Final
Application for
Alternate Concentration Limits
For
Gas Hills, Wyoming

Volume I

Application

Umetco Minerals Corporation
2754 Compass Drive, Suite 280
Grand Junction, Colorado 81506

May 2001

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EXECUTIVE SUMMARY

Umetco Minerals Corporation is submitting the following application to revise groundwater protection standards at its facility in Gas Hills, Wyoming. The document supports Alternate Concentration Limits at the Points of Compliance that are protective of human health and the environment at the Point of Exposure. This document has been revised to incorporate responses to the U.S. Nuclear Regulatory Commission comments, received after review of the draft submittals, dated February 1999 and January 2001.

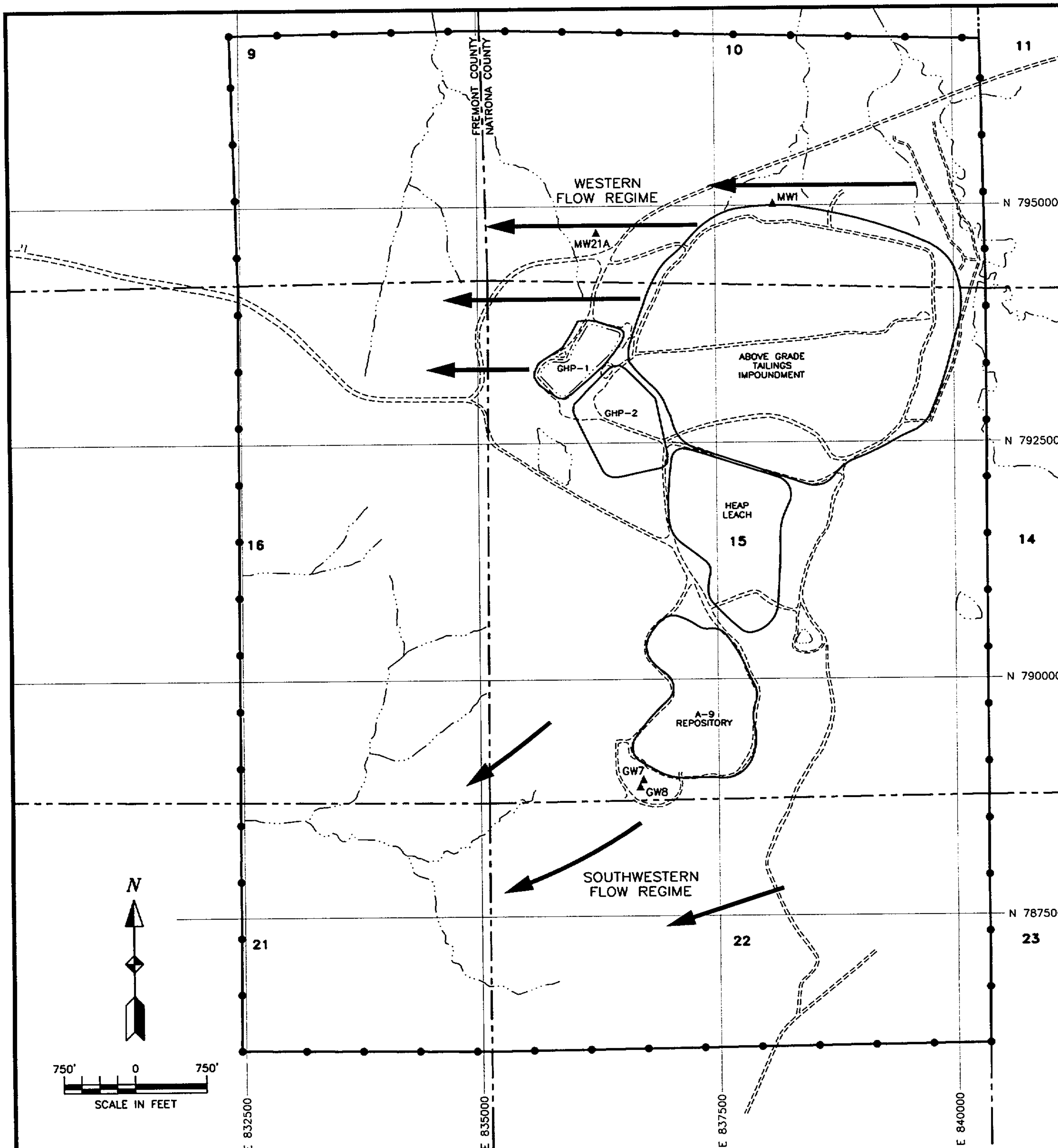
Umetco is requesting Alternate Concentration Limits for two flow regimes in the Wind River aquifer (see Exhibit A) as follows:

- A western flow component in the deep, reducing portion of the aquifer, and
- A southwestern flow component in the shallow, oxidized portion of the aquifer.

The Western Flow Regime underflows the Above Grade Tailings Impoundment. Point of Compliance wells MW1 and MW21A monitor radial and westerly flow from the Above Grade Tailings Impoundment, respectively. The Southwestern Flow Regime underflows the A-9 Repository. Point of Compliance wells GW7 and GW8 monitor groundwater quality in the vicinity of the A-9 Repository.

Revised groundwater protection standards are justifiable for the following reasons:

- The present groundwater protection standards are not representative of ambient conditions;
- The occurrence of widespread ambient contamination is a result of naturally-occurring uranium mineralization and the effects of mining and reclamation activities not related to milling operations;
- The naturally-occurring conditions and impacts from mining and reclamation are indistinguishable from groundwater impacts associated with milling;
- It is technically impracticable and economically infeasible to remediate groundwater to present groundwater protection standards. Corrective action alternatives would require between 80 and 200 years of extraction and treatment at net present value costs of $30 to $100 million. Furthermore, additional corrective action would not improve water quality from its current class of use because of widespread ambient contamination.;
- The Alternate Concentration Limit values at the Points of Compliance will be reduced by natural attenuation to below background levels at the points of exposure;
- The proposed Alternate Concentration Limits are As Low As Reasonably Achievable; and
- The U.S. Department of Energy has accepted the proposed site boundaries for the Umetco Gas Hills facility, pending approval of the Alternate Concentration Limits by the U.S. Nuclear Regulatory Commission, resolution of property and title issues, and any other outstanding issues that may arise.



LEGEND:

- PROPOSED LONG TERM CARE BOUNDARY
- GW8 ▲ – POINT OF COMPLIANCE MONITOR WELLS
- GROUNDWATER FLOW DIRECTION
- SECTION LINE
- 15 – SECTION DESIGNATION
- N 787500 — UMETCO SITE 2500' GRID SYSTEM
- UNPAVED ROAD
- SURFACE WATER

UMETCO MINERALS CORPORATION

PLAN VIEW

GAS HILLS SITE

APRIL 2001

EXHIBIT A

FIGEX-A2.DWG

Contents

Contents

Contents

Contents

Tables

Tables

Figures

Figures

Appendices

Acronyms and Abbreviations

Acronym	Definition
#obs	Number Observed
%	Percent
11e.(2)	Tailings or waste produced by the extraction or concentration of source material from any ore processed primarily for source material content
ACL	Alternate Concentration Limit
AEA	Atomic Energy Act
Ag	Silver
AgCl	Silver Chloride
AGTI	Above Grade Tailings Impoundment
ALARA	As Low As Reasonably Achievable
AML	Abandoned Mine Lands
As	Arsenic
Be	Beryllium
BLM	U.S. Bureau of Land Management
CAP	Corrective Action Program
Cl	Chloride
Conc.	Concentration
D&M	Dames & Moore
DCF	Dose Conversion Factor
DO	Dissolved Oxygen
DOE	U.S. Department of Energy
Eh	Oxidation/Reduction Potential Relative to Standard Hydrogen Electrode
EPA	U.S. Environmental Protection Agency
F	Fahrenheit
Fe	Iron
Fe(+2)/Fe(+3)	Ferric/Ferris Iron Redox Couple
ft/d	Feet per Day
ft/ft	Feet per Foot
ft/y	Feet per Year

Acronyms and Abbreviations

Acronym	Definition
ft^2/d	Square Feet per Day
gal	Gallons
gpd/ft	Gallons per Day per Foot
gpm	Gallons per Minute
GWPS	Groundwater Protection Standard
HDPE	High Density Polyethylene
HQ	Hazard Quotient
HydEng	Hydro-Engineering
in/y	Inches per year
IX/RO	Ion Exchange/Reverse Osmosis
Jacob	Jacob Method
LA	Lidstone Anderson
L&A	Lidstone and Anderson
LTCB	Long-Term Care Boundary
mg/l	Milligrams per Liter
Mrad	Millirad
mrem	Millirem
mrem/y	Millirem per Year
mV	Millivolt
µmhos/cm	Micromhos per centimeter
n	Number
ND	Not Detected
Ni	Nickel
NM	Not Measured
NPV	Net Present Value
NRC	U.S. Nuclear Regulatory Commission
ORP	Oxygen Reduction Potential
O&M	Operation and Maintenance
pCi/l	picoCuries per Liter

Acronyms and Abbreviations

Acronym	Definition
pH	Acidity/Alkalinity
POC	Point of Compliance
POE	Point of Exposure
PRI	Power Resources, Inc.
RA	Restricted Area
Ra-226	Radium-226 + 228
Redox	Reduction/Oxidation
S(-2)/S(+6)	Sulfide/Sulfate Couple
Se	Selenium
SO_4^{2-}	Sulfate
s.u.	Standard Units
Sv/Bq	Sieverts/Becquerels
SWFR	Southwestern Flow Regime
TDS	Total Dissolved Solids
Theis D	Theis Method for Drawdown
Theis R	Theis Method for Recovery
Th-230	Thorium-230
TVA	Tennessee Valley Authority
U_3O_8	Uranium Oxide
Umetco	Umetco Minerals Corporation
UMTRCA	Uranium Mill Tailings Recovery Control Act
U-nat	Uranium-natural
USES	U.S. Environmental Services
USGS	United States Geological Survey
vs	versus
WDEQ	Wyoming Department of Environmental Quality
WFR	Western Flow Regime

1.0 GENERAL INFORMATION

1.1 Introduction

Umetco Minerals Corporation (Umetco) submits this application to revise groundwater protection standards (GWPS) for its facility in Gas Hills, Wyoming. This document supports the establishment of Alternate Concentration Limits (ACLs) as being protective of human health and the environment at the proposed point of exposure (POE). This application was prepared in accordance with 10 CFR 40, Appendix A (Criteria 5B(5) and 5B(6)) and generally follows *Staff Technical Position Alternate Concentration Limits for Title II Uranium Mills* (NRC 1996). Upon acceptance and approval of the ACLs, Umetco proposes to eliminate the groundwater corrective action program (CAP) that is being conducted in accordance with U.S. Nuclear Regulatory Commission (NRC) Source Materials License SUA-648, Docket No. 40-0299, Condition 35.

Staff Technical Position Alternate Concentration Limits for Title II Uranium Mills (NRC 1996) states that in making the present and potential hazard finding, the NRC will consider 19 factors related to potential adverse effects on water quality for the site. Table 1.1 lists these 19 factors, and provides text references for each factor to be addressed.

The CAP was implemented to abate milling impacts to groundwater by reducing constituent concentrations at point of compliance (POC) wells to the GWPS set forth in License SUA-648. However, ambient groundwater conditions render the current GWPS at the POC wells impractical and unattainable. Mineralization, mining, and reclamation activities have caused widespread ambient groundwater contamination that is unrelated to but inseparable from milling impacts. The characterization of ambient groundwater quality is presented in Appendix A.

These ambient conditions make reduction of constituent concentrations to the current GWPS technically impracticable at the POC wells in the Wind River aquifer; however, geochemical and hydrologic processes reduce constituent concentrations to values below background that are protective of human health and the environment at the proposed POE. The proposed POE is the proposed long-term care boundary (LTCB). Geochemical and groundwater flow models were used to evaluate the effects of these processes on the distribution and movement of constituents. The results of the geochemical modeling are provided in Appendix B and the results of the groundwater flow model are presented in Appendix C. Appendix D contains information on the water rights search. The basis for the proposed ACLs used in the geochemical model is presented in Appendix E. Copies of correspondence regarding the site transfer are in Appendix F.

1.2 Facility Description

Gas Hills is located in Fremont and Natrona Counties, Wyoming, approximately 60 miles east of Riverton in a remote area of central Wyoming (Figure 1.1). The site lies within the Gas Hills Uranium District of the Wind River Basin, in portions of Sections 10, 15, 16, and 22, Township 33 North, Range 89 West. The Restricted Area (RA), including tailings disposal and heap leach area, consists of approximately 542 acres, of which Umetco owns 280 acres. The site plan map,

Figure 1.2, shows the RA boundary and locations of the reclaimed Above Grade Tailings Impoundment (AGTI), the A-9 Repository, and the former heap leach area.

1.2.1 Physiography and Meteorology

The Umetco Gas Hills site is typical of the Wyoming high plains, characterized by rolling terrain dissected by dry washes. The dry washes drain into a series of ephemeral creeks that eventually discharge to the Wind River approximately 45 miles north-northwest of the project area. Vegetation in the area is sparse, consisting primarily of low grasses and sagebrush. Elevation at the facility ranges from 6,800 to 7,050 feet.

Precipitation measured at the mill site from 1963 to 1991 ranged from 4.2 to 14.7 inches per year (in/y) with an average of 9.2 in/y. April and May are normally the wettest months. The annual mean lake evaporation for the site is approximately 42 inches (Umetco 1992).

The prevailing wind direction is from the south to southwest with strong winds frequent throughout the year (Umetco 1996).

Temperatures at the site range from winter lows near –40 degrees Fahrenheit (F) to summer highs near 100 degrees F with average temperatures of 18 degrees F in January to 68 degrees F in July (Umetco 1992).

1.2.2 Mining History

Gas Hills uranium reserves were mined from the late 1950s until 1984. The locations of mined areas are shown on Figure 1.3. Mining operations disturbed a considerable amount of the area as indicated on the figure. Open-pit mines were developed east, west, and south by Pathfinder Mines Corporation, Umetco, and the Tennessee Valley Authority (TVA) and a number of smaller mining companies. Initial reclamation consisted of the placement of overburden and mine spoils in the old mines as new mines were developed, and is continuing. Mining and reclamation activities are shown in aerial photographs taken in 1959, 1967, 1979, 1987, and 1997 (Figures 1.4, 1.5, 1.6, 1.7, and 1.8 respectively). Table 1.2 summarizes the mining reclamation. Underground mines, between 300 and 500 feet deep, were developed to the southwest of the Umetco project area (Figure 1.3). Power Resources, Inc. (PRI) is currently permitting an in situ leach uranium mine immediately downgradient of the Umetco facility.

Former open-pit mines located upgradient and to the east of the Umetco site have been reclaimed by the Wyoming Abandoned Mine Lands (AML) Division under Project 16E. Project 16E included reclamation of upgradient pits A-8, B2, B3, and Tee (Figure 1.3). Reclamation of these AML pits has impacted groundwater.

1.2.3 Milling History

Conventional uranium milling began at the Umetco Gas Hills facility in 1960. A total of eight million tons of ore was processed from 1960 through 1984. The daily average production was approximately 900 tons with an average ore grade of 0.11 percent uranium. From the startup of mill operations until 1979, tailings were placed in the AGTI by slurry methods (Figure 1.2). Since removal from service, the AGTI has been stabilized and an engineered cover placed on the impoundment. A rock protective layer will be placed on the existing cover by December 2002 as part of Umetco's enhanced reclamation plan.

The NRC approved the A-9 Repository for tailings placement in 1979 (Figure 1.2). The bottom of the A-9 Repository was lined with three feet of compacted clay before use. From 1979 through 1984, approximately 1.6 million tons of tailings from milling were slurried into the A-9 Repository. In 1988 approximately 1.8 million cubic yards of dewatered Susquehanna tailings from the Riverton Title I site were placed in the A-9 Repository. Additional discussion regarding the Susquehanna tailings is provided in Section 2.1 of this submittal. An interim cover of compacted clay that varies in thickness from approximately one to five feet was placed over the A-9 Repository from July 1988 to August 1989.

The North and South Evaporation Ponds were constructed in 1979 on top of a mine spoils pile located west of the A-9 Repository. The ponds were clay lined and constructed for storage and evaporation of tailings liquids. The liquids were pumped from the A-9 Repository and decant system in accordance with License Condition 36. In addition, groundwater recovered from the Wind River aquifer downgradient of the A-9 Repository was placed in the South Evaporation Pond from 1983 to 1991. Decommissioning of the North and South Evaporation Ponds began in 1991. The clay liner material was partially removed and placed in the A-9 Repository. The remaining liner material will also be placed in the A-9 Repository. All 11e.(2) materials will be removed and the mine spoils reclaimed in accordance with mining regulations. The mine spoils are not a source of 11e.(2) materials to the groundwater by regulatory definition.

In addition to the conventional milling procedures, heap leach operations were used to recover uranium from low-grade ore in an area south of the mill between 1963 and 1967. Another heap leach was operated in an area south of the AGTI from 1973 to 1978 (Figure 1.2) A third heap leach operation was started in 1979 and continued until 1987. The heap leach areas used a gravel and perforated pipe underdrain collection system over a one-foot layer of compacted clay. A compacted clay cover has been placed over the heap leach areas. An erosion protection layer will be placed over the heap leach in 2001. Umetco initiated groundwater remediation at Gas Hills in 1983 with the installation of extraction wells in the Wind River aquifer downgradient of the A-9 Repository (Figure 1.2). Groundwater extraction downgradient of the AGTI began in 1990. From 1983 to the present, additional wells have been installed to increase the rate of groundwater extraction. The extracted groundwater was pumped into the South Evaporation Pond until 1991. The clay-lined evaporation ponds were replaced by synthetic-lined ponds GHP1 and GHP2, constructed in 1991 and 1996, respectively. GHP1 was decommissioned in 2000.

In 1990, Umetco constructed a water treatment system using ion exchange (IX) and reverse osmosis (RO) to treat the recovered groundwater. Treated water was injected into wells upgradient and downgradient of the AGTI and A-9 Repository to increase groundwater flux within the aquifer and enhance remediation. The IX/RO treatment and injection was discontinued because it was not effective in treating groundwater. Currently the CAP consists of extraction of groundwater downgradient of the AGTI and A-9 Repository with evaporation in GHP2. Approximately 250 million gallons of water have been pumped and treated from 1983 through 2000 at an approximate cost of $12.6 million.

1.3 Extent of Groundwater Contamination

The extent of groundwater contamination was evaluated based on an assessment of the geology, hydrology, and geochemistry of the site.

1.3.1 Geology

The Umetco Gas Hills facility is located in the Wind River Basin of Central Wyoming. The Wind River Basin is a large sediment filled, northwest-trending structural depression that was formed as a result of Late Cretaceous and Early Cenozoic tectonic activity. During the Eocene, continued uplift of the surrounding mountain ranges and subsequent erosion resulted in the deposition of the Wind River Formation. The Wind River Formation outcrops throughout most of the Wind River Basin. The Wind River Formation is composed predominantly of debris eroded from surrounding highland areas, deposited in alluvial fans, stream channels, flood plains, lakes, and swamps. The thickness of the formation varies from a few feet near the basin margin to several thousand feet in the northern part of the basin.

In the vicinity of Gas Hills, these sediments were deposited in a series of coalescing alluvial fans and are characterized as a sequence of alternating and discontinuous layers of sandstone, siltstone, claystone, and conglomerate. This depositional environment resulted in the discontinuous occurrence of uranium deposits both vertically and laterally (Figures 1.9, 1.10, 1.11, 1.12, and 1.13). The Wind River Formation pinches out west, east, and south against Cretaceous and older age deposits (Whitcomb and Lowry 1968, and Van Houten and Weitz 1956) within a few thousand feet to a few miles from the site (Figure 1.14). The formation is approximately 300 feet thick at the Umetco mill site.

Uranium occurs in rocks of nearly every age in the Wind River Basin, including crystalline rocks in the adjacent Precambrian uplifts (Hausel and Holden 1978). In the Gas Hills District, uranium typically occurs as roll-front deposits within the Wind River Formation. Roll-front uranium deposits occur at the interface between oxidized and reduced rock in an arcuate pattern with the convex side of the arc pointing in the direction of groundwater flow (Figure 1.15). The uranium trend extends to the west of the Umetco facility as indicated by the mining operations of Pathfinder (Figure 1.3). The trend also extends east and south of the Umetco site.

1.3.2 Hydrology

The south-central margin of the Wind River Basin is delineated by Beaver Divide. This divide is a southwest trending erosional escarpment 500 to 1,000 feet in height. It is the topographic divide between the Sweetwater Plateau and the Wind River Basin. Regionally, groundwater and surface water north of the divide flow into the Wind River Basin (Figure 1.16).

There are no perennial surface water bodies in the vicinity of the mill with the exception of manmade impoundments or evaporation ponds. The nearest large body of water is Boysen Reservoir, approximately 50 miles to the northwest. Most of the drainages north of Beaver Divide are dry except during periods of runoff following precipitation and in areas near seeps and springs.

The mill site is located within the Canyon Creek drainage, a sub-basin of the Wind River Basin. Surface drainage outside of the RA flows into ephemeral West and East Canyon Creeks. These drainages join Canyon Creek four miles northwest of the mill site. Canyon Creek joins Deer Creek and then Poison Creek eight miles to the north. Poison Creek discharges into Boysen Reservoir. Surface runoff from the site is collected in the C18 Pit and transferred into GHP2 .

Groundwater occurs under confined, unconfined, and perched hydrostatic conditions within the Wind River Formation as shown on Figure 1.17. Although the Wind River Formation contains an extensive regional aquifer system, locally the aquifer is discontinuous and of limited use. Factors that control groundwater occurrence and the direction of groundwater flow include lithologic variability, distribution of pre-Wind River deposits, and sources of recharge to the aquifer.

Two flow regimes are identified and characterized in this ACL application. The first (shallowest) occurrence of groundwater beneath the A-9 Repository is defined as the Southwestern Flow Regime and includes the upper portion of the Wind River Formation. The Southwestern Flow Regime is characterized by more oxidizing conditions in the immediate vicinity of the A-9 Repository, becoming more reducing away from the site. The first occurrence of groundwater beneath the AGTI is defined as the Western Flow Regime and includes the lower portion of the Wind River Formation. The Western Flow Regime is characterized by deeper, more reducing conditions. A mudstone unit separates the flow regimes. The Southwestern Flow Regime is discontinuous and is absent below the AGTI and west of the site.

In the vicinity of Gas Hills, the groundwater flow is constrained by pre-Wind River deposits. To the west, truncation of the Wind River Formation results in discharge of groundwater at springs. Medicine Spring, Lincoln Spring and Iron Spring are examples of discharge points along West Canyon Creek (Figure 1.16). East of the site, the Wind River Formation pinches out against the Rattlesnake Hills. Granites, gneisses, and schists of the Granite Mountains south of Beaver Divide delineate the southern extent of the Wind River Formation. Recharge to the Wind River aquifer is derived from several sources. Recharge occurs as a result of direct infiltration, discharge from pre-Wind River deposits, and from streams and surface drainages. Localized recharge has also occurred from infiltration of impounded waters associated with mining and reclamation. Before placement of the reclamation cover, infiltration through the AGTI was a source of recharge to the Wind River aquifer. In addition, a portion of the water treated under the Umetco CAP was injected into the Wind River aquifer from 1990 until 1996.

The regional groundwater flow pattern within the aquifer is toward the Wind River, northwest of the site. Locally, in the northern portion of the site, groundwater flows to the west (Western Flow Regime), whereas in the southern portion flow is to the southwest (Southwestern Flow Regime). Groundwater flows southwest until reaching the area of the Lucky Mc property approximately five miles from the site. In the vicinity of Lucky Mc, groundwater flows to the north and eventually discharges at springs.

Within the framework of the CAP and Condition 35 of Source Materials License SUA-648, the Wind River Formation has historically been differentiated into upper and lower hydrostratigraphic units. This differentiation has been incorporated into the Source Materials

License and hydrogeologic studies. However, the aquifer system is more accurately described in terms of flow directions and reduction/oxidation (redox) conditions. The conceptual model focuses on the geochemical processes that control the distribution of constituents within the aquifer. Natural widespread ambient contamination and mill-related impacts to groundwater are limited to the uppermost occurrence of groundwater where oxidizing conditions predominate. Groundwater in the reducing portions of the aquifer is not affected by oxidation of mineralized zones, mining, or milling activities. Therefore, the Upper Wind River and Lower Wind River designations are used in the context of historical reference and the aquifer is more accurately described by groundwater flow directions and geochemical conditions. Additional information regarding the site hydrology is provided in Section 2.0.

1.3.3 Geochemistry

The Wind River aquifer was geochemically altered by mineral deposition characterized by multiple, sinuous redox fronts hosting the uranium deposits of Gas Hills. These redox fronts are distributed throughout the Wind River Formation and are extensive in vertical and horizontal directions. Beginning in the 1950s, mineralized redox fronts were identified and delineated by drilling and mining activities. Exploratory and development drilling was followed by open-pit and underground mining. Mining exposed the mineral-rich sections of the redox fronts to oxidation and facilitated infiltration of surface water through pits and mine spoils. However, the occurrence of unmined redox fronts provides for natural attenuation of mill-related constituents, as well as those related to naturally-occurring conditions and mining. Additional description of the geochemical conditions at the site is provided in Section 2.0.

Constituents derived from the milling process are the same as constituents related to uranium deposition, mining, and reclamation. Chemical parameters typically considered indicators of milling impacts include chloride and sulfate. However, the concentrations of these parameters vary by orders of magnitude in areas not impacted by milling activities. As an example, elevated sulfate levels attributable to acid mine drainage have been detected in background monitor wells. Characterization of ambient water quality is provided in Appendix A. Additionally, treated water with chloride concentrations in excess of 200 milligrams per liter (mg/l) was injected as part of the CAP from 1990 to 1996. Discussion regarding historic injection is presented in Section 3.0.

Evaluation of data indicates that groundwater quality impacts are also related to leaching of naturally-occurring uranium deposits. It cannot be determined what portion of elevated uranium levels observed at POC well GW7 is related to milling impacts, mining impacts, or dissolution of naturally-occurring uranium deposits. Additional discussion concerning constituent concentrations observed in GW7 is provided in Section 2.0.

Conversely, the occurrence of relatively low concentrations is an indication that milling or mining impacts have not occurred. Data collected from the monitor well network (Figure 1.18) indicate that water quality improves downgradient of the AGTI. Monitor wells MW28 and MW71B, approximately 2,500 feet downgradient of the AGTI, do not have elevated concentrations. The water quality at MW70B, approximately 1,600 feet west of the AGTI also shows no impacts from milling. The source terms and contaminant characterization are discussed in Section 2.1.

1.4 Current Groundwater Protection Standards

The GWPS established in 1989 in Source Materials License SUA-648, Condition 35 were based on short-term monitoring conducted approximately ten years ago from background wells LA2 and MW2 (Figure 1.18). The GWPS listed in Table 1.3 are currently applied to the two POC wells in the vicinity of the AGTI (MW1 and MW21A), and the two POC wells in the vicinity of the A-9 Repository (GW7 and GW8).

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." (NRC 1993)*

The GWPS currently prescribed in the license do not account for the widespread ambient contamination present at Gas Hills resulting from mineralization and mining activities.

1.5 Proposed Alternate Concentration Limits

Based on the results of the hazard assessment and analytical data from the site monitoring network, Umetco has developed site-specific ACLs that are protective of human health and the environment at the POE and are "As Low As Reasonably Achievable" (ALARA). The proposed ACLs are presented in Table 1.4. The hazard assessment indicates geochemical conditions result in attenuation of constituent concentrations to background levels before reaching the proposed POE, regardless of whether these constituents are derived from mineralization, mining, or milling activities.

The location of the POE was selected to ensure a sufficient distance for attenuation of licensed constituents to background levels. The distance from the POC to the POE was based on the results of the geochemical and groundwater flow models (Appendices B and C respectively). Additional information supporting the proposed ACLs is provided in Section 4.0.

1.6 Proposed Long-Term Care Boundary

The LTCB coincides with the POE determined from the results of the geochemical (Appendix B) and groundwater models (Appendix C). The land to be transferred to the U.S. Department of Energy (DOE) for long-term surveillance and maintenance is shown on Figure 1.19. The legal description of the area within the LTCB is as follows:

> All of Section 15, the north half of Section 22, the northeast quarter of Section 21, the east half of Section 16, the southeast quarter of Section 9, and the south half of Section 10, Township 33 North, Range 89 West, 6th Principal Meridian.

The Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978 (42 USC § 7901) as amended, provides for reclamation and regulation of uranium mill tailings at two categories of mill tailings sites, *i.e.*, Title I and Title II. Title I includes former uranium mill sites that were unlicensed, as of January 1, 1978, and essentially abandoned. Title II includes uranium mill sites under specific license as of January 1, 1978. In both cases, the licensing agency is the U.S. Nuclear Regulatory Commission (NRC), or in the case of certain Title II disposal sites, an Agreement State. The Umetco Gas Hills, Wyoming site is a Title II site under UMTRCA. The State of Wyoming is not an Agreement State and ownership of Section 16 changed from State of Wyoming to Umetco last year. That is, no land within the LTCB is currently owned by the State of Wyoming.

Specific regulatory requirements with respect to land and license transfer are established in 10 CFR 40. 10 CRF 40, Appendix A, Criterion 11C states in part:

> *"Title to the byproduct material licensed under the Part and land, including any interest therein (other than land owned by the United States or by a State) which is used for the disposal of any such byproduct material, or is essential to ensure the long term disposal of any such byproduct material, or is essential to ensure the long term stability of such disposal site must be transferred to the United States or the State in which such land is located, at the option of the State."*

10 CFR § 40.28 establishes licensing requirements upon termination of Umetco's license and states in part:

> *"The licensee will be the Department of Energy, another Federal agency designated by the President, or a State where the disposal site is located."*

Termination of Umetco's license occurs upon completion and acceptance of reclamation activities. At this time Umetco anticipates long-term custodial care being transferred to the DOE since the State of Wyoming declined to take title (letter of July 15, 1994 from D. Hemmer to J. Virgona).

All land inside of the proposed LTCB is currently under the control of either Umetco or the Bureau of Land Management (BLM). At this time Umetco anticipates completion of reclamation obligations and transfer of the site in 2004 or 2005. Umetco will work during 2001 with the BLM (Casper and Lander Districts) to establish the transfer mechanisms. A letter of commitment for the transfer of the land from Umetco to the DOE and correspondence from the DOE regarding acceptance of the land transfer is provided in Appendix F.

2.0 HAZARD ASSESSMENT

The hazard assessment evaluates the sources and distribution of constituents, the direction and rate of transport of the constituents in groundwater and surface water, and the risk to human health at the proposed POE. The hazard assessment demonstrates that the proposed ACLs are protective of human health and the environment at the proposed POE. The hazard assessment includes the following sections: a source term and contaminant characterization, a transport assessment, and an exposure assessment.

2.1 Source Term and Contaminant Characterization

The sources of hazardous constituents are naturally-occurring mineralization, mining, and reclamation impacts, and milling activities. The following sections discuss ambient sources and mill-related impacts. Additional information regarding ambient contamination is provided in Appendix A.

2.1.1 Naturally-Occurring Mineralization

Constituents from natural mineral deposits are the same as constituents derived from mining, milling, and reclamation activities. For the majority of the site the ambient contamination is unrelated to, but inseparable from, milling impacts. Elevated concentrations occur naturally because constituents associated with mineral deposits contribute to the variable water quality that is characteristic of the Wind River aquifer. Naturally-occurring mineralization is evident in areas upgradient, within, and downgradient of the Umetco site.

The Gas Hills uranium district was a major uranium-producing region of the United States. Uranium occurs in an area approximately five miles wide and twenty miles long in three north-trending belts known as East, Central, and West Gas Hills (Figure 2.1). Uranium ore bodies can be areally extensive as seen in the Lucky Mc ore trend that is approximately 2,300 feet long, 600 feet wide, and contains nine ore zones averaging five feet in thickness distributed throughout a stratigraphic interval 150 feet thick (USAEC 1959). The uranium ore occurs in sandstone and conglomerate beds of the Wind River Formation.

The Wind River aquifer was geochemically altered during a post-depositional period of uranium concentration and mineral deposition. The geochemical alteration is characterized by multiple, sinuous redox fronts in the Gas Hills. These redox fronts are distributed throughout the Wind River stratigraphic section. The network of redox fronts is extensive in both vertical and horizontal directions. The heterogeneous nature of the sedimentary units and the sinuous and stacked configuration of the mineralized redox fronts ensure that a number of geochemical processes are taking place concurrently. These processes result in the variability of natural groundwater quality in the Wind River aquifer.

Most of the mined ore occurred in coarse-grained sandstone beds, with minor amounts in fine-grained silt and carbonaceous shale beds. Uraninite and coffinite are the most important uranium minerals in the reduced mineral deposits. Meta-autunite, phosphuranylite, and uranophane are common oxidized uranium minerals. Accessory minerals include pyrite, carbon, marcasite, arsenic, calcite, jordisite, molybdenum, and one or more selenium minerals. Selenium is common as a brick red precipitate of amorphous native selenium on the walls of open pits in the area.

Four types of uranium deposits are recognized at Gas Hills. These types, in order of economic significance, are as follows:

1. roll-front deposits,
2. transitional bedded deposits,
3. near-surface oxidized deposits, and
4. residual remnant deposits.

The roll-front deposits account for over 90 percent of the reserves in the Gas Hills district. These deposits consist of minerals that formed at the solution front or interface between oxidized and reduced environments in sedimentary rock and are found at or below the water table. The mineral bodies are lens-like features, tongue-shaped in plan and crescent-shaped in vertical section with elongated horns corresponding to the upper and lower limbs of the roll (Figure 1.15). The limbs of the roll may extend hundreds of feet along the upper and lower contacts.

