of the alternative.

Table 3.2. Summary of cost-effectiveness of corrective action activities relative to the base case.

			Estimated Groundwater Concentration Reductions*				
	Corrective Action Alternative	Estimated Present Value (2001 $)	Lead-210 (pCi/L)	Radium-226 (pCi/L)	Radium-228 (pCi/L)	Thorium-230 (pCi/L)	Uranium (mg/L)
CAP to Date	Current CAP	$5 million	0.26	-0.30	-0.95	5.57	0.32
Optimistic 50 % Scenario	Enhanced Tailings Dewatering	$4.01 million	5.10	1.51	1.80	2.45	0.09
	Continuing the Current CAP	$61.2 million	5.10	1.51	1.80	2.45	0.09

*The estimated change in concentrations at the POC were based on a very optimistic 50 percent reduction in the concentration in POC Well 31-61.

It is uncertain how much the concentrations of the constituents of concern in groundwater might be reduced at the POC in the Alluvium as a result of implementing either enhanced tailings dewatering or continuation of the current CAP. An estimated 50 percent reduction in the U-nat concentration at the POC in the Alluvium was considered the most optimistic reduction that could possibly be expected. It is expected that any reduction in concentration for the other constituents of concern in groundwater at the POC well would be within the wide variation in the concentrations of these constituents observed at the POC wells. A 50 percent reduction was assumed for purposes of performing an ALARA demonstration.

As shown in Section 3.5, the alternative corrective actions considered would not significantly reduce constituent concentrations in alluvial groundwater. An analysis was performed to determine potential dose averted by the alternative corrective actions for ALARA evaluation consistent with the NRC's draft regulatory guidance DG-4006 (NRC

1998). The collective averted dose that would result for the alternative corrective action for each of the constituents was determined using the method described below.

The intake of hazardous constituents averted from consumption of groundwater containing reduced levels of constituents and used as drinking water for a lifetime was calculated as follows:

$I_{dw} = (C_{gw})((IW)(EF)(ED))$

Where:

> I_{dw} = Intake from groundwater, uCi
>
> C_{gw} = Groundwater concentration reduced by alternative corrective action, uCi/L
>
> IW = Average daily water intake of 1.11 liters per day (Schleien 1992)
>
> EF = Exposure frequency of 350 days/year (USEPA 1998)
>
> ED = Exposure duration of 30 years.

The annual intake in pCi per year was converted to uCi per lifetime by multiplying the annual intake in pCi by 1 x 10-6 (uCi/pCi).

The total annual intake of hazardous constituents averted from other food sources potentially impacted by groundwater at reduced constituent concentrations was not considered for the following reasons: (1) the water in the Alluvium is not used for irrigation or livestock watering and is not expected to be used in this manner in the future, and (2) the contribution from other food sources is expected to be insignificant in comparison to the contribution assumed from using groundwater as a drinking water source.

The averted dose was calculated as follows:

AD = (I)(CF)(P)

Where:

AD = Averted effective dose equivalent in person-rem

I = Intake of a constituent by an individual

CF = Intake to dose conversion factor in mrem/uCi

P = Number of persons exposed or 4. A hypothetical family of four was assumed for the unlikely scenario of consuming groundwater for domestic purposes at the potential POE.

The averted dose in mrem was converted to person-rem by dividing by 1000. The averted dose due to a potential reduction in groundwater concentrations caused by implementation of alternative corrective actions was calculated for each constituent of concern using the above method. The results are summarized below in Table 3.3.

Using the estimated present value of the less expensive corrective action alternative considered (four million dollars), the cost of one person-rem averted by implementing the alternative corrective action of enhanced tailings dewatering would be approximately $1.7 million dollars. This would far exceed the NRC's ALARA guidance of $2,000 per person-rem as specified in NRC's draft regulatory guidance DG-4006. If the more expensive corrective action, continuation of the current CAP, were implemented at a cost of $61.2 million dollars, the cost of one person-rem averted by implementing the corrective action would be approximately $59 million dollars. Furthermore, the $1.7 million spent averting the one per person-rem also exceeds the $20,000 per person-rem for demonstration of "Prohibitively expensive" criteria. Per the NRC (1998), if the cost per person-rem averted is greater than $2,000, ACLs are considered to be ALARA. Therefore, the alluvial groundwater concentrations at the Facility are ALARA.

Table 3.3. Averted collective dose calculation summary, QMC Facility, Ambrosia Lake, New Mexico.				
Constituent	Concentration Reduced(CGW) (pCi/L)	Averted Intake from ingestion of Groundwater (I) (uCi)	Intake to Dose Conversion Factor (mrem/uCi)	Averted Collective Dose (AD) (person-rem)
U-nat	0.09 mg/L or 61 pCi/L	0.716	268.9	0.77
Pb-210	5.1	0.059	5365	1.27
Th-230	2.45	0.029	547.6	0.06
Ra-226	1.51	0.018	1324.6	0.1
Ra-228	1.8	0.021	1435.6	0.12
Total				**2.32**

4 PROPOSED ALTERNATE CONCENTRATION LIMITS

The proposed ACLs are protective of human health and the environment. As demonstrated in Section 3.6, the proposed ACLs are ALARA. The Alluvium was not, and never will be, a groundwater resource. Futhermore, the elimination of treated mine water discharge to the Arroyo del Puerto will result in the dewatering of the Alluvium. The hazard assessment (Section 2.0) demonstrates that geochemical conditions result in the attenuation of constituent concentrations within short distances from potential sources, regardless of whether the constituents are derived from QMC milling activities, mine pumping and discharge, seepage from the nearby DOE facility, or runoff/erosion from abandoned mine spoils and ore piles. Geochemical modeling indicates that the attenuation capacity of the Alluvium is such that constituents derived from ongoing tailings impoundment seepage (or any other source) will be mitigated long before they could possibly reach the proposed POE. The proposed POE for the Alluvium is at the southeastern edge of the QMC Land Withdrawal Area where the Alluvium is present adjacent to the Arroyo del Puerto (Figure 4.1). The evaluation of wide spread ambient groundwater contamination shows that continued corrective actions will have little or no effect on improving the water quality of the Alluvium. Results of groundwater flow modeling indicate that once discharge of treated mine water is eliminated, the Alluvium will dewater in 65-100 years, and cease to be even a poor source of groundwater. The corrective actions already implemented at the facility have been effective, seepage from the tailings impounds is declining and will be nearly nonexistent in 100 years.

QMC is requesting ACLs for the following constituents for which GPS are listed in NRC License SUA-1473: molybdenum, nickel, selenium, gross alpha, radium-226+228, thorium-230, natural uranium, and lead-210. The proposed ACL values are presented in Table 1.2 and were selected as the higher of the following: (1) the 95 percent Upper Tolerance Limit of background groundwater concentrations, or (2) from the highest observed concentration in Monitor Well 31-63 (currently considered to be the most contaminated well at the facility) during the period from 1994 to the present.

Data indicate that the Alluvium contains sufficient attenuation capacity to ensure that the ACL values listed in Table 1.2 are below the risk-based thresholds before reaching the proposed POE. QMC considers groundwater quality in Monitor Wells 5-04 and 5-08 to be representative of the alluvial flow regime and proposes to monitor these two wells at the proposed POE. The natural-occurring levels of constituents of concern are greater than any potential mill-related incremental increases of constituents at the proposed POE. The health effects associated with a potential exposure at the proposed POE have been evaluated (Section 2.0), and show they are protective of human health and the environment.

The approach presented herein, proposing the elimination of the CAP and acceptance of ACLs, is consistent with the NRC approval of Supplemental Standards (40 CFR 192.21) for the Ambrosia Lake DOE Title I UMTRA facility. Supplemental Standards for the Ambrosia Lake facility were based on the fact that the saturated portion of the Alluvium at the Title I facility is not a current or potential groundwater resource because the quantity of water reasonably available for sustained continuous use is less that 150 gallons per day. Adoption of an approach consistent with the Ambrosia Lake DOE Title I facility is appropriate because hydrogeologic and geochemical conditions at the QMC facility are consistent with those of the DOE Ambrosia Lake UMTRA facility.

4.1 Proposed Implementation Measures

QMC proposes to continue the surface reclamation process, which will take place in accordance with the approved reclamation plans, and will continue to abate potential sources of adverse impact to groundwater quality. In addition, QMC is proposing ACLs as GPS for the Alluvium because these values are ALARA and are below risk-based thresholds before reaching the proposed POE location.

Assuming the ACLs are approved and the CAP is eliminated, QMC propose to monitor groundwater annually at POC locations 31-61 and 32-59 and at the representative proposed POE locations 5-04 and 5-08. QMC proposes herein that the current POC location, MW-24, be eliminated through an amendment to License SUA-1473, since this well is hydraulically downgradient from the proposed POE, and outside of the Land

Withdrawal Area. Groundwater from these four monitor wells (31-61, 32-59, 5-04, and 5-08) will be analyzed for the same constituents currently listed in License SUA-1473, Condition 34: specifically, molybdenum, nickel, selenium, gross alpha, radium-226+228, thorium-230, natural uranium, and lead-210.

QMC intends to transfer the land shown in Figure 4.1 to the DOE for long-term surveillance and maintenance. Current ownership of the area consists of State of New Mexico and QMC. Formal request to the State will be submitted to convey the land to the DOE. Based on meetings with the DOE Project Manager for Long-term Surveillance and Maintenance, the DOE is able to receive these lands once NRC has approved QMC's reclamation and the U.S. Army Corps of Engineers has cleared title on the lands delineated in Figure 4.1.

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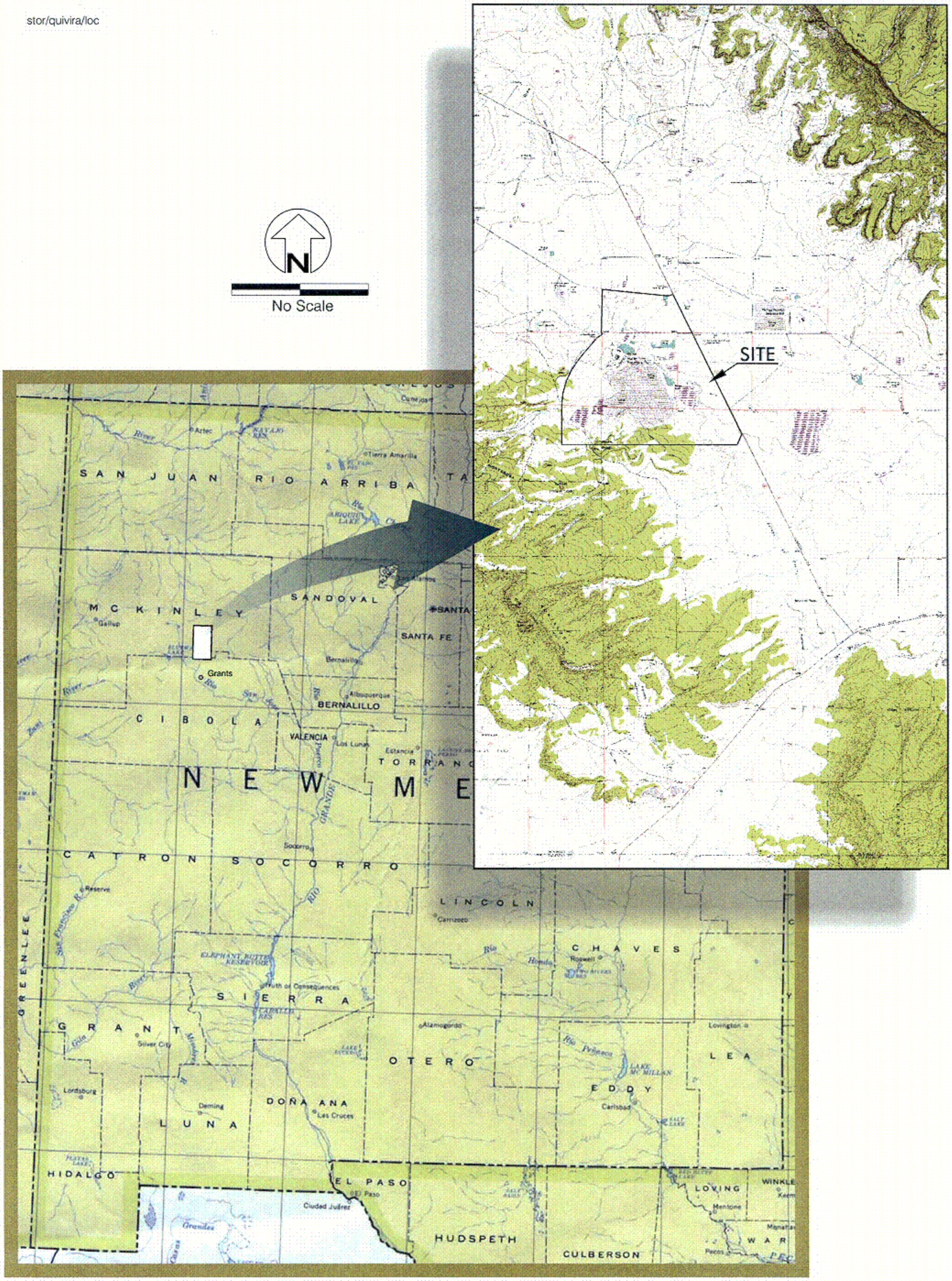
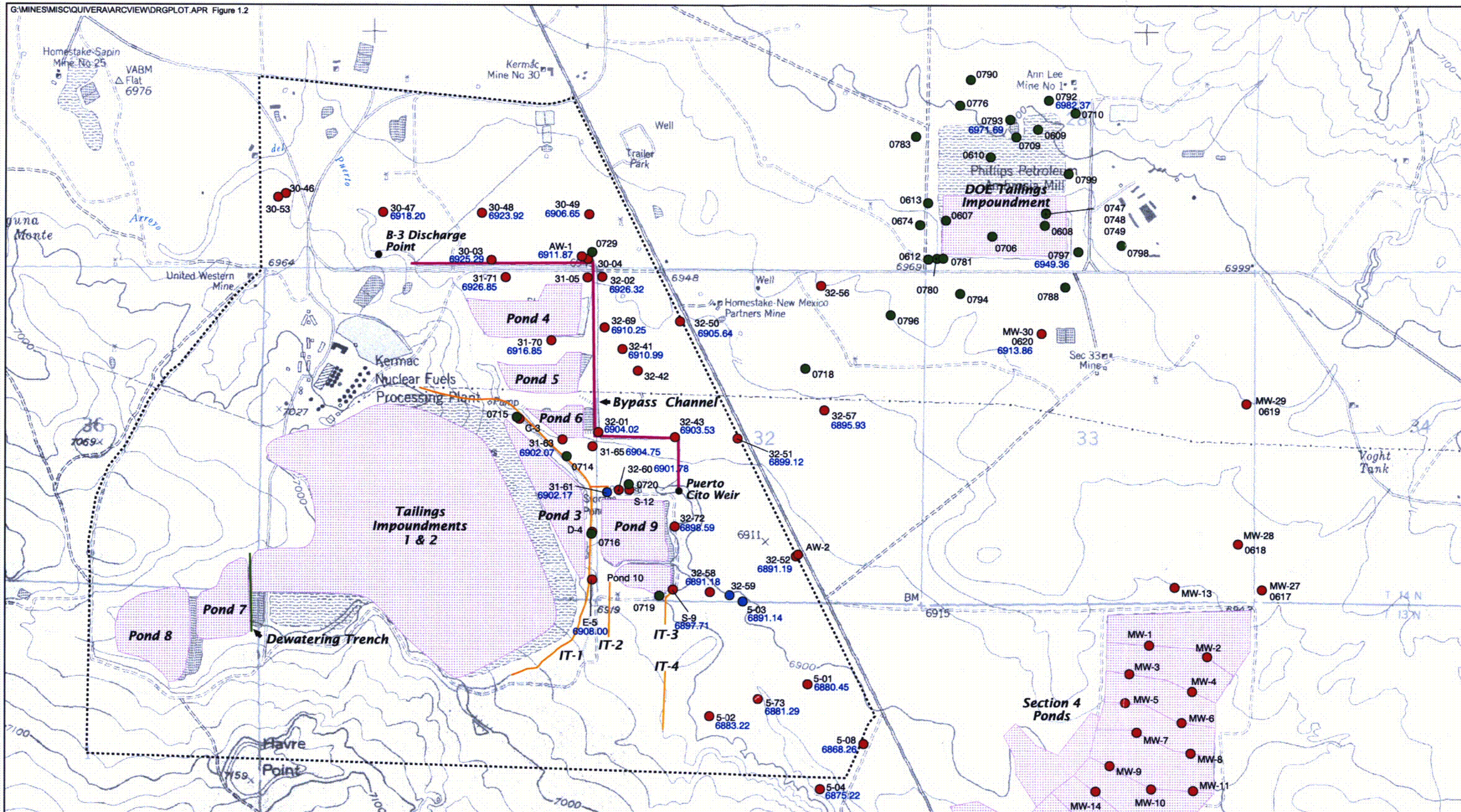
stor/quivira/loc



MAXIM

Location Map
QMC Ambrosia Lake Facility
Near Grants, New Mexico
FIGURE 1-1

C02



USGS 7.5 Minute Quadrangle - Ambrosia Lake (reprojected to stateplane NM West feet, NAD27)

N

0 Feet 1500

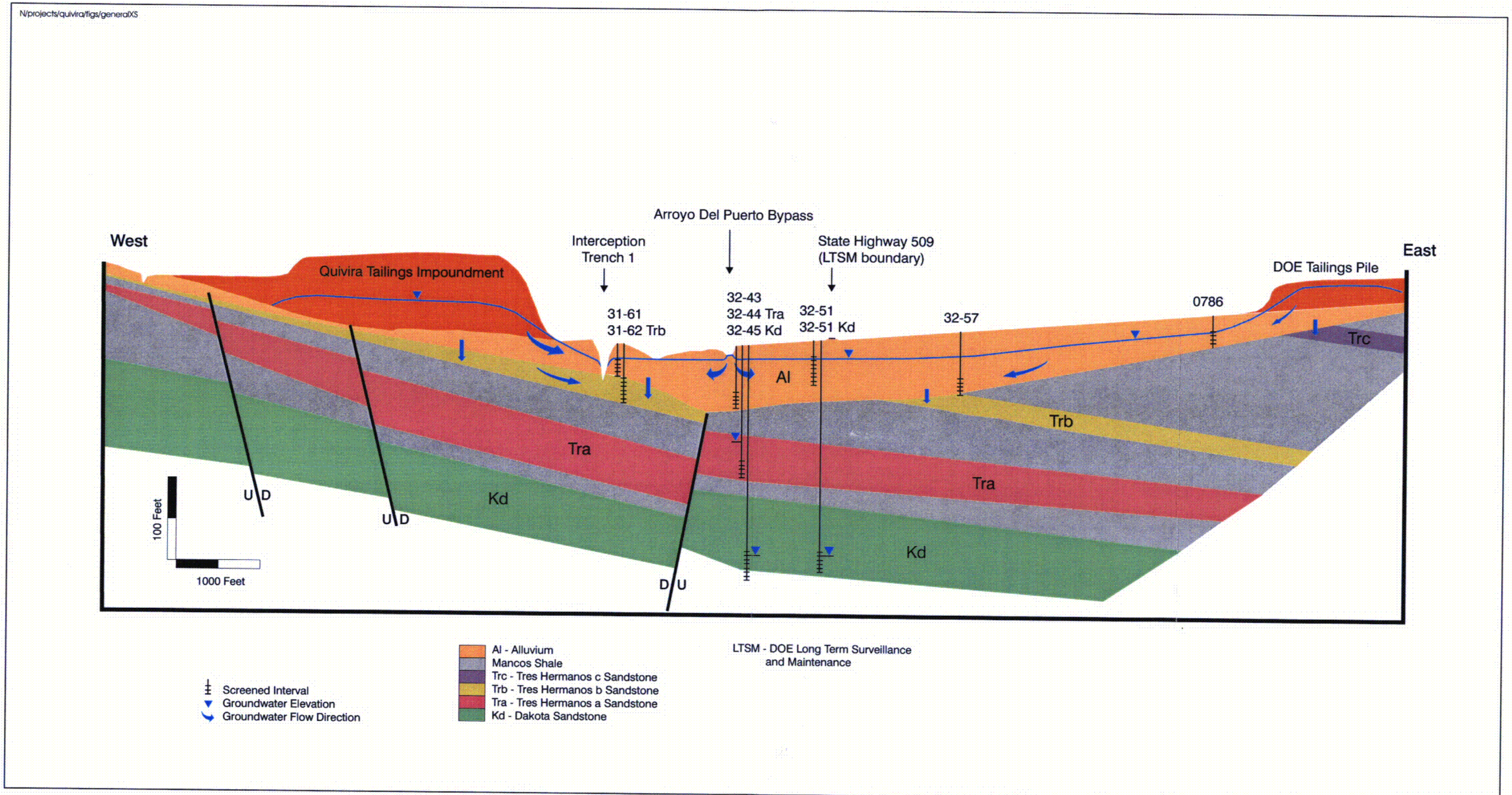
MAXIM 2007209-100

- Proposed Withdrawal Area
- Interception Trenches (IT-1 to IT-4)
- Bypass Channel
- Dewatering Trench

- DOE Alluvial Wells
- Quivira Alluvial Wells
- NRC Point of Compliance Wells

C03

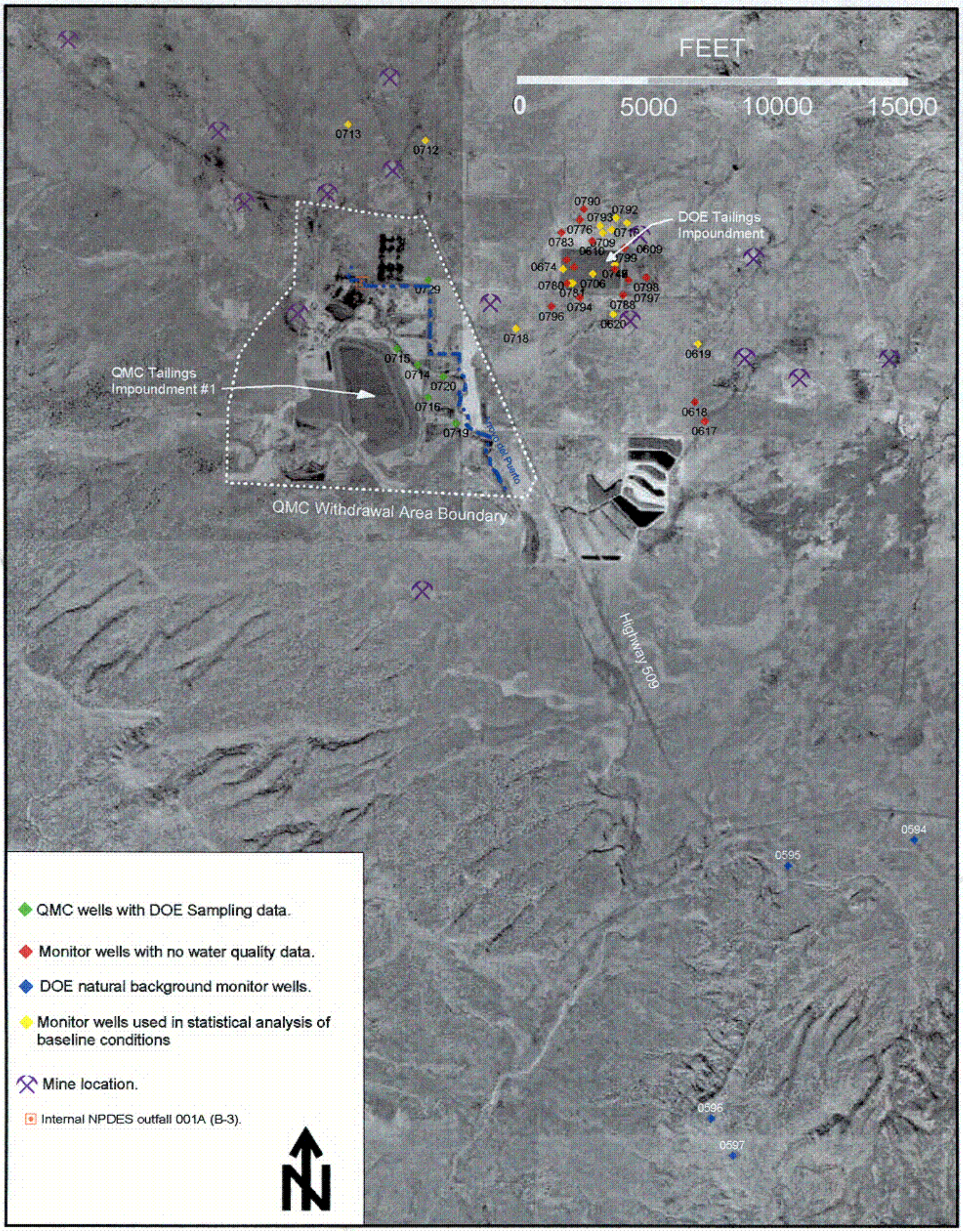
Facility Plan Map
QMC Site
Ambrosia Lake, New Mexico
FIGURE 1.2