The barren interior on the concave side of the roll-front deposit extends upgradient beyond the limits of uranium deposition typically a mile or more. The rich ore section is several feet wide and is adjacent to the convex side of the solution front. The intermediate section, which contains medium- to low-grade mineralization, is typically less than 100 feet wide. The protore section (mineralization not of mineable grade) can extend over a hundred feet. The solution front is a relatively sharp, elongated boundary separating the ore in a roll from the barren rock on the unmineralized side. A series of roll front deposits may extend along the front for several miles, but the entire distance is usually not mineralized to the degree of being economically viable for mining. In plan view, the front is sinuous and the ore bodies are located in the sharper curves.

Transitional bedded deposits are found throughout the district. The ore occurs in fine-grained beds that contain abundant clay and silt. Downward leaching of uranium minerals, derived from the oxidized solution-front ore bodies located in strata higher in the section, has produced local enrichment in the fine-grained underlying beds.

The near-surface, oxidized deposits were mined during the early development of the district. Weathering and surface leaching have caused the deposits to be low in uranium content and discontinuous. Most of the oxidized minerals are the remains of solution-front deposits exposed by erosion. Uranium phosphates, silicates, and hydrous oxides are the dominant minerals in the oxidized zone.

Residual remnant deposits are of minor economic importance. These deposits were formed in local thin layers of lignite and carbonaceous shale that were enveloped by mineralizing solutions. The encasing sands allowed these solutions to pass through, and carbon acted as a reducing agent resulting in uranium precipitation. The residual remnant deposits are found in the altered barren interiors of the roll-front deposits.

In the reduced sections of the Wind River aquifer the concentrations of metals are low. An example of this can be seen in monitor well LA2. This background well was used to develop the original groundwater standards for the site. However, this well is not representative of the full range of naturally-occurring conditions associated with a mineralized area. The low concentrations of chemical constituents in groundwater samples from monitor well LA2 are consistent with uranium mineralization in reduced sandstone.

In areas where mineralized materials are exposed to oxygen by erosion or mining, the groundwater concentrations of metals may be orders of magnitude higher. The highest concentrations of metals and sulfate are near mineralized materials exposed to oxygen such as natural drainages, open mine pits, and mine waste rock piles. An example of poor water quality as a result of erosional processes is Iron Spring, a surface water named for the natural precipitation of iron. Water discharging from Iron Spring had pH values of 3.9 in 1954 before mining began, indicating naturally-occurring acidic conditions associated with the oxidation of uranium minerals. Poor ambient water quality is not unique to Iron Spring as indicated by other surface waters in the region named Badwater Creek and Poison Creek.

2.1.1.2 Impacts from Mining and Reclamation

Uranium was mined from open pits in the Wind River Formation upgradient, crossgradient, within, and downgradient of the Umetco project area. These mines were developed by Pathfinder, TVA, Umetco, PRI, and others. Geochemical processes related to mining and reclamation have affected groundwater quality because oxygenated surface water has percolated through open-pit mines, mine spoils, and backfill materials dissolving previously reduced minerals. Figure 2.2 identifies areas where the upper or lower portion of the Wind River Formation was penetrated by mining. The figure also identifies mine pits that intercepted groundwater. Mine pits within the LTCB that encountered groundwater are generally restricted to areas upgradient of the site. The effects of mining and mine reclamation in those upgradient areas on groundwater flow direction and velocity have been evaluated using a groundwater flow model (Appendix C). The impacts of mining and mine reclamation on water quality are addressed in the geochemical model (Appendix B), and the basis for ACL selection is discussed in Section 4.

The A-9 Repository is a former open-pit mine. Figures 1.9 through 1.13 are fence diagrams depicting the vertical and horizontal distribution of uranium ore within the southern part of the A-9 Repository. The fence diagrams were developed using exploratory geophysical data. The ore zones extend laterally through permeable sand horizons and are exposed to oxidizing conditions at the mine pit wall.

Evaluation of data collected from POC well GW7 provides an example of groundwater quality that may have been partly impacted by milling, but exhibits greater impacts associated with mining and naturally-occurring mineralization. Based on gamma survey results from 1983, uranium mineralization is approximately coincident with the water table at GW7 (Figure 1.13). Fluctuations in the elevation of the water table within the borehole alternately expose and cover the mineralized zone. When water levels fall, the mineralized zone is exposed to oxygen. When water levels rise and resaturate the mineralized zone, acids are released into the groundwater.

These acids are similar to the acidic mine drainage that occurs with mine spoils at the ground surface.

The ratio of chloride to uranium concentrations is another indication that groundwater quality has been impacted by sources other than milling. For example the chloride to natural uranium ratio calculated from analytical results from GW7 is not consistent with results associated with the materials placed in the A-9 Repository or with the ratios calculated from other monitor wells in the area. Chloride concentrations in the tailings solution averaged 3,200 mg/l and the natural uranium concentrations averaged 18.6 mg/l. The average chloride and uranium concentrations are summarized in Table 2.1. Using these averages, the ratio of chloride to natural uranium in the tailings solution was approximately 150 to 1. Therefore, seepage from the A-9 Repository should have a chloride to uranium ratio of minimally 150 to 1. The ratio may be significantly higher as chloride is non-reactive and should not be attenuated along the flowpath between the A-9 Repository and monitor well GW7 whereas uranium attenuates by a number of processes (as described in Section 2.2.). The average ratio of chloride to natural uranium collected from POC well GW7 is 8 to 1, indicating either a net decrease in the mass of chloride or a net increase in the mass of uranium.

Since chloride is not appreciably attenuated, the decrease in the chloride to natural uranium must be the result of an increase in impacts from naturally-occurring mineralization. Therefore, the chloride to natural uranium ratio in GW7 indicates greater impacts to the groundwater from mining and naturally-occurring mineralization than from milling.

Further, evaluation of groundwater level data indicate the impacts to groundwater quality in GW7 are attributable to mining or naturally-occurring mineralization. Under natural conditions, POC well GW7 is downgradient of the A-9 Repository. However, during periods of extraction the hydraulic gradient is reversed and groundwater flows to the north. Therefore, the elevated concentrations observed in samples collected from GW7 originate from the south, away from the A-9 Repository. Based on the gamma survey results, groundwater quality data, and groundwater elevations, milling impacts in the vicinity of GW7 cannot be quantified or differentiated from naturally-occurring mineralization.

Open-pit uranium mining and subsequent reclamation at Gas Hills have created acidic mine drainage. During mining, overburden and low-grade ore were stockpiled in the vicinity for use during reclamation. Stockpiled material was typically exposed to oxidation processes for many years before being used as backfill in the open-pit mines. Infiltration of oxidizing surface water was facilitated by the increased porosity, permeability, and particle surface area of backfill material. Increased infiltration of oxidizing water resulted in acidic mine drainage that has adversely impacted groundwater quality in reclamation areas. Some examples include upgradient monitor well LA8 to the east of the A-9 Repository. Monitor well LA8 is in an area reclaimed by the Wyoming Department of Environmental Quality (WDEQ) under the AML Program. Time versus concentration data for iron, uranium, sulfate, and total dissolved solids (TDS) for LA8 indicate impacts to groundwater quality that are not mill-related (Figure 2.3). Modeling corroborates that groundwater impacted by AML reclamation is moving toward and through compliance wells GW7, and GW8 under the current pumping configuration for the CAP (Appendix C).

2.1.2 Mill-Related Constituents

Characterization of the mill-related sources requires description of the uranium recovery processes, the types and quantities of reagents used in the extraction process, and the chemical composition and handling of byproduct material.

2.1.2.1 Mill and Heap Leach Operations

Aerial photographs show the Gas Hills uranium mill was under construction in September of 1959 (Figure 1.4). The average amount of ore processed at the mill was approximately 900 tons per day. As technology advanced, the milling operations changed. The following milling processes were used at some time during the operation of the Gas Hills mill:

- crushing and grinding of the ore;
- chemical oxidation;
- sulfuric acid leaching;
- classification;
- solid/liquid separation;
- resin-in-pulp ion exchange extraction;
- solvent extraction;
- precipitation; and
- product drying and calcination.

The mill process is shown in detail on Figure 2.4.

Processing of mined uranium ore at Gas Hills ended in 1984. From 1960 through 1984, the mill processed approximately eight million tons of ore with an average uranium content of 0.11 percent uranium. Table 2.2 shows the amount of ore processed per year, the average uranium content, and the amount of uranium produced. During the operation of the mill, limited amounts of materials from operations in Maybell, Rifle, and Uravan, Colorado were also processed.

Heap leach operations began in 1963 when extraction of uranium from low-grade ore became viable. In 1963, three test cells were constructed south of the mill and ore stockpile area. Five cells were added in 1966. The heap leach operation was terminated by 1967. Information about the design of these early cells is limited, but during construction of the evaporation pond GHP2, portions of the cells and a plastic liner were excavated. An experimental heap leach operation consisting of six cells was constructed in 1973 just south of the AGTI. By the end of this operation in early 1978, fourteen cells were in place. A third heap leach operation began in 1979. The 1983 aerial photograph shows 28 cells to the south of the AGTI (Figure 2.5). This operation added six cells that are visible in the September 1987 aerial photograph. The heap leach operations ended in late 1987. From 1963 to 1987 approximately 304 tons of uranium oxide were produced by heap leach operations.

Acid leaching of sandstone uranium ores contributed sulfuric acid to the tailings piles (Merritt 1971). Sodium chlorate and manganese dioxide were added to the process as oxidizers to bring the solution to an Eh between 0.400 and 0.425 volts. Additionally, ammonia gas was used as a neutralizer and ammonium nitrate was used as an eluant in the resin in pulp ion exchange process. Sodium chlorate, used as an oxidizer in later years resulted in maximum chloride concentrations in the process solution of 7,030 mg/l.

Mill tailings were placed in two areas: the AGTI and the A-9 Repository. During ore processing from 1960 to 1984, approximately 16 million tons of tailings were placed in the AGTI and the A-9 Repository.

Placement of tailings in the AGTI began in 1960. In 1969, the impoundment was expanded approximately 12 acres to the east, and in 1972 an additional 27 acres was added to the north in 1972. In 1974, the impoundment was expanded 55 acres to the east. The AGTI expansions are shown on Figure 2.6. The AGTI was used until 1979.

Tailings were placed in the A-9 Repository from December 1979 until 1984. During that period, approximately 1.6 million cubic yards of tailings were placed in the A-9 Repository. Additionally, between 1988 and 1990, 1.8 tons of tailings from the DOE Riverton Title I site were placed in the A-9 Repository. Based on review of the environmental assessment prepared by DOE June 1987, the Riverton tailings did not contribute to groundwater quality at the Gas Hills site. Specifically, the following factors were noted.

- Milling ceased in 1963, therefore the tailings dewatered approximately 25 years before placement at Gas Hills.

- A deposit of cobbly alluvium underlies the entire pile. The alluvium was relatively thick, ranging from 14 to 18 feet. Transport of tailings liquid was facilitated by the permeability of this underlying formation.

- The moisture content of the tailings averaged 6 percent.

2.1.2.2 Chemical Composition of Tailings

Approximately 465,000 tons of tailings slurry, containing 20 to 30 percent solids by volume (NRC 1980a), were discharged annually into the AGTI. Groundwater quality representative of chemical characteristics of the tailings placed in the AGTI is shown in Table 2.3. After tailings placement into the AGTI ceased in 1979, the impoundment was stabilized by placement of engineered cover materials. The AGTI and the adjacent heap leach area comprise approximately 215 acres.

The A-9 Repository was lined with a 3-foot compacted clay layer and equipped with a decant system to dewater the tailings. Tailings were placed into the A-9 Repository between 1980 and 1984. The chemical composition of tailings in the A-9 Repository is listed in Table 2.1. The impacts of the Susquehana tailings in the A-9 Repository are minimal because the tailings were placed dry and capped with an interim cover.

2.1.2.3 Indicator Parameters

Indicator parameters associated with mill operations typically include chloride and sulfate. These constituents are also present in the groundwater as a result of naturally-occurring mineralization and mining and reclamation activities. As stated previously, milling impacts are difficult to discern from naturally-occurring mineralization or mining impacts.

Chloride is typically a good indicator of mill-related impacts because it is non-reactive and moves at approximately the same velocity as groundwater. However, based on ambient chloride concentrations and historic groundwater remediation efforts, it cannot be assumed that elevated chloride concentrations are indicative of mill-related impacts. Specifically, the highest observed ambient chloride concentration is 124 mg/l in the vicinity of the Veca Pit. Further, injection of treated water occurred during the operation of the IX/RO groundwater treatment system. The injected water contained an average chloride concentration of 240 mg/l, further obscuring mill-related impacts. These factors result in chloride being a poor indicator parameter.

Sulfate contamination may have been caused by acid infiltration from mining and reclamation, in addition to being indicative of milling impacts. Evaluation of sulfate data from MW76, located approximately 8,000 feet west of the AGTI, indicates that the highest observed ambient concentration was 1,920 mg/l. Sulfate concentrations associated with mill-related impacts are difficult to differentiate from naturally-occurring or mining-related impacts.

2.1.2.4 Distribution of Constituents

The spatial and temporal distribution of licensed constituents and indicator parameters provides the potential migration pathways, rate of movement of constituents in groundwater, and maximum concentrations that can be anticipated at the POCs. Concentration trend plots and isoconcentration maps were used to evaluate the distribution of constituents in groundwater.

Elevated concentrations of licensed constituents upgradient of the POCs from either ambient or mill-impacted groundwater could result in an exceedance of a proposed ACL, particularly if the proposed ACL is based on a maximum concentration observed to date at the POC. Therefore, an analysis was conducted to estimate the maximum concentrations that may occur at the POC wells for both the A-9 Repository (Southwestern Flow Regime) and the AGTI (Western Flow Regime). The results are the proposed ACLs for each flow regime as well the source term for the geochemical model (Table 1.4). Water quality data for each flow regime were ranked to identify wells that consistently recorded the highest concentrations for each constituent. Concentration trend plots were developed for the wells having the highest concentrations to identify outliers and evaluate trends. The ACLs were based on the 95 percent upper confidence limit calculated for the upper 95th quantile for each constituent data set. The ACL for thorium-230 in the Southwestern Flow Regime was the only exception. The ACL for thorium-230 was set equivalent to the highest observed value at POC well GW7.

Monitor well HW4 was excluded from the ACL analysis for the Southwestern Flow Regime because anomalously high concentrations of arsenic, beryllium, nickel, lead-210, thorium-230, natural uranium, and sulfate have been detected. HW4 is located southwest of the former mill area and is screened above the mudstone unit that separates the Southwestern and Western Flow

Regimes. HW4 is used to monitor environmental conditions in perched water that represents the upgradient extent of the Southwestern Flow Regime. The "hot spot" identified at HW4 is limited in extent both vertically and laterally and will not impact groundwater quality at the POC wells. The basis for determining the ACLs is provided in Section 4.

In the Western Flow Regime, the highest concentrations for licensed constituents were generally observed at wells MWI43, MWI64, MWC55, and MW67 (Figures E-1 through E-9). These wells are located along the central and western parts of the AGTI. Typically the highest concentrations of selenium occurred at POC well MW1 with the exception of MW67(Figure E-8).

For the Southwestern Flow Regime, the highest concentrations for the radionuclide constituents were generally observed at POC well GW7, and monitor well MW7 (Figures E-12, 13, 14, 16, 18). MW7 is located along the northern extent of the A-9 Repository. The highest concentrations for nickel and beryllium were recorded at GW3 and MW61 (Figures E-11 and E-15). The highest values for arsenic were observed at well PW7, which is located cross-gradient of the A-9 Repository and is considered a background well (Figure E-10). Selenium was highest at GW5 and RW2 (Figure E-17). The concentration plots did not indicate significant upward trends for any of the constituents although there was a sharp increase in radionuclide concentrations at POC well GW7 around 1996-97 followed by a gradual decrease (Figures E-10, 12, 13, 14, 16, 18).

Isoconcentration maps were developed from water quality data for the Southwestern and Western Flow Regimes. These maps are presented for arsenic, beryllium, nickel, selenium, lead-210, radium-226+228, thorium-230, natural uranium, and chloride for 1990, 1995, and 2000. The maps are included in Appendix G. When interpreting the maps, it must be noted that the data sets for each of the time periods are not identical. For example, installation of a new monitoring well between two of the reporting periods may cause the appearance of a significant change in the direction or rate of movement of a constituent plume.

As in the concentrations plots, the isoconcentration maps for the Western Flow Regime show the highest concentrations for arsenic, beryllium, nickel, natural uranium and radium-226+228 are generally beneath the western and central portions of the AGTI (Figures G-1 through G-5). The highest concentrations of selenium and lead-210 are found beneath the northern portion of the AGTI (Figures G-6 and G-7). Thorium-230 concentrations are sporadic, both temporally and spatially, and do not define a consistent plume (Figure G-8).

Monitor wells MW28 and MW71B are located directly downgradient and west of the AGTI. None of the licensed constituents were detected above the GWPS in either of these wells. Chloride has also been historically low at these locations (Figure G-9). These factors provide evidence that milling-related impacts have not reached these wells. However, because of ambient conditions radium-226+228 concentrations at these two wells and at MW77 located further to the west, exceed the Class III groundwater standard of 5 picoCuries per liter (pCi/l). The radium valves confirm that ambient water quality downgradient of the site does not meet WDEQ classifications for domestic, agricultural, or livestock use.

For the Southwestern Flow Regime, the isoconcentration maps are also generally consistent with the data observed in the concentration trend plots. With the exception of HW4 as previously discussed, the highest concentrations of beryllium, lead-210, radium-226+228, thorium-230, and natural uranium are found in the vicinity of the POC well GW7 (Figures G-10 through G-14). Elevated arsenic concentrations are present in the vicinity of background location PW7 (Figures G-15). Selenium is highest at GW5 and RW2 (Figure G-16) and nickel is more diffusely distributed with highest concentrations at PW1 (Figure 3.17). Chloride concentrations have generally been highest in the vicinity of GW5 (Figure G-18).

2.1.2.5 Vertical Distribution of Constituents

Mineralization, mining/reclamation, and mill-related impacts are limited to the uppermost portion of the groundwater where oxidizing conditions are present. In the vicinity of the site, the thickness of the Wind River Formation exceeds 300 feet. In the deep, more reducing portions of the aquifer, groundwater is not impacted. Evaluation of groundwater quality data from monitor wells completed in the deeper portions of the Wind River aquifer (MW28, MW30, MW70B, and MW71B) indicates that licensed constituents do not exceed current GWPS (Table 2.4) and vertical migration is not occurring (Figure 2.7 and 2.8). Concentration trend plots for the licensed constituents are included in Appendix H. Chloride would provide the earliest indication of milling-related impacts because it is non-reactive and does not attenuate. Chloride trend plots illustrate that there has been no significant increase in any of the four wells and that concentrations are low and within the range of background (Figure 2.7).

Recent well replacements provide additional comparative data between the Western and Southwestern Flow Regimes in the area of the A-9 Repository. In 1999, monitor wells MW6, MW7, and MW10, which had been completed above and/or across the mudstone aquitard, were abandoned and replaced with MW6D, MW7D, and MW10D. The replacement wells were completed beneath the mudstone unit (US Environmental Services 1999). Monitor well MW24D, installed adjacent to existing wells MW24 and DW4 (which were not abandoned), was also completed beneath the mudstone. DW4 is also a deep completion. A comparison of chloride data from the deep- and shallow-completed wells indicates that chloride concentrations are much higher in the shallow wells (Figure 2.8). Chloride levels are very low in most of the deep-completed wells with the exception of MW7D. Injection of treated water in the vicinity of MW7 between 1991 and 1995 resulted in a localized increase in the water table of approximately 80 feet (Figure 2.9). The increased hydraulic head in the area of MW7 may have forced shallow groundwater into the deeper aquifer system beneath the mudstone. The low chloride levels indicate that milling-impacted groundwater has not migrated into the deeper portions of the Wind River Aquifer except in areas where artificially induced vertical gradients may have temporarily facilitated such movement. The recharge mound associated with injection has dissipated and migration of milling-related constituents into the deeper portions of the Wind River Aquifer in the area of the A-9 Repository has ceased.

2.1.2.6 Evaluation of the HW4

Anomalously high concentrations of arsenic, beryllium, nickel, lead-210, thorium-230, natural uranium and sulfate have been detected in monitor well HW4. The increase in constituent concentrations at HW4 started gradually in early 1993 and then rapidly between mid-1997 and early 1998 (Appendix I). Field pH has been measured between 2 and 3 s.u. since 1993. The specific cause of the increase has not been determined although the source may be residual tailings seepage, experimental heap leach liquor, or laboratory leach field liquor. Regardless of the source, water level and water quality data demonstrate the limited vertical and lateral extent of the high concentrations.

Saturated thickness in HW4 is less than 10 feet and has been steadily declining since the well was installed in 1984 (Appendix I). The decline in water levels indicates that there is no source of recharge to the perched water zone. The perched zone does not extend to the north and terminates a few hundred feet to the west. Monitor well HW3, the nearest downgradient monitoring point to HW4 completed above the mudstone, has a saturated thickness of approximately 5 feet. The saturated thickness at monitor well MW10D, located approximately 2500 feet west and southwest of HW4, was less than 5 feet at the time of its abandonedment in 1999. The limited saturated zone, coupled with declining water levels, indicates a finite and diminishing volume of shallow groundwater above the mudstone north of the A-9 Repository.

As shown in the isoconcentration maps, constituent concentrations measured in surrounding monitor wells are typically an order of magnitude less than HW4 (Appendix G, Figures G-10 through G-18). Furthermore, HW3, located closest to HW4 and completed above the mudstone, is near or below the GWPS for all of the constituents, with the exception of nickel. This indicates that lateral migration from HW4 has been limited and has not reached HW3.

Monitor well DW3 is located adjacent to HW4 but is completed beneath the mudstone. Water quality data from DW3 indicates that all licensed constituents, except for radium 226+228, are below GWPS (Appendix H). Note that radium 226+228 was not anomalously high at HW4. The data confirm that the HW4 "hot spot" has not impacted the deeper aquifer.

Previous attempts to pump water from HW4 have provided minimal quantities of water. The well typically pumps dry within a matter of minutes (at rates of approximately 1 gpm) and then takes several days to recover. In order to determine if the low yield from this well is caused by poor or damaged well construction or is the result of intrinsic aquifer characteristics, an offset well was drilled recently drilled. The replacement well was located within ten feet of HW4 and was drilled to the top of the mudstone unit (total depth of 144 feet). No groundwater was encountered in the borehole during drilling. Subsequent attempts to measure the water level in the borehole a week after drilling indicated the well was still dry. The lack of saturated conditions within 10 feet of HW4 confirms the limited extent of the "hot spot".

2.1.2.7 Constituent Seepage Rates

Based on water balance calculations seepage rates for the AGTI reached a maximum of approximately 100 gallons per minute (gpm) in 1979, ulations. Seepage declined rapidly following closure of the AGTI. Current seepage rates are estimated to be between 20 and 30 gpm based on modeling (SMI 1997). The model indicates continuous decline in seepage rates to less than 1 gpm within the next 10 to 20 years. Stabilization of the tailings and placement of an engineered clay cover over the AGTI have eliminated infiltration of surface water.

The 1998 seepage rate for the A-9 Repository was estimated at 3.3 gpm (Shepherd Miller, Inc. 1998). Continued pumping under the current CAP will extract seepage from the A-9 Repository, but will also continue to import constituents related to natural-occurring conditions and mining activities.

2.2 Transport Assessment

The transport assessment evaluated potential migration pathways for regulated constituents. Key components were hydrologic and geochemical factors that control solute transport. The hydrologic component defines the rate and direction of groundwater flow within the aquifer. The geochemical component considers the reduction in solute concentrations that occur along groundwater flowpaths. The Wind River aquifer directly below the Gas Hills site was the focus of this assessment because it is the uppermost aquifer and no other aquifers are impacted by mill-related constituents.

The nearest aquifers above the Wind River are the Miocene Split Rock, Oligocene White River, and the Eocene Wagon Bed Formations. These formations are found in outcrops along the Beaver Divide several miles to the south and are topographically 500 to 1,000 feet or more above the water levels observed at Gas Hills. The presence of the topographic divide indicates that groundwater from the site can not reach the post-Wind River aquifers to the south. Therefore, aquifers above the Wind River were not evaluated in this transport assessment.

Mineralization, mining/reclamation, and mill-related impacts are limited to the uppermost occurrence of groundwater where oxidizing conditions are present. In the deep, more reducing portions of the aquifer, groundwater is not impacted. Evaluation of groundwater quality data from monitor wells completed in the deeper portions of the Wind River indicates that vertical migration is not occurring (as discussed in Section 2.1.2). For this reason, aquifers beneath the Wind River aquifer are not considered in this assessment.

The direction of groundwater flow from the site is predominately west and southwest as shown on Figure 1.16. The Wind River Formation is truncated by Paleozoic rocks of the Granite Mountains south of the site. To the west and northwest, the Wind River Formation pinches out against the Cretaceous Cloverly Formation, Cody Shale, Frontier Formation and Mowry Shale, the Jurassic Nugget Sandstone, Sundance and Morrison Formations, and the Triassic Chugwater Formation. All of these formations are considered aquitards with the exception of the Cloverly Formation and the Nugget Sandstone. Those formations receive recharge west of the site on the flanks of the Dutton Basin Anticline and discharge into the Wind River Formation. Consequently, because groundwater does not discharge into any other aquifers within several miles of the site, the transport assessment focused on evaluating the Wind River aquifer.

2.2.1 Hydrologic Assessment

Direction and velocity of groundwater flow are critical hydrologic factors that determines solute transport. Determination of the groundwater flow direction is based on water-level data that are routinely collected from an extensive monitor well network (Figure 1.18). The velocity of groundwater flow depends on hydraulic conductivity, hydraulic gradient, and porosity.

The hydraulic conductivity and porosity are intrinsic properties of the aquifer matrix and do not vary with time. Hydraulic conductivity estimates are derived from pumping tests. Porosity estimates are derived from core data and literature. Hydraulic gradient varies in time and space depending on changes to the groundwater flow regime. Under normal non-stressed conditions, changes in hydraulic gradients within an aquifer tend to be minor and occur gradually. When a groundwater flow regime is stressed (due to extraction, injection, mine dewatering, mounding from seepage, etc.) hydraulic gradients may change abruptly, resulting in measurable changes in groundwater flow velocity and direction.

2.2.1.2 Hydrostratigraphic Units

As previously described, two flow regimes, or hydrostratigraphic units, are defined and characterized for purposes of the ACL application. The Southwestern Flow Regime includes the upper portion of the Wind River Formation and is present beneath the A-9 Repository. It is characterized as a shallow unconfined system with a southwesterly flow direction and a saturated thickness typically less than 20 feet. This shallow flow system generally occurs within 150 feet of the ground surface and contains most of the ore-grade uranium mineralization. Oxidizing conditions prevail in the vicinity of the A-9 Repository, becoming more reducing away from the site. The Southwestern Flow Regime is absent beneath the AGTI and west of the site. The Southwestern Flow Regime, where present, is separated from the Western Flow Regime by a mudstone unit.

The mudstone unit is an aquitard that acts as a confining unit between the Southwestern and Western Flow Regimes. The base of the mudstone unit is the top of the Western Flow Regime. The mudstone varies from 20 to 40 feet in thickness across the site and dips to the south-southwest at approximately 1 degree. The mudstone unit crops out in surface drainages along the north side of the AGTI.

The Western Flow Regime includes the lower portion of the Wind River Formation and lies beneath the mudstone unit. The Western Flow Regime is characterized as a deeper, more reducing system, a saturated thickness on the order of 300 feet, and a general flow direction to the west. The Western Flow Regime is confined in areas to the south where the Southwestern Flow Regime is present. It is unconfined to the north, where the Southwestern Flow Regime is absent.

Hydrogeologic cross sections illustrate the absence of saturated conditions in the upper portion of the Wind River Formation north of the A-9 Repository and west of the AGTI (Figure 2.10). The north-south cross section (A-A') shows saturated conditions in the Southwestern Flow Regime (above the mudstone unit) in the vicinity of the A-9 Repository (wells MW24, MWI54, MW7, and MW7D). Note that the shallow water table is depressed in the vicinity of MW24 as a result of pumping under the CAP. Saturated conditions do not exist above the mudstone unit at the AGTI (wells MWC46, MWI66, MWC47A, MWC48, and MWC49). Between the A-9 Repository and the AGTI there is a transitional area where a perched water table is present above the mudstone (wells MW10 and MW10B). On the east-west cross section, the first occurrence of groundwater beneath the AGTI is more than 30 feet below the mudstone unit (wells MWC47A and MWI61). The water table in monitor wells MW28 and MW77 (located approximately 2,400 and 3,800 feet west of the AGTI, respectively) occurs more than 100 feet below the base of the mudstone unit. The water table in the Rim Pit, over 5,000 feet west of the AGTI, occurs 60 feet below the base of the mudstone unit. These cross sections demonstrate the absence of saturated conditions above the mudstone unit west of the AGTI, and that the Southwestern Flow Regime is present only to the southwest.

2.2.1.3 Groundwater Flow Direction and Hydraulic Gradient

The transport assessment was used to evaluate potential for constituent migration if no further corrective action is implemented. To determine the direction of groundwater flow under natural, non-pumping conditions, all pumping activities were stopped, in early 1996, to allow the groundwater to equilibrate to static or nearly static conditions. A comprehensive water-level measurement survey was performed approximately two months after pumping was stopped. The results of the survey are shown on Figure 2.11.

Based on the 1996 water-level elevations, the natural groundwater flow direction in the vicinity of the A-9 Repository is to the southwest. The hydraulic gradient beneath the A-9 Repository was approximately 0.022 ft/ft. In the vicinity of the AGTI, the water-level measurements indicated that the direction of groundwater flow under non-pumping conditions was predominately to the west with a hydraulic gradient of 0.03 ft/ft on the west side and less than 0.01 ft/ft on the east side. Hydraulic gradients and estimated groundwater flow velocities are summarized in Table 2.5.

Mining, milling, and reclamation activities have affected the groundwater flow regime. Seepage from the A-9 Repository and AGTI, extraction and injection of water during implementation of the CAP, and reclamation of mined areas have resulted in fluctuations in groundwater levels. These changes in groundwater levels impact both the direction and velocity of groundwater flow.

The most apparent change to the groundwater flow regime was under the AGTI. Previous investigations indicate that a recharge mound formed beneath the AGTI due to seepage from tailings placed between 1960 and 1979 (Figure 2.12) (Dames & Moore 1979, Hydro-Engineering 1983). A water balance indicates that seepage rates were approximately 100 gpm at the time the AGTI was taken out of service. This rate coincided with maximum elevation of the tailings in the impoundment. The seepage caused a perched water table to develop south of the impoundment. Water levels continued to rise in most monitor wells surrounding the impoundment until late 1983. Hydrographs of wells in the vicinity of the AGTI show a decline in water levels from 1986 through 1995 indicating dissipation of the recharge mound. Water levels rebounded slightly after 1995, particularly in wells east of the AGTI. This rebound is interpreted to be the result of regional recharge events. In 1979 the hydraulic gradients were from 0.09 ft/ft to the south between MW10 and MW6, and approximately 0.4 ft/ft along the edges of the AGTI with radial flow from the center of the impoundment. Water levels in monitor well MW10, located approximately 500 feet from the southern edge of the AGTI, were approximately 65 feet higher in 1979 than in 1998 (Figure 2.13).

To evaluate if the decreasing water-level elevations are associated with decreased recharge from precipitation infiltration, a plot of precipitation versus time for the same period is also included on Figure 2.12. This trend indicates a general increase in precipitation during the time water levels declined. The water-level and precipitation data support the assumption that the declining levels are indicative of decreases in the tailings seepage rate and are not related to drought conditions.

The decline in water levels associated with the diminished tailings seepage has several implications. First, decline indicates reduction of the source. Second, the dissipation of the recharge mound has eliminated the artificially induced hydraulic head that was the driving force for transport.

Implementation of the CAP altered groundwater flow in the vicinity of the AGTI and A-9 Repository. Extraction of groundwater caused localized cones of depression while injection of treated water caused localized recharge mounds. Extraction rates are historically greater in the area of the AGTI (Table 2.6) but drawdown is more evident in the area of the A-9 Repository due to the thinner aquifer.

Injection of treated water in the vicinity of MW7, upgradient of the A-9 Repository, resulted in a localized increase in water levels of approximately 80 feet above those observed in 1998. The injection began around the end of 1991 and continued into 1995. Hydrographs of MW7, GW1, and GW2 (Figure 2.9) show the migration of injected water downgradient, south towards the A-9 Repository.

More recently, extraction rates have increased in the area of the A-9 Repository to enhance capture. A contour map was constructed using water level data collected during the 1998 groundwater extraction program (Figure 2.14). The extraction of groundwater at the south end of the A-9 Repository has resulted in a gradient reversal. Based on the water-level contour map, the extraction system has established hydraulic capture across the southern boundary of the A-9 Repository. Additional discussion regarding the benefits and impacts of complete capture is provided in Section 3.0.

Results of dewatering mine pits and subsequent rebound of the water table following reclamation can be observed in hydrographs of monitor wells in the vicinity of the A-9 Repository (Figure 2.15). Limited saturation conditions existed at monitor well PW7, east of the A-9 Repository before 1992. These conditions were the result of dewatering the A-8 open-pit mine. During 1991 and 1992, the A-8 area was backfilled with weathered mine spoils, causing water levels to rise in PW7, beginning in 1992 and peaking around 1995. Water levels have also been rising in several other wells east of the A-9 Repository including PW6 and LA2. However, similar trends are not observed in wells west of the site indicating that the increase in water levels east of the A-9 Repository are from rebound of the water table following reclamation by the WDEQ AML Program. Increasing concentrations of sulfate, TDS and uranium observed at PW7 coincide with the water level rise from 1992 through 1995 (Figure 2.16). Chloride, considered an indicator of mill impacts (including reclamation activities as previously discussed) remained relatively constant during this period. These data indicate that poor water quality at PW7 is the result of migration of groundwater impacted by mining and reclamation activities.

The rise in water levels east of the A-9 Repository indicates increases in the hydraulic gradient and flow velocity between the reclaimed mine areas and the A-9 Repository. Water levels and hydraulic gradients in the vicinity of the mill site may also be affected by the underground Thunderbird Mine, located approximately 1,700 feet southwest of the A-9 Repository (shown on Figure 1.3). This underground mine may be acting as a sink for groundwater flow in the area.

Finally, precipitation, infiltration, and recharge from other aquifers are affecting water levels on a more regional scale. Evidence of regional recharge is seen in the hydrographs of the wells north of AGTI (Figure 2.12). Following a period of steady decline, a slight rebound in water levels occurs in most of these wells nearly simultaneously. The plot of precipitation versus time shows that a period of abnormally high precipitation occurred just before this regional increase in water-level elevations.

2.2.1.4 Aquifer Properties

The transmissivity, hydraulic conductivity, and storativity values of the Wind River aquifer are estimated from single well and multi-well pumping tests. Transmissivity is defined as the quantitative measure of the ability of an aquifer to transmit water. Hydraulic conductivity is a quantitative measure of the ability of an aquifer to transmit water per unit of saturated thickness. Hydraulic conductivity values can be determined by dividing the transmissivity calculated for a specific well by the saturated thickness in the well. Storativity (or storage coefficient) defines the volume of water released by a confined aquifer from storage per unit surface area per unit decline in the potentiometric surface (Freeze 1979). For an unconfined aquifer, the storage term is known as the specific yield. The specific yield is a measure of the fraction of water that will drain from a given volume of the aquifer material.

Pumping tests have been conducted in the vicinity of the AGTI and A-9 Repository (Dames & Moore 1979, Hydro-Engineering 1980, 1982, and 1983, and U. S Environmental Services 1995 and 1997). Pumping tests have also been conducted west of the site in the Rim Pit area (Hydro-Engineering 1980) and east of the site in the AML 16-E reclamation area (Lidstone & Anderson 1989). A summary of results, including the method of analysis, the hydrostratigraphic unit tested, and the reference for the source of the data, is presented in Table 2.7. The locations of the pumping tests are shown on Figure 2.17. Transmissivity values range from 4 to 7,200 gallons per day per foot (gpd/ft) or 0.5 to 960 $feet^2$ per day (ft^2/d). Hydraulic conductivity values range from less than 0.01 to 8.1 ft/d with an average value of approximately 1 ft/d. The distribution of hydraulic conductivity values is shown on Figure 2.17. Permeability measurements for the mudstone unit indicate a range of 1.6 x 10-3 to 1.3 x 10-1 ft/d. Values for specific yield ranged from -0.002 to 0.3. The range of storage coefficients is between 7.0×10^{-6} and 3.5×10^{-3}.

2.2.1.5 Groundwater Velocity

Linear groundwater velocity for a specific interval within an aquifer can be calculated by multiplying the hydraulic conductivity by the hydraulic gradient and dividing the product by the effective porosity. Groundwater velocity for the aquifer under natural static conditions is estimated to be between 0.0006 and 2.2 ft/d (0.26 and 300 ft/y) using a hydraulic conductivity range of 0.01 to 8.0 ft/d, a range of hydraulic gradient from 0.01 to 0.04, and a porosity of 0.15. Groundwater velocities for specific areas of the site under different hydraulic conditions are presented in Table 2.5. Under current conditions, the calculated velocity of groundwater beneath and immediately west of the AGTI is between 0.04 to 0.3 ft/d. The travel time for groundwater beneath the western edge of the AGTI to reach monitor well MW77 (a distance of 3,800 ft) using the range of velocities, is between 34 and 2,600 years.

An estimate of groundwater velocity in the vicinity of the AGTI can be made indirectly by using water quality data from monitor wells MW28, and MW25. Chloride was present at monitor well MW25 at a concentration of 125 mg/l in March 1988. At that time, the chloride concentration at MW28 was 8 mg/l. As recently as January 1999, the chloride concentration at MW28 was 6 mg/l. Chloride is considered a conservative constituent because does not chemically react in groundwater and should not be attenuated as it moves along a groundwater flowpath. Therefore, the levels of chloride observed at MW25 should eventually reach MW28 (with some minor attenuation due to dispersion and dilution). The distance between the two wells is approximately 400 feet. The time period from March 1988 to January 1999 is approximately 3,950 days. Chloride concentrations at MW28 have remained steady from March 1988 to January 1999 indicating that groundwater carrying the elevated chloride has not reached MW28. The distance of 400 feet divided by 3,950 provides an upper bound for groundwater velocity of 0.1 ft/d.

2.2.1.6 Groundwater Flow Model

A groundwater flow model was developed to evaluate groundwater flowpaths and velocities, mining impacts on the flow system, and the effectiveness of the current corrective action, as well as alternative corrective actions at the Gas Hills site. Additionally, the groundwater flow model was used to analyze the fate and transport of non-reactive conservative constituents, chloride and sulfate.

Three-dimensional analysis of groundwater flow and advective transport in the Wind River aquifer system was performed using MODFLOW (McDonald 1988), a finite difference groundwater flow model and MODPATH (Pollock 1989 and 1994), a particle-tracking model, both developed by the United States Geological Survey. Development and calibration of the model is described in Appendix C. The model was initially calibrated to current site hydrologic conditions. The calibrated model was then used for further analysis. Results of the model are summarized in the following paragraphs.

Variability in groundwater flowpaths and velocity was addressed using a probabilistic or stochastic modeling approach (Appendix C). One hundred simulations were performed using the stochastic model. Hydraulic conductivity was randomly varied over a range of 0.01 to 5 ft/d. In an effort to evaluate model simulations that were representative of the site hydrologic system, only the twenty simulations with the best fit to calibration statistics were selected for further analysis. Particle tracking was performed on those simulations to identify the range of flowpaths and groundwater velocity.

The range of flowpaths determined from the stochastic models was used to determine placement of the POE along potential groundwater pathways. All groundwater leaving the site via either the Southwestern or Western Flow Regime eventually intercepts a plane 2,600 feet west of the site. This plane was selected as the proposed west edge for the LTCB.

The average and maximum groundwater velocities for flowpaths in each of the twenty simulations for each flow regime were calculated (Appendix C). The maximum velocity calculated for the Western Flow Regime was 0.33 ft/d and the average of the twenty simulations was 0.15 ft/d. The maximum velocity calculated for the Southwestern Flow Regime was 0.28 ft/d and the average was 0.1 ft/d. The maximum velocities of 0.33 ft/d and 0.28 ft/d were used as an upper limit for the geochemical speciation model for the Western and Southwestern Flow Regimes, respectively. Geochemical model simulations were also run for both the Western and Southwestern Flow Regimes using a more typical and representative groundwater velocity of 0.167 ft/d as described in Section 2.2.2.

The average and minimum travel times to reach the LTCB from the downgradient edge of the AGTI and A-9 Repository for each stochastic simulation and each flow regime were also calculated (Appendix C). The minimum and average travel times for the Western Flow Regime were 30 and 101 years, respectively. The minimum travel time for the Southwestern Flow Regime was 40 years and the average was 139 years.

The groundwater flow model was also used to assess impacts on the flow system resulting from mining activities west, south, and east of the site (Appendix C). Of particular concern are the hydraulic properties of backfilled material used to reclaim many of the mines in the area. As previously discussed, there were no mine pits within the proposed LTCB that penetrated groundwater downgradient of the AGTI or A-9 Repository. However, some mines upgradient and east of the site penetrated groundwater and were reclaimed by backfilling. A sensitivity analysis was conducted to determine the impacts these mines might have on groundwater flow direction and velocity. Results of the sensitivity analysis indicate there were no perturbations to groundwater flow outside the range previously determined from the stochastic model simulations. Groundwater velocities also were within the range of the stochastic simulations.

The effectiveness evaluation of the CAP and the analysis of alternative corrective action are addressed in Section 3.0.

The groundwater flow (MODFLOW) and solute transport (MT3D, Zheng 1990) models were used to evaluate the reduction in concentrations of sulfate and chloride between the POC and POE as a result of advective processes. Description of the model is provided in Appendix C, and the results are summarized in Section 2.2.2. The groundwater flow and transport model was used because attenuation of these non-reactive constituents is not adequately addressed by the geochemical speciation model (PHREEQC). PHREEQC is used to evaluate migration and attenuation of constituents that are influenced and controlled by redox conditions and the neutralization capacity of the aquifer matrix (Section 2.2.2 and Appendix B).

2.2.2 Geochemical Assessment

2.2.2.1Geochemical Conditions

Wyoming type roll-front uranium deposits have been extensively studied and Gas Hills has been used as a type location for roll-front deposits (DeVoto 1978, Harshman 1974, King and Austin 1966). These studies provide site-specific information on mineral phases found upgradient, downgradient, and within the ore zone. These mineral phases control the solubility of constituents associated with the ore deposits.

The studies also provide information on pH and redox conditions in the vicinity of ore deposits. These parameters vary across an ore deposit and influence the transportability of constituents in groundwater. For example, many constituents that are mobile in acidic-oxidizing environments are immobile in more neutral and reducing environments. Figure 2.18 summarizes conditions determined by Harshman (1966) for ore deposits at Gas Hills and Shirley Basin, Wyoming. The oxidation/reduction potential relative to standard hydrogen electrode (Eh) ranges from +300 to –300 millivolts and the range of pH is from 4 to 8 s.u. depending on position relative to the ore deposit.

During August 1998 field measurements for redox couples were collected to determine site specific redox conditions. Measurements were made for the ferrous/ferric iron redox couple, the sulfur redox couple, and redox potential using a silver/silver chloride probe. Results revealed disequilibrium between redox couples, but supported Harshman's (1966) model (Table 2.8). Sulfide/sulfate measurements were generally most consistent with Harshman's model. However, both redox couples show a decline in values with distance from the site with lowest values occurring in areas containing ore deposits. The presence of sulfide gas as a distinct phase in some wells indicates the presence of reducing conditions as shown on Figure 2.19. Sulfide gas acts as a reductant, and even small amounts in solution represent excess reductive capacity.

2.2.2.2 Speciation and Transport Modeling

The geochemical model evaluated attenuation capacity and constituent behavior in the groundwater. Modeling results were used to determine constituent transport from one geochemical environment to another. Evaluation of the results indicates reductions in concentrations in groundwater over time and distance from the AGTI and A-9 Repository. The following constituents were addressed in the model:

- Arsenic;
- Beryllium;
- Nickel;
- Chloride;
- Selenium;
- Lead-210;
- Radium-226+228;
- Sulfate;
- Thorium-230; and
- Natural uranium.

Total dissolved solids and gross alpha were not included in the model because they are composites of other parameters. However, gross alpha concentrations at the POE were calculated based on the modeled concentrations of the alpha contributors (excluding uranium and radon). Section 5.2 of Appendix B describes the results associated with gross alpha.

As previously described, it is difficult to discern between naturally-occurring mineralization, mining, reclamation, and milling impacts to groundwater at the Gas Hills site. Consequently, it is difficult to quantify the distance the mill-related constituents have migrated. However, the distribution of geochemical environments in the vicinity of Gas Hills has been established from government and private scientific studies and from Umetco exploration, development, and reclamation activities.

Geochemical modeling shows that natural attenuation processes, associated with geochemical conditions that produced uranium mineralization, have limited the mobility of constituents from all sources. The bulk of the Wind River aquifer is reducing and has a high neutralization capacity. As a result, elevated concentrations near sources do not persist more than a few hundred feet downgradient.

2.2.2.3 Model Code

The computer code PHREEQC (Parkhurst 1995) was chosen for this study to model chemical speciation, mass transfer (for example, dissolution, precipitation, ion exchange, adsorption), and mass transport (movement of successive pore volumes through an environment). Reaction-transport modeling simulates advection and chemical reactions as water moves through a one-dimensional column. Dilution, dispersion, and source reduction are not factored into the model and the calculated constituent incremental increases at the proposed POE are considered to represent worst-case conditions. The column is divided into a number of cells (n) defined by the user. The initial conditions and set of reactants in each cell can be defined individually. The cells initially contain solutions, phase assemblages, and surface assemblages. Figures 2.20 and 2.21 illustrate the model grids for the two flow regimes.

Advection is simulated by moving the solution in each cell into the next higher numbered cell. Solution 0 (source term) is moved into cell 1, and the solution in cell 1 is moved into cell 2, and so on, until the solution from cell n-1 is moved into cell n. At this point the solution in the last cell is discarded. After each cell has received the solution, irreversible reactions are applied within the cell, and the solution is equilibrated with the reversible reactants. The equilibrium compositions of the solution and reversible reactants are saved. All reversible and irreversible reactants except the solution remain in the original cells.

The MINTEQ database (Allison et al 1991) was used for this study because it contains several uranium species and phases applicable to Gas Hills conditions. Thermodynamic data for thorium were imported from the EQ3/6 database (Wolery 1992) and radium data were taken from Langmuir and Riese (1985).

PHREEQC uses ion-association and Debye Huckel expressions to account for the non-ideality of aqueous solutions. The ion-exchange model assumes that the thermodynamic activity of an exchange species is equal to its equivalent fraction. The surface complexation module uses the diffuse double layer (Dzombak and Morel 1990) and the non-electrostatic surface complexation models (Davis and Kent 1990).

2.2.2.4 Model Development

The groundwater flow regime at the Gas Hills site has two distinct components. A local mudstone unit separates the Southwestern Flow Regime from the deeper Western Flow Regime. The southwestern flow is toward a proposed in-situ leach operation. The Western Flow Regime moves into regionally reduced portions of the Wind River aquifer. Because unique conditions are present in the two flow regimes, each was modeled separately. Both models assume a porosity of 15 percent, a hydraulic conductivity of one foot per day (ft/d) and a hydraulic gradient of 0.025, resulting in a groundwater velocity of 0.167 ft/d. Both models are based on the conservative assumption that constituent sources are constant and do not diminish with time. The selection of minerals and solutions that were included in each model is described in Appendix B.

The flow model used the AGTI as the primary source of mill-related impacts associated with the Western Flow Regime. The model grid extends from the western edge of the AGTI, through POC well MW21A, monitor well MW28, and monitor well MW77 to monitor the POE, approximately 4,600 feet from the edge of the AGTI (Figure 2.20).

The western flow model grid consists of 46 cells, each representing an aquifer unit 100 feet long by 100 feet deep (Figure 2.20). The model construction featured the regionally reduced conditions in the Wind River Formation in this area and the presence of an oxidized, carbonate-depleted halo at the downgradient edge of the AGTI.

The model grid for the Southwestern Flow Regime begins at POC well GW7 and extends approximately 5,400 feet downgradient (Figure 2.21). The model grid consists of 54 cells, each representing an aquifer unit 100 feet long by 100 feet deep.

The proposed ACLs were used as input values for the geochemical model. The basis for the ACLs is presented in Appendix E. Use of these values in the geochemical model is conservative.

2.2.2.5 Model Assumptions

The primary model assumptions factored into the geochemical model are as follows:

- Constant source – Using a constant source is conservative since the actual source concentrations will diminish over time. This assumption also increases confidence that the incremental increases in concentrations from the mill-related sources at the proposed POE do not pose risks to human health and the environment.

- Selection of solutions in model cells/model calibrations - Groundwater quality is variable on a local scale at the site. In addition to mill-related impacts, there are impacts from naturally-occurring mineralization, mining, and reclamation activities. Solutions were selected to reflect transport of the mill-related sources, however ambient contamination in wells near the proposed POE were not factored into the model.

- The solutions input at each cell have uniform concentration throughout the entire 100 foot thickness of the cell. Site data indicate that elevated concentrations of key constituents are limited to the upper 50 feet or less of the saturated Wind River Formation.

2.2.2.6 Model Prediction

Two flow rates were modeled for the Western Flow Regime: 0.167 ft/d (Section 2.2.2.4) and 0.33 ft/d (Section 2.2.1.6). For these flow rates, the model was assigned 644 and 1,242 shifts, respectively, corresponding to 1,000 years of transport time. Two flow rates were modeled for the Southwestern Flow Regime: 0.167 ft/d (Section 2.2.2.4) and 0.28 ft/d (Section 2.2.1.6). For these flow rates, the model was assigned 648 and 1,026 shifts, respectively, corresponding to 1,000 years of transport time.

Results of the models are shown in Table 2.9. Profiles of concentrations of each constituent along the flow path after more than 1,000 years are shown in Appendix B. Concentrations of constituents remain below background values at the proposed POE after more than 1,000 years despite of the conservative assumption that the source term remains constant throughout the model.

Conclusions from geochemical modeling are as follows:

- The presence of excess reductive and neutralization capacity in the Wind River aquifer will attenuate the migration of constituents from the mill-related sources at Gas Hills.

- Geochemical modeling shows reduction in concentrations in groundwater over time and over distance from the source.

- Based on the geochemical model results, incremental increases in concentrations from mill-related sources at the proposed POE are at or below background values.

2.2.2.7 Transport Modeling of Chloride and Sulfate

Sulfate and chloride migration and attenuation were evaluated using the groundwater flow and solute transport model as described in Appendix C. These non-hazardous constituents were selected for evaluation because of their non-reactive behavior. It is conservatively assumed that these constituents will provide the "worst-case" scenario (i.e., fastest travel time and minimum attenuation) for migration from the POC to the POE and receptor points beyond the POE. Although the groundwater flow model domain does not extend as far as Iron Springs, model results for the POE can be used as an upper limit for constituent concentrations migrating to the springs. Additional attenuation will occur along the 6,000-foot flowpath from the POE to the nearest spring. Model simulations were only run for a period of 400 years because the concentration versus time plots generated from the model output indicate that the concentration peaks for sulfate and chloride will have passed through the POE for both flow regimes within that time. Chloride concentrations remained below the Wyoming Department of Environmental Quality (WDEQ) Class I standard at the POE for both flow regimes throughout the simulated time. Based on the model results, there will be no significant impacts from chloride at the POE. Therefore, there will be no impacts to groundwater quality from chloride at Iron Springs. As indicated in Appendix C, sulfate concentration slightly exceeded the Wyoming Class III standard for a brief period of time. However, conservative assumptions used in the model probably overestimated the total mass of the sulfate plume by a factor of 1.5 to 4. Additional attenuation of sulfate between the POE and the nearest spring will result in further reduction in sulfate concentration to levels below the WDEQ Class III standard. The range of background values indicates that ambient groundwater quality for the area is, at best, Class III. Migration from the site will not result in an exceedance of the Class III sulfate standard at Iron Springs, or any of the other distant springs. Based on a projection of the model results, and the existing water quality, there will be no future impacts to groundwater at the springs resulting from implementation of the proposed ACLs.

2.3 Exposure Assessment

According to NRC requirements for ACL applications (NRC 1996), the objectives of the exposure assessment are to: 1) identify the maximum permissible levels that are protective of human health and the environment; 2) evaluate human and environmental exposures to hazardous constituents; and 3) demonstrate that the proposed ACLs do not pose substantial present or potential future hazards to human health or the environment. Based on the geochemical model results presented in Section 2.2, combined with the evaluation of ambient groundwater quality provided in Appendix A, the modeled hazardous constituent concentrations at the potential POE are not distinguishable from ambient conditions when the concentrations at the POCs are at or below the proposed ACLs. This finding is demonstrated in Table 2.10, which compares the modeled values at the proposed POE for both the Western and Southwestern Flow Regimes with the corresponding ambient groundwater quality concentrations.

Because mill-related sources at the Gas Hills facility will pose no incremental risks to human health or the environment, a quantitative analysis of potential exposures and human health and environmental hazards is not required. However, because certain elements of the exposure assessment are still germane, and in general accordance with NRC requirements for ACL applications, this section presents pertinent qualitative information regarding current and potential future land and water resource uses identified for the Gas Hills study area. To facilitate review, the general ACL outline format has been adhered to where possible, but some sections are brief due to lack of relevance.

2.3.1 Water Resource Classification and Uses

A fundamental component of the exposure assessment is the extent to which human or environmental receptors are, or may be, exposed to groundwater or hydraulically connected surface water potentially affected by the site. To assess this endpoint, this section describes existing and potential future land and water uses in the Gas Hills site vicinity.

2.3.1.1 Area Description and Land Use

The Gas Hills uranium district is located in a sparsely populated area covering portions of Natrona and Fremont Counties in central Wyoming. The principal land use surrounding the Gas Hills site is uranium mining, although some land is used for livestock grazing and hunting on a seasonal basis. Soils in the Gas Hills area are classified as generally unsuitable for cultivation (USDA 1973 in NRC 1980a). Consequently, agriculture is not a viable land use.

Most of the land within five miles of the Gas Hills site is public domain under BLM jurisdiction; only a small percentage of land is privately owned. The nearest private residence located five miles northeast (upgradient) of the site, is inhabited on a seasonal basis only. The nearest downgradient residence is approximately 20 miles from the site.

2.3.1.2 Current Water Resource Uses

Table 2.11 summarizes the results of a search of ground and surface water rights in the vicinity of the Gas Hills site (Wyoming State Engineer's Office 1999). Figure 2.22 identifies corresponding land and water uses. The water rights search yielded 178 distinct water uses, the majority of which (59 percent) are permitted for monitoring purposes. The remaining uses are classified as miscellaneous (14 percent), industrial (13 percent), stock watering (12 percent), and irrigation (3 percent). Information documenting the Water Rights Search, including location, status, and water yield data, is provided in Appendix D.

Of particular relevance to this assessment is the fact that all irrigation and stock water uses correspond to surface water sources. The five irrigation uses correspond to the CBC, Diamond Ring, and Cross L ditches located upgradient to the north/northeast of the Gas Hills site (Figure 2.22). Stock watering uses include the Rattlesnake springs/ditches located east of the site and several springs located west of the site (e.g., Iron Spring and Lincoln Spring). These springs have not been impacted by site activities, nor are any site-related water quality impacts expected in the future.

Groundwater in the region is used principally for monitoring, miscellaneous (for example, dewatering), and industrial purposes. No municipal, domestic, irrigation, or stock uses of groundwater in the area were identified (Table 2.11). This reflects the lack of permanent residents in the area, historical land uses, and/or the local ambient groundwater quality (Appendix A), which is not suitable for domestic or agricultural purposes.

2.3.1.3 Potential Future Groundwater Uses

In defining potential future groundwater uses, the following factors were considered.

1) *Ambient Groundwater Quality*. Widespread ambient contamination within the uppermost aquifer has resulted in groundwater quality that is not compatible with domestic, agricultural, or livestock groundwater uses (Appendix A, Table 2.12). Comparison of ambient levels of constituents with WDEQ groundwater quality standards yields a Class IV (industrial) designation as shown in Table 2.12, this finding applies to radium-226+228 and gross alpha (uranium excluded) for both flow regimes and arsenic for the Southwestern Flow Regime.

2) *Demographic Projections*. The sparse population that characterizes the Gas Hills area is expected to remain stable. This prediction is based on 1997 census projections as well as other factors, including the harsh climate, lack of arable land, and the lack of a foreseeable economic base.

3) *Institutional Controls on Future Land and Water Use*. As shown in Figure 2.22 and documented in Appendix F, 1,920 acres of land will be transferred to the DOE in perpetuity. As part of the DOE long-term surveillance and maintenance requirements, groundwater will be restricted within this land transfer area.

None of the factors identified above are expected to change in the future. A related issue is the fact that PRI recently applied for an in situ mining permit from the Land Quality Division of the State of Wyoming for the area located due south of the Gas Hills facility (PRI 2001; Appendix A, Figure A.1).[1] Proposed operation is scheduled to begin in 2003 and is estimated to continue until 2020. The groundwater to be affected, which includes all ore zones presently known and identified within PRI's permit boundary, will automatically be classified Class V (uranium commercial), as required by Chapter VIII of the Water Quality Division regulations. According to PRI's permit application, the land will be returned to native rangeland for wildlife and livestock grazing after mining is complete (PRI 2001). The aforementioned factors support the assumption that groundwater at and in the vicinity of the Gas Hills site is suitable, at best, for industrial use only. Additional discussion regarding the proposed PRI in situ leach mine operation and potential impacts to groundwater quality is provided in Appendix K.

2.3.1.4 Potential Future Uses of Hydraulically Connected Surface Water

A hydraulic connection exists between groundwater and springs located west of the site (e.g., Medicine Spring, Lincoln Spring, and Iron Spring), some of which, are used for stock watering purposes. However, historical results of biannual surface water samples collected from these springs indicate no impacts related to the Gas Hill site. In fact, water quality in some of the springs, in particular Iron Spring, is influenced by acidic conditions associated with naturally-occurring mineralization (Section 2.1.1). Given the lack of demonstrated water quality impacts and the hydrogeological characteristics of the site precluding potential future impacts (Section 2.2), the exposure assessment focuses solely on groundwater-related exposure pathways.

2.3.2 Evaluation of Human Health Hazards

Because the modeled constituent concentrations at the POE are at or below background for all parameters (Tables 2.6, 2.10, and 2.12), no adverse human health impacts are anticipated, thereby precluding the need for a quantitative assessment of human health hazards or risks. For reference, Table 2.13 presents information regarding the likelihood of various exposure pathways. [This information is presented irrespective of the geochemical modeling results, which yield levels of hazardous constituents at the POE that are at or below background levels.]

2.3.3 Evaluation of Environmental Hazards

The potential for environmental exposures in the vicinity of the Gas Hills site is expected to be limited due to the lack of permanent surface water bodies, the poor soil quality precluding use of groundwater for irrigation purposes, and the other factors discussed in the preceding sections.

[1]The mining permit area will be located in the Gas Hills in all, or parts, of Section 6, T32N, R89W, Sections 21, 22, 27, 28, 29, 31, 32, 33 and 34, T33N, R89W, and Sections 1, 2, 3, 10, 11 and 12, T32N, R90W, Fremont and Natrona Counties, Wyoming, approximately 45 miles southeast of Riverton (PRI 2001).

Consequently, the environmental hazard evaluation provided below is semi-quantitative in nature. Again, modeled values at the POE are at or below background for all parameters, precluding the need for a quantitative assessment. Where available, wildlife benchmark values are provided for comparison purposes only.

2.3.3.1 Potential Effects on Aquatic and Terrestrial Wildlife Life

Based on the physical setting of the Gas Hills site, the only likely exposure pathway for wildlife receptors would be ingestion of water from a stock watering tank supplied by a well and/or ingestion of irrigated forage. The proposed ACLs and the modeled POE hazardous constituent concentrations were compared to benchmarks developed for limiting exposure to wildlife listed in Table 2.14. The benchmarks for radionuclides are based on a limiting dose of 100 millirads per day (Higley 1995). The benchmarks for inorganic constituents are based on No Observed Adverse Effect Levels derived for DOE's Oak Ridge facility site (Sample 1996). As demonstrated in Table 2.14, the modeled concentrations at the proposed POE are orders of magnitude below both the wildlife benchmark values and the WDEQ groundwater standards for livestock.

2.3.3.2 Potential Effects on Agricultural Crops and Plants

The modeled constituent concentrations at the proposed POE are orders of magnitude below the WDEQ standards for agricultural water use, demonstrating that no adverse impacts to crops or plants are anticipated. Note, however, that application of the Class II agricultural limits is not appropriate for the Gas Hills site given the ambient groundwater quality which exceeds these limits for some constituents—in particular, arsenic, gross alpha, and radium-226+228 in both flow regimes, and nickel in the Western and selenium in the Southwestern Flow Regime. Consequently, the Class II standards are presented in Table 2.14 for comparison purposes only.

2.3.3.3 Potential Adverse Effects on Physical Structures

There are no physical structures in the flow path of the groundwater that could be adversely affected by groundwater quality.

Section 3

To be Provided Under

Separate Cover

4.0 PROPOSED ALTERNATE CONCENTRATION LIMITS

The proposed ACLs are protective of human health and the environment. As demonstrated in Section 3.0, the proposed ACLs meet ALARA. Furthermore, the evaluation of widespread ambient groundwater contamination shows that continued corrective actions will have little or no effect on water quality. The hazard assessment (Section 2.0) demonstrates that geochemical conditions result in attenuation of constituent concentrations within short distances from the potential sources, regardless of whether the constituents are derived from mineralization, mining, or milling activities. Results of geochemical and groundwater flow modeling indicate attenuation of constituent concentrations to levels at or background at the proposed POE (Figure 4.1).

An analysis was conducted to provide an estimate of the maximum concentrations that may occur at the POC wells for both the A-9 Repository and the AGTI in the future. These maximum concentrations were then evaluated using the geochemical model to determine the degree of attenuation and reduction along the flowpath to the POE. The revised geochemical model is provided as Appendix B. Geochemical modeling using input values representative of maximum concentrations that may be observed at the POC wells indicates that the proposed ACLs are protective of human health and the environment at the POE. The model also shows that concentrations at the POE will be below background values established for the area, as described in Appendix A. The results of the analysis provide the basis for revised ACLs. The methods used in the analysis and the resulting values are described in the following sections.

4.1 METHODOLOGY

The determination of the ACLs consisted of the following .

1) Water quality data for each flow regime (southwestern and western) were ranked for the following licensed constituents: arsenic, beryllium, nickel, selenium, lead-210, radium-226+228, thorium-230, natural uranium, and gross alpha. Only data collected after 1992 were included in the ranking. The ranking determined which monitoring wells consistently recorded the highest concentrations for each constituent.

2) Concentration trend plots were developed for those wells with consistent highest values that were also hydraulically upgradient or crossgradient of the POC wells. This was done to identify and eliminate outliers from the data and to evaluate trends. Based on the trend plots, wells were selected as representative of the highest concentrations within the flow regime for each of the constituents.

3) A statistical evaluation of data from the wells with the highest values was performed to determine the mean, standard deviation, and upper 95^{th} quantile of the data set. The 95 percent upper confidence limit (UCL) was then calculated for the upper 95^{th} quantile of each data set. The 95 percent UCL was selected to provide assurance that the ACLs will not be exceeded at the POC wells.

In some cases, the wells that consistently provided the highest observed concentrations for a specific constituent were actually the POC wells. For instance, POC well GW7 had the highest concentrations for the Southwestern Flow Regime for the radionuclides. In other cases, wells upgradient of the POCs represented the maximum observed concentrations. Attenuation of constituents is expected along the flowpath from upgradient wells to the POC. However, the attenuation will not be of the scale anticipated further downgradient from the POC because the geochemical environment is different (oxidizing versus reducing). Therefore, selection of the 95 percent UCL of the 95th quantile for data from either the POCs or from wells hydraulically upgradient of the POCs is appropriate. These ACLs, as revised, are representative of the maximum concentrations that may occur at the POC wells and are protective of human health and the environment, as shown with the geochemical modeling efforts.

4.2 RESULTS

4.2.1 Southwestern Flow Regime

The water quality data ranking for the Southwestern Flow Regime is provided for arsenic, beryllium, nickel, selenium, lead-210, radium-226+228, thorium-230, natural uranium, and gross alpha minus natural uranium in Table E-1. The wells selected as representative of the maximum concentrations present in the Southwestern Flow Regime are summarized below. The concentration trend plots for the wells representing maximum concentrations (exclusive of anomalous data) are provided in Figures E-1 through E-9. The proposed ACL for each constituent for the Southwestern Flow Regime is presented in Table 1.4. The data used to calculate the proposed ACL for each constituent are provided in Table E-3. The proposed ACL for each constituent is equivalent to the 95 percent UCL of the upper 95th quantile of the representative data set with one exception. Specifically, the ACL for thorium-230 was set equal to the highest observed value at POC Well GW7, because that value exceeded the 95 percent UCL of the upper 95th quantile.

Southwestern Flow Regime

Constituent	ACL[1]	Wells Used as Basis for ACL
Arsenic (mg/l)	1.36	PW7
Beryllium (mg/l)	1.70	GW3 and MWC61
Gross Alpha minus Natural Uranium (pCi/l)	6,223	GW7
Lead-210 (pCi/l)	46.7	GW7 and MW7
Natural Uranium (mg/l)[2]	34.1	GW7 and MW7
Nickel (mg/l)	9.34	GW3 and MWC61
Radium-226+228(pCi/l)	353	GW7, MWC61and MW7
Selenium (mg/l)	0.53	GW5 and RW2
Thorium-230 (pCi/l)[3]	44.8	GW7

(1) $UL_{0.95}(X_{0.95})$ 95% upper confidence limit of the upper 95th quantile of the data set (based on analytical data collected since January 1993 .

Equation: $UL_{0.95}(X_{0.95})$ = (arithmetic mean of analytical data from indicated wells since 1993) + (Constant for data set size * standard deviation of that data set)

mg/l milligrams per liter

pCi/l picoCuries per liter

(2) Natural uranium values were converted from pCi/l to mg/l using a factor of 677.

(3) Proposed ACL based on highest observed concentration

4.2.2 Western Flow Regime

The water quality data ranking for the Western Flow Regime is provided for arsenic, beryllium, nickel, selenium, lead-210, radium-226+228, thorium-230, natural uranium, and gross alpha minus natural uranium in Table E-2. The wells selected as representative of the maximum concentrations present in the Western Flow Regime are summarized below. The concentration trend plots for the wells representing maximum concentrations in the Western Flow Regime (exclusive of anomalous data) are provided in Figures E-10 through E-18. The proposed ACLs for the Western Flow Regime are presented in Table 1.4. The data used to calculate the proposed ACLs are provided in Table E-4. The 95 percent UCL of the upper 95th quantile of the representative data set was used as the proposed ACL for each constituent.