C04

MAXIM 2007209

Generalized Hydrogeologic Cross Section
Ambrosia Lake Facility
Near Grants, New Mexico
FIGURE 1.3



Monitor Wells Included in DOE Data
from the DOE Site, Locations of Mines
Near the QMC Site, and Location of
Internal NPDES Outfall 001A (B-3)
FIGURE 2.1

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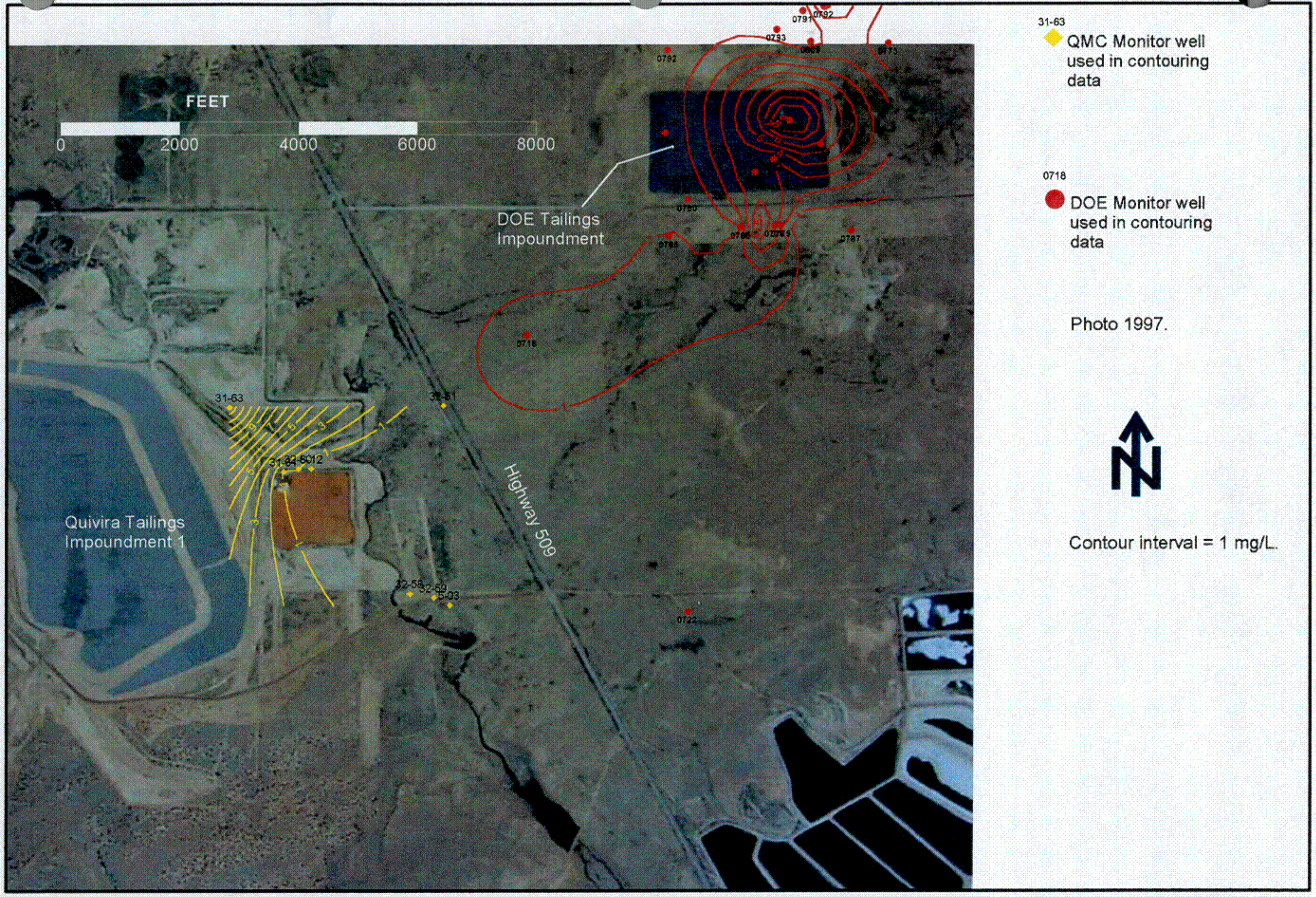
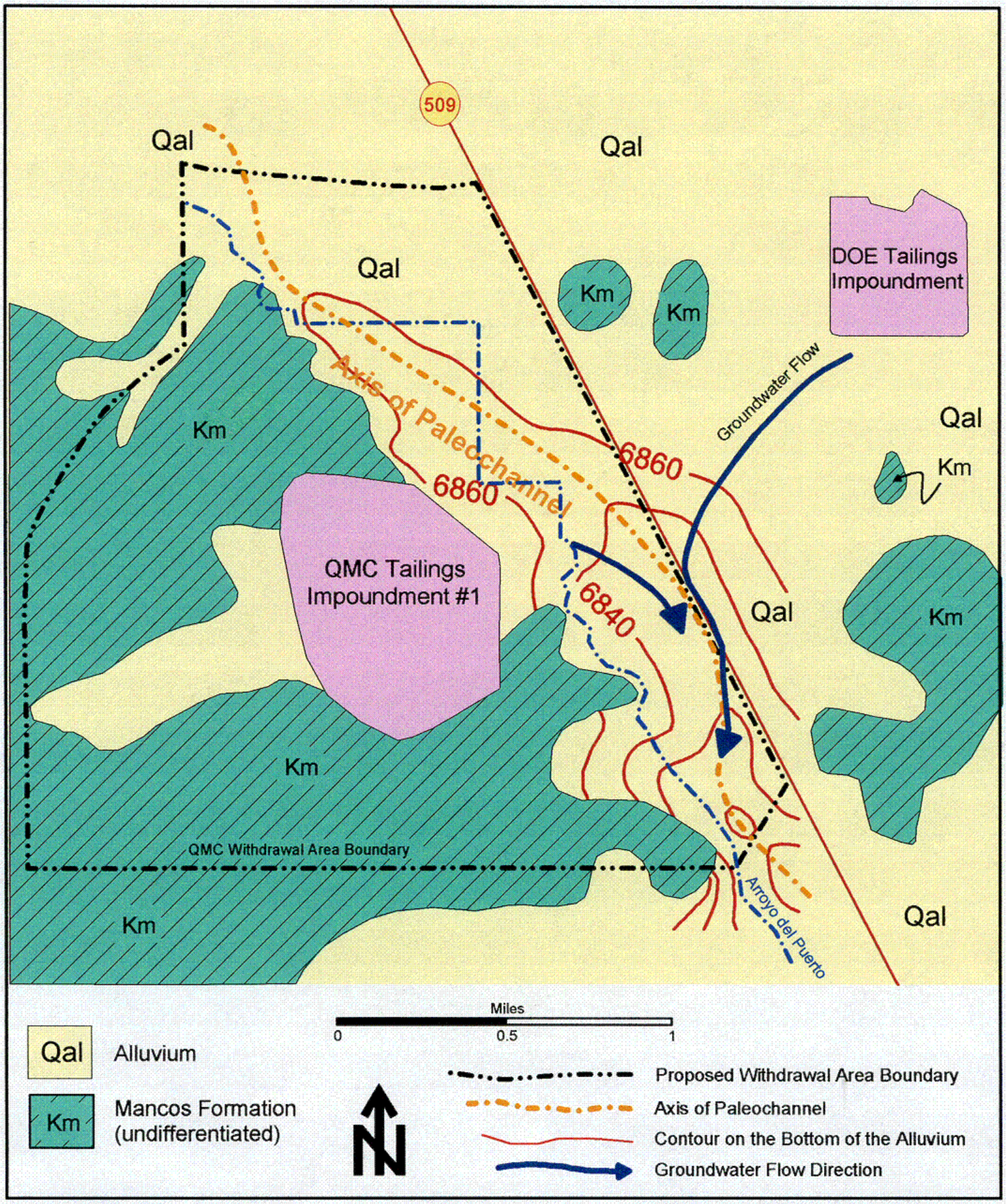
C05



C06

Uranium Concentrations Using
1986 QMC data and
1986 DOE data.
FIGURE 2.2

MAXIM TECHNOLOGIES INC 2007209



Simplified Geologic Map of the QMC Site Showing Contours on the Bottom of the Alluvium and the Trace of the Axis of the Paleochannel.
FIGURE 2.3

MAXIM TECHNOLOGIES INC 2007209

C07

Photo 1997

MILES

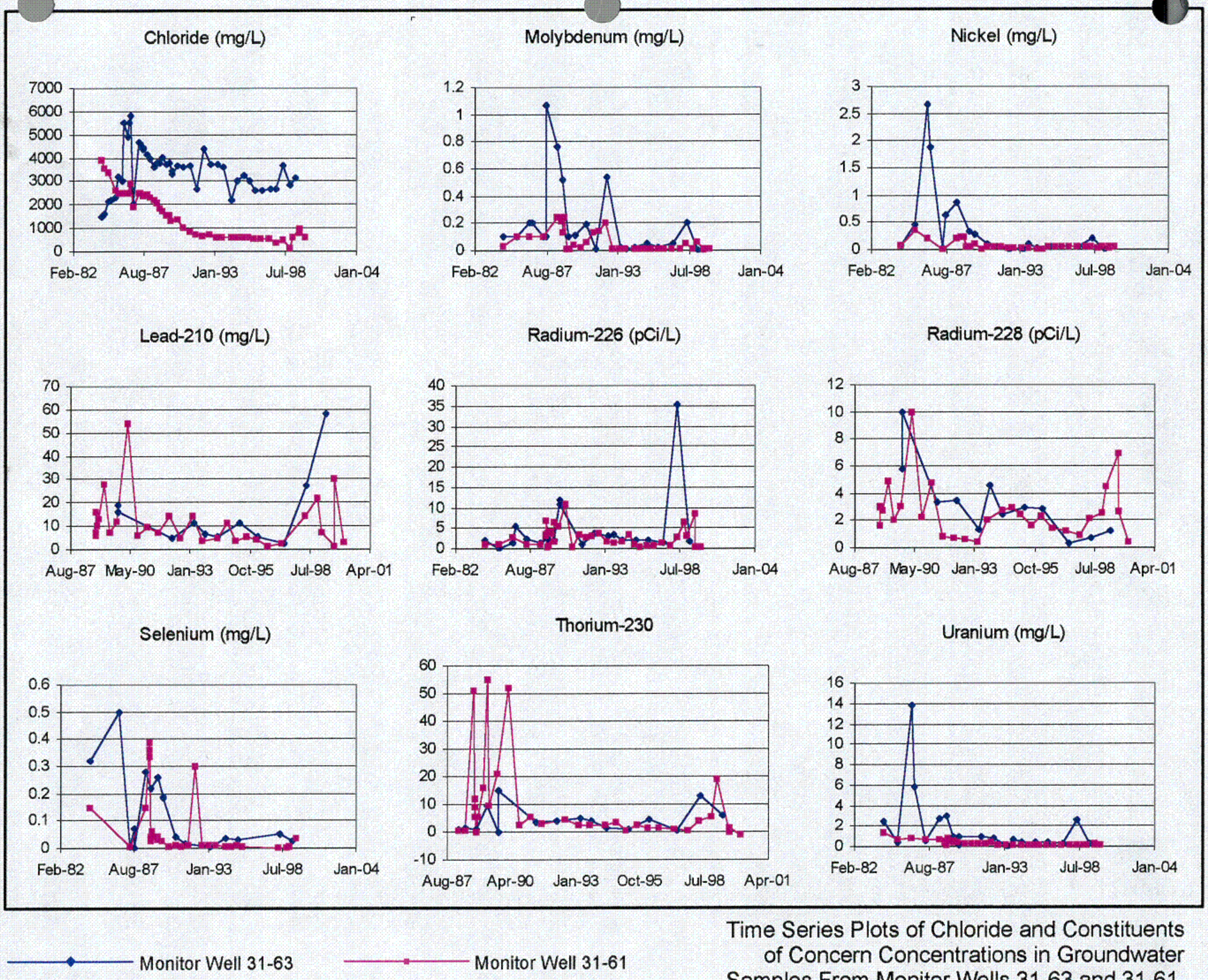
0 0.5 1

85 Line of equal TDS/chloride ratio in alluvial groundwater.
Contour interval = 200 mg/L.

Contours of Total Dissolved Solids (TDS)/Chloride Ratios in Groundwater from QMC Site Monitor Wells Completed in the Alluvium.
FIGURE 2.4