Western Flow Regime

Constituent	ACL[(1)]	Wells Used as Basis for ACL
Arsenic (mg/l)	1.80	MWC56 and MWI43
Beryllium (mg/l)	1.64	MWI43 and MWI64
Gross Alpha minus Natural Uranium (pCi/l)[(2)]	3,338	MWC55, MWI64, and MW67
Lead-210 (pCi/l)	35.4	MWC55, MWI64, and MW67
Natural Uranium (mg/l)	11.9	MWC55, MWI64, and MW67
Nickel (mg/l)	13.0	MWC42, MWI43, MWI64, and MW67
Radium-226+228 (pCi/l)	250	MWC59, MWI43, and MWI64
Selenium (mg/l)	0.161	MW1 and MW67
Thorium-230 (pCi/l)	57.4	MWC55 and MW67

(1) $UL_{0.95}(X_{0.95})$ 95% upper confidence limit of the upper 95th quantile of the data set (based on analytical data collected since January 1993 from indicated wells)

Equation: $UL_{0.95}(X_{0.95})$ = (arithmetic mean of analytical data from indicated wells since 1993) + (Constant for data set size * standard deviation of that data set)

mg/l milligrams per liter

pCi/l picoCuries per liter

(2) Natural uranium values were converted from pCi/l to mg/l using a factor of 677.

4.3 SUMMARY

A methodology was used to develop constituent values that are representative of the maximum concentrations that may occur at the POC wells. In some cases, the maximum values are represented by water quality observed at the POC wells, and in other cases maximum values are derived from wells upgradient or crossgradient to the POC wells. The proposed ACL is equivalent to the 95 percent UCL of the upper 95th quantile of the representative data set. One exception was for thorium-230, which was set equal to the highest observed value at POC Well GW7 because it exceeded the statistical threshold used for the other constituents. The proposed ACLs were used as input into the geochemical model (Appendix B) to determine the degree of attenuation that is predicted along the flowpaths between the POC wells and POE. Results of the geochemical model confirm that these ACLs are protective of human health and the environment at the POE.

The Wind River aquifer contains sufficient attenuation capacity to ensure that the ACL values listed in Table 1.4 will attenuate below background values at the proposed POE. The concentrations of the naturally-occurring constituents of concern are greater than potential incremental increases of mill-related constituents at the proposed POE. To demonstrate the natural attenuation capacity of the aquifer, geochemical modeling was performed using the ACLs as input values (Appendix B).

4.3.1 Proposed Implementation Measures

Umetco proposes to continue the surface reclamation process, which will take place in accordance with the approved reclamation plans. In addition, Umetco is proposing ACLs as groundwater protection standards because these values are ALARA and are background values at the proposed POE locations.

Assuming the ACLs are approved and the CAP is eliminated, Umetco proposes to monitor groundwater annually at POC locations MW1, MW21A, GW7, and GW8. Groundwater from these monitor wells will be analyzed for the constituents currently listed in License SUA-648, Condition 35: specifically, arsenic, beryllium, gross alpha, lead-210, natural uranium, nickel, radium-226+228, selenium, and thorium-230.

Umetco intends to transfer the land shown in Figure 1.19 to the DOE for long-term surveillance and maintenance. Current ownership of the area consists of U.S. Bureau of Land Management (BLM) and Umetco. 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 Umetco's reclamation and the U.S. Army Corps of Engineers has cleared title on the land.

5.0 REFERENCES

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TABLES

Table 1.1 Factors Considered in Making Present and Potential Hazard Findings (10 CFR Part 40, Appendix A, Criterion 5B(6)), Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado

A.	**Potential Adverse Effects on Groundwater Quality**
1.	Physical and chemical characteristics of the waste in the licensed site, including its potential for migration.
	Location: *Sections 2.1 and 2.2*
	Location: *Appendices B, C and E*
2.	Hydrogeological characteristics of the facility and surrounding land.
	Location: *Sections 1.2, 2.1 and 2.2*
	Location: *Appendices A, B, and C*
3.	Quantity of groundwater and the direction and rate of groundwater flow.
	Location: *Sections 1.3, 2.2 and 3.3*
	Location: *Appendix C*
4.	Proximity and withdrawal rates of groundwater users.
	Location: *Section 2.3*
	Location: *Appendix D*
5.	Current and potential future uses of groundwater in the area.
	Location: *Sections 2.3 and 3.6*
	Location: *Appendix D and K*
6.	Existing quality of groundwater, including other sources of contamination and their cumulative impact on groundwater quality.
	Location: *Sections 1.2, 1.3, 2.1, 2.2*
	Location: *Appendices A , B, D, E, G, H, I, J, and K*
7.	Potential for health risks caused by human exposure to waste constituents.
	Location: *Sections 2.3, and 3.6*
	Location: *Appendix B*
8.	Potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to waste constituents.
	Location: *Section 2.3*
	Location: *Appendix B*
9.	Persistence and permanence of potential adverse effects.
	Location: *Section 2.3*

Table 1.1 Factors Considered in Making Present and Potential Hazard Findings (10 CFR Part 40, Appendix A, Criterion 5B(6)), Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado. (continued)

B.	Potential Adverse Effects on Hydraulically Connected Surface Water Quality
1.	Volume and physical and chemical characteristics of waste in the licensed site.
	Location: *Sections 1.2, 1.3, 2.1, and 2.2*
2.	Hydrogeological characteristics of the facility and surrounding land.
	Location: *Sections 1.2 2.1, and 2.2*
	Location: *Appendices A, B, and C*
3.	Quantity and quality of groundwater, and the direction and rate of groundwater flow.
	Location: *Sections 1.2, 1.3, 2.1, 2.2 and 3.3*
	Location: *Appendices A, B, and C*
4.	Patterns of rainfall in the region.
	Location: *Section 1.2*
5.	Proximity of the licensed site to surface waters.
	Location: *Sections 1.2, 2.2 and 2.3*
	Location: *Appendices A and D*
6.	Current and future uses of surface waters in the area and any water-quality standards established for those surface waters.
	Location: *Section 2.3*
	Location: *Appendices D and K*
7.	Existing quality of surface water, including other sources of contamination and the cumulative impact on surface water quality.
	Location: *Sections 1.2, 1.3, 2.1, 2.2 and 2.3*
	Location: *Appendices A, B, C and K*
8.	Potential for health risks caused by human exposure to waste constituents.
	Location: *Sections 2.2 and 3.6*
9.	Potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to waste constituents.
	Location: *Sections 2.2 and 2.3*
10.	Persistence and permanence of potential adverse effects.
	Location: *Sections 2.3 3.3 and 3.6*

Table 1.2 Mine Area Reclamation Summary, Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado

Mine Pit	Year Mining Began	Status	Source of Backfill	Stratigraphic Unit Penetrated	Groundwater Encountered?
A-1	1959	Backfilled	C-2	SWFR	No
A-2	1960	Backfilled	Mine spoils	SWFR	No
A-3	1961	Backfilled	A-5 and A-7	SWFR	No
A-4	1961	Backfilled	A-10	SWFR	No
A-5	1968	Backfilled	A-7	SWFR	No
A-6	1963	Backfilled	A-8	SWFR	No
A-7	1969	Backfilled	A-9 and A-10	SWFR	No
A-8	1971	Backfilled	A-8	SWFR	Yes
A-9	1973	Repository	NA	SWFR	No
A-10	1972	Backfilled	A-10 and C-14	SWFR	No
B-1	1965	Backfilled	C-3	SWFR	No
B-2	1965	Backfilled	A-8	SWFR	Yes
B-3	1975	Backfilled	Mine spoils	SWFR	Yes
B-4	1978	Backfilled	C-3 and C-12	SWFR	No
B-5	1983	Not Backfilled	Not Applicable	SWFR	No
C-1	1965	Backfilled	C-3	SWFR	No
C-2	1975	Backfilled	C-11	SWFR	No
C-3	1979	Backfilled	C-3	SWFR	No
C-5	1972	Partially Backfilled	C-14	SWFR	No
C-11	1975	Backfilled	C-14 and C-12	SWFR	No
C-12	1975	Backfilled	Mine spoils	SWFR	No
C-13	1982	Backfilled	C-18	SWFR	No
C-14	1977	Backfilled	Mine spoils	SWFR	No
C-15	1977	Backfilled	C-14	SWFR	No
C-17	1982	Backfilled	Mine spoils	SWFR	No
C-18	1982	Not Backfilled	Not Applicable	SWFR	No[1]
C-19	1982	Backfilled	C-18	SWFR	No
Veca Pit	1960s	Not Backfilled	Not Applicable	SWFR	Yes[2]
Tee Pit	1960s	Backfilled	Unknown	SWFR	Yes
Rim Pit No.1	Unknown	Not Backfilled	Unknown	WFR	No
Rim Pit No.2	Unknown	Not Backfilled	Unknown	WFR	Yes
Pathfinder	1960s	Backfilled	Unknown	SWFR	No
Thunderbird/ROX	Unknown	Unknown	Unknown	SWFR	Yes

SWFR Southwestern Flow Regime
WFR Western Flow Regime
[1] Used as surface water runoff impoundment for the Umetco site.
[2] Original pit encountered groundwater in SWFR. Reclaimed as a surface water impoundment - partially filled with water from the Buss I Pit (Lidstone and Anderson 1994).

Table 1.3 Groundwater Protection Standards, Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado

Constituent	Western Flow Regime Groundwater Protection Standard	Units	Southwestern Flow Regime Groundwater Protection Standard	Units
Arsenic [1]	0.05	mg/l	0.05 mg/l	mg/l
Beryllium [1]	0.05	mg/l	0.01 mg/l	mg/l
Nickel [1]	0.05	mg/l	0.04 mg/l	mg/l
Selenium [1]	0.06	mg/l	0.01 mg/l	mg/l
Natural Uranium [1]	89.0	pCi/l	199 pCi/l	pCi/l
Radium-226 + 228 [1]	31.5	pCi/l	24.9 pCi/l	pCi/l
Thorium-230 [1]	6.6	pCi/l	4.8 pCi/l	pCi/l
Lead-210 [1]	5.0	pCi/l	4.6 pCi/l	pCi/l
Gross Alpha [1]	146.0	pCi/l	17.8 pCi/l	pCi/l
Chloride [2]	2,000	mg/l	2,000 mg/l	mg/l
Sulfate [2]	3,000	mg/l	3,000 mg/l	mg/l
Total Dissolved Solids [2]	5,000	mg/l	5,000 mg/l	mg/l

mg/l milligram per liter
pCi/l picoCurie per liter
[1] Values based on the Groundwater Protection Standards listed in License Condition 35, SUA-648.
[2] Values based on standards listed in WDEQ, Water Quality Rules and Regulations, Chapter 8, livestock values.

Table 1.4 Proposed Alternate Concentration Limits, Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado

NRC Constituent[1]	Proposed ACL
Western Flow Regime	
Arsenic (mg/l)	1.80
Beryllium (mg/l)	1.64
Gross Alpha-Natural Uranium(pCi/l)	3,338
Lead-210 (pCi/l)	35.4
Natural Uranium (mg/l)	11.9
Nickel (mg/l)	13.0
Radium-226 + 228 (pCi/l)	250
Selenium (mg/l)	0.161
Thorium-230 (pCi/l)	57.4
Southwestern Flow Regime	
Arsenic (mg/l)	1.36
Beryllium (mg/l)	1.70
Gross Alpha-Natural Uranium(pCi/l)	6,223
Lead-210 (pCi/l)	46.7
Natural Uranium (mg/l)	34.1
Nickel (mg/l)	9.34
Radium-226 + 228 (pCi/l)	353
Selenium (mg/l)	0.53
Thorium-230 (pCi/l)	44.8

NRC U.S. Nuclear Regulatory Commission
ACL Alternate Concentration Limit
mg/l milligrams per liter
pCi/l picoCuries per liter
[1] Constituents that may be of concern to the State of Wyoming, Department of Environmental Quality (for example, chloride and sulfate) are addressed in the ACL Application.

Table 2.1 Chemical Characteristics of Tailings, Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado

Parameter	6/13/79	10/3/79	9/11/81	10/1/81	12/30/81
TDS (mg/l)	28,500	28,400	7,460	-	31,880
Conductivity	2,350[1]	31,800	-	-	-
pH (s.u.)	-	-	2.0	-	1.7
Chloride (mg/l)	1,290	4,550	2,160	-	7,030
Sulfate (mg/l)	21,900	23,900	7,730	-	8,440
Calcium (mg/l)	600	-	-	-	-
Magnesium (mg/l)	70	56	-	-	-
Potassium (mg/l)	176	220	-	-	-
Sodium (mg/l)	368	480	-	-	-
Nitrate (mg/l)	279	307	35	107	26
Ammonia (mg/l)	767	1,220	21	-	620
Aluminum (mg/l)	1,050	900	-	-	-
Arsenic (mg/l)	0.035	4.170	1.82	2.0	1.38
Barium (mg/l)	0.10	<0.01	-	-	-
Cadmium (mg/l)	0.31	0.30	-	-	-
Chromium (mg/l)	2.0	2.8	-	-	-
Copper (mg/l)	2.4	2.37	-	-	-
Fluoride (mg/l)	2	<1	-	-	-
Iron (mg/l)	2,000	1,560	900	-	272
Lead (mg/l)	1.0	0.44	0.18	0.22	1.1
Manganese (mg/l)	70	56	-	-	-
Molybdenum (mg/l)	-	-	0.38	-	0.27
Mercury (mg/l)	<0.001	<0.001	-	-	-
Nickel (mg/l)	-	-	-	-	-
Selenium (mg/l)	0.32	0.19	0.06	0.13	0.75
Zinc (mg/l)	20.5	19	-	-	-
Uranium (pCi/l)	10,000	15,900	7,910	14,000	19,100
Uranium (mg/l)	14.8	23.5	11.7	20.7	28.2
Radium-226 (pCi/l)	787	513	563	172	510
Thorium-230 (pCi/l)	148,000	90,200	32,700	10,900	82,800
Lead-210 (pCi/l)	6,240	8,480	5,770	-	9,700
Polonium-210 (pCi/l)	2,600	71	1,220	-	580

TDS Total Dissolved Solids
mg/l milligrams per liter
μmhos/cm micromhos per centimeter
s.u. standard units
pCi/l picoCuries per liter

[1] Results appear anomalous. Data from Table 3.1-1 Quality of the Tailings Solution in Groundwater Hydrology Near the Inactive Tailings (Hydro-Engineering, February 1983).

Table 2.1 Chemical Characteristics of Tailings, Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado (continued)

Parameter	3/12/82	3/24/82	3/25/82	6/16/82	9/8/82
TDS (mg/l)	15,200	16,000	15,000	25,800	22,200
Conductivity (µmhos/cm)	-	-	-	-	25,300
pH (s.u.)	1.74	1.28	1.32	1.67	1.76
Chloride (mg/l)	380	5,200	4,500	-	442
Sulfate (mg/l)	7,630	8,000	8,000	20,100	17,400
Calcium (mg/l)	-	348	329	-	1,056
Magnesium (mg/l)	-	327	337	-	282
Potassium (mg/l)	-	122	129	-	236
Sodium (mg/l)	-	189	213	-	449
Nitrate (mg/l)	32	50	59	120	6.67
Ammonia (mg/l)	301	570	600	1.9	553
Aluminum (mg/l)	-	424	437	-	645
Arsenic (mg/l)	7.50	6.33	6.46	9.06	3.0
Barium (mg/l)	-	0.019	0.026	-	0.20
Cadmium (mg/l)	-	0.075	0.064	-	0.312
Chromium (mg/l)	-	1.47	1.41	-	1.66
Copper (mg/l)	-	0.705	0.683	-	1.86
Fluoride (mg/l)	-	<1	<1	-	<0.03
Iron (mg/l)	979	822	842	369	1,830
Lead (mg/l)	0.111	0.800	0.500	<0.005	1.49
Manganese (mg/l)	-	21.1	22.7	-	26.2
Molybdenum (mg/l)	0.164	0.100	0.495	0.063	0.41
Mercury (mg/l)	-	<0.001	<0.001	-	<0.001
Nickel (mg/l)	-	5.08	5.20	-	12
Selenium (mg/l)	<0.01	0.05	0.05	0.046	0.034
Zinc (mg/l)	-	7.59	7.78	-	34.8
Uranium (pCi/l)	-	-	-	-	13,400
Uranium (mg/l)	-	-	-	-	34.9
Radium-226 (pCi/l)	-	-	-	-	-
Thorium-230 (pCi/l)	-	-	-	-	-
Lead-210 (pCi/l)	-	-	-	-	-
Polonium-210 (pCi/l)	-	-	-	-	-

TDS Total Dissolved Solids
mg/l milligrams per liter
µmhos/cm micromhos per centimeter
s.u. standard units
pCi/l picoCuries per liter

Table 2.2 Annual Uranium Production Data, Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado

Year	Ore (Tons/Year)	Percent U_3O_8 in Ore	Mass U_3O_8 Recovered (pounds)	Colorado Yellow Cake Reprocessed (pounds)[1]
1960	233,825	0.15	724,026	---
1961	264,913	0.12	641,376	---
1962	266,922	0.12	647,555	---
1963	206,893	0.16	658,981	---
1964	149,666	0.17	514,169	---
1965	131,786	0.18	467,009	---
1966	147,653	0.18	489,319	---
1967	183,139	0.11	388,710	---
1968	203,896	0.10	396,945	---
1969	298,395	0.13	798,814	---
1970	416,334	0.11	867,657	522,899
1971	356,245	0.09	571,294	1,309,856
1972	392,542	0.11	782,069	604,986
1973	390,886	0.13	848,063	98,656
1974	393,365	0.12	845,915	5,238
1975	421,995	0.12	958,866	---
1976	497,351	0.12	1,062,914	---
1977	497,650	0.11	1,051,302	139,266
1978	515,922	0.10	1,021,027	---
1979	504,234	0.10	1,066,823	27,208
1980	546,250	0.11	1,152,548	---
1981	265,636	0.11	589,551	190,559
1982	338,381	0.09	527,201	28,768
1983	180,533	0.08	302,758	---
1984	258,623	0.08	397,050	---
Total	8,063,035	---	17,771,942	2,927,436
Average	322,521	0.11	710,878	---

U_3O_8 Uranium Oxide

[1] From Umetco Minerals Corporation operations in Maybell, Rifle, and Uravan, Colorado

Table 2.3 Groundwater Quality Associated with the Above Grade Tailings Impoundment, Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado

Parameter	Average[1]	Units
Sulfate	3,272	mg/l
Chloride	164	mg/l
Alkalinity	84	mg/l
Calcium	386	mg/l
Sodium	206	mg/l
Magnesium	233	mg/l
Iron	51	mg/l
Arsenic	0.01	mg/l
Beryllium	0.13	mg/l
Lead-210	5	pCi/l
Nickel	2.5	mg/l
Radium-226 + 228	53	pCi/l
Selenium	0.03	mg/l
Thorium-230	5.5	pCi/l
Uranium	1,537.5	pCi/l

mg/l milligrams per liter
pCi/l picoCuries per liter

[1] Averages were calculated using analytical data collected between May 1991 and July 1996 from monitor wells installed in the Above Grade Tailings Impoundment: MW67, MWC66, MWC55, MWC52, MWC51, MWI50, MWC49, MWC48, MWC46, and MWC45.

Table 2.4 Comparison of Water Quality for Wells MW28, MW30, MW70B, and MW71B to Standards in License SUA-648, Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado

Constituent	License Standard for Western Flow Regime	MW28	MW30[1]	MW70B	MW71B
Arsenic (mg/l)	0.05	0.008	0.006	0.006	0.007
Beryllium (mg/l)	0.05	<0.01	<0.01	<0.01	<0.01
Nickel (mg/l)	0.06	0.06	<0.01	<0.01	<0.01
Selenium (mg/l)	0.01	<0.005	<0.005	<0.005	<0.002
Natural Uranium (pCi/l)	89.0	1.66	39.94	1.39	1.24
Radium-226 + 228 (pCi/l)	31.5	15.1	28.5	9.0	13.8
Thorium-230 (pCi/l)	6.6	-0.014	-0.01	0.03	-0.04
Lead-210 (pCi/l)	5.0	0.55	3.08	1.27	0.52
Gross Alpha (pCi/l)[2]	146.0	31.22	43.19	9.44	18.93

The values listed are the average concentrations from 1997-1998 data.

mg/l milligrams per liter
pCi/l picoCuries per liter

[1] Although MW30 is located downgradient of the A-9 Repository, it is screened below the mudstone, and is included as part of the Western Flow Regime monitoring system.

[2] Average natural uranium values were subtracted from average gross alpha values.

Table 2.5 Hydraulic Gradients and Estimated Groundwater Velocities, Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado

Feature	Time	Area	Hydraulic Gradient (ft/ft)	Flow Direction	Wells Used	Hydraulic Conductivity[1] (ft/d)	Groundwater Velocity (ft/d)
AGTI	1979	West	No Control	No Control			
		East	No Control	No Control			
		South	0.068	Southwest	MW10, MW7	1.37	0.62
		North	0.015	Northwest	MW1, MW17	1.29	0.13
	1983	West	No Control	No Control			
		East	No Control	No Control			
		South	0.046	Southwest	MW6, MW10	1.37	0.42
		North	0.0074	Northwest	MW1, MW17, MW18	1.29	0.06
	1996	West	0.031	West	MW21, MW28	1.43	0.30
		East	0.0062	West	MW27, MW4	1.03	0.04
		South	0.023	Southwest	MW10, MW7	1.37	0.21
		North	0.01	Northwest	MW1, MW17	1.29	0.09
	1998	West	0.029	West	MW21, MW28	1.43	0.28
		East	0.006	West	MW27, MW1	1.03	0.04
		South	0.035	Southwest	MW10, MW7	1.37	0.32
		North	0.013	West	MW1, MW2	1.29	0.11
A-9 Repository	1979	West	0.005	Southeast	GW2, GW3	1.01	0.03
		Central	0.029	South	MW7, GW3	1.02	0.20
		East	0.044	West	PW6, GW4	0.26	0.08
	1982	West	0.005	Southwest	PW3A, EPW3	1.01	0.03
		Central	0.024	South	MW7, GW3	1.02	0.16
		East	0.03	West	PW6, GW4	0.26	0.05
	1996	West	0.015	Southeast	PW2, GW3	1.01	0.10
		Central	0.022	South	MW7, GW3	1.02	0.15
		East	0.053	West	PW6, GW4	0.26	0.09
	1998	West	0.088	East	PW2, MWC62	1.01	0.59
		Central	0.025	South	MW7, MW24	1.02	0.17
		East	0.068	Northwest	LA8, GW6	0.26	0.12

AGTI Above Grade Tailings Impoundment
ft/d feet per day
ft/ft feet per foot
[1] Hydraulic Conductivity taken as the average from the following wells:

AGTI West	MW2, MW16, MW21A, MW70B, MW71B, MW81, MWC33, MWC34, MWC35, MWC36, MWI37, MWI39, MWC42, MWC56, MWC57, MWC58, MWC59.
AGTI East	MW3, MW18, MW19, MW20.
AGTI North	MW2, MW18, MW19.
AGTI South	the average of all the wells listed for the other AGTI areas.
A-9 West	EPW1, EPW2, EPW3, MW72, MW74, PW1.
A-9 Central	GW3, GW4, MW9, MW79, MWC62, PW4.
A-9 East	GW5, LA5, MW73, PW6.

Table 2.6 Extraction and Injection Rates for the Groundwater Corrective Action Program, Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado

Injection	1991		1992		1993		1994		1995	
	Rate (gpm)	Volume Pumped (gal)	Rate (gpm)	Volume Pumped (gal)	Rate (gpm)	Volume Pumped (gal)	Rate (gpm)	Volume Pumped (gal)	Rate (gpm)	Volume Pumped (gal)
A-9 Repository Injection Wells										
MW29	2.5	720,000	6.0	3,153,600	15.5	8,146,800	20.0	10,512,000	20	-
MW31	2.5	720,000	2.5	1,314,000	1.0	525,600	1.0	525,600	1	-
MW53	5.0	1,440,000	3.5	1,839,600	8.0	4,204,800	8.0	4,204,800	8	-
MW54	5.0	1,440,000	3.0	1,576,800	2.0	1,051,200	2.0	1,051,200	2	-
MW63	-	-	-	-	2.0	532,800	2.5	1,314,000	2.5	-
GW3C	-	-	-	-	2.5	385,200	2.5	1,314,000	2.5	-
GW3D	-	-	-	-	2.5	385,200	2.5	1,314,000	2.5	-
Total- A-9 Repository		**4,320,000**		**7,884,000**		**15,231,600**		**20,235,600**		**7,799,250**
AGTI Injection Wells										
MWI37	1.5	432,000	1.5	788,400	1.5	568,080	-	-	-	-
MWI38	0.5	144,000	0.5	262,800	0.5	189,360	-	-	-	-
MWI39	7.4	2,131,200	3.5	1,839,600	1.5	568,080	-	-	-	-
MW16	1.5	432,000	1.5	788,400	1.0	275,040	-	-	-	-
MW43	1.5	432,000	2.0	1,051,000	1.5	788,400	1.5	788,400	1.5	-
MW44	1.8	518,400	2.2	1,156,320	1.5	788,400	1.5	788,400	1.5	-
MW45	1.0	288,000	1.5	788,400	-	-	-	-	-	-
MW46	1.0	288,000	1.5	788,400	-	-	-	-	-	-
MW47	1.0	288,000	-	-	-	-	-	-	-	-
MW50	0.5	144,000	0.5	262,800	1.0	525,600	1.0	525,600	1	-
MW51	4.3	1,238,000	9.3	4,888,080	16.0	8,409,600			16	-
MWI64	-	-	-	-	3.5	504,000	3.5	1,839,600	3.5	-
MWI65	-	-	-	-	2.5	583,200	2.5	547,200	-	-
MWI66	-	-	-	-	13.0	2,695,000	13.0	6,832,800	13	-
Total-AGTI		**6,335,600**		**12,614,200**		**15,894,760**		**11,322,000**		**7,394,094**

gpm gallons per minute
gal gallons
AGTI Above Grade Tailings Impoundment

Table 2.6 Extraction and Injection Rates for the Groundwater Corrective Action Program, Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado (continued)

Extraction	1991		1992		1993		1994		1995		1996		1997		1998	
	Rate (gpm)	Volume Pumped (gal)	Rate (gpm)	Volume Pumped (gal)	Rate (gpm)	Volume Pumped (gal)	Rate (gpm)	Volume Pumped (gal)	Rate (gpm)	Volume Pumped (gal)	Rate (gpm)	Volume Pumped (gal)	Rate (gpm)	Volume Pumped (gal)	Rate (gpm)	Volume Pumped (gal)
A-9 Repository Extraction Wells																
MW60	-	-	-	-	2.00	323,471	1.40	612,550	2.30	1,208,880	0.80	249,080	1.54	796,530	1.42	569,410
MW61	-	-	-	-	1.00	131,778	1.40	633,550	1.70	892,520	0.86	268,013	1.51	722,450	1.40	633,280
MW62	-	-	-	-	1.00	221,750	1.20	517,870	2.20	1,156,320	0.91	283,794	2.39	1,218,482	2.73	1,390,740
GW3D	0.24	85,120	0.24	92,072	0.18	44,056	-	-	-	-	-	-	-	-	-	-
GW3C	0.40	152,638	0.20	73,596	0.20	73,843	-	-	-	-	-	-	-	-	-	-
MW24	0.17	69,589	0.19	26,297	0.63	256,032	1.56	707,440	2.40	1,261,440	0.85	262,398	1.13	555,580	0.78	364,110
MW29	1.89	414,959	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW31	2.00	565,903	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW32	0.80	328,763	0.07	15,621	0.98	436,403	0.70	298,530	1.10	578,160	0.89	275,827	0.59	271,630	0.35	164,790
MW78	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.44	1,243,180
MW79	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.87	611,980
MW80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.34	689,504
Total	**5.50**	**1,616,972**	**0.70**	**207,586**	**5.99**	**1,487,333**	**6.26**	**2,769,940**	**9.70**	**5,097,320**	**4.31**	**1,339,112**	**7.15**	**3,564,672**	**18.33**	**5,666,994**

gpm gallons per minute
gal gallons
Extraction/injection rates are based on the proportion of the year that the wells were operating and do not include periods of well shut-in.

Table 2.6 Extraction and Injection Rates for the Groundwater Corrective Action Program, Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado (continued)

Extraction	1991 Rate (gpm)	1991 Volume Pumped (gal)	1992 Rate (gpm)	1992 Volume Pumped (gal)	1993 Rate (gpm)	1993 Volume Pumped (gal)	1994 Rate (gpm)	1994 Volume Pumped (gal)	1995 Rate (gpm)	1995 Volume Pumped (gal)	1996 Rate (gpm)	1996 Volume Pumped (gal)	1997 Rate (gpm)	1997 Volume Pumped (gal)	1998 Rate (gpm)	1998 Volume Pumped (gal)
AGTI Extraction Wells																
MWC33	0.1	17100	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MWC34	1.0	705600	2.0	794880	-	-	-	-	-	-	-	-	-	-	-	-
MWC35	2.0	705600	2.0	835200	-	-	-	-	-	-	-	-	-	-	-	-
MWC36	10.0	2116800	6.0	2730240		16985.00	-	-	-	-	-	-	-	-	-	-
MWC42	10.0	2822400	8.0	3813120	9[1]	4204800	11[1]	4,193,290	8.00	1,808,640	-	-	-	-	-	-
MWC45	-	-	-	-	1[1]	-	<0.5[1]	259,200	0.50	113,040	-	-	-	-	-	-
MWC46	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-
MWC47	-	-	3.5	700560		1839600	16[1]	1,925,630	3.60	813,888	-	-	-	-	-	-
MWC48	-	-	6.0	2858940		3153600	6[1]	3,466,090	6.70	1,514,736	-	-	-	-	-	-
MWC49	-	-	10.0	4766400	3[1]	5256000	5[1]	5,290,000	10.00	2,260,800	-	-	-	-	-	-
MWC52	-	-	11.0	5243040	15[1]	5781600	15[1]	6,087,760	11.80	2,667,744	-	-	-	-	-	-
MWC55	-	-	-	-	3[1]	274773	1[1]	2,689,580	5.20	2,733,120	0.50	143,316	-	-	-	-
MWC56	-	-	-	-	2[1]	128730	1.5[1]	1,572,400	2.80	633,024	-	-	-	-	-	-
MWC57	-	-	-	-	2[1]	170800	1.5[1]	1,898,000	3.70	836,496	-	-	-	-	-	-
MWC58	-	-	-	-	2.5[1]	172120	1[1]	1,525,950	2.80	633,024	0.50	143,545	4.26	2,192,200	2.31	1,128,950
MWC59	-	-	-	-	2[1]	195626	1[1]	1,649,900	3.20	723,456	-	-	-	-	-	-
MWI43	-	-	-	-	-	-	-	-	-	-	-	-	1.86	1,188,143	1.59	820,330
MWI64	-	-	-	-	-	-	-	-	-	-	-	-	4.35	959,183	1.07	537,760
Total	**23.06**	**6,367,500**	**48.50**	**21,742,380**	**39.50**	**21,194,634**	**59.00**	**30,557,800**	**58.30**	**14,737,968**	**1.00**	**286,861**	**10.47**	**4,339,526**	**4.98**	**2,487,040**

Extraction/injection rates are based on the proportion of the year that the wells were operating and do not include periods of well shut-in.

gpm gallons per minute
gal gallons
AGTI Above Grade Tailings Impoundment
[1] Estimated pumping rate from strip charts.

Table 2.7 Summary of Pumping Test Results, Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado

Well Identification	Reference	Method of Analysis	Hydraulic Conductivity (feet/day)	Transmissivity (feet²/day)	Saturated Thickness (feet)	Specific Yield or Storativity	Hydro-stratigraphic Unit Tested
A-9 Pit Pz-9	D&M[1]	Boulton	0.87	8.7	10	---	SWFR
A-9 Pit Obs 9B	D&M[1]	Boulton	0.84	12	14.1	0.005	SWFR
A-9 Pit Obs 9B	D&M[1]	Boulton	1.4	20	14.1	0.0015	SWFR
A-9 Pit Pz-A-9-5	D&M[1]	Boulton	0.02	0.47	20.5	---	SWFR
A-9 Pit Pz-A-9-5	D&M[1]	Theis	0.25	5.3	20.5	---	SWFR
A-9 Pit Pz-A-9-4	D&M[1]	Boulton	0.74	19.4	26.2	0.025	SWFR
A-9 Pit Pz-A-9-4	D&M[1]	Theis	0.5	13.4	26.2	0.08	SWFR
Mudstone	D&M[1]	USBR Air Permeability	1.6 E-3 to 1.3 E-1	---	---	---	Mudstone
MW2	D&M[2]	Boulton	0.62	168	273	---	WFR
MW2	D&M[2]	Theis (Recovery)	0.67	183	273	---	WFR
MW3	D&M[2]	Boulton	0.01	1.34	122	---	WFR
MW3	D&M[2]	Theis (Recovery)	0.09	10.7	122	---	WFR
MW16	D&M[2]	Boulton	0.18	3.3	18	---	WFR
MW16	D&M[2]	Theis (Recovery)	0.27	5.3	18	---	WFR
MW18	D&M[2]	Boulton	2.54	241	95	---	WFR
MW18	D&M[2]	Theis (Recovery)	2.54	241	95	---	WFR
OW18	D&M[2]	Boulton	4.11	390	95	---	WFR
OW18	D&M[2]	Theis (Recovery)	8.05	766	95	0.01	WFR
MW19	D&M[2]	Boulton	0.66	50	76	---	WFR
MW19	D&M[2]	Theis (Recovery)	0.68	51	76	---	WFR
MW20-1st Test	D&M[2]	Boulton	0.79	67	86	---	WFR
MW20-1st Test	D&M[2]	Theis (Recovery)	0.82	71	86	---	WFR
MW20-2nd Test	D&M[2]	Boulton	0.93	80	86	---	WFR
MW20-2nd Test	D&M[2]	Theis (Recovery)	0.9	76	86	---	WFR
OW20-1st Test	D&M[2]	Boulton	0.19	160	86	---	WFR
OW20-1st Test	D&M[2]	Theis (Recovery)	2.73	241	86	0.3	WFR
OW20-2nd Test	D&M[2]	Boulton	3.83	321	86	---	WFR
OW20-2nd Test	D&M[2]	Theis (Recovery)	5.37	455	86	0.02	WFR

SWFR Southwestern Flow Regime – equivalent to Upper Wind River
WFR Western Flow Regime – equivalent to Lower Wind River
D&M[1] Dames & Moore, 1979. Environmental Assessment of Below Grade Uranium Tailings Disposal in the A-9 Open Pit, East Gas Hills Uranium Mine & Mill, Wyoming, prepared for Union Carbide Corporation, February 1979.
D&M[2] Dames & Moore, 1979. Evaluation of Groundwater Contamination, Existing Tailings Impoundment, East Gas Hills, Wyoming, prepared for Union Carbide Corporation, June 1979.

Table 2.7 **Summary of Pumping Test Results, Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado, (continued)**

Well Identification	Reference	Method of Analysis	Hydraulic Conductivity (feet/day)	Transmissivity ($feet^2$/day)	Saturated Thickness (feet)	Specific Yield or Storativity	Hydro-stratigraphic Unit Tested
DW2	HydEng[1]	Jacob	1.89	200	106	---	WFR
DW1 (MW22)	HydEng[1]	Theis	1.56	370	239	4.90 E-4	WFR
DW1 (MW22)	HydEng[1]	Jacob	1.72	410	239	---	WFR
RMW1	HydEng[2]	Theis (Recovery)	5.1	572	113	---	WFR
RMW1-1	HydEng[2]	Dagan	1.5	175	113	0.03	WFR
RMW1-2	HydEng[2]	Dagan	4	455	113	0.025	WFR
RMW1-3	HydEng[2]	Dagan	2.7	307	113	0.0035	WFR
RMW2	HydEng[2]	Theis (Recovery)	4.4	807	183	---	WFR
RMW2-1	HydEng[2]	Dagan	1	187	183	0.034	WFR
RMW3	HydEng[2]	Theis (Recovery)	7.86	582	74	---	WFR
RW3-1	HydEng[2]	Dagan	4	428	74	0.032	WFR
GW1	HydEng[3]	Jacob	0.45	13.4	30	---	SWFR
GW3	HydEng[3]	Jacob	0.92	41.4	45	---	SWFR
GW3	HydEng[3]	Neuman	0.65	29.4	45	0.025	SWFR
GW4	HydEng[3]	Jacob	0.89	8	9	---	SWFR
GW5	HydEng[3]	Jacob	0.28	14.7	53	---	SWFR
PW1	HydEng[3]	Jacob	0.06	1.2	20	---	SWFR
PW3	HydEng[3]	Jacob	0.58	22.7	39	---	SWFR
PW4	HydEng[3]	Jacob	0.99	160.4	40	---	SWFR
PW6	HydEng[3]	Jacob	0.54	21.4	39	---	SWFR
MW9	HydEng[3]	Neuman	1.15	52	40	0.11	SWFR
MW9	HydEng[3]	Jacob	0.9	36	40	0.27	SWFR
MW7A	HydEng[3]	Jacob	0.18	9.4	52	---	SWFR
EPW1	HydEng[3]	Jacob	0.31	2.4	8	---	SWFR/WFR
EPW2	HydEng[3]	Jacob	0.43	4.3	10	---	SWFR/WFR
EPW3	HydEng[3]	Jacob	3.1	82.9	27	---	SWFR
MW30 (30026)	HydEng[3]	Jacob	0.014	0.82	57	---	WFR

WFR Western Flow Regime – equivalent to Lower Wind River
SWFR Southwestern Flow Regime – equivalent to Upper Wind River
HydEng1 HydroEngineering, 1980, A-9 Leaky Aquifer Test, prepared for Union Carbide Corporation, 1980.
HydEng2 HydroEngineering, 1980, Rim Pit Hydrology, prepared for Union Carbide Corporation, September 1980.
HydEng3 HydroEngineering, 1982, Groundwater Hydrology Near the A-9 Pit Below Grade Tailings, prepared for Union Carbide Corporation, September 1982.

Table 2.7 Summary of Pumping Test Results, Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado, (continued)

Well Identification	Reference	Method of Analysis	Hydraulic Conductivity (feet/day)	Transmissivity (feet²/day)	Saturated Thickness (feet)	Specific Yield or Storativity	Hydro-stratigraphic Unit Tested
MW21A	HydEng[4]	Jacob	1.13	270	240	---	WFR
MWC33	HydEng[4]	Jacob	0.22	53	240	---	WFR
MWC34	HydEng[4]	Jacob	0.28	67	240	---	WFR
MWC35	HydEng[4]	Jacob	0.78	187	240	---	WFR
MWC36	HydEng[4]	Jacob	1.23	341	240	---	WFR
MWI37	HydEng[4]	Jacob	1.13	271	240	---	WFR
MWI39	HydEng[4]	Jacob	4.02	960	240	---	WFR
MWC42	HydEng[4]	Jacob	0.6	165	240	---	WFR
MWO40	HydEng[4]	Jacob	0.7	167	240	0.1	WFR
MWO41	HydEng[4]	Jacob	0.9	219	240	---	WFR
LA-1	L&A[1]	Thompson	0.04	---	---	---	SWFR
LA-2	L&A[1]	Thompson	0.3	---	---	---	SWFR
LA-3	L&A[1]	Thompson	0.0006	---	---	---	SWFR
LA-4	L&A[1]	Thompson	0.003	---	---	---	SWFR
LA-5	L&A[1]	Thompson	0.1	---	---	---	SWFR
LA-6	L&A[1]	Thompson	0.4	---	---	---	SWFR
LA-7	L&A[1]	Thompson	0.003	---	---	---	SWFR
MW70B	USES[1]	Theis	0.95	95	60	0.016	WFR
MW70B	USES[1]	Jacob	0.9	90	60	0.02	WFR
MW71B	USES[1]	Theis	1.15	117	102	0.019	WFR
MW71B	USES[1]	Jacob	1.15	117	102	0.019	WFR
MW72	USES[1]	Theis	2.1	62.2	30	0.0004	SWFR
MW72	USES[1]	Jacob	2.2	65	30	0.0003	SWFR
MW73	USES[1]	Jacob	0.11	5.6	50	0.0015	SWFR
MW74	USES[1]	Bouwer	0.04	0.5	12	Not Applicable	SWFR
MW79	USES[1]	Theis	1.6	47.6	30	0.0001	SWFR
MW79	USES[1]	Jacob	2	58.4	30	0.000007	SWFR
MW81	USES[1]	Theis	1.9	113	60	0.016	WFR
MW81	USES[1]	Jacob	2	119	60	0.01	WFR

WFR Western Flow Regime – equivalent to Lower Wind River
SWFR Southwestern Flow Regime – equivalent to Upper Wind River
L&A1 Lidstone & Anderson, 1989, Groundwater Investigation of the East Gas Hills AML 16-E, prepared for Worthington, Lenhart & Carpenter, December 1989.
USES1 U.S. Environmental Services, Drilling and Construction and Testing of Monitoring Wells MW70A, MW70B, MW71A, MW71B, MW72, MW73, MW74 and Extraction Wells MW78, MW79, MW80 and MW81, East Gas Hills, Wyoming, prepared for Umetco Minerals Corporation, September 1997.
HydEng4 HydroEngineering, 1990, Lower Wind River Aquifer Properties, prepared for Umetco Minerals Corporation, October 1990.

Table 2.7 Summary of Pumping Test Results, Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado, (continued)

Well Identification	Reference	Method of Analysis	Hydraulic Conductivity (feet/day)	Transmissivity ($feet^2$/day)	Saturated Thickness (feet)	Specific Yield or Storativity	Hydro-stratigraphic Unit Tested
MWC33	USES[2]	Theis	0.23	22.7	100	---	WFR
MWC33	USES[2]	Jacob	0.45	45.1	100	---	WFR
MWC35	USES[2]	Theis	0.12	12	100	---	WFR
MWC36	USES[2]	Theis	2.1	105	50	---	WFR
MWC36	USES[2]	Jacob	3.3	163	50	---	WFR
MWC37	USES[2]	Theis	2.7	53.5	20	---	WFR
MWC37	USES[2]	Jacob	2	40.8	20	---	WFR
MWC42	USES[2]	Theis	1	90	90	---	WFR
MWC42	USES[2]	Jacob	3.34	301	90	---	WFR
MWC56	USES[2]	Theis	0.95	95	100	---	WFR
MWC56	USES[2]	Jacob	0.95	94.9	100	---	WFR
MWC57	USES[2]	Theis	3.25	325	100	---	WFR
MWC57	USES[2]	Jacob	3.26	326	100	---	WFR
MWC58	USES[2]	Theis	4.05	405	100	---	WFR
MWC58	USES[2]	Jacob	4.05	405	100	---	WFR
MWC59	USES[2]	Theis	2.52	278	110	---	WFR
MWC59	USES[2]	Jacob	2.65	292	110	---	WFR
MWC62	USES[2]	Theis	1.08	70	65	---	WFR
MWC62	USES[2]	Jacob	1.06	69	65	---	WFR

WFR Western Flow Regime – equivalent to Lower Wind River
USES2 U.S. Environmental Services, unpublished data

Boulton, N.S., 1963. Analysis of Data from Non-equilibrium Pumping Tests Allowing for Delayed Yield from Storage. Proceedings Institute of Civil Engineers, Volume 26, pp 469-482.
Bouwer, H. and R.C. Rice, 1978. A Slug Test for Determining Hydraulic Conductivity on Unconfined Aquifers with Completely or Partially Penetrating Wells. Water Resources Research, Volume 12, pp 423-428.
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Jacob, C.E., 1947. Drawdown Test to Determine Effective Radius of Artesian Well. Transactions American Society of Civil Engineers, Volume 112, Paper 2321, pp 1047-1064.
Neuman, S.P., 1972. Theory of Flow in Unconfined Aquifers Considering Delayed Response of the Water Table. Water Resources Research, Volume 8, pp 1031-1045.
Theis, C.V., 1935. The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Groundwater Storage. Transactions American Geophysical Union, Volume 2, pp 519-524.
Thompson, D.B., 1987. A Microcomputer Program for Interpreting Time Lag Permeability Tests. Groundwater, Volume 25, Number 2 1987. pp 212-218.
U.S. Bureau of Reclamation, 1974. Standard Permeability Procedure E-18.

Table 2.8 Eh Redox Couples, Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado

Location Code	Date Sampled	Eh Calculated from ORP Field (mV)	Eh Fe(+2)/Fe(+3) (mV)	Eh S(-2)/S(+6) (mV)	Field DO mg/l
EPW2	9-Sep-98	NM	572	56	6.2
GW1	2-Sep-98	204	270	-133	0.42
GW5	2-Sep-98	335	ND	ND	8.23
GW7	2-Sep-98	474	513	ND	0.53
LA8	9-Sep-98	101	404	-108	3.77
MW21A	10-Sep-98	215	342	ND	3.21
MW25	8-Sep-98	225	381	ND	2.85
MW28	10-Sep-98	140	233	ND	2.6
MW30	9-Sep-98	136	264	ND	2.6
MW70A	10-Sep-98	680	NM	55	3.28
MW70B	10-Sep-98	109	235	ND	3.6
MW72	9-Sep-98	181	279	-136	7.45
MW74	9-Sep-98	252	339	-133	3.9
MW76	3-Sep-98	237	396	-92	0.36
MW77	8-Sep-98	191	294	ND	2.39
PIX-MO97	2-Sep-98	59	83	-238	0.58

Eh	Oxidation/Reduction Potential Relative to Standard Hydrogen Electrode
ORP	Oxidation Reduction Potential
mV	millivolts
Fe(+2)/Fe(+3)	Ferrous/Ferric iron redox couple
S(-2)/S(+6)	Sulfide/Sulfate sulfur redox couple
DO	Dissolved Oxygen
mg/l	milligrams per liter
NM	Not measured
ND	Not detected

Table 2.9 Results of Geochemical Modeling, Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado

Constituent	Initial Concentration Western Flow	Modeled Value at POE	Initial Concentration Southwestern Flow	Modeled Value at POE 0.167 ft/d[1] / 0.28 ft/d[2]
Licensed Constituents				
Arsenic (mg/l)	1.8	0.10 / 0.11	1.4	0.109 / 0.092
Beryllium (mg/l)	1.6	3×10^{-4} / 2.3×10^{-4}	1.7	1.3×10^{-4} / 1.7×10^{-4}
Lead-210 (pCi/l)	35	0.23 / 0.18	47	0.005 / 0.008
Natural Uranium (mg/l)	12	3.7×10^{-5} / 5.2×10^{-5}	34	4.7×10^{-5} / 2.7×10^{-5}
Nickel (mg/l)	13	0.005 / 0.004	9.3	2.2×10^{-8} / 7.6×10^{-8}
Radium-226 + 228 (pCi/l)	250	<0.14 / <0.35	353	79.4 / <1.33
Selenium (mg/l)	0.16	2×10^{-13} / 1.8×10^{-13}	0.53	1.9×10^{-8} / 1.0×10^{-8}
Thorium-230 (pCi/l)	57	$<2.6 \times 10^{-19}$ / $<1.8 \times 10^{-15}$	44.8	0.004 / 0.003
Non-Licensed Constituents				
Chloride (mg/l)	270	13 / 13	160	120 / 120
Sulfate (mg/l)	3,480	1,902 / 1,902	2,650	1,600 / 1,600

Composite parameters Gross Alpha and Total Dissolved Solids are not modeled.

1	Representative groundwater velocity based on site hydrologic data.
2	Maximum groundwater velocity calculated from stochastic groundwater flow model.
POE	Point of Exposure
ft/d	feet per day
mg/l	milligrams per liter
pCi/l	picoCuries per liter

Table 2.10 Summary of Ambient Groundwater Quality, POE Modeled Values, and Class III Groundwater Standards, Gas Hills, Wyoming

Constituent	Western Flow Regime Background	Western Flow Regime POE Value	Southwestern Flow Regime Background	Southwestern Flow Regime POE Value	Class III WY Std.	Comments
LICENSED CONSTITUENTS						
Arsenic (mg/l)	0.1	0.11	**0.95***	0.109	0.2	Modeled arsenic values at POE are below background for the southwestern flow regime (SWFR), and equivalent to background for the western flow regime (WFR). SWFR background exceeds Class III.
Beryllium (mg/l)	0.01	3×10^{-4}	--	1.7×10^{-4}	0.1 Class II	Beryllium presence is negligible at Gas Hills; both background and modeled POE values are well below the Class II standard (Class III standard is not available).
Gross Alpha (pCi/l)	**107***	(1)	**322***	(1)	15	Background gross alpha, listed here *excluding* uranium (see Table 2.12) exceeds Class III standard in both flow regimes.
Lead-210 (pCi/l)	4.2	0.23	3.0	0.008	--	Modeled lead-210 values at POE are below background for both flow regimes.
Natural Uranium (mg/l)	0.25	5.2×10^{-5}	0.81	4.7×10^{-5}	5.0	Modeled uranium values at the POE are well below background for both flow regimes and background values are below the Class III standard.
Nickel (mg/l)	**2.1***	0.005	0.06	7.6×10^{-8}	0.2 Class II	Modeled nickel values at POE are below background for both flow regimes. Background nickel in WFR exceeds the Class II standard (Class III standard not available).
Radium$^{226+228}$ (pCi/l)	**53***	<0.35	**160***	79.4	5.0	Background radium exceeds the Class III standard for both flow regimes. Modeled radium values at POE locations are negligible for WFR and below background for SWFR.
Selenium (mg/l)	--	2×10^{-13}	0.02	1.9×10^{-8}	0.05	For both flow regimes, selenium is below the Class III standard at both the POE and in ambient groundwater samples.
Thorium-230 (pCi/l)	0.5	$<1.8 \times 10^{-15}$	0.8	0.004	--	Th-230 is below background at the POE in both flow regimes.

Table 2.10 Summary of Ambient Groundwater Quality, POE Modeled Values, and Class III Groundwater Standards, Gas Hills, Wyoming (continued)

Constituent	Western Flow Regime Background	Western Flow Regime POE Value	Southwestern Flow Regime Background	Southwestern Flow Regime POE Value	Class III WY Std.	Comments
NON-LICENSED CONSTITUENTS						
Chloride (mg/l)	13	13	118	120	2,000	Modeled chloride values at POE are comparable to background for both flow regimes. Both background and the modeled values are below the Class III standard.
Sulfate (mg/l)	1,900	1,902	1,600	1,600	3,000	See explanation above (for chloride); sulfate exhibits a similar trend.

Notes:

Background values listed in bold and asterisked denote cases where ambient groundwater quality exceeds the corresponding Class III groundwater standard.
-- Not applicable (e.g., in cases of low or zero detection frequencies) or no data available (e.g., no standard has been derived).
Modeled POE values listed are the highest predicted values listed in Table 2.9 (for the two assumed groundwater flow velocities).
Appendix A, Tables A.5 and A.8 document the rationales for the background values listed above for the southwestern and western flow regimes, respectively.
(1) Gross Alpha was not modeled because it is a composite parameter.

Table 2.11 Summary of Water Uses within 5 Kilometers of the Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado

Water Use Category**	Number	Specific Use Designations	Comment
Domestic Use Designations	2 (0.7%)	DOM – 2: Allison #4 (Tns 33, Rng 88, Sec 22) and Sagebrush #1 (Tns 33, Rng 90, Sect 32)	These two uses are located far outside the influence from the Gas Hills site. In fact, both are off the map provided on Figure 2.22.
Irrigation Uses	35 (12.8%)	IRR – 35	All 35 designations correspond to surface water uses; see Table D.1.
Stock Watering Uses	73 (26.6%)	STO – 55 STO, DOM – 1 STO, WIL – 4 STO, IRR – 1 STO, IRR, DOM – 9 STO, MIS – 1 WIL, STO, MIS – 1	All STO designations correspond to surface water uses. Of the 10 stock uses that include domestic (DOM) uses, only 4 are located within the requested 5-km search boundary (the rest are off the map). The single STO, DOM record corresponds to Cross L #2 spring (Tns 33, Rng 88, Sec 7), located upgradient of the site (Figure 2.22). Two of the STO, IRR, DOM designations correspond to the CBC ditch (Tns 33, Rng 89, Sections 4 and 33). Another is for the Holliday (Tns 33, Rng 88, Sec 7), coinciding with the X-L #2 spring.
Industrial Uses	52 (19%)	IND – 34 IND, MIS – 1 IND,TEM – 11 DEW, RES, IND, MIS – 1 OIL, TEM, IND, DRI – 1 RES, IND, MIS – 2 TEM, IND, DRI – 1 TEM, IND, MIN, DRI – 1	See Table D.1 for detailed information.
Monitoring Uses	81 (29.6%)	MON; MIS,MON (also MON, MIS); or MON, DEW, RES, MIS	See Table D.1 for detailed information.
Other (Miscellaneous) Uses	31 (11.3%)	MIS – 26 MIS, DEW, RES – 2 RES – 2 TEM, FLO – 1	See Table D.1 for detailed information.

***See notes and definition of terms on following page.*

Table 2.11 Summary of Water Uses Within 5 Kilometers of the Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado (continued)

Notes:

1. This table presents the results of a search of ground and surface water rights within 5 kilometers of the Gas Hills site that was based on Wyoming State Engineer's Office records dated August 2000 (electronic file version). That office was contacted in April 2001 to obtain more recent information. However, electronic data were not provided for the entire database, precluding computerized analysis of the current water rights search records (n=1273 based on the Aug-2000 search). A hardcopy of the April 2001 water rights search was provided; this file appears to be consistent with the August 2000 search reflected here. Additionally, although the request was for data applying to the area located within 5 km of the Gas Hills site, some records included in the water rights file apply to areas outside this 5-km radius. For example, the two records with a domestic (DOM) designation apply to water uses that are located outside of the search boundary shown on Figure 2.22.

2. The original search yielded 1273 records, many of which reflected multiple records for a single permit number and/or use. To manage this file, all duplicate records were eliminated from the original water rights search file (see "n records" variable in Table D.1), yielding a total of 281 records. Also, a "Use Category" variable was added to facilitate data management and review. Detailed information documenting the Water Rights Search, including location (township, range, sections, quarter), uses, facility name, applicant, etc. is provided in Appendix D. As indicated above and in Appendix D, most records have multiple water use designations (e.g., IND, TEM). Consequently, some overlap may exist in the water use categories listed above. Also, the search results file provided by the State Engineer's Office does not distinguish between groundwater and surface water rights records. In most cases, the applicable medium (groundwater vs. surface water) was apparent based on the facility name (e.g., a given "well" or "ditch"). However, in some cases such a distinction could not be made.

3. The April 2001 search results were caveated as follows: "These are the groundwater rights of record in this office and may or may not represent the actual situation on the ground." (letter from D. Parkin, State Engineer's Office, April 18, 2001). The issues discussed in Appendix D regarding spurious records for Pathfinder's Lucky Mc wells (in particular, those with domestic use designations) substantiate the reasoning underlying such a caveat.

Definition of Terms

DEW	Dewatering
DOM	Domestic
DRI	Oil/gas drilling
FLO	Flood Control
IND	Industrial
IRR	Irrigation
MIN	Mining
MIS	Miscellaneous
MON	Monitoring
RES	Reservoir Supply
Rng	Range
Sec	Section
STO	Stock (watering)
TEM	Temporary Use (e.g., for road construction or well drilling)
Tns	Township
WIL	Wildlife

Table 2.12 Comparison of Ambient Groundwater Quality with Wyoming, Groundwater Class and Use Suitability Designations, Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado

	Ambient Groundwater Quality[1]		Wyoming DEQ Groundwater Class[2]		
Parameter	**Western Flow Regime**	**Southwestern Flow Regime**	**Class I: Domestic**	**Class II: Agriculture**	**Class III: Livestock**
Licensed Parameters					
Arsenic	0.10 mg/l	**0.95 mg/l**	0.05 mg/l	0.1 mg/l	0.2 mg/l
Beryllium	0.01 mg/l	--	--	0.1 mg/l	--
Gross Alpha[3]	276 pCi/l (inc. U-nat); **107 pCi/l** (exc. U-nat)	870 pCi/l (inc. U-nat); **322 pCi/l** (exc. U-nat)	15 pCi/l (exc. U-nat; see Note 3)	15 pCi/l	15 pCi/l
Lead-210	4.2 pCi/l	3.0 pCi/l	--	--	--
Natural Uranium[3]	0.25 mg/l (=169 pCi/l)	0.81 mg/l (=548 pCi/l)	5 mg/l	5 mg/l	5 mg/l
Nickel	**2.1 mg/l**	0.06 mg/l	--	0.2 mg/l	--
Radium$^{226+228}$	**53 pCi/l**	**160 pCi/l**	5 pCi/l	5 pCi/l	5 pCi/l
Selenium	--	0.02 mg/l	0.01 mg/l	0.02 mg/l	0.05 mg/l
Thorium-230	0.5 pCi/l	0.8 pCi/l	--	--	--
Non-Licensed Parameters					
Chloride	13 mg/l	118 mg/l	250 mg/l	100 mg/l	2000 mg/l
Sulfate	1,900 mg/l	1,600 mg/l	250 mg/l	200 mg/l	3000 mg/l
TDS	2,710 mg/l	2,760 mg/l	500 mg/l	2000 mg/l	5000 mg/l

Shaded constituents and values listed in boldface denote cases where ambient groundwater quality exceeds the Class III groundwater standard.
-- Not applicable (e.g., given non-detectable levels in ambient groundwater) and/or no value reported.

Notes:

[1] The basis for the ambient levels listed above is provided in Appendix A, Ambient Groundwater Quality.

[2] *Source:* Wyoming Department of Environmental Quality (WDEQ) Water Quality Rules and Regulations, Chapter VIII, Table I (Wyoming DEQ Water Quality Division, March 1993). In accordance with this document, groundwater classifications are defined as follows:

> *Class I Groundwater* — This water is suitable for domestic use. The ambient quality of underground water of this suitability does not have a concentration in excess of any of the standards for Class I groundwater listed above.
>
> *Class II Groundwater* — This water is suitable for agricultural use where soil conditions and other factors are adequate. The ambient quality of underground water of this suitability does not have a concentration in excess of any of the standards for Class II groundwater listed above.
>
> *Class III Groundwater* — This water is suitable for livestock. The ambient quality of underground water of this suitability does not have a concentration in excess of any of the standards for Class III groundwater listed above.

Comparison of ambient groundwater quality with the WDEQ standards listed above indicates that groundwater in the vicinity of the Gas Hills site is suitable only for livestock (Class III) purposes.

[3] The Wyoming DEQ standards listed above for gross alpha particle radioactivity include radium-226, but exclude radon and uranium. Background uranium (U-nat) was converted to activity units by multiplying the mass unit background values by 677.

Table 2.13 Potential Exposure Pathways Identified for the Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado

Exposure Route[1]	Description of Pathway Likelihood and Associated Exposure Scenarios
Ingestion of groundwater associated with agricultural and/or domestic groundwater uses	This pathway is considered unlikely given that groundwater in the Gas Hills area is currently used for monitoring, miscellaneous, and industrial purposes only. Regarding potential future uses, ingestion of groundwater on anything but an ephemeral basis (e.g., that associated with agricultural uses or a limited ranch scenario) is not likely given current and anticipated future water uses in the Gas Hills site vicinity, the ambient groundwater quality (which exceeds Class III groundwater standards for several constituents as demonstrated in Tables 2.10 and 2.12), and the other factors discussed in Section 2.3.1.
Ingestion of beef from livestock consuming groundwater (used for stock watering) and forage irrigated with groundwater	This pathway is possible; however, water uses for stock watering currently correspond to surface water sources only (e.g., springs and ditches); see Table 2.11 and Appendix D.
Ingestion of meat from wild game grazing on irrigated land and consuming groundwater	This exposure pathway is possible, given that hunting does occur on a seasonal basis. However, exposures to groundwater constituents would likely be less than those associated with the livestock pathway described above.
Ingestion of milk from livestock grazing on irrigated land and consuming groundwater	No dairies are located in the vicinity of the Gas Hills site, nor are agricultural uses of this nature expected in the future.

[1] As discussed in the text, the modeled hazardous constituent concentrations at the potential POEs are not distinguishable from ambient conditions when the concentrations at the POCs are at or below the proposed ACLs. This finding precludes the need to quantitatively assess potential exposures and human health and environmental hazards/risks. That is, no exposures are anticipated given that concentrations of hazardous constituents are projected to be below background). Acknowledging the latter, the purpose of this table is to provide qualitative information regarding current and potential future exposure pathways in the Gas Hills site vicinity (irrespective of the lack of site-related impacts).

Table 2.13 Potential Exposure Pathways Identified for the Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado (continued)

Exposure Route	Description of Pathway Likelihood and Associated Exposure Scenarios
Dermal contact with groundwater	Most of the wells in the vicinity of the Gas Hills site are permitted for monitoring, miscellaneous, and/or industrial uses. Although dermal contact with groundwater is possible under these scenarios, the potential for adverse human health or environmental effects associated with such uses is negligible for the radionuclide and inorganic constituents evaluated herein, especially if requisite health & safety regulations are adhered to (e.g., for PRIs ISL mining workers).
Surface water exposure pathways, including: • direct ingestion of surface water, • dermal contact with surface water, and/or • ingestion of fish from potentially affected surface water bodies.	Although springs located west of the site are used for stock watering purposes (e.g., Medicine Spring, Lincoln Spring, and Iron Spring), these springs have not been impacted by site activities, nor are any site-related water quality impacts expected in the future, based on modeling results. Any historical presence of hazardous constituents (e.g., uranium) in samples collected from these springs is attributable to naturally occurring uranium mineralization. Furthermore, there are no surface water bodies in the vicinity of the Gas Hills site of sufficient size and character to support a fish population.

Table 2.14 Comparison of Wildlife Benchmark Concentrations and Agricultural Standards with Modeled POE Concentrations, Gas Hills Site, Umetco Minerals Corporation, Grand Junction, Colorado

Parameter	Maximum Modeled Value at POE Locations[1]	Groundwater Benchmark for Wildlife Receptors[2]	WY DEQ Class II: Agriculture[3]	WY DEQ Class III: Livestock[3]
Radionuclide Parameters				
Natural Uranium	5.2×10^{-5} mg/l	7 mg/l	5 mg/l	5 mg/l
Thorium-230	0.004 pCi/l	--	--	--
Lead-210	0.23 pCi/l	--	--	--
Ra-226+228	79.4 pCi/l	420 pCi/l	5 pCi/l	5 pCi/l
Inorganic Parameters				
Arsenic	0.11 mg/l	0.3 mg/l	0.1 mg/l	0.2 mg/l
Beryllium	0.0003×10^{-8} mg/l	2.8 mg/l	0.1 mg/l	--
Nickel	0.005 mg/l	171 mg/l	0.2 mg/l	--
Selenium	1.9×10^{-8} mg/l	0.086 mg/l	0.02 mg/l	0.05 mg/l
Sulfate	1902 mg/l	--	200 mg/l	3000 mg/l

-- No data available and/or value not determined.

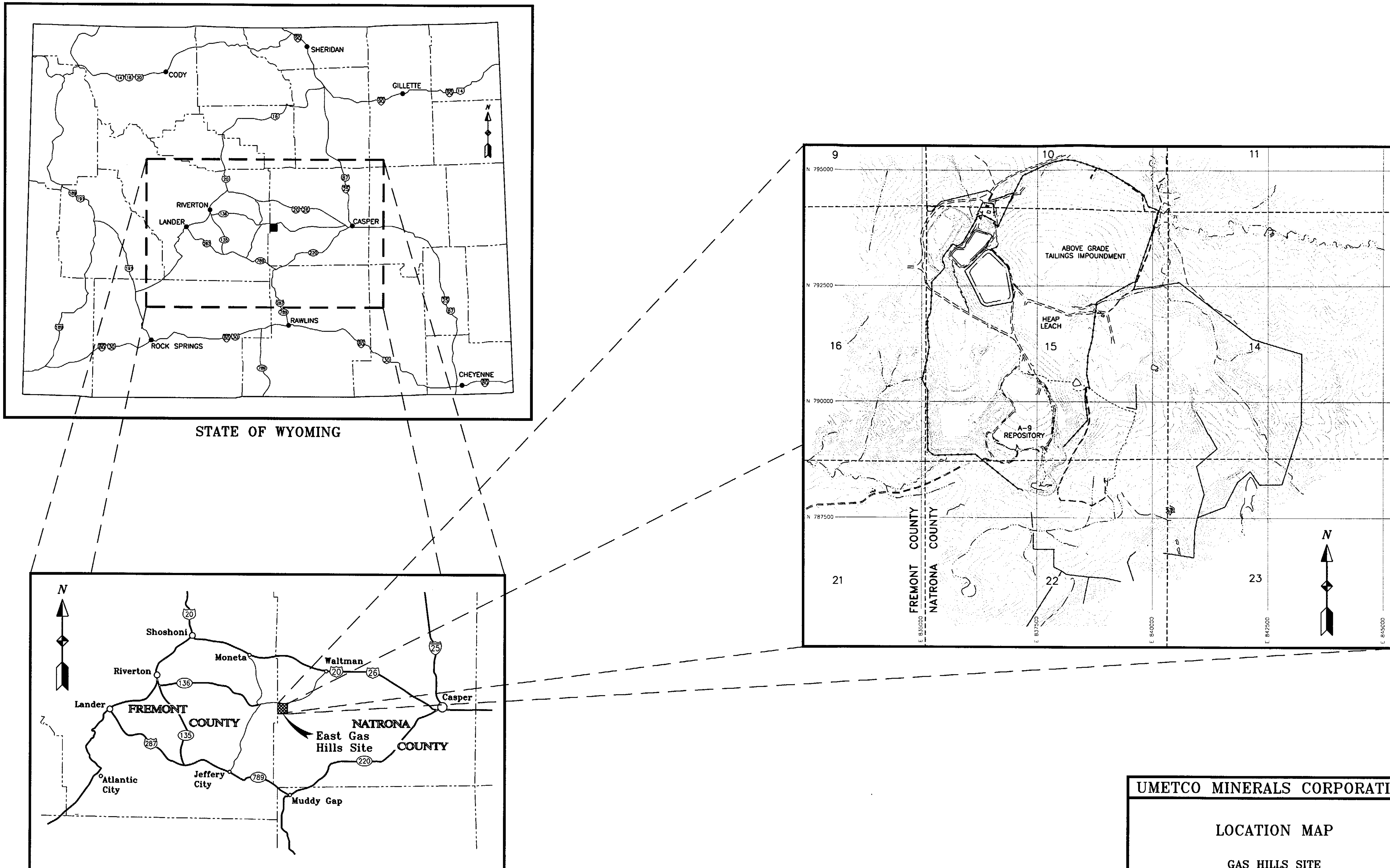
[1] The POE concentrations listed above are the highest of those projected for the western and southwestern flow regimes.

[2] The radionuclide groundwater benchmark concentrations for wildlife are based on a limiting dose of 100 mrad per day (Higley 1995). The wildlife benchmarks for inorganic constituents are based on No Observed Adverse Effect Levels (NOAELs) derived for white-tailed deer (considered the most sensitive terrestrial receptor for chemical constituents) for DOE's Oak Ridge facility (Sample 1996).

[3] Source: Wyoming Department of Environmental Quality (WDEQ) Water Quality Rules and Regulations, Chapter VIII, Table I (WDEQ Water Quality Division, March 1993). In accordance with this document, groundwater classifications are defined as follows:

Class II Groundwater — This water is suitable for agricultural use where soil conditions and other factors are adequate. The ambient quality of underground water of this suitability does not have a concentration in excess of any of the standards for Class II groundwater listed above.

Class III Groundwater — This water is suitable for livestock. The ambient quality of underground water of this suitability does not have a concentration in excess of any of the standards for Class III groundwater listed above.