MAXIM TECHNOLOGIES INC 2007209

C08



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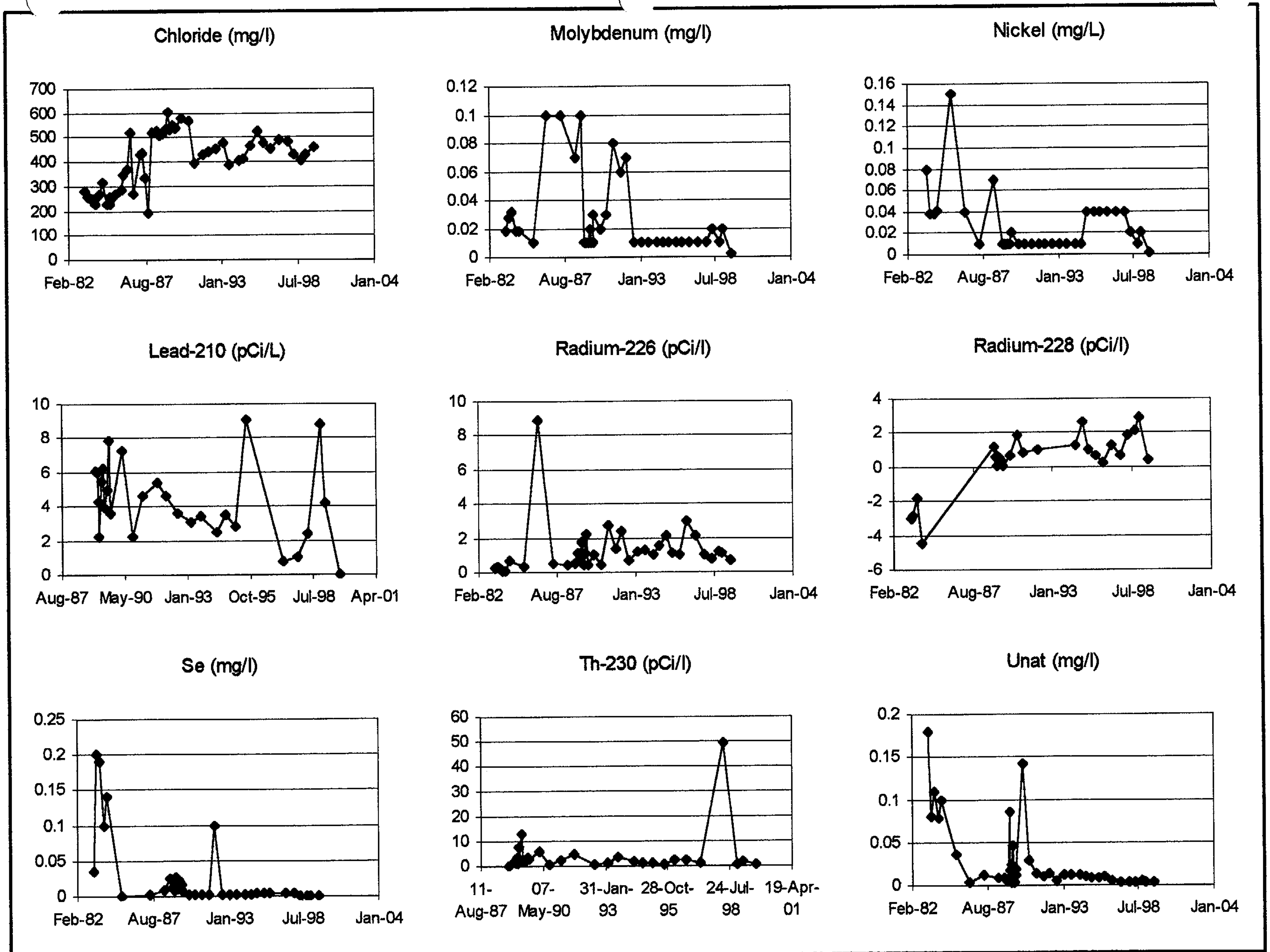
Time Series Plots of Chloride and Constituents of Concern Concentrations in Groundwater Samples From Monitor Wells 31-63 and 31-61, RAMC Site, Ambrosia Lake, New Mexico.

FIGURE 2.5

C09



Time Series Plots of Chloride and Constituents of Concern Concentrations in Groundwater Samples From Background Monitor Well 5-03, QMC Site, Ambrosia Lake, New Mexico.
FIGURE 2.6

MAXIM TECHNOLOGIES INC 2007209

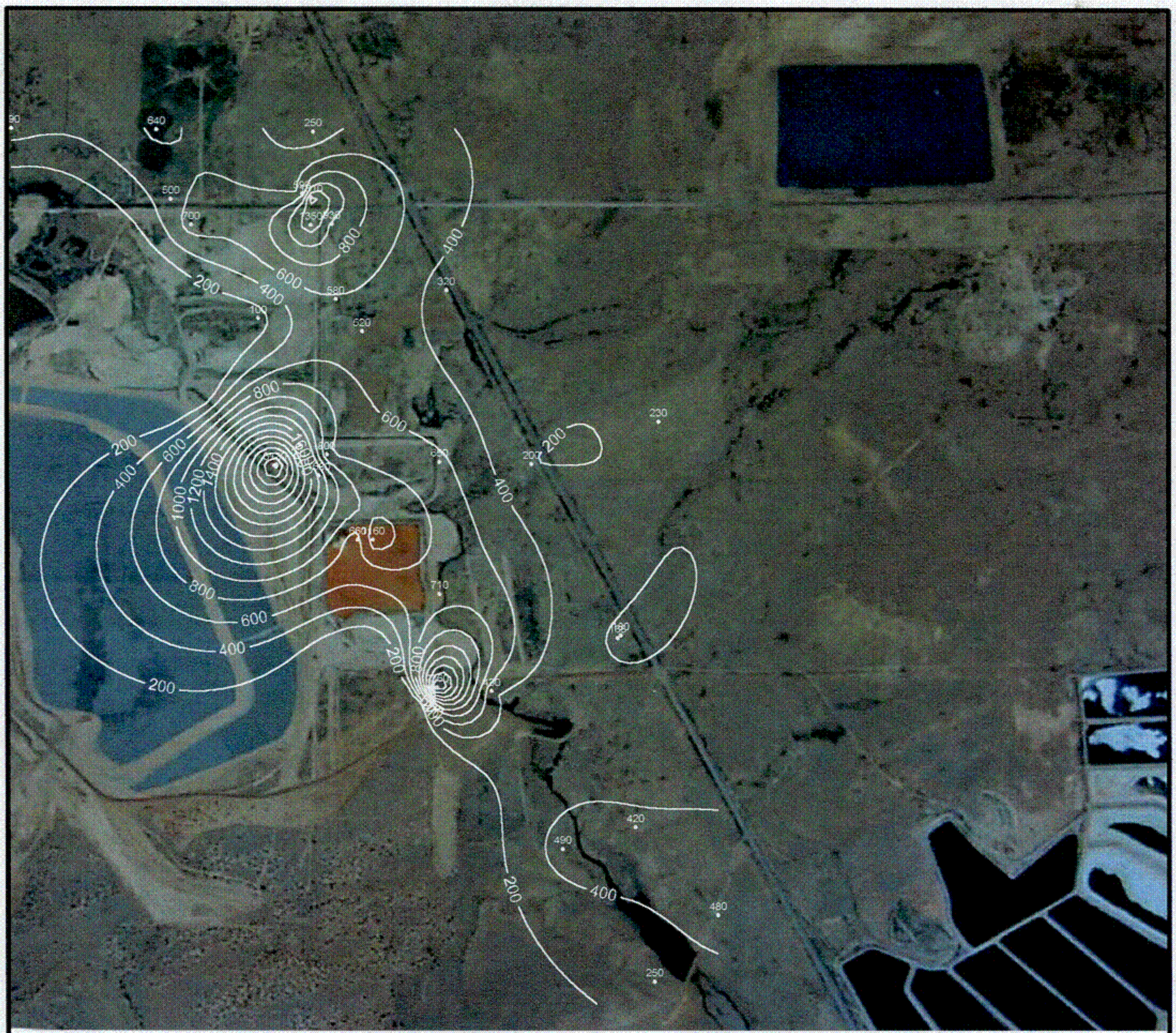


Photo 1997

MILES

0 0.5 1

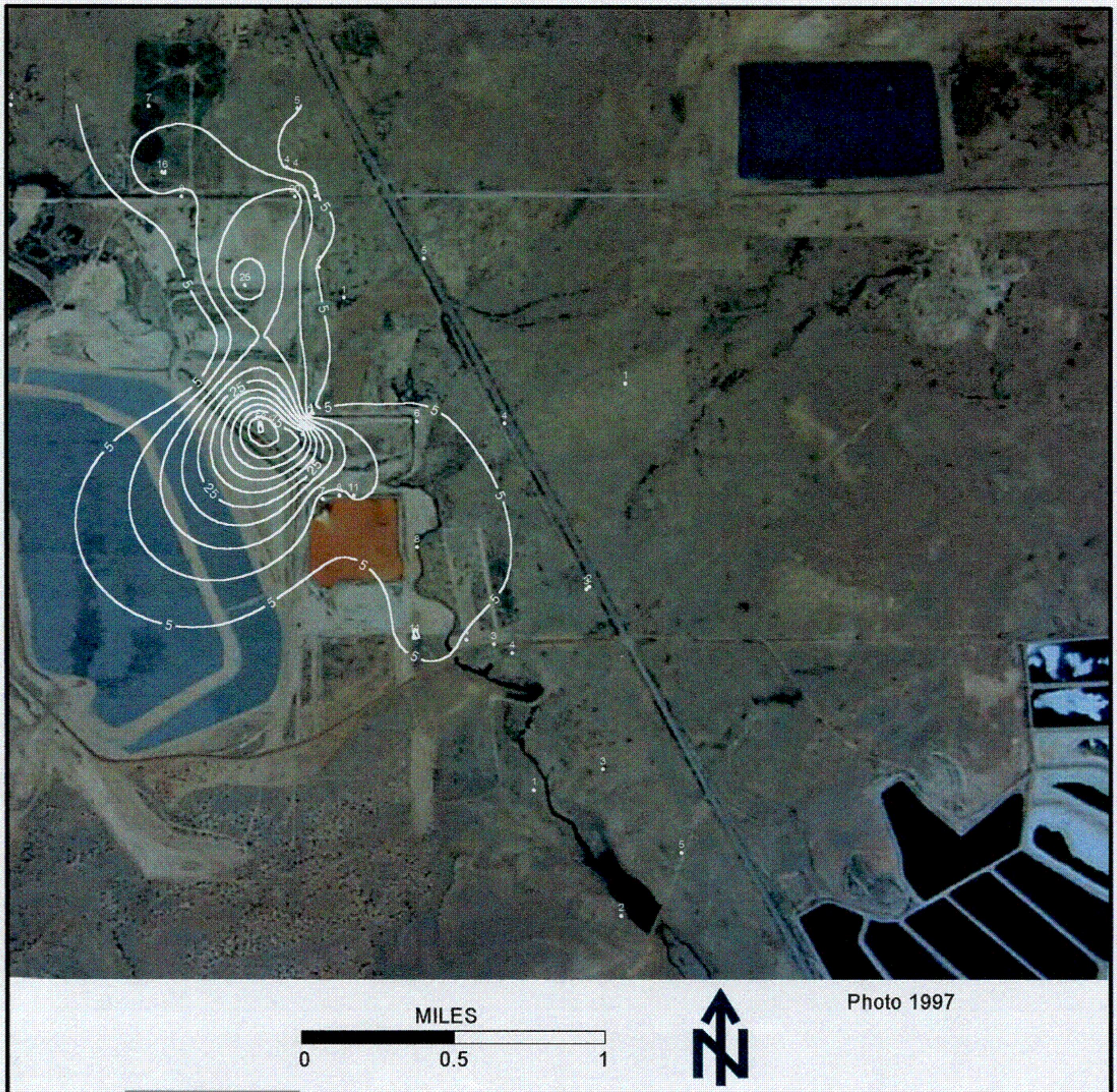
200 Line of equal chloride concentration in alluvial groundwater.
Contour interval = 200 mg/L.

C10

Chloride Concentrations in the Alluvium, 1999, QMC Site, Ambrosia Lake, New Mexico

FIGURE 2.7

MAXIM TECHNOLOGIES INC 2007209



5 Line of equal Lead-210 concentration in alluvial groundwater.
Contour interval = 5 pCi/L .
Groundwater Protection Standard = 4.9 pCi/L.