UMETCO MINERALS CORPORATION

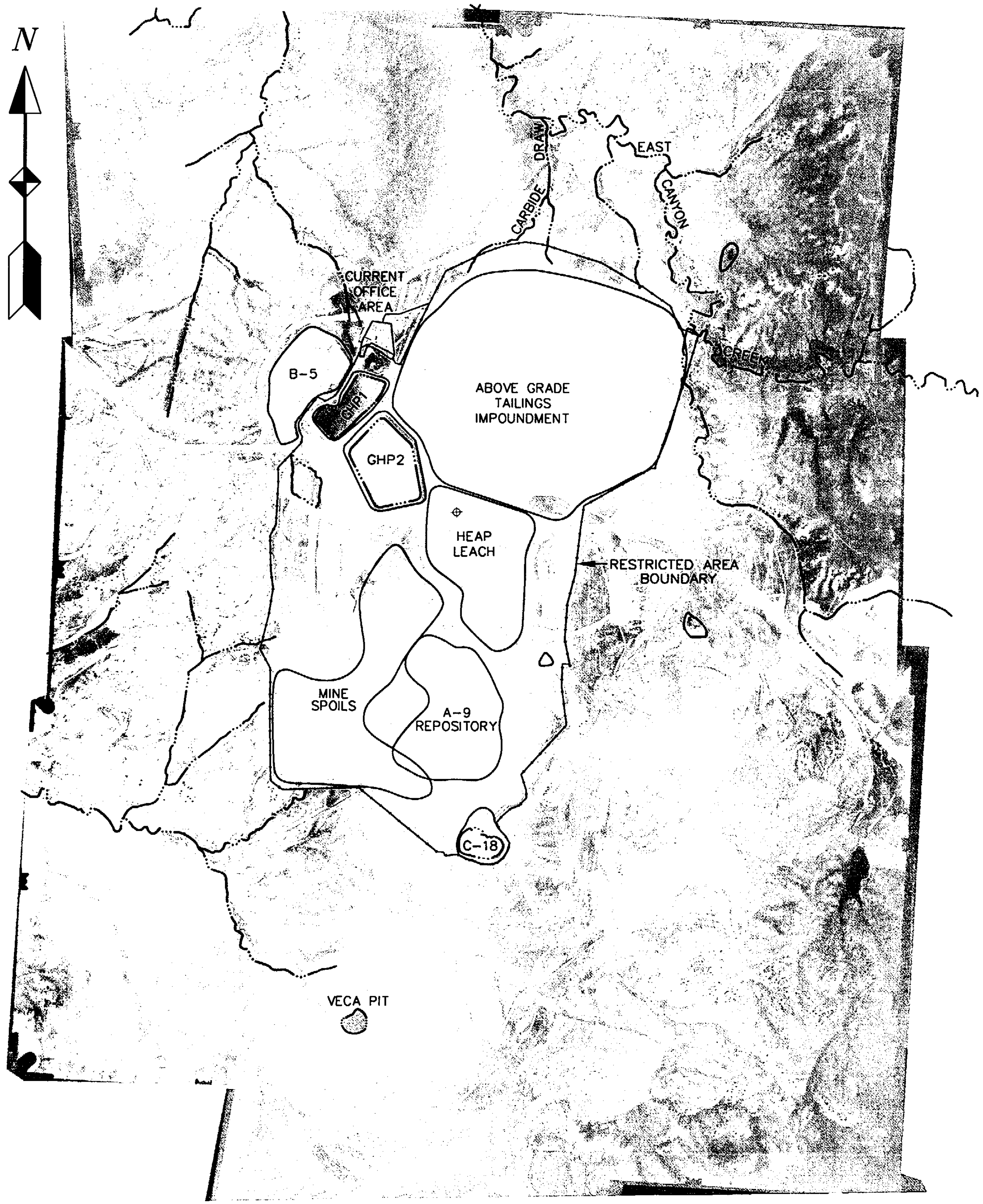
LOCATION MAP

GAS HILLS SITE

APRIL 2001

FIGURE 1.1

FIG1-1.DWG



SCALE: 1" = 1500'

FEATURE	AREA (ACRES)
A-9 REPOSITORY	37
ABOVE GRADE TAILINGS IMPOUNDMENT	175
B-5	18
GHP1	9
GHP2	18
HEAP LEACH	38
OFFICE AREA	3
MINE SPOILS	66
C-18	7
RESTRICTED AREA BOUNDARY	542

LEGEND:

- RESTRICTED AREA BOUNDARY
- FEATURE BOUNDARIES
- DRAINAGEWAYS
- PONDED WATER

UMETCO MINERALS CORPORATION

SITE PLAN MAP

GAS HILLS SITE

APRIL 2001

FIGURE 1.2

FIG1-2.DWG

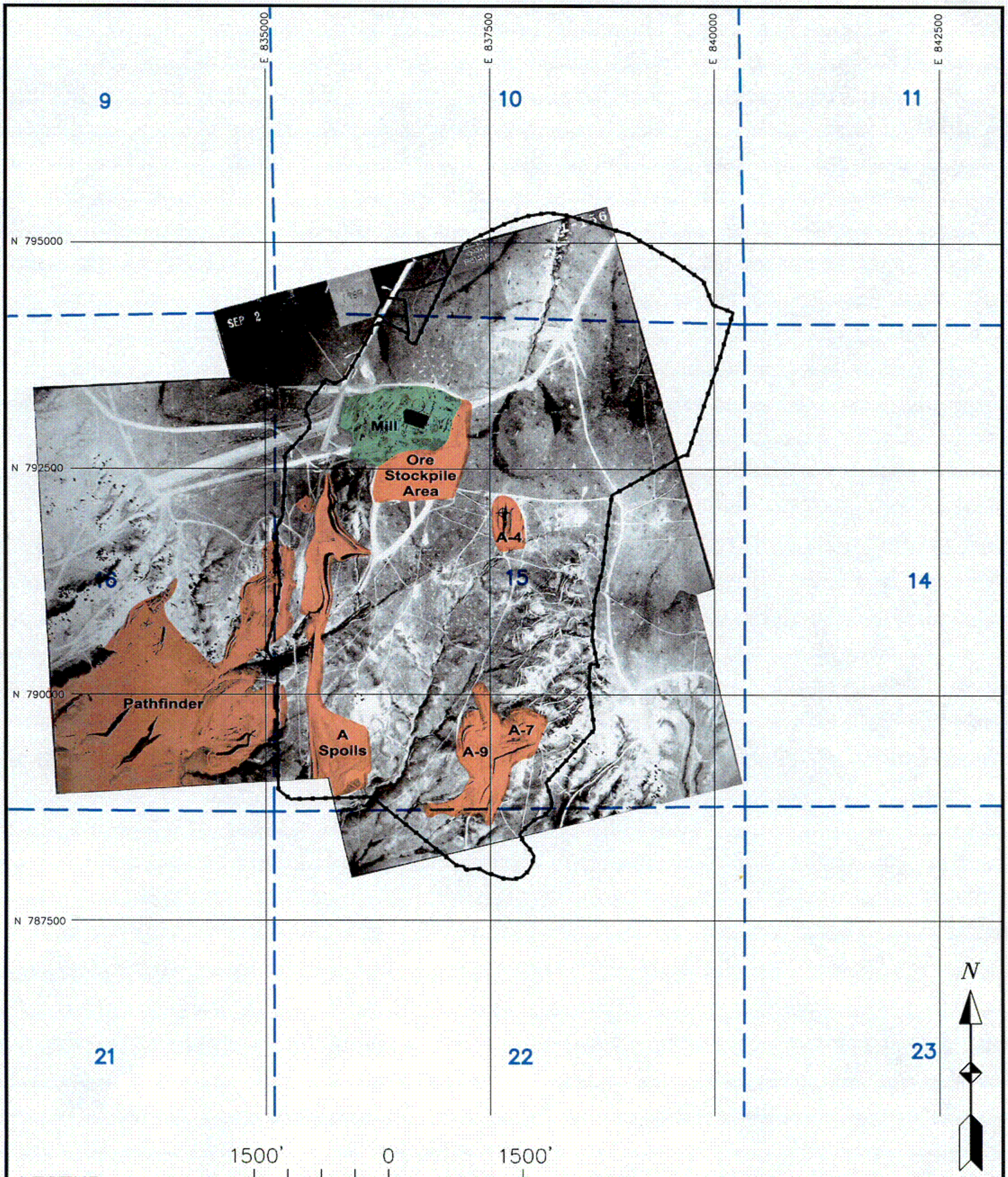
THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED:

FIGURE 1.3:
MINING AREAS
GAS HILLS SITES

WITHIN THIS PACKAGE...OR, BY SEARCHING USING THE DRAWING NUMBER:
FIGURE 1.3

NOTE: Because of this page's large file size, it may be more convenient to copy the file to a local drive and use the Imaging (Wang) viewer, which can be accessed from the Programs/Accessories menu.



LEGEND:

15 SECTION NUMBER

SECTION LINE

RESTRICTED AREA BOUNDARY

MILLING RELATED AREAS

MINING RELATED AREAS

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1959 AERIAL PHOTOGRAPH

GAS HILLS SITE

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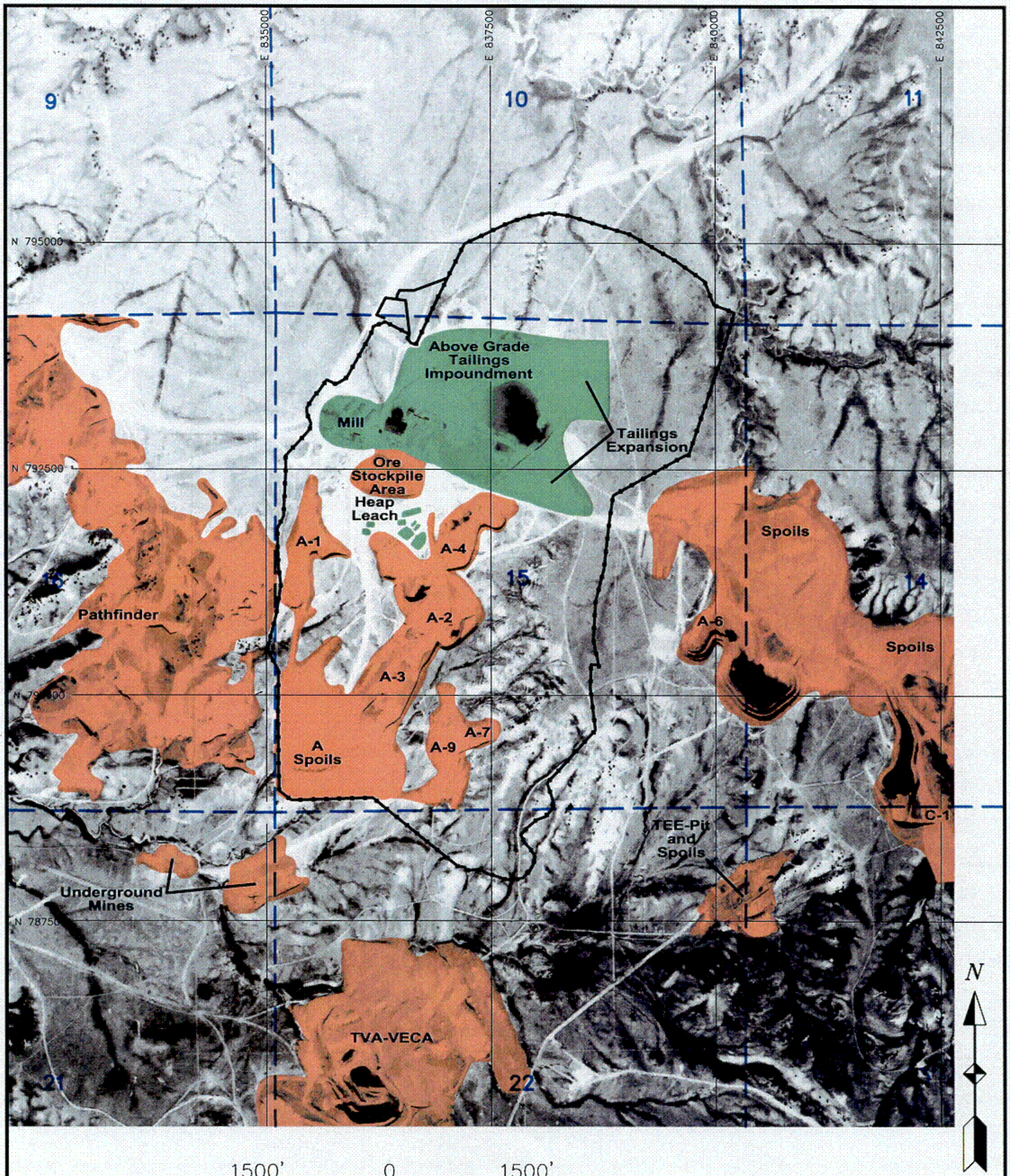
FIGURE 1.4

FIG1-4.DWG

C-1



1500' 0 1500'

SCALE IN FEET

LEGEND:

15 SECTION NUMBER

SECTION LINE

RESTRICTED AREA BOUNDARY

MILLING RELATED AREAS

MINING RELATED AREAS

UMETCO MINERALS CORPORATION

1967 AERIAL PHOTOGRAPH

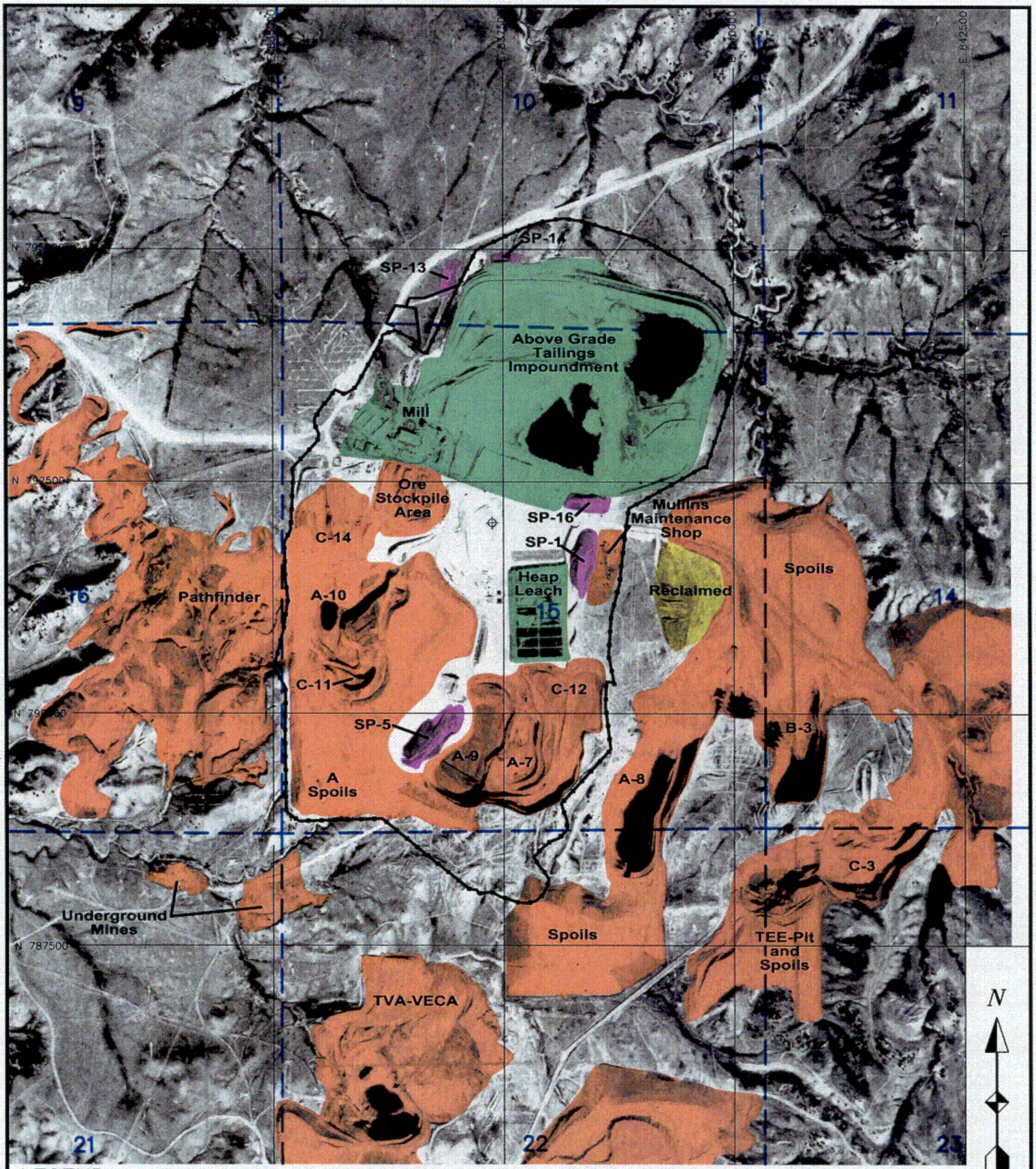
GAS HILLS SITE

APRIL 2001

FIGURE 1.5

FIG1-5.DWG

L-2



LEGEND:

15 SECTION NUMBER

SECTION LINE

RESTRICTED AREA BOUNDARY

MILLING RELATED AREAS

MINING RELATED AREAS

SOIL STOCKPILES

RECLAIMED MINING AREAS

1500' 0 1500'

SCALE IN FEET

UMETCO MINERALS CORPORATION

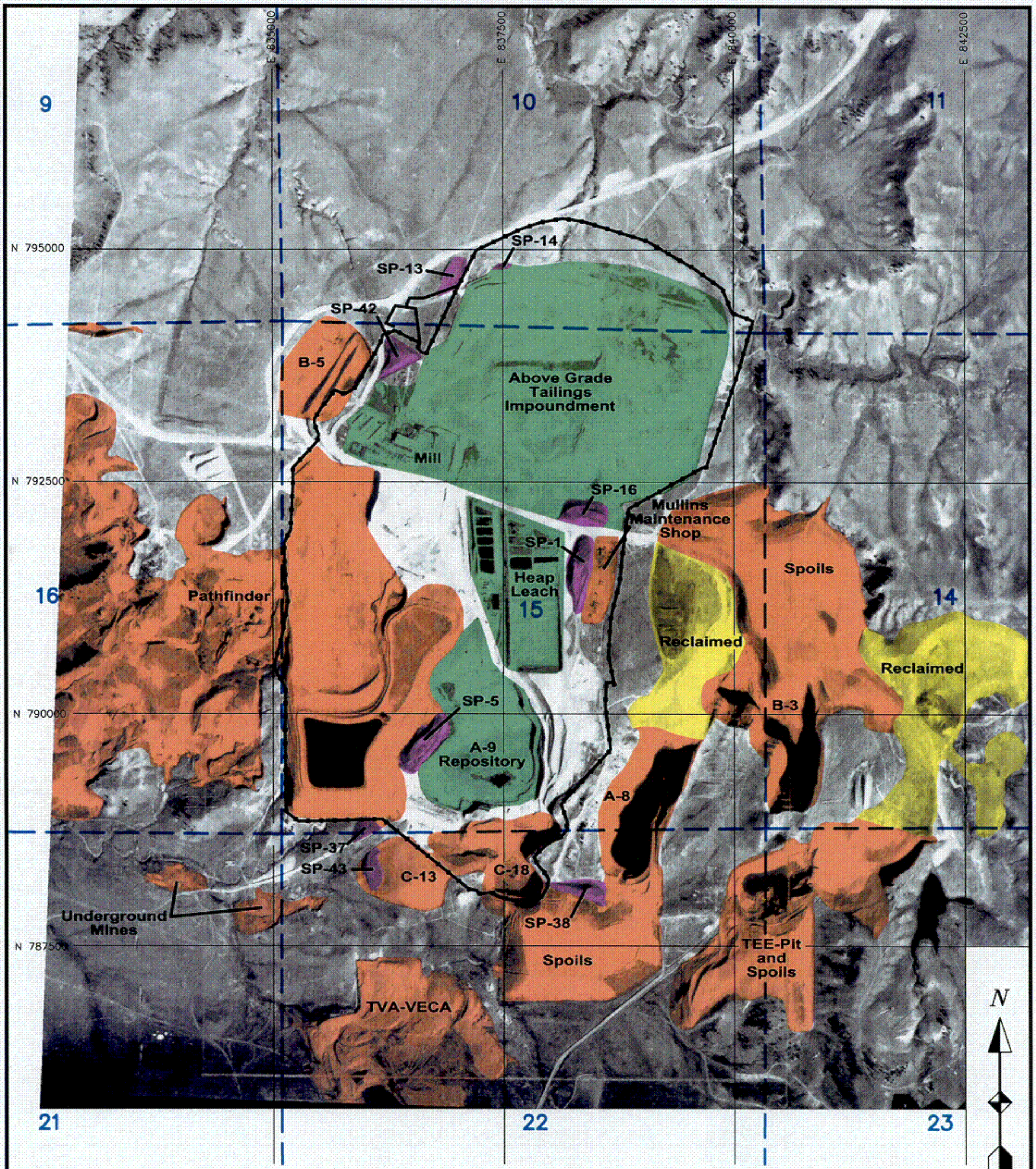
1979 AERIAL PHOTOGRAPH

GAS HILLS SITE

APRIL 2001 FIGURE 1.6

FIG1-6.DWG

L-3



LEGEND:

15 SECTION NUMBER

SECTION LINE

RESTRICTED AREA BOUNDARY

MILLING RELATED AREAS

MINING RELATED AREAS

SOIL STOCKPILES

RECLAIMED MINING AREAS

1500' 0 1500'

SCALE IN FEET

UMETCO MINERALS CORPORATION

1987 AERIAL PHOTOGRAPH

GAS HILLS SITE

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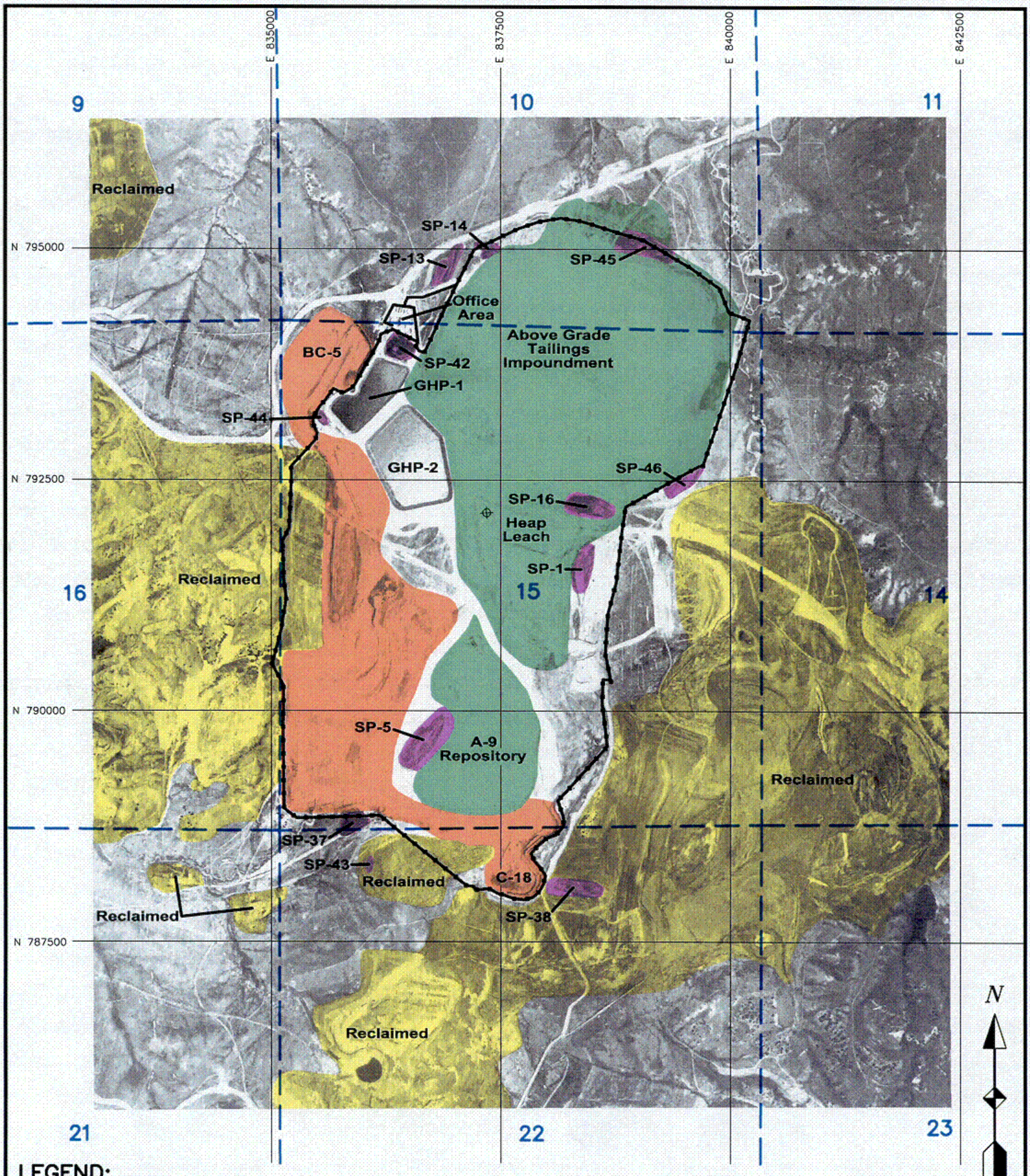
FIGURE 1.7

FIG1-7.DWG

C-4



LEGEND:

15	SECTION NUMBER
— — —	SECTION LINE
-•-•-•-	RESTRICTED AREA BOUNDARY
(green)	MILLING RELATED AREAS
(orange)	MINING RELATED AREAS
(purple)	SOIL STOCKPILES
(yellow)	RECLAIMED MINING AREAS

1500' 0 1500'

SCALE IN FEET

UMETCO MINERALS CORPORATION

1997 AERIAL PHOTOGRAPH

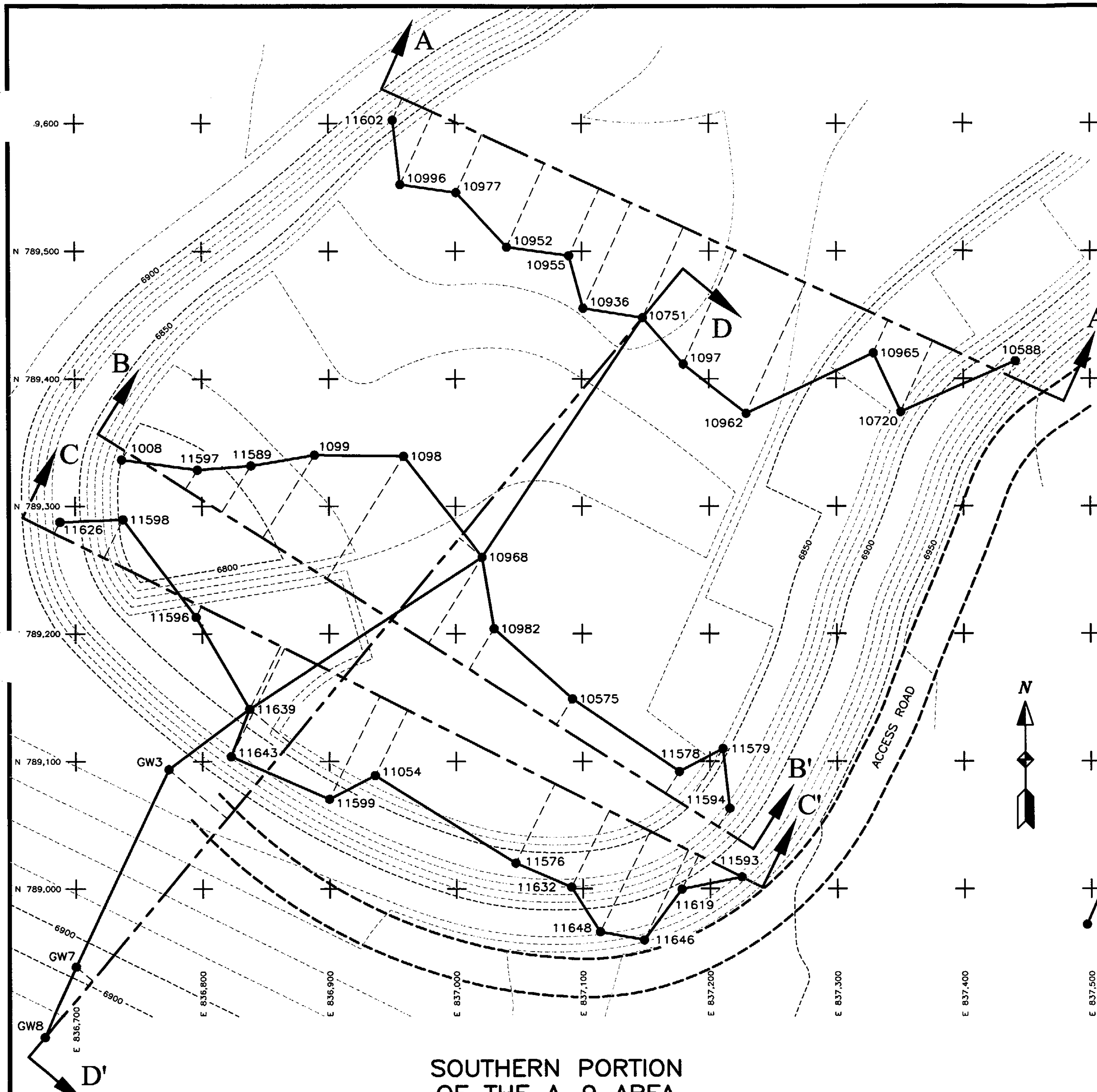
GAS HILLS SITE

APRIL 2001

FIGURE 1.8

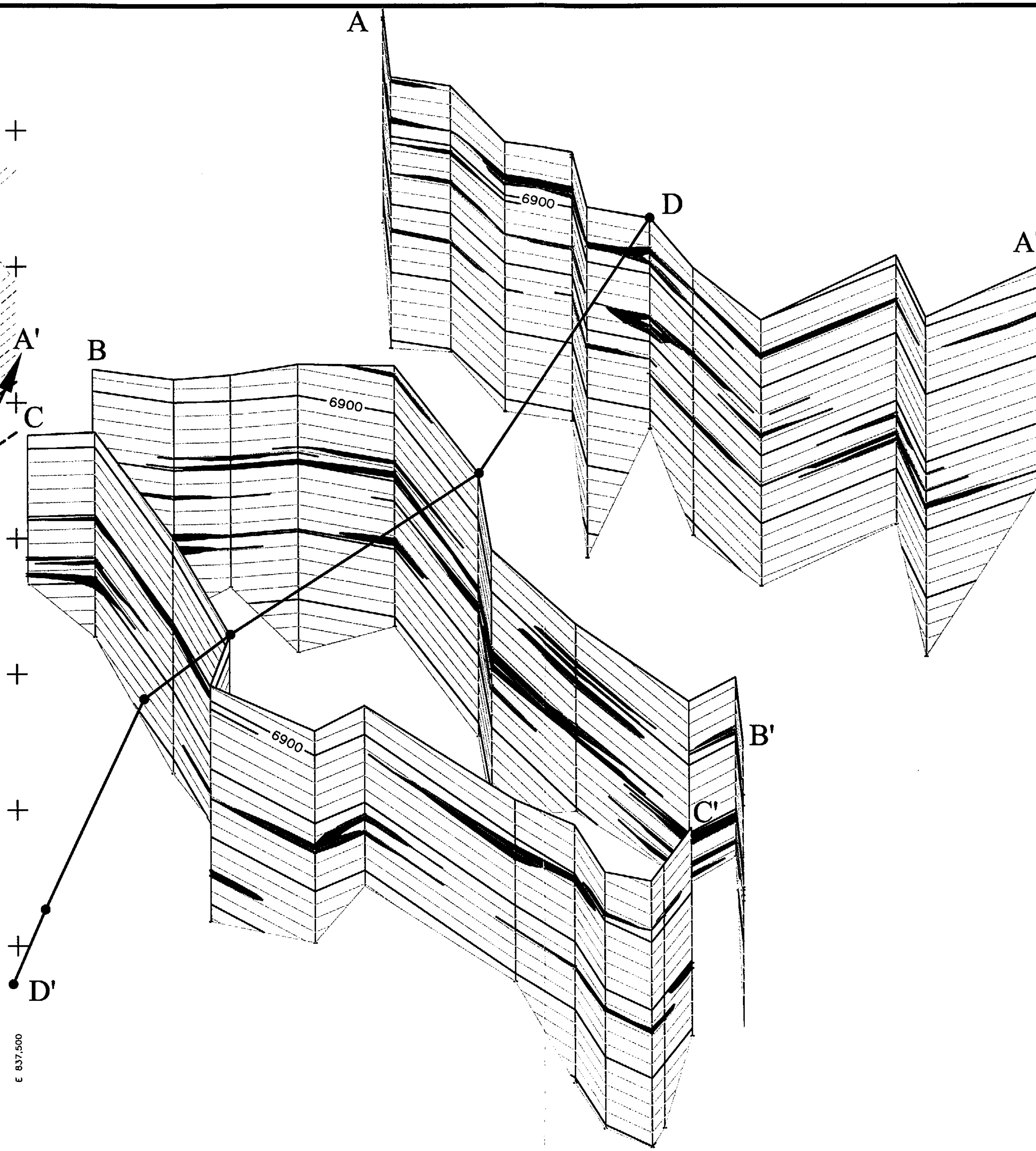
FIG1-8.DWG

C-5



SOUTHERN PORTION OF THE A-9 AREA

SCALE: 1" = 100'



FENCE DIAGRAMS

SCALE: 1" = 100'

LEGEND:

- ● 1098 — BOREHOLE LOCATION
- URANIUM ROLL FRONT
- 6900 CONTOUR LINE (50', 10')
- PROJECTION LINE
- CROSS SECTION LINE
- N 789,100 + — GAS HILLS 100' SITE GRID

NOTES:

1). SEE FIGURES 1.10, 1.11, 1.12 AND 1.13 FOR PROJECTED BOREHOLE CROSS SECTIONS WITH ROLL FRONTS.