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Lead-210 Concentrations In the
Alluvium, 1999, QMC Site,
Ambrosia Lake, New Mexico.
Figure 2.8

C11

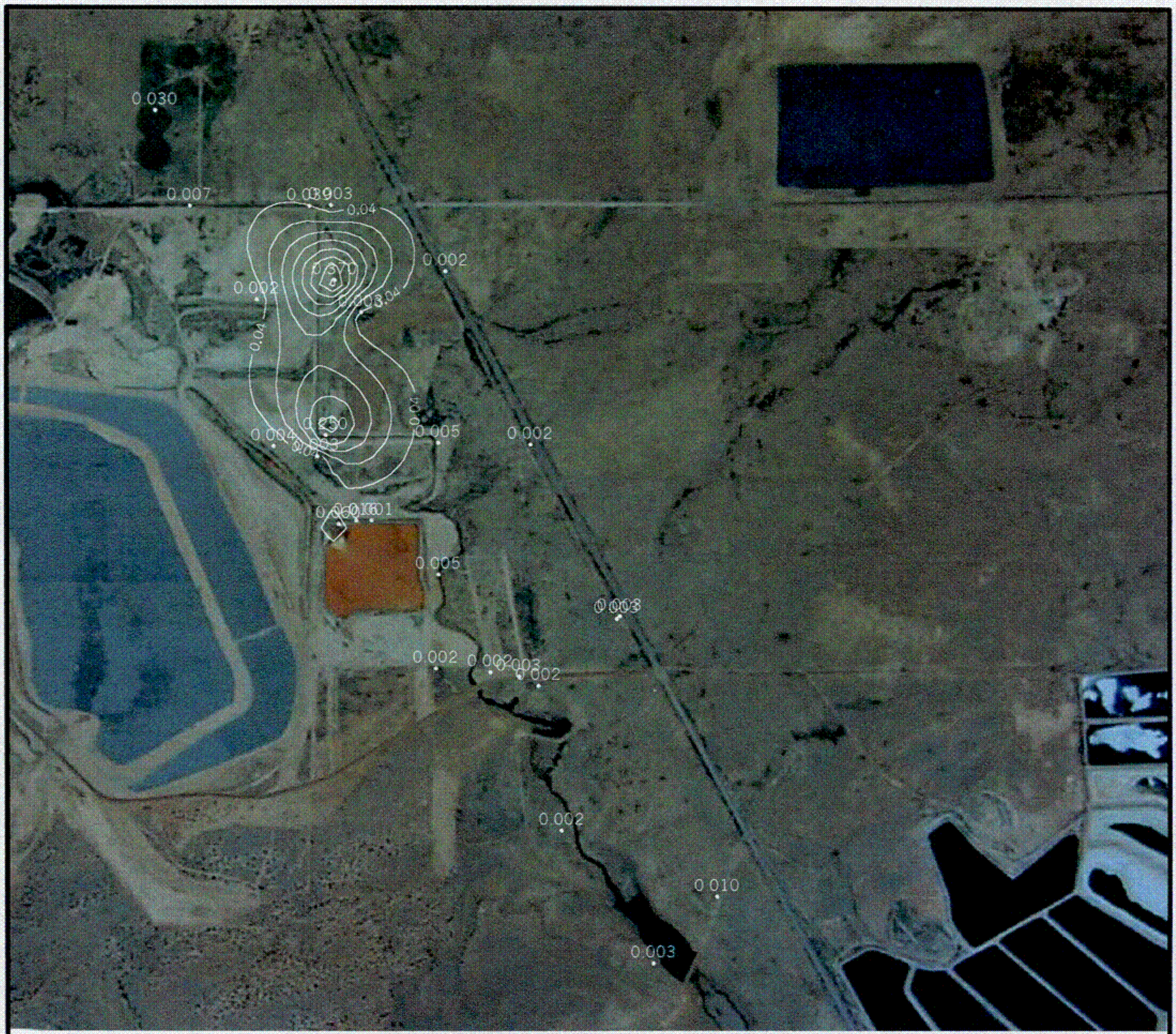

Photo 1997

MILES

0 0.5 1

N

0.04 Line of equal Molybdenum concentration in alluvial groundwater.
Contour Interval = 0.04 mg/L
Groundwater Protection Standard = 0.06 mg/L

Molybdenum:Concentrations in the Alluvium, 1999, QMC Site, Ambrosia Lake, New Mexico.

FIGURE 2.9

C12

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Line of equal Nickel concentration in alluvial groundwater.
Contour interval = 0.002 mg/L
Groundwater Protection Standard = 0.06 mg/L

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Nickel Concentrations in the Alluvium, 1999, QMC Site, Ambrosia Lake, New Mexico.

FIGURE 2.10

C13

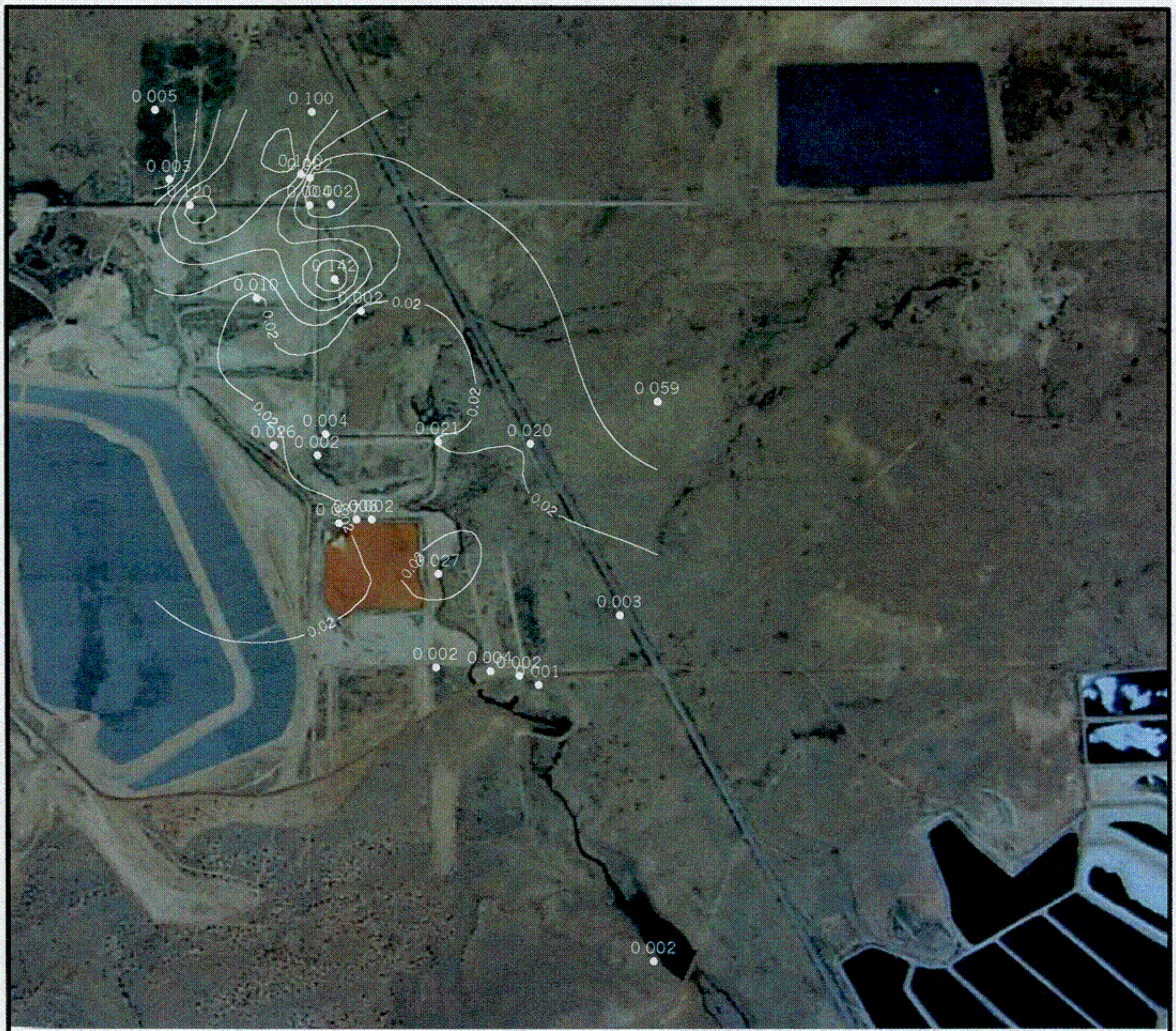

Photo 1997

MILES

0 0.5 1

N

0.02 Line of equal Selenium concentration in alluvial groundwater.
Contour interval = 0.02 mg/L
Groundwater Protection Standard = 0.05 mg/L

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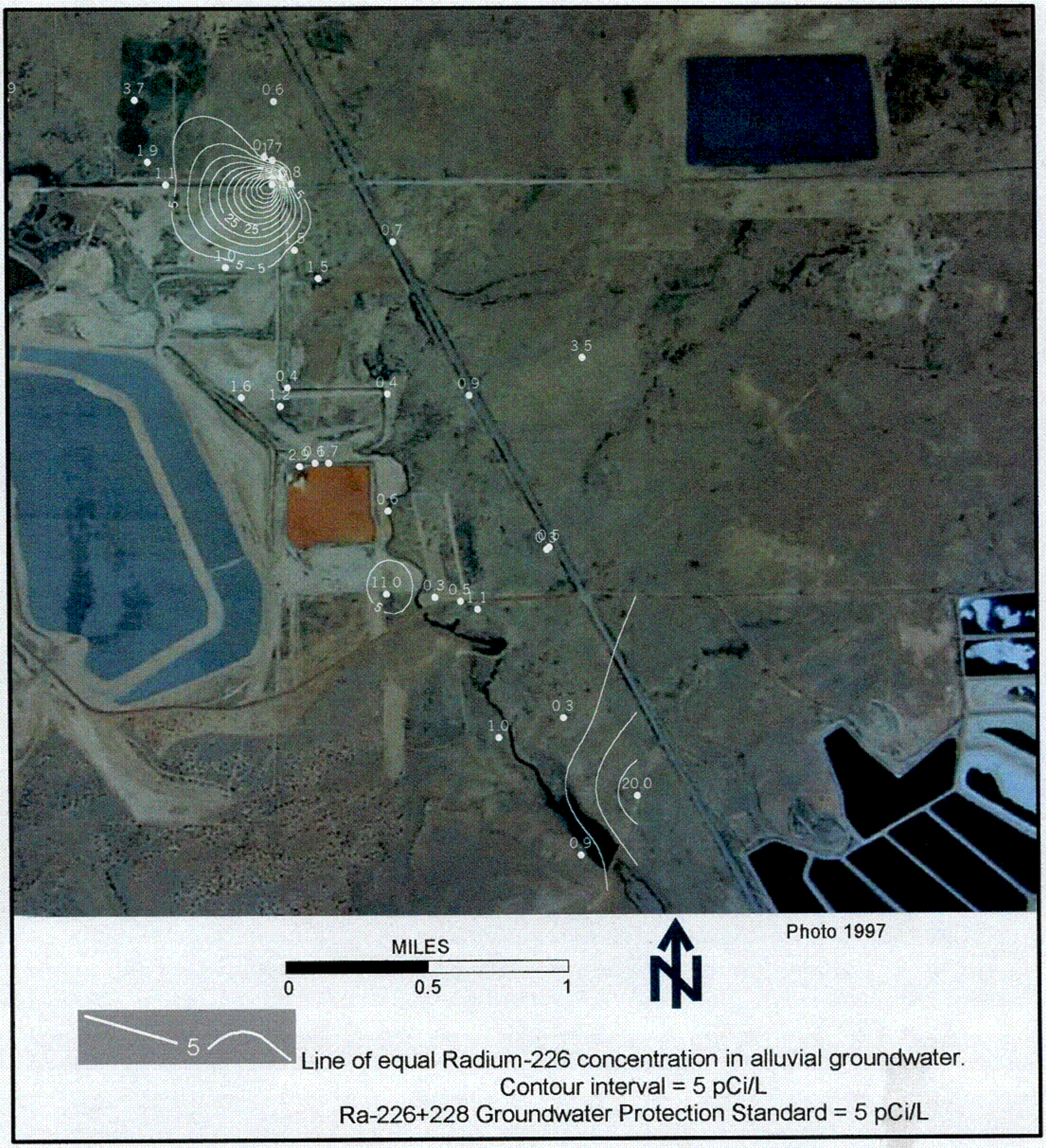
Seleniuim Concentrations in the
Alluvium, 1999, QMC Site,
Ambrosia Lake, New Mexico.

FIGURE 2.11

C14



Radium-226 Concentrations in the
Alluvium, 1999, QMC Site,
Ambrosia Lake, New Mexico.
FIGURE 2.12

MAXIM TECHNOLOGIES INC 2007209

C15

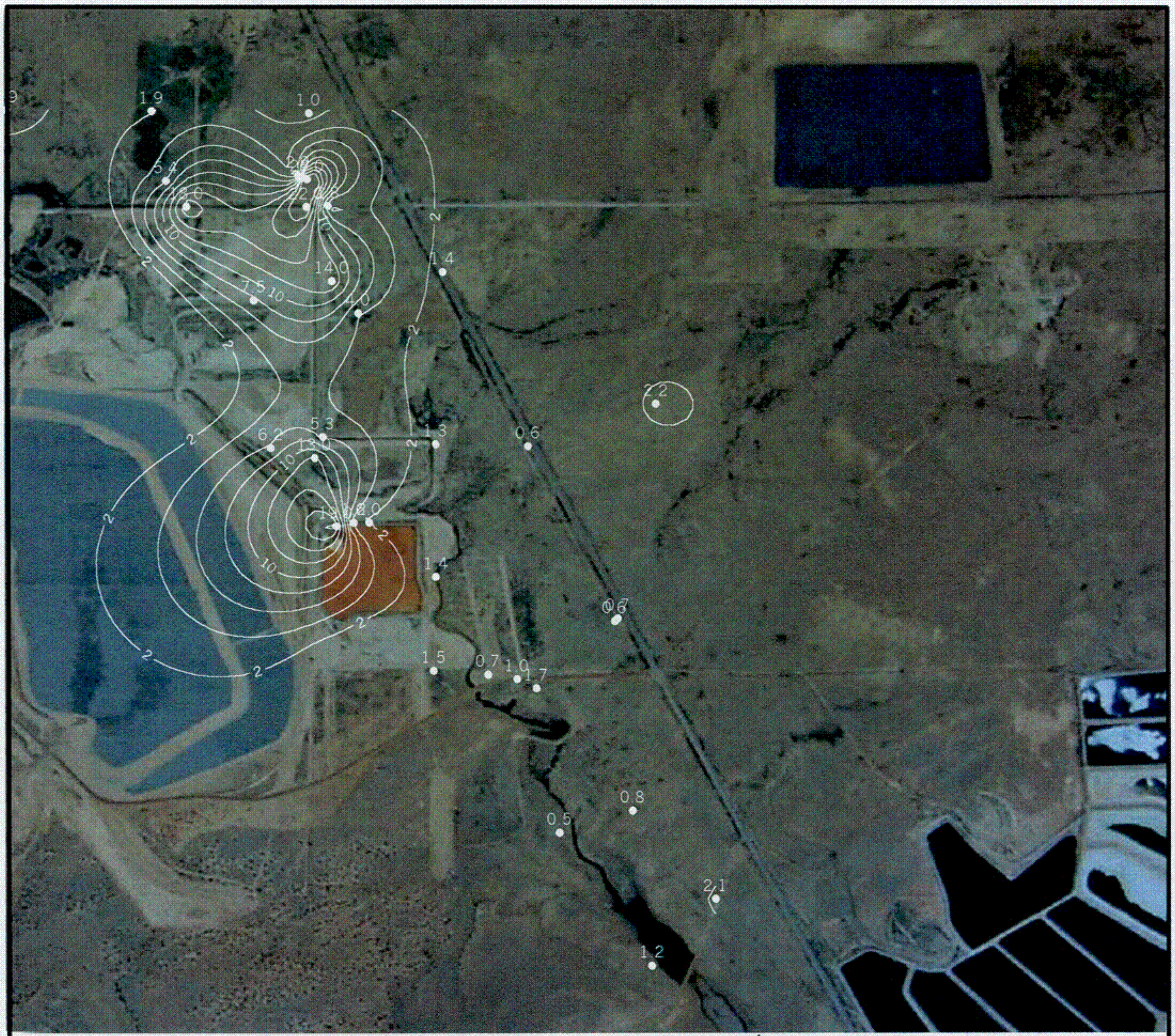


Photo 1997

MILES

0 0.5 1

N

2 Line of equal Thorium-230 concentration in alluvial groundwater.
Contour interval = 2 pCi/L
Groundwater Protection Standard = 3.1 pCi/L

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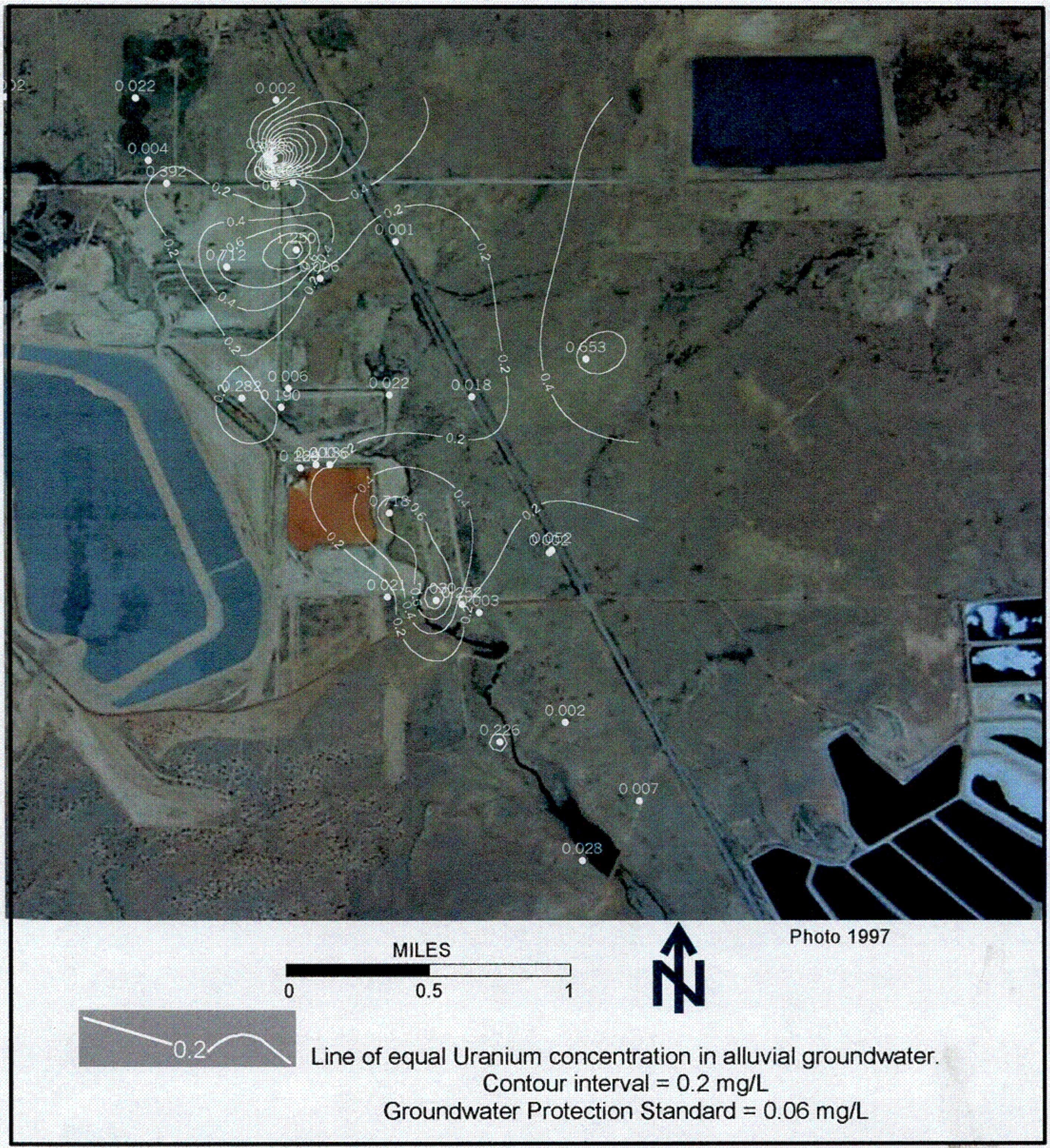
Thorium-230 Concentrations in the Alluvium, 1999, QMC Site, Ambrosia Lake, New Mexico.

FIGURE 2.13

C16



Uranium Concentrations in the
Alluvium, 1999, QMC Site,
Ambrosia Lake, New Mexico.
FIGURE 2.14

MAXIM TECHNOLOGIES INC 2007209

C17

Line of equal Gross Alpha concentration in alluvial groundwater.
Contour interval = 50 mg/L
Groundwater Protection Standard = 57 pCi/L

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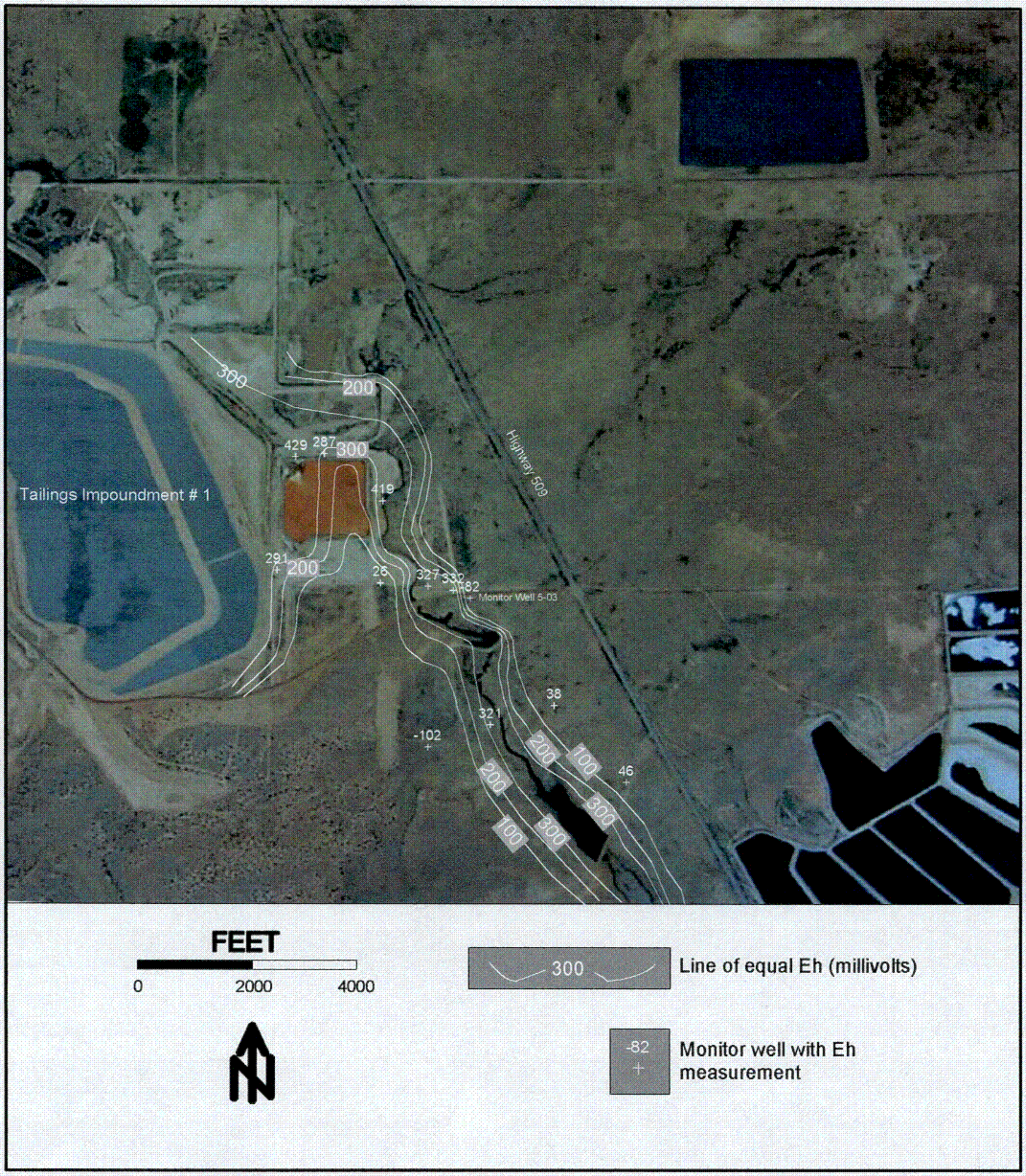
Gross Alpha concentrations in the Alluvium, 1999, QMC Site, Ambrosia Lake, New Mexico.