2). INFORMATION DIGITIZED FROM THE A-9 PIT MINE PLAN (DRAWING# A4-019-3), REVISION DATE OF 10-13-75.

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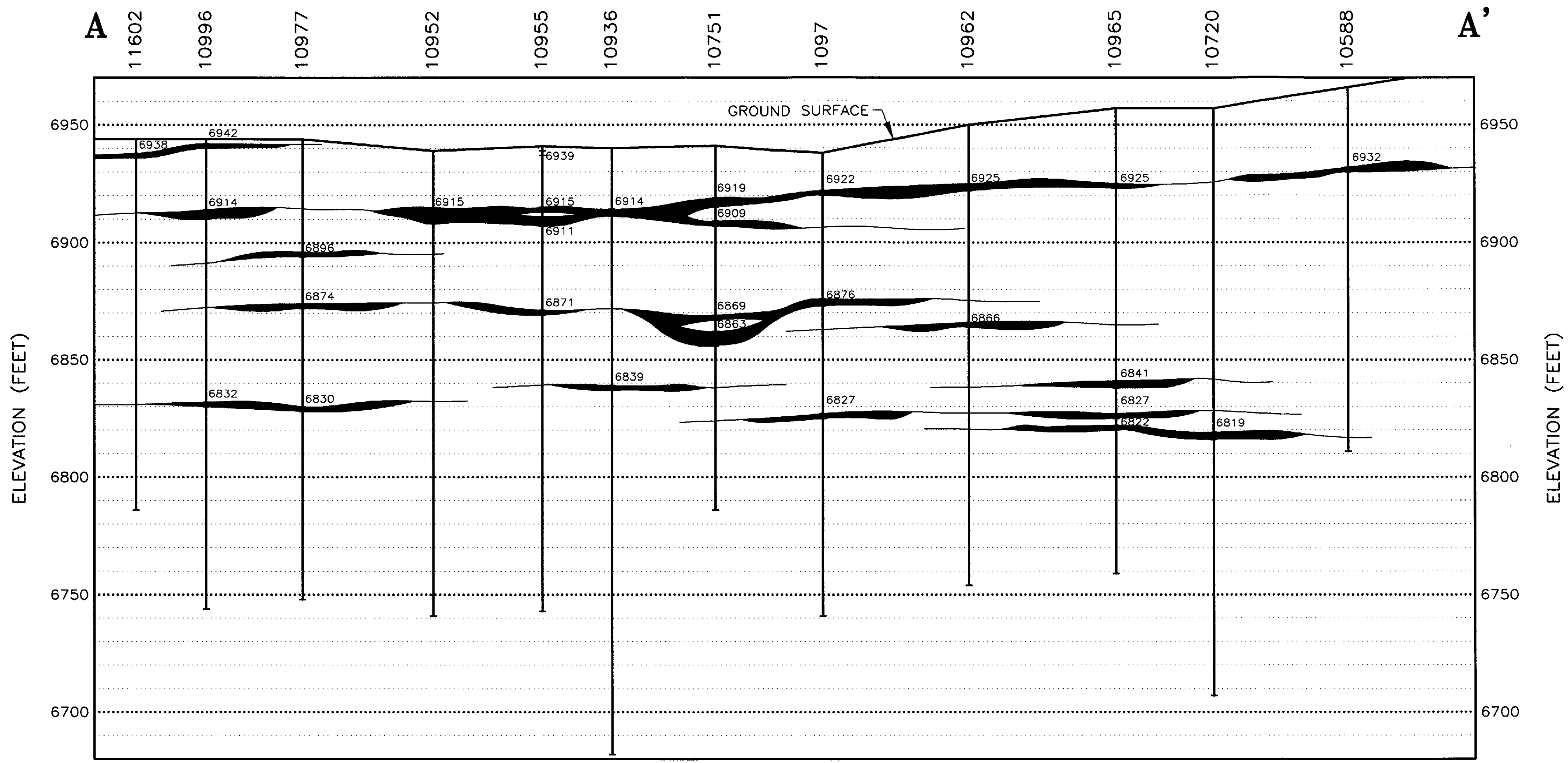
DISTRIBUTION OF ROLL FRONTS IN THE SOUTHERN PORTION OF THE A-9 AREA

GAS HILLS SITE

APRIL 2001

FIGURE 1.9

FIG1-9.DWG



CROSS SECTION A–A'

SCALE: 1" = 50'

LEGEND:

- 1097 ← BOREHOLE DESIGNATION
- GROUND SURFACE
- CONTACT ELEVATION (6869)
- URANIUM ROLL FRONT (SEE NOTE 2)

NOTES:

1). SEE FIGURE 1.9 FOR SECTION A–A' LOCATION.

2). URANIUM DEPOSITS WERE BASED ON PERCENTAGES LISTED ON THE A–9 PIT MINE PLAN (DWG# A4–019–3).

UMETCO MINERALS CORPORATION

A–9 AREA

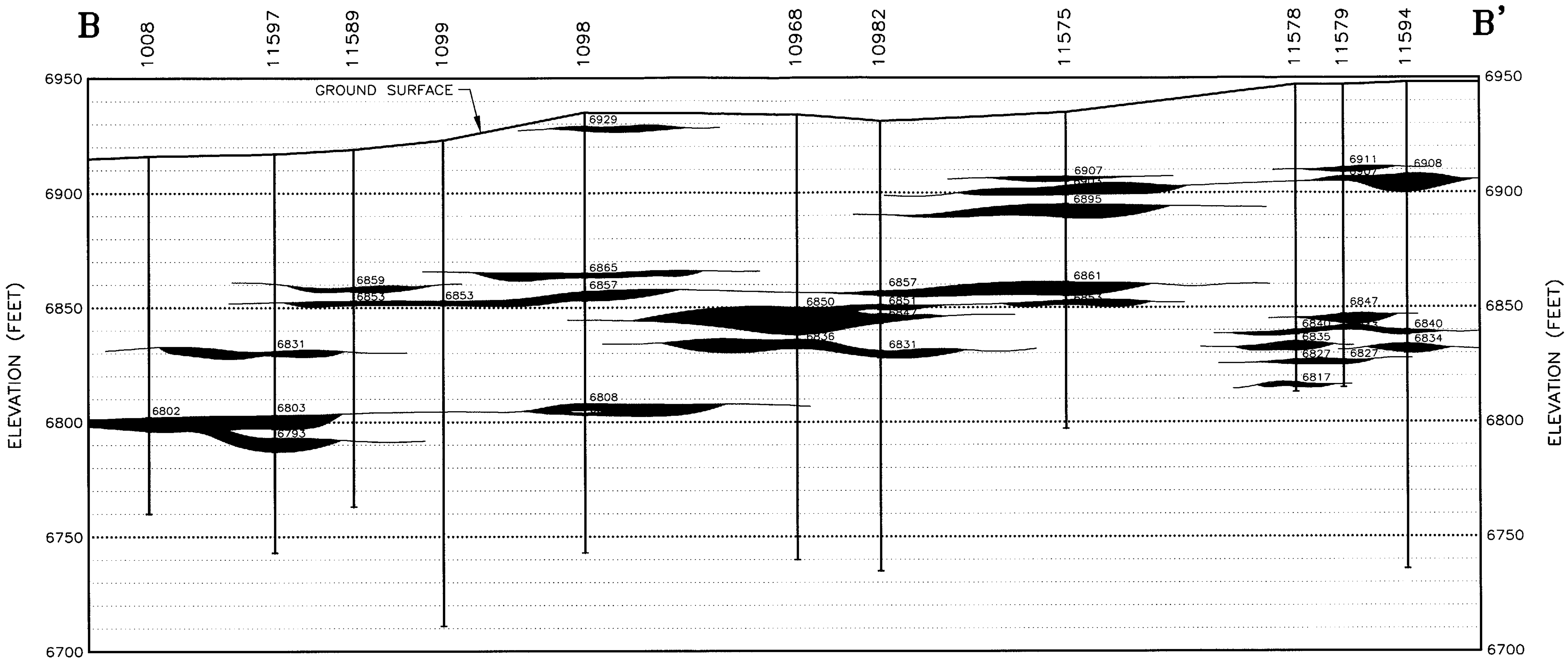
CROSS SECTION A–A'

GAS HILLS SITE

APRIL 2001

FIGURE 1.10

FIG1–10.DWG



CROSS SECTION B–B'

SCALE: 1" = 50'

LEGEND:

1099 ← BOREHOLE DESIGNATION

GROUND SURFACE

CONTACT ELEVATION

6869 URANIUM ROLL FRONT (SEE NOTE 2)

NOTES:

1). SEE FIGURE 1.9 FOR SECTION B–B' LOCATION.

2). URANIUM DEPOSITS WERE BASED ON PERCENTAGES LISTED ON THE A–9 PIT MINE PLAN (DWG# A4–019–3).

UMETCO MINERALS CORPORATION

A–9 AREA

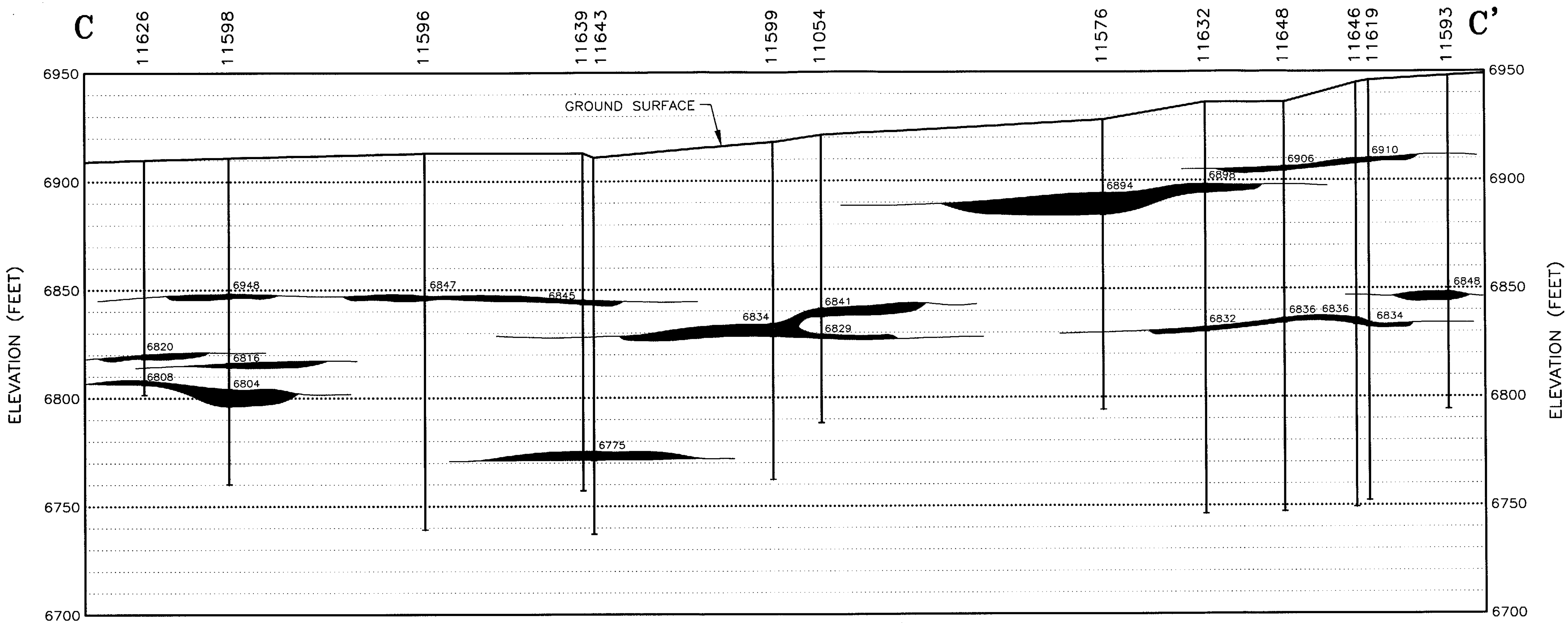
CROSS SECTION B–B'

GAS HILLS SITE

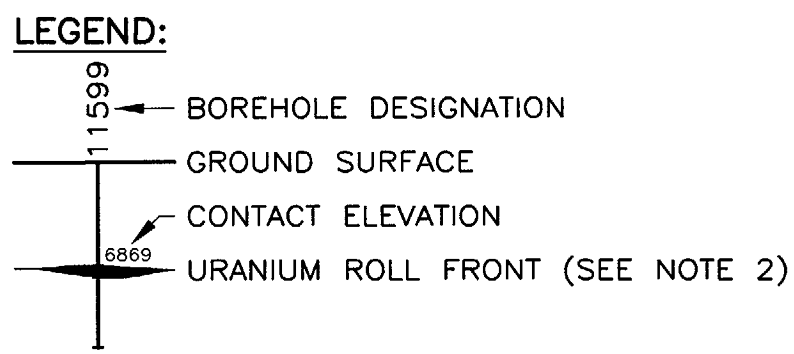
APRIL 2001

FIGURE 1.11

FIG1–11.DWG



CROSS SECTION C–C'
SCALE: 1" = 50'



NOTES:

1). SEE FIGURE 1.9 FOR SECTION C–C' LOCATION.
2). URANIUM DEPOSITS WERE BASED ON PERCENTAGES LISTED ON THE A–9 PIT MINE PLAN (DWG# A4–019–3).

UMETCO MINERALS CORPORATION

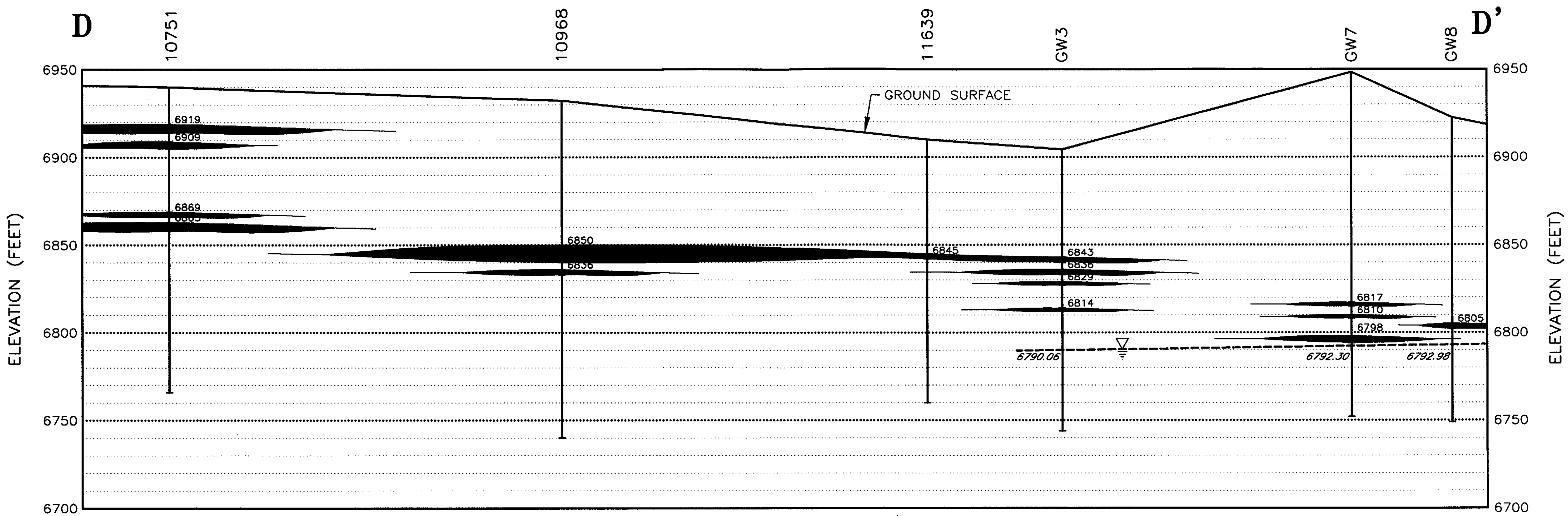
A–9 AREA

CROSS SECTION C–C'

GAS HILLS SITE

APRIL 2001 FIGURE 1.12

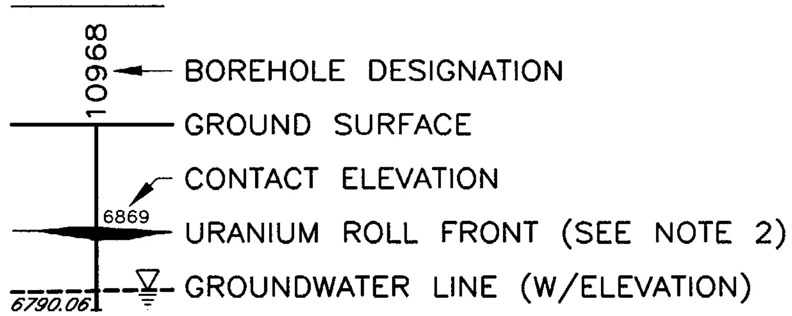
FIG1–12.DWG



CROSS SECTION D–D'

SCALE: 1" = 60'

LEGEND:



NOTES:

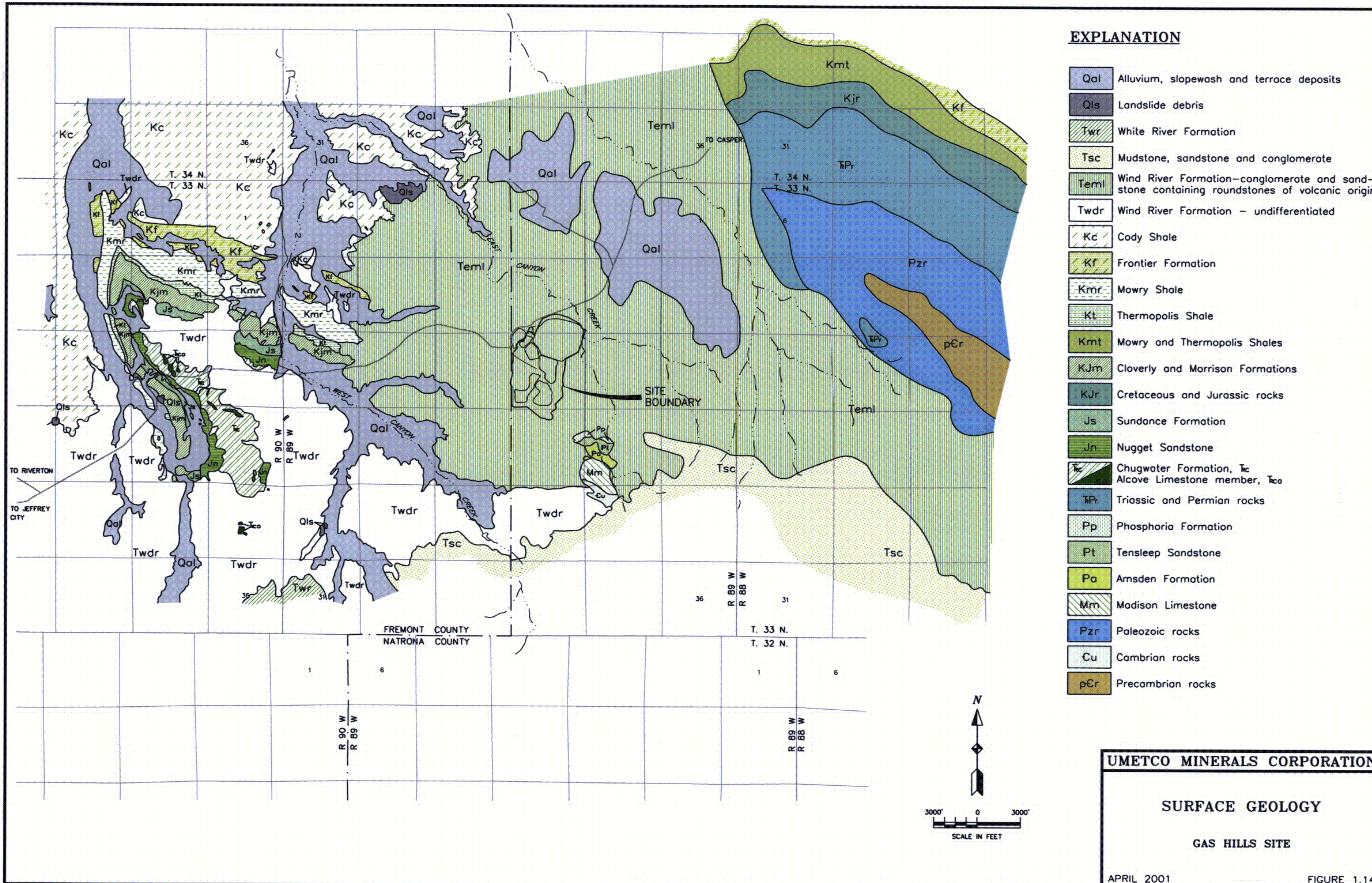
1). SEE FIGURE 1.9 FOR SECTION D–D' LOCATION.

2). URANIUM DEPOSITS WERE BASED ON PERCENTAGES LISTED ON THE A–9 PIT MINE PLAN (DWG# A4–019–3), AND FROM GAMMA SURVEY LOGS FROM GW3, GW7 AND GW8.

3). GROUNDWATER ELEVATIONS BASED ON DATA COLLECTED SECOND QUARTER 1998.

UMETCO MINERALS CORPORATION	
A–9 AREA CROSS SECTION D–D' GAS HILLS SITE	
APRIL 2001	FIGURE 1.13

FIG1–13.DWG



UMETCO MINERALS CORPORATION

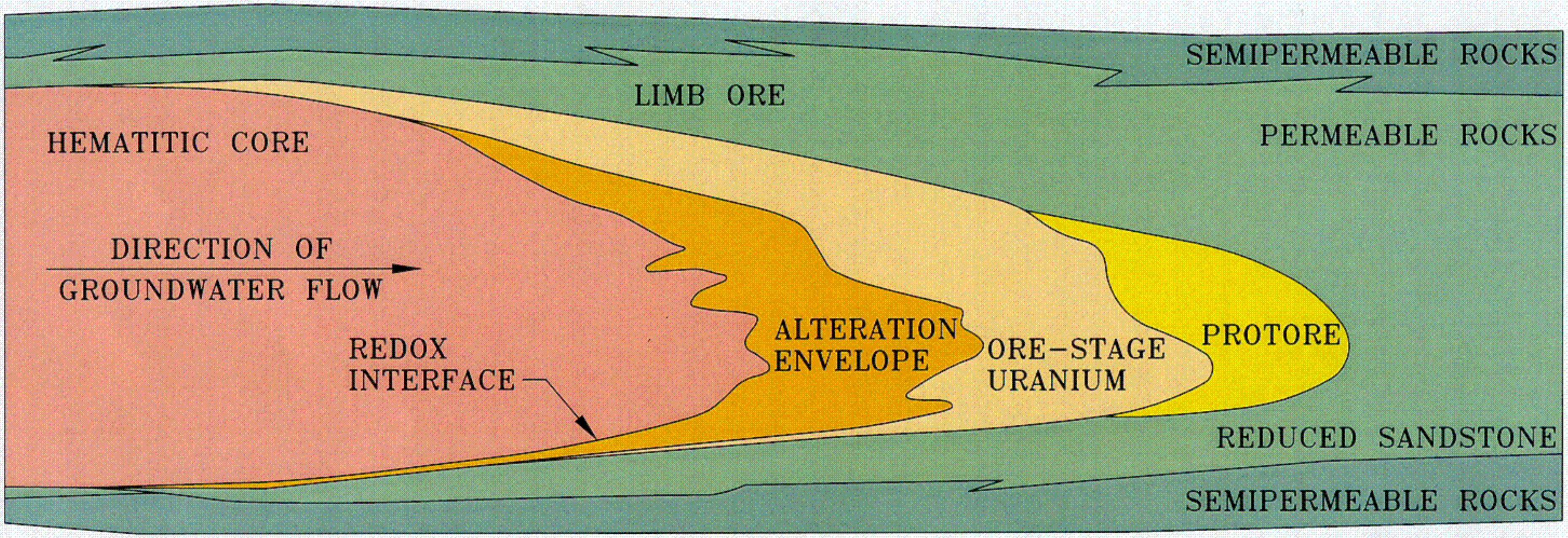
SURFACE GEOLOGY

GAS HILLS SITE

APRIL 2001

FIGURE 1.14

FIG1-15.DWG



Hematitic Core	Alteration Envelope	Ore-Stage Uranium	Protore	Reduced Sandstone
Hematite	Siderite	Uraninite	Molybdenite	Pyrite
Magnetite	Sulfur-S°	Pyrite	Pyrite	Jordisite
	Ferroselite	FeS	FeS	Calcite
	Goethite	Selenium	Jordisite	
		Ilsemanite	Calcite	

UMETCO MINERALS CORPORATION

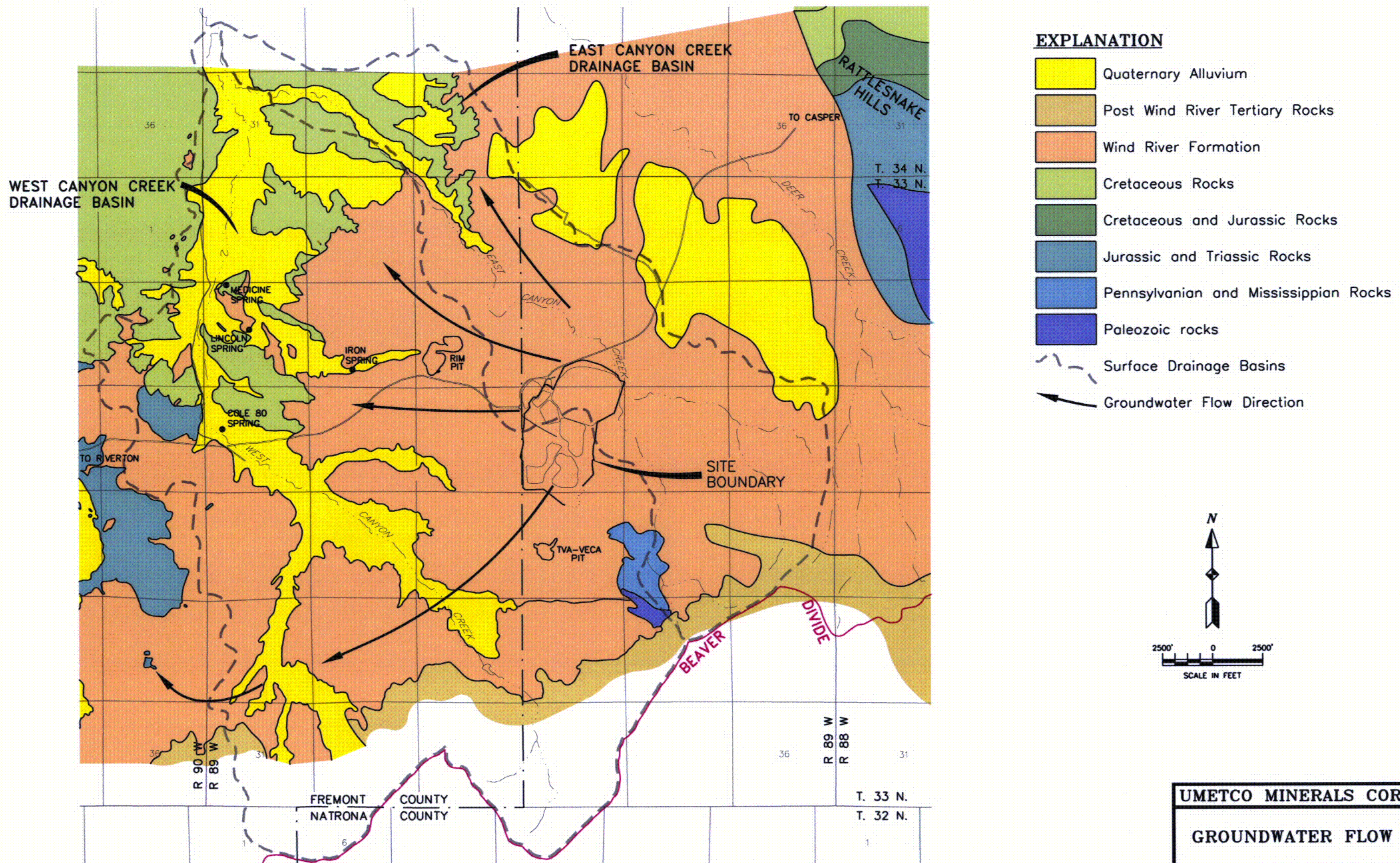
CONCEPTUAL MODEL OF A
URANIUM ROLL FRONT DEPOSIT