FIGURE 2.15

C18

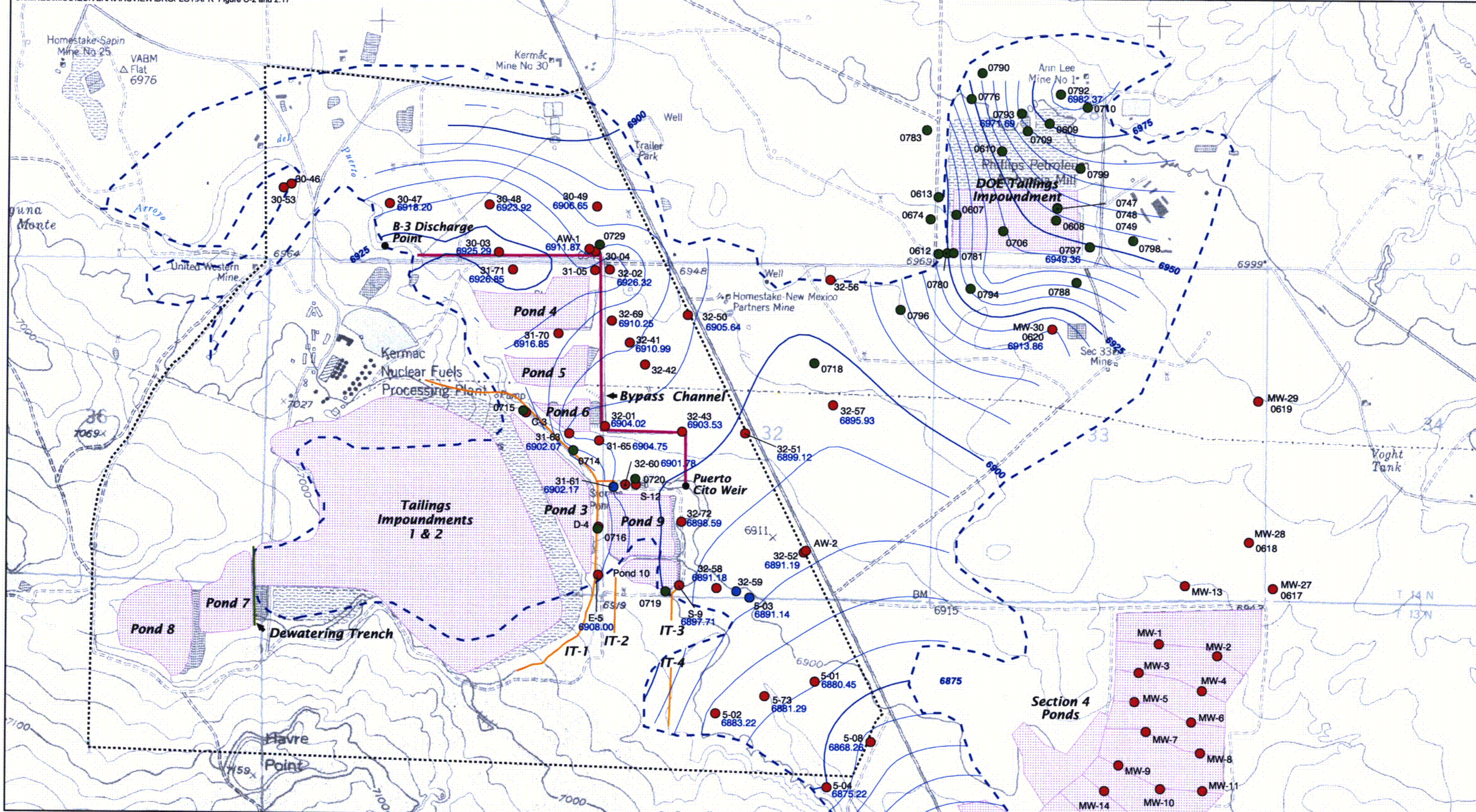


Contours of Eh Measurements
(milliVolts) in Groundwater
from Monitor Wells Completed
in the Alluvium, QMC Site,
Ambrosia Lake, New Mexico.
FIGURE 2.16

MAXIM TECHNOLOGIES INC 2007209

C19

G:\MINES\MISC\QUIVERA\ARCVIEW\DRGPLOT.APR Figure C-2 and 2.17



USGS 7.5 Minute Quadrangle - Ambrosia Lake (reprojected to stateplane NM West feet, NAD27)

N

0 Feet 1500

MAXIM 2007209-100

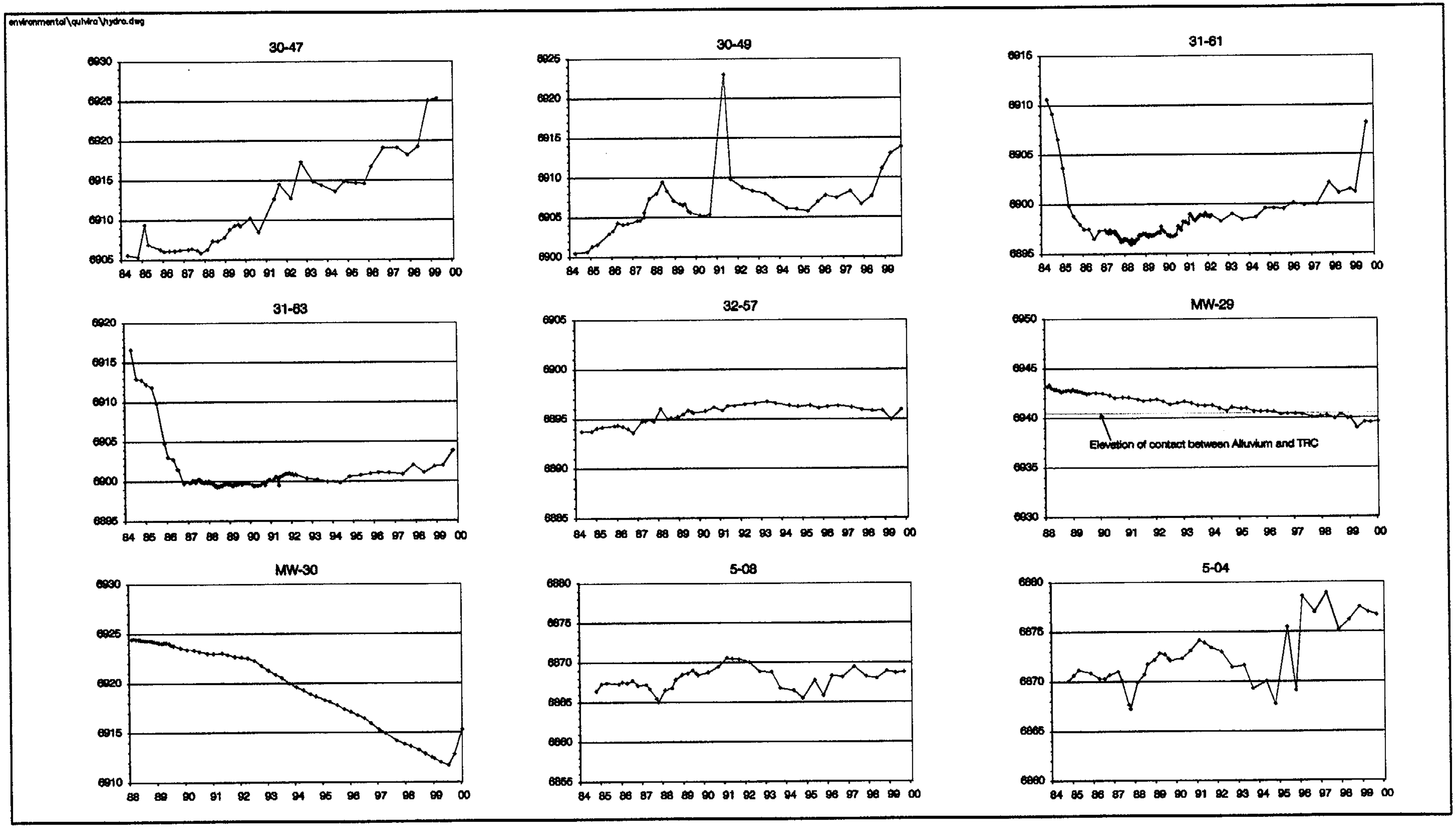
- Proposed Withdrawal Area
- Approximate Extent of Saturated Alluvium Boundary
- Interception Trenches (IT-1 to IT-4)
- Bypass Channel
- Dewatering Trench
- DOE Alluvial Wells
- Quivira Alluvial Wells
- NRC Point of Compliance Wells
- Groundwater Elevation Contour

Contour Interval 5 feet

Water table elevation readings based on November/December 1997 readings.

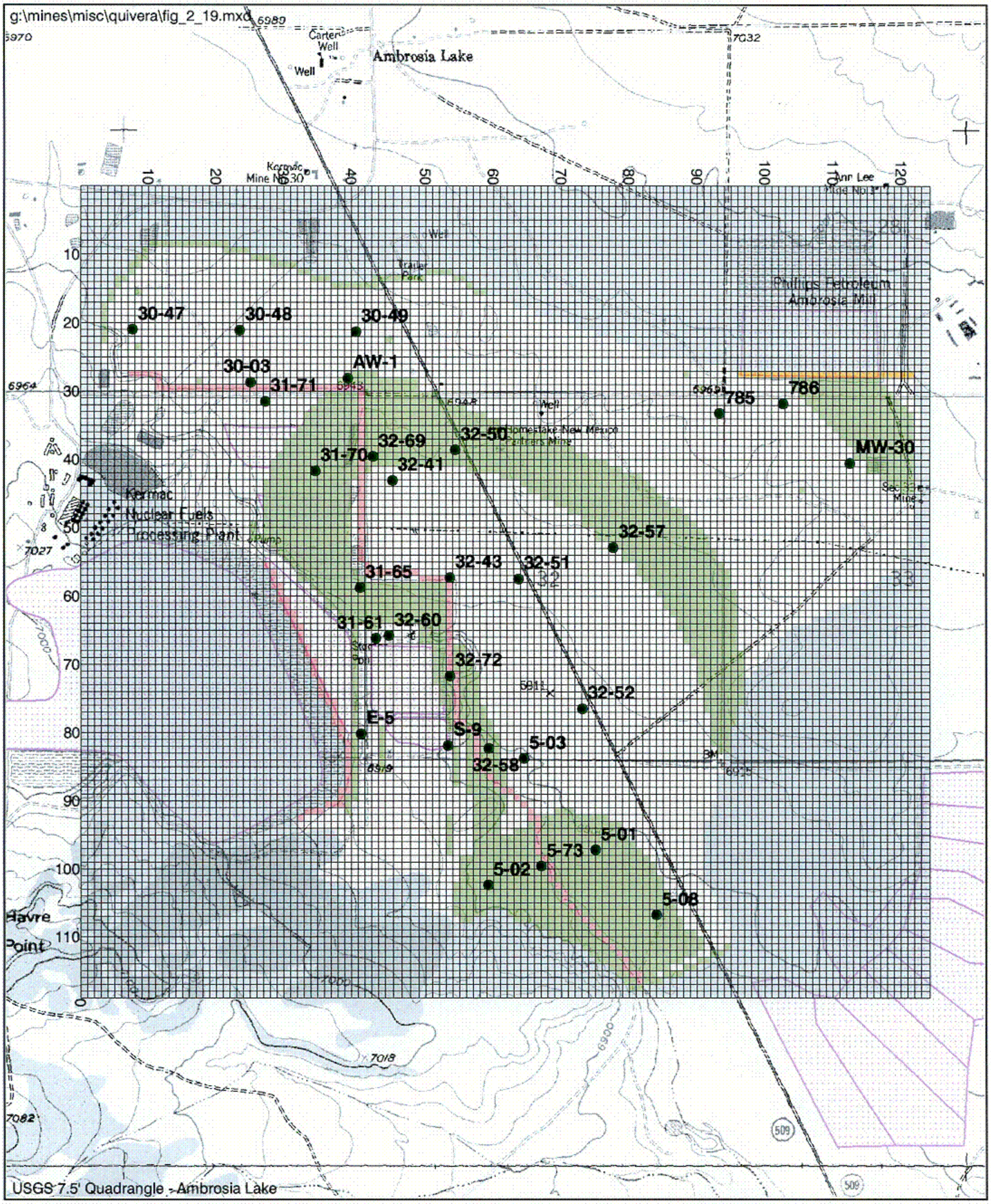
C20

Groundwater Elevation Map
Ambrosia Lake Area
Near Grants, New Mexico
FIGURE 2.17



Groundwater Hydrographs for
Selected Alluvial Wells
Ambrosia Lake Facility
Near Grants, New Mexico
FIGURE 2-18

MAXIM 2007209



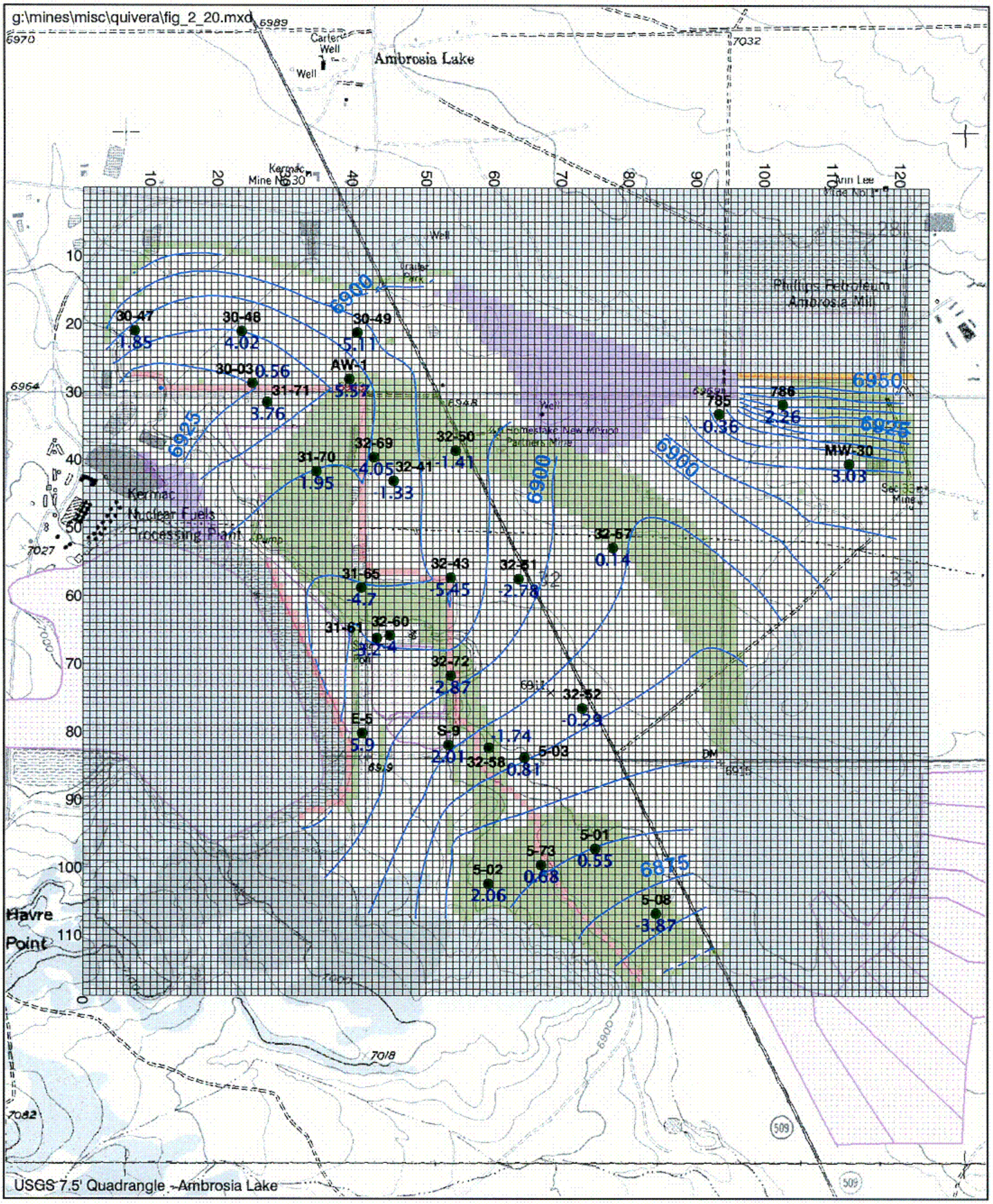
2,000 1,000 0 Feet

MAXIM 2007209

- Calibration Target Well
- Drains Cells
- No Flow Cells
- Constant Head Cells
- Constant Flux Cells

Model Boundary Conditions and Grid Layout
Ambrosia Lake Area
Near Grants, New Mexico
FIGURE 2.19

C21



N

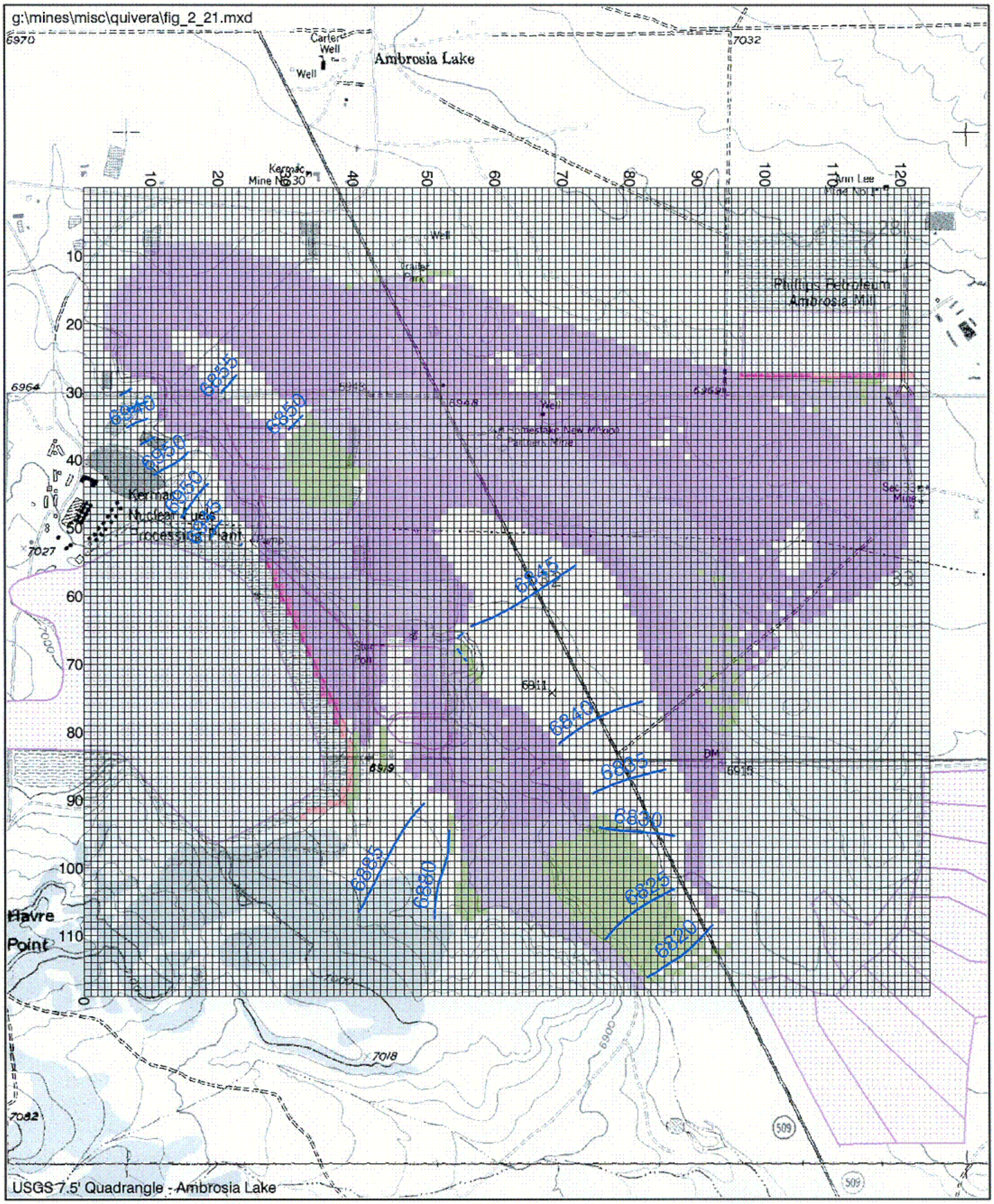
2,000 1,000 0 Feet

MAXIM 2007209

- Groundwater Elevation Contours
- Dry Cells
- Calibration Target Well
- Well Residual 5-08 -3.87
- Drains Cells
- No Flow Cells
- Constant Head Cells
- Constant Flux Cells

Model Calibration Results
Ambrosia Lake Area
Near Grants, New Mexico
FIGURE 2.20

C22

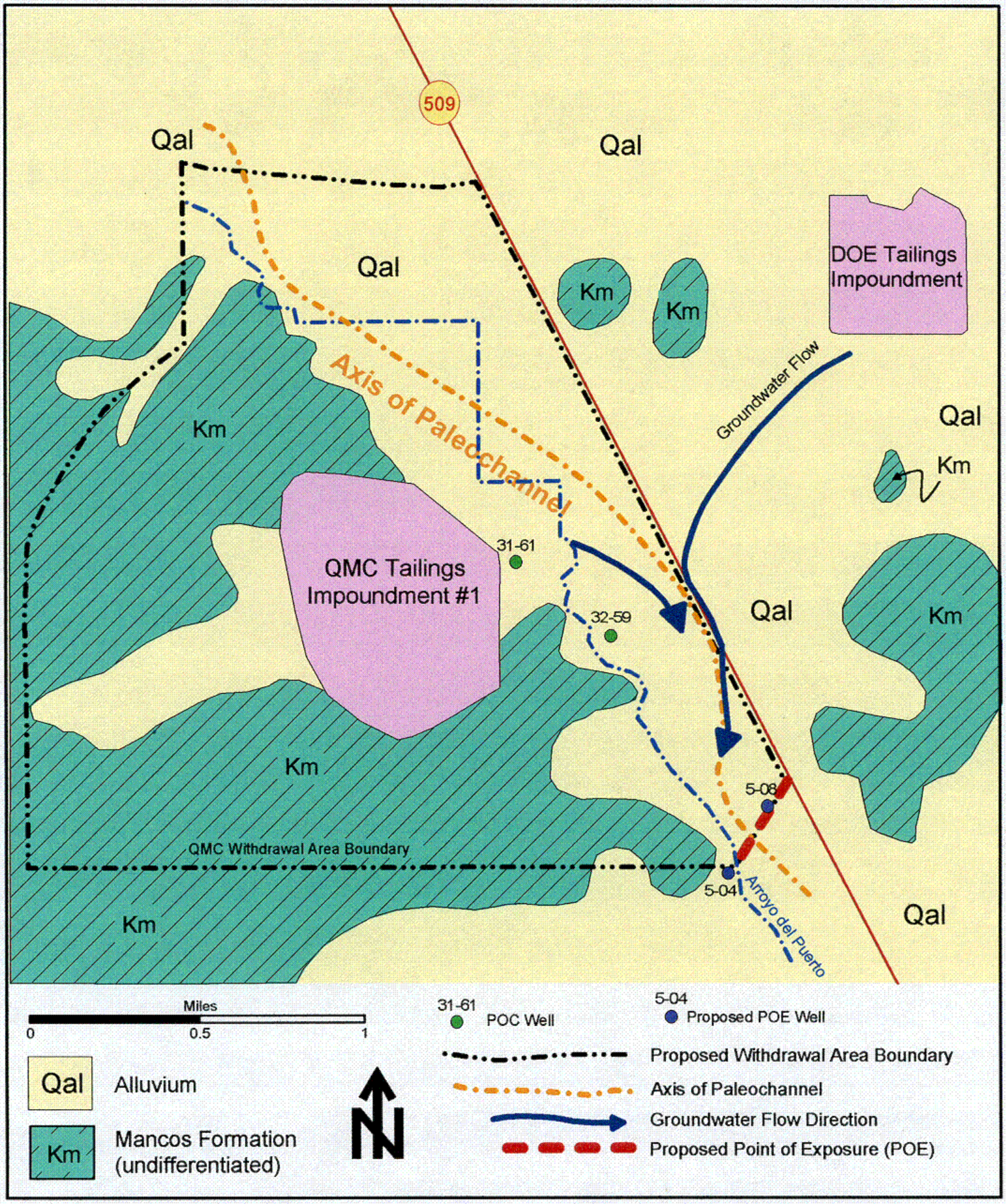


MAXIM 2007209

- Groundwater Elevation Contours
- Dry Cells
- No Flow Cells
- Drain Cells
- Contant Flux Cells

Water Table Elevations After 65 Years for
Discontinued CAP Scenario
Ambrosia Lake Area
Near Grants, New Mexico
FIGURE 2.21

C23



Simplified Geologic Map of the QMC Site Showing Location of POC Wells and the Proposed Point of Exposure.
FIGURE 4.1

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C24