GAS HILLS SITE

APRIL 2001

FIGURE 1.15

C-7



UMETCO MINERALS CORPORATION

GROUNDWATER FLOW SYSTEM

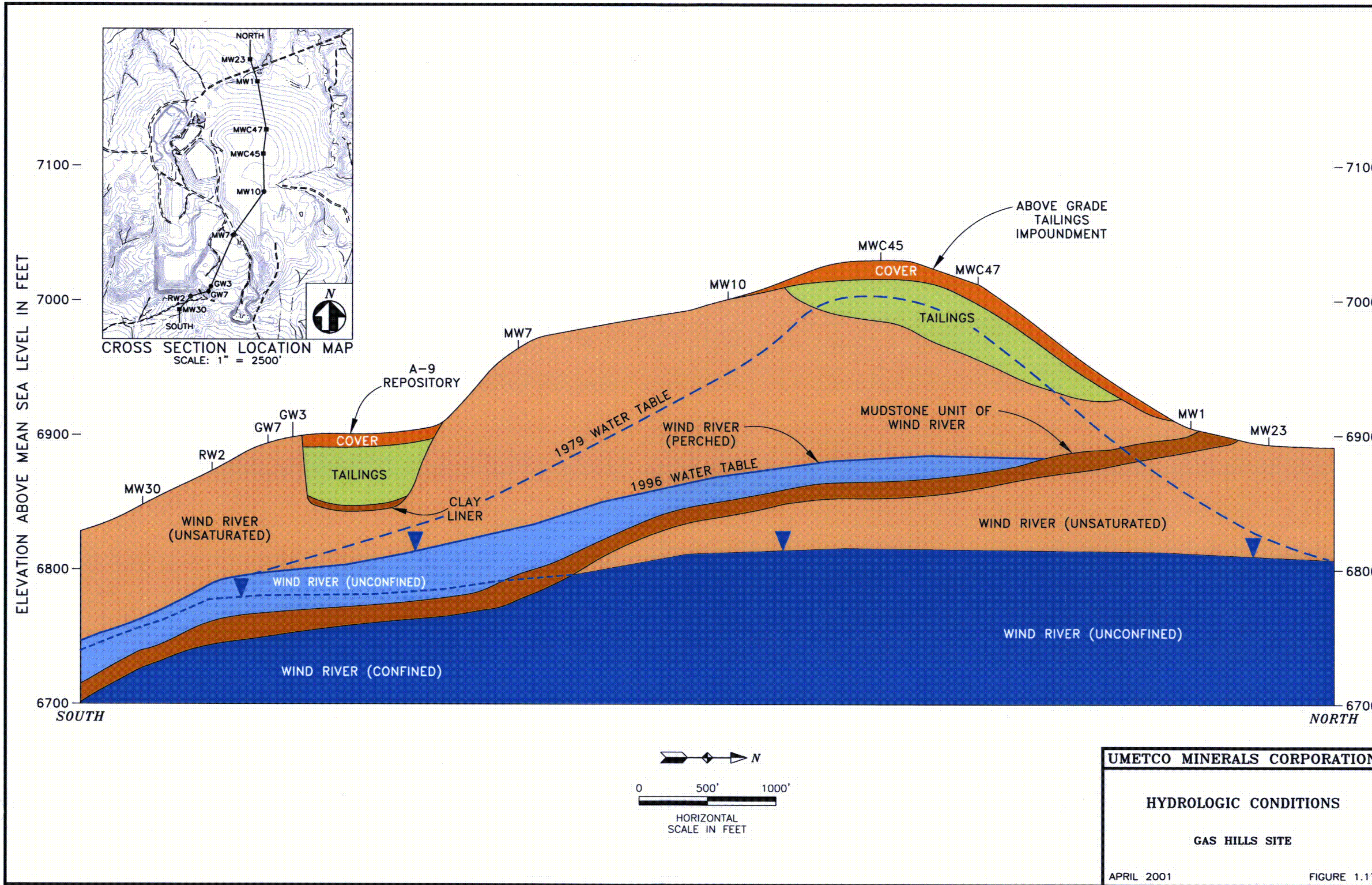
WIND RIVER BASIN

GAS HILLS SITE

APRIL 2001 FIGURE 1.16

Fig1-16.Dwg

C-8



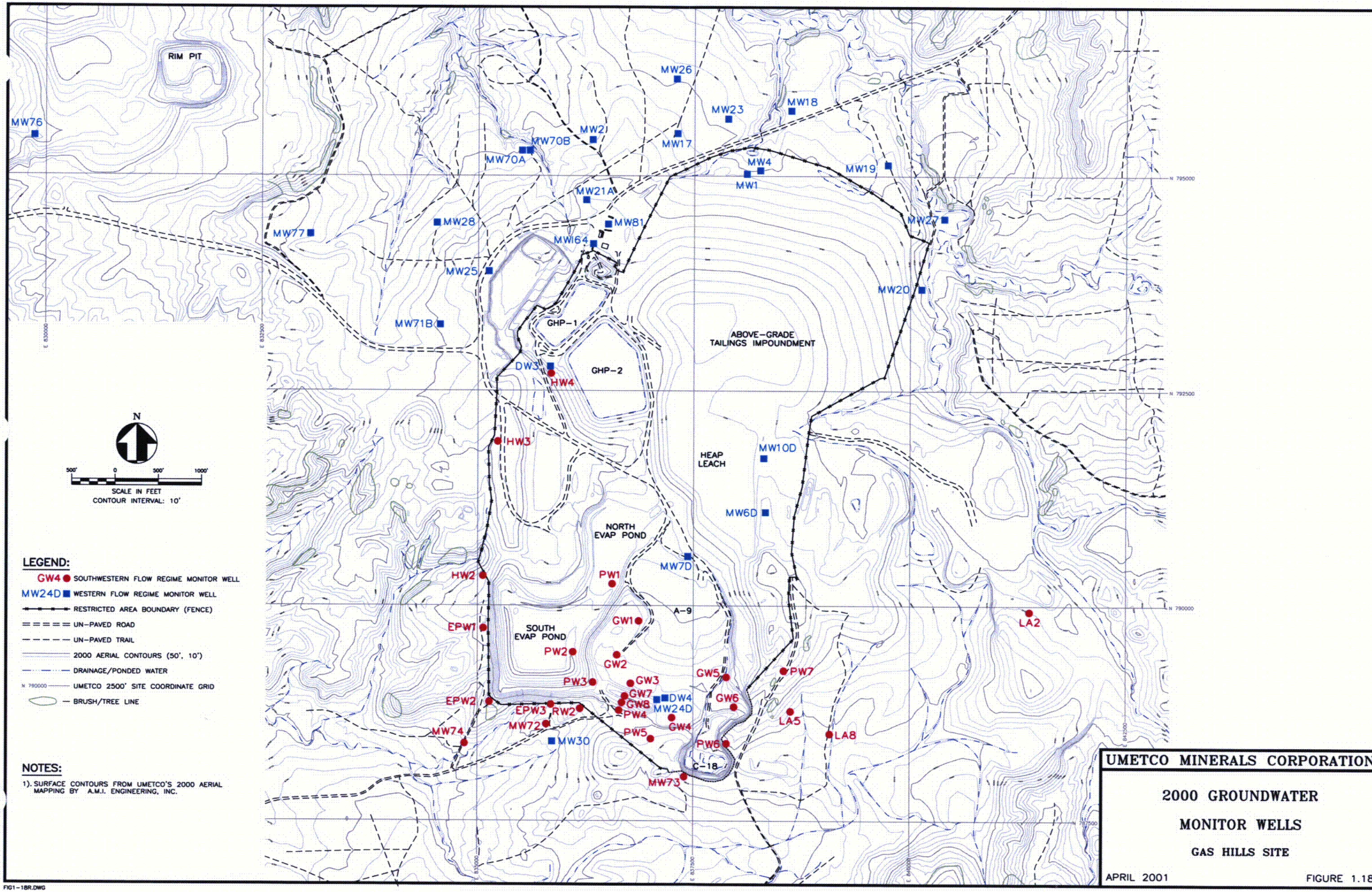
UMETCO MINERALS CORPORATION

HYDROLOGIC CONDITIONS

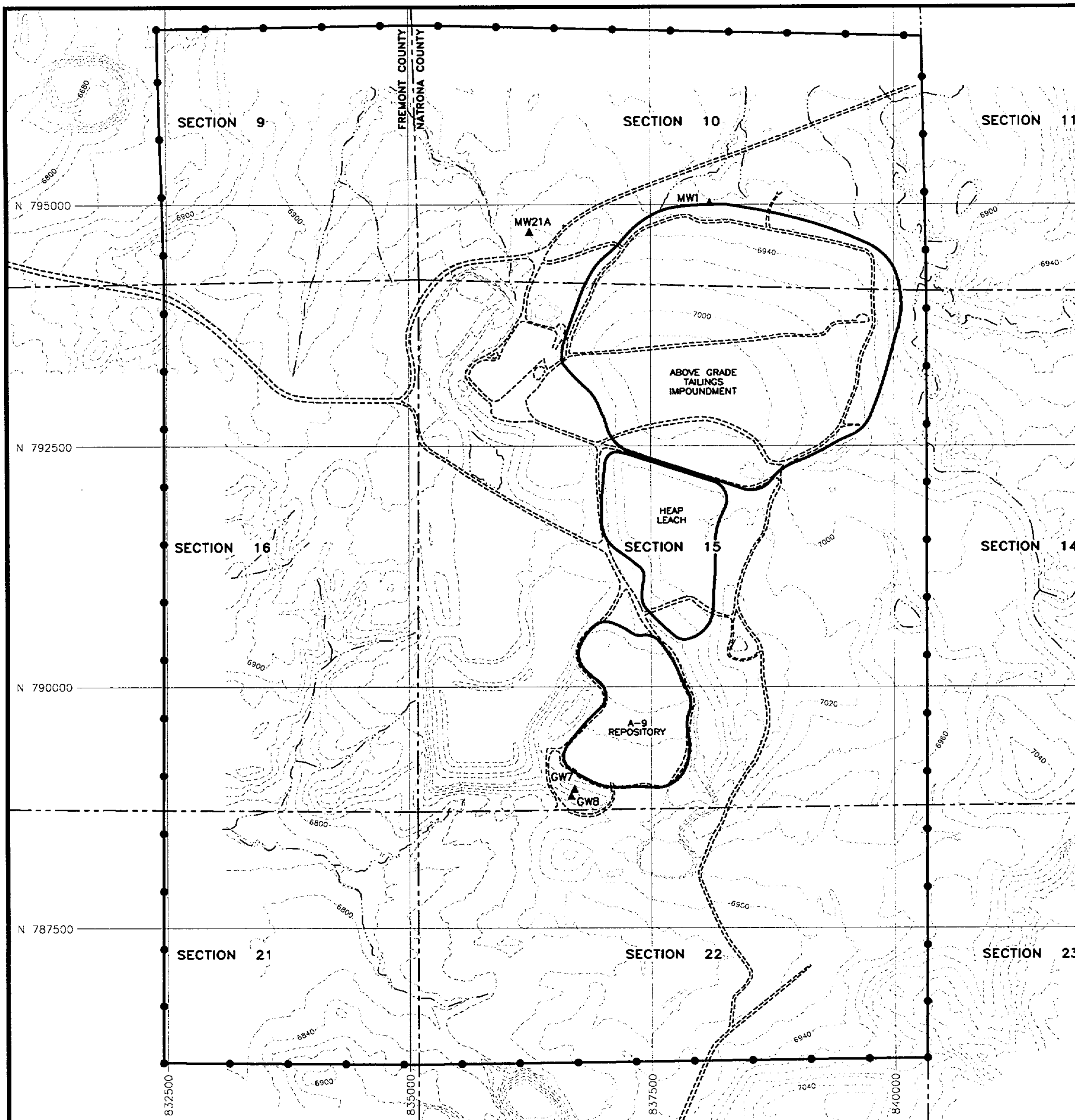
GAS HILLS SITE

APRIL 2001

FIGURE 1.17


RIM PIT
MW76
MW26
MW23
MW18
MW2
MW70B
MW70A
MW17
MW4
MW1
MW19
MW21A
MW28
MW81
MW77
MW64
MW27
MW25
MW20
MW71B
GHP-1
GHP-2
ABOVE-GRADE
TAILINGS IMPOUNDMENT
DW3
HW4
HW3
HEAP
LEACH
MW10D
MW6D
NORTH
EVAP POND
MW7D
HW2
PW1
A-9
GW1
EPW1
SOUTH
EVAP POND
PW2
GW2
GW5
PW7
PW3
GW3
GW7
GW8
DW4
MW24D
GW6
EPW2
EPW3
RW2
PW4
GW4
LA5
LA8
LA2
MW72
MW74
MW30
PW5
PW6
C-18
MW73
N 795000
N 792500
N 790000
N 787500
E 830000
E 832500
E 835000
E 837500
E 840000
E 842500
N
500' 0 500' 1000'
SCALE IN FEET
CONTOUR INTERVAL: 10'
LEGEND:
GW4 SOUTHWESTERN FLOW REGIME MONITOR WELL
MW24D WESTERN FLOW REGIME MONITOR WELL
RESTRICTED AREA BOUNDARY (FENCE)
UN-PAVED ROAD
UN-PAVED TRAIL
2000 AERIAL CONTOURS (50', 10')
DRAINAGE/PONDED WATER
N 790000 UMETCO 2500' SITE COORDINATE GRID
BRUSH/TREE LINE
NOTES:
1). SURFACE CONTOURS FROM UMETCO'S 2000 AERIAL MAPPING BY A.M.I. ENGINEERING, INC.
FIG1-18R.DWG
UMETCO MINERALS CORPORATION
2000 GROUNDWATER
MONITOR WELLS
GAS HILLS SITE
APRIL 2001
FIGURE 1.18

C-10



NOTE:

1). LONG TERM CARE BOUNDARY INCLUDES ALL OF SECTION 15, THE NORTH 1/2 OF SECTION 22, THE NORTHEAST 1/4 OF SECTION 21, THE EAST 1/2 OF SECTION 16, THE SOUTHEAST 1/4 OF SECTION 9 AND THE SOUTH 1/2 OF SECTION 10, ALL LOCATED IN TOWNSHIP 33 NORTH, RANGE 89 WEST OF THE SIXTH PRINCIPAL MERIDIAN. SAID LAND CONTAINS 1920 ACRES MORE OR LESS.

LEGEND:

- GW8 ▲ – POINT OF COMPLIANCE MONITOR WELLS
- PROPOSED LONG TERM CARE BOUNDARY
- SECTION LINE
- N 787500 — UMETCO SITE 2500' GRID SYSTEM
- 7000 — SURFACE CONTOUR LINE (20')
- UNPAVED ROAD
- SURFACE WATER

N

750' 0 750'

SCALE IN FEET

CONTOUR INTERVAL : 20'

UMETCO MINERALS CORPORATION

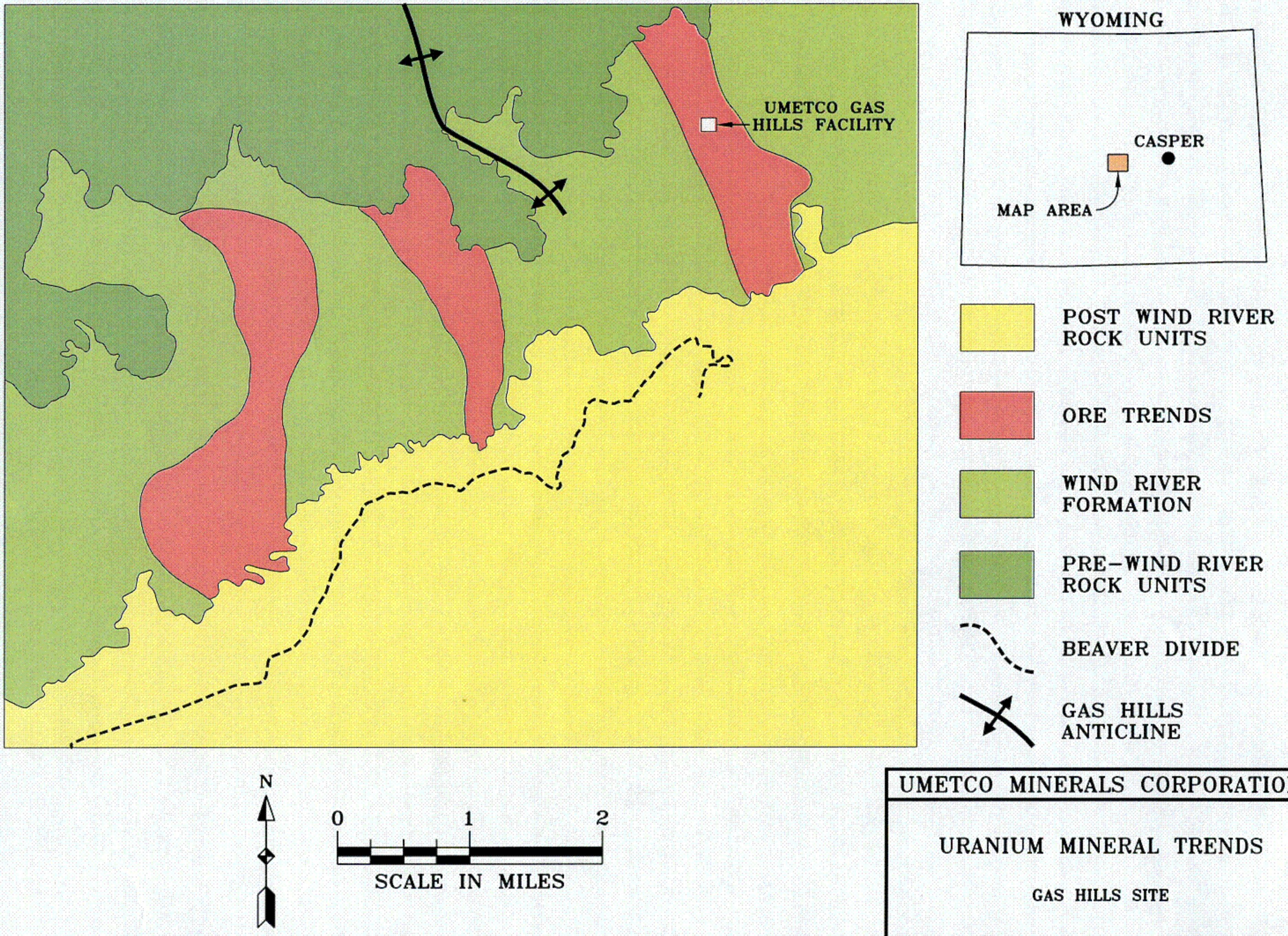
LONG TERM CARE BOUNDARY

GAS HILLS SITE

APRIL 2001

FIGURE 1.19

FIG1-19.DWG



UMETCO MINERALS CORPORATION

URANIUM MINERAL TRENDS

GAS HILLS SITE

APRIL 2001

FIGURE 2.1

C-11

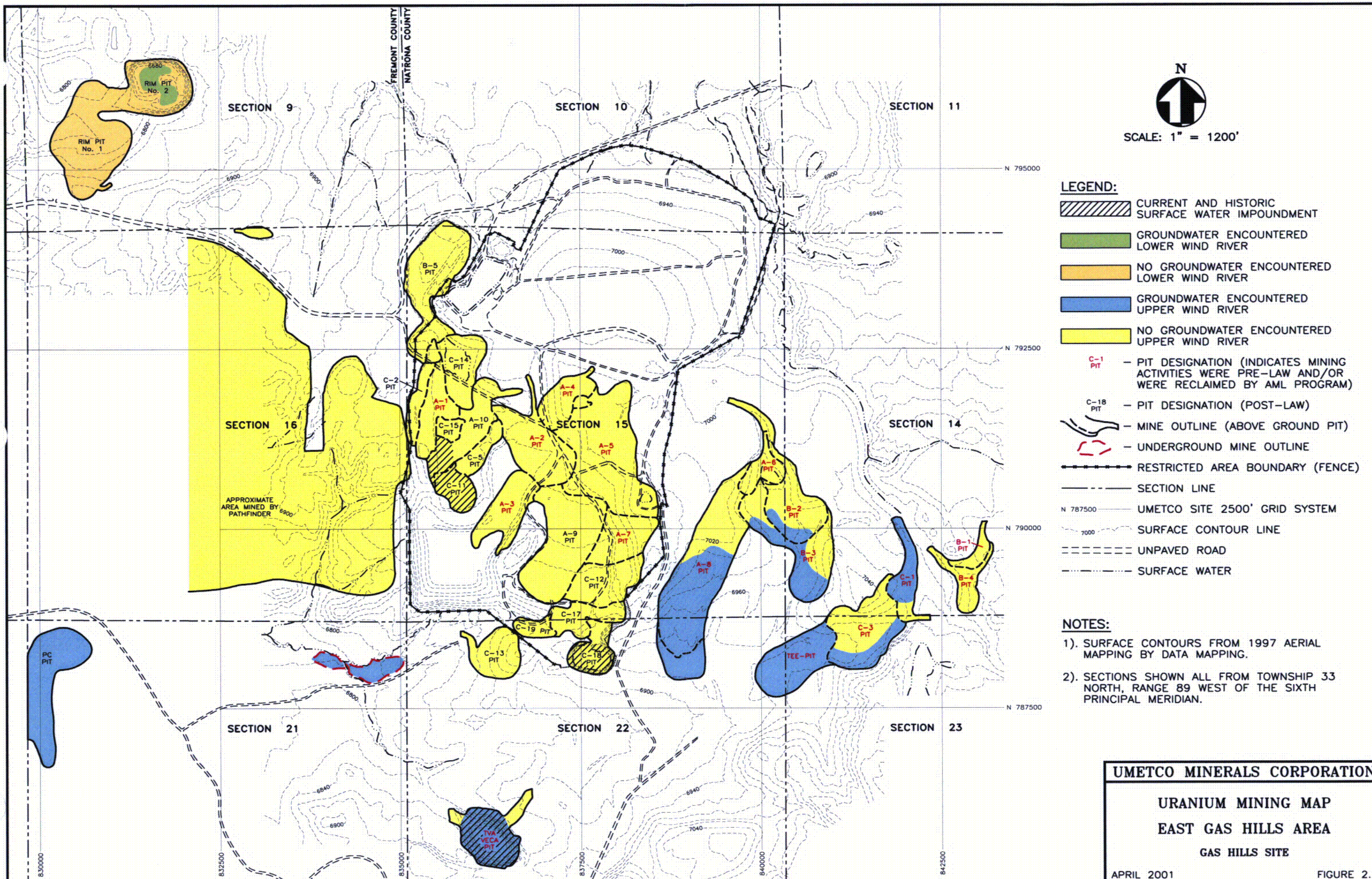
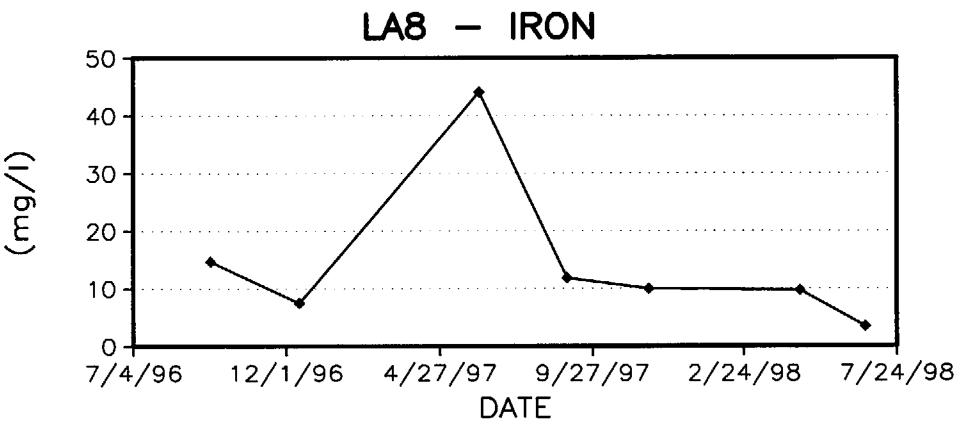
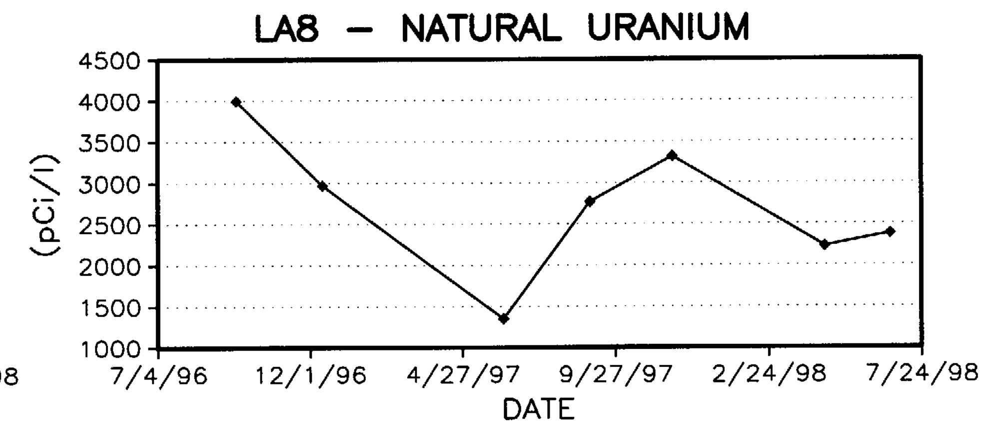
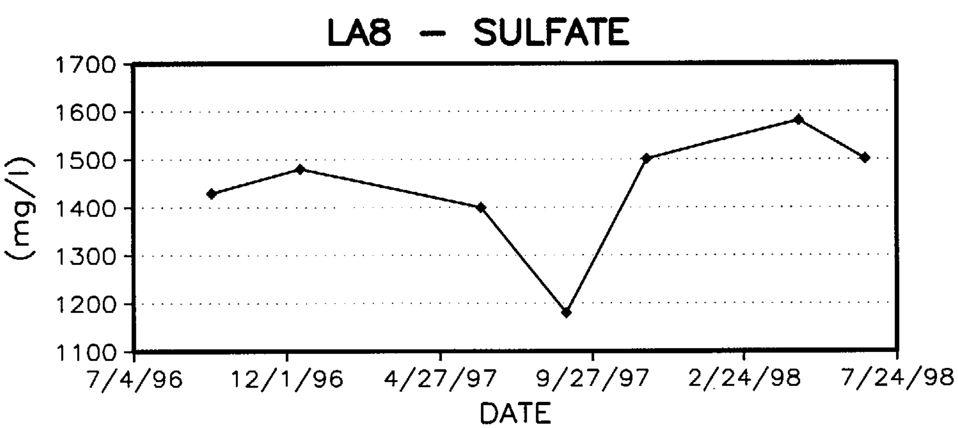
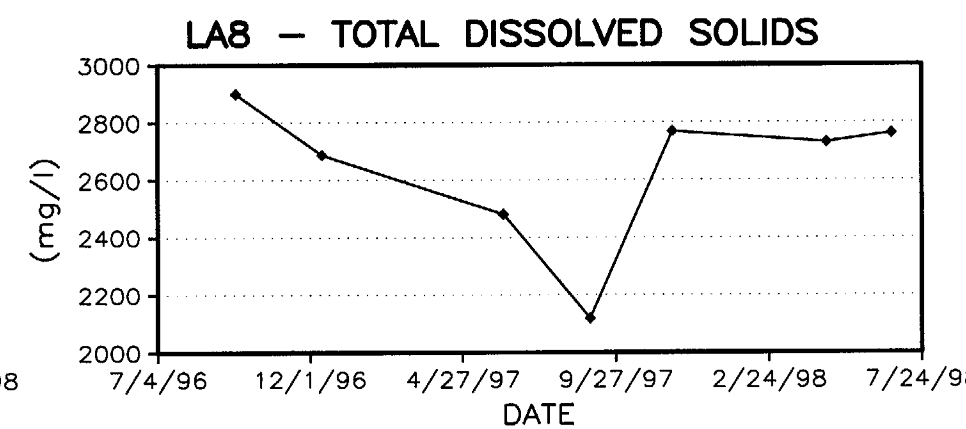

N
SCALE: 1" = 1200'
SECTION 9
SECTION 10
SECTION 11
SECTION 14
SECTION 15
SECTION 16
SECTION 21
SECTION 22
SECTION 23
FREMONT COUNTY
NATRONA COUNTY
RIM PIT No. 2
RIM PIT No. 1
APPROXIMATE AREA MINED BY PATHFINDER
B-5 PIT
C-14 PIT
C-2 PIT
A-1 PIT
C-15 PIT
A-10 PIT
C-5 PIT
C-11 PIT
A-4 PIT
A-2 PIT
A-5 PIT
A-3 PIT
A-9 PIT
A-7 PIT
C-12 PIT
C-17 PIT
C-19 PIT
C-13 PIT
C-18 PIT
A-6 PIT
B-2 PIT
B-3 PIT
A-8 PIT
C-1 PIT
C-3 PIT
TEE-PIT
B-1 PIT
B-4 PIT
PC PIT
TVA VECA PIT
N 795000
N 792500
N 790000
N 787500
E 830000
E 832500
E 835000
E 837500
E 840000
E 842500
LEGEND:
CURRENT AND HISTORIC SURFACE WATER IMPOUNDMENT
GROUNDWATER ENCOUNTERED LOWER WIND RIVER
NO GROUNDWATER ENCOUNTERED LOWER WIND RIVER
GROUNDWATER ENCOUNTERED UPPER WIND RIVER
NO GROUNDWATER ENCOUNTERED UPPER WIND RIVER
C-1 PIT – PIT DESIGNATION (INDICATES MINING ACTIVITIES WERE PRE-LAW AND/OR WERE RECLAIMED BY AML PROGRAM)
C-18 PIT – PIT DESIGNATION (POST-LAW)
– MINE OUTLINE (ABOVE GROUND PIT)
– UNDERGROUND MINE OUTLINE
RESTRICTED AREA BOUNDARY (FENCE)
SECTION LINE
N 787500 UMETCO SITE 2500' GRID SYSTEM
7000 SURFACE CONTOUR LINE
UNPAVED ROAD
SURFACE WATER
NOTES:
1). SURFACE CONTOURS FROM 1997 AERIAL MAPPING BY DATA MAPPING.
2). SECTIONS SHOWN ALL FROM TOWNSHIP 33 NORTH, RANGE 89 WEST OF THE SIXTH PRINCIPAL MERIDIAN.
UMETCO MINERALS CORPORATION
URANIUM MINING MAP
EAST GAS HILLS AREA
GAS HILLS SITE
APRIL 2001
FIGURE 2.2

FIG2-2R.DWG









UMETCO MINERALS CORPORATION

TIME SERIES PLOTS

MONITOR WELL LA8

GAS HILLS SITE

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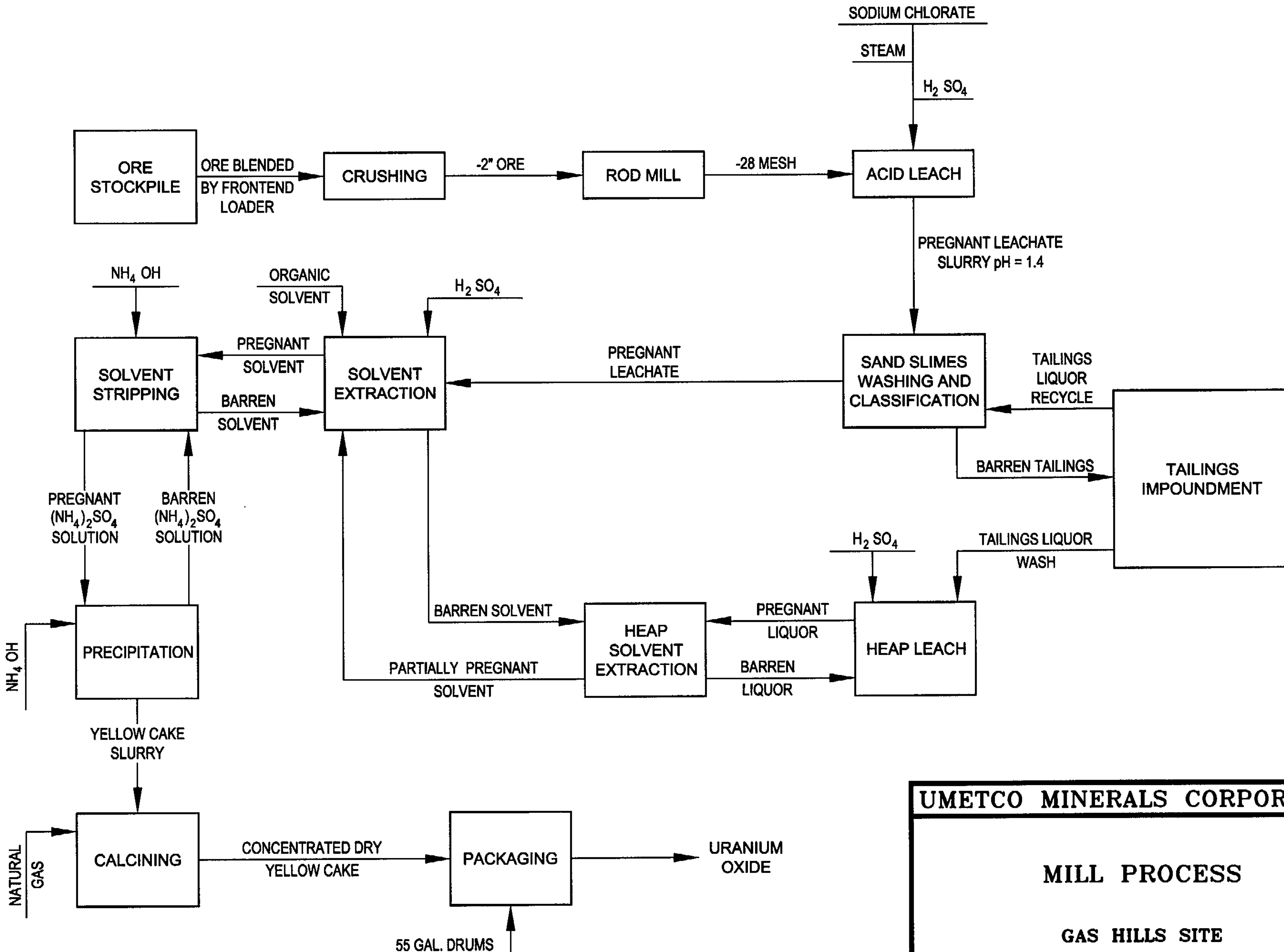
FIGURE 2.3

FIG2-4R.DWG



UMETCO MINERALS CORPORATION

MILL PROCESS

GAS HILLS SITE

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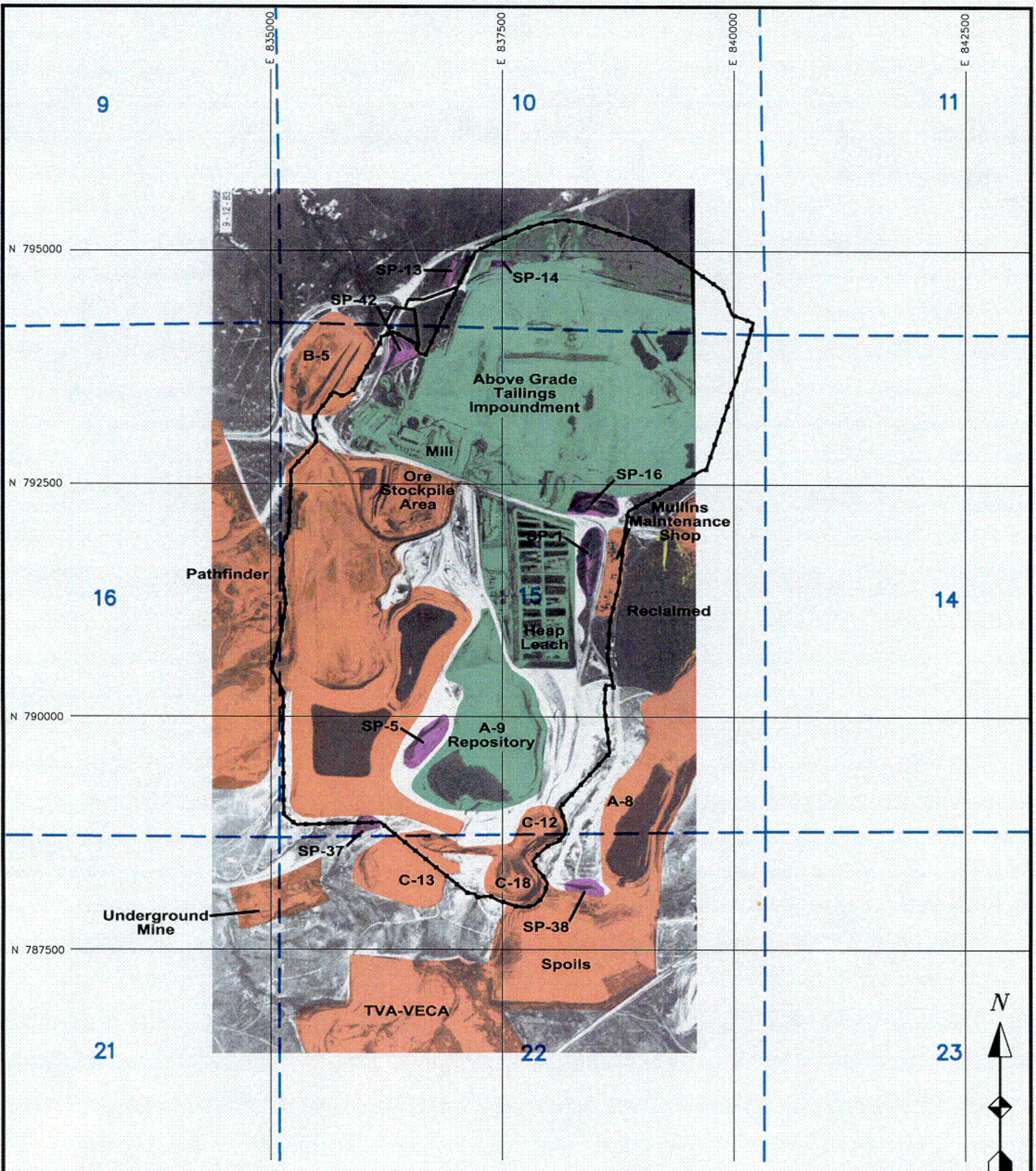
FIGURE 2.4



LEGEND:

- **15** SECTION NUMBER
- SECTION LINE
- RESTRICTED AREA BOUNDARY
- MILLING RELATED AREAS
- MINING RELATED AREAS
- SOIL STOCKPILES
- RECLAIMED MINING AREAS

1500' 0 1500'

SCALE IN FEET

UMETCO MINERALS CORPORATION

1983 AERIAL PHOTOGRAPH

GAS HILLS SITE

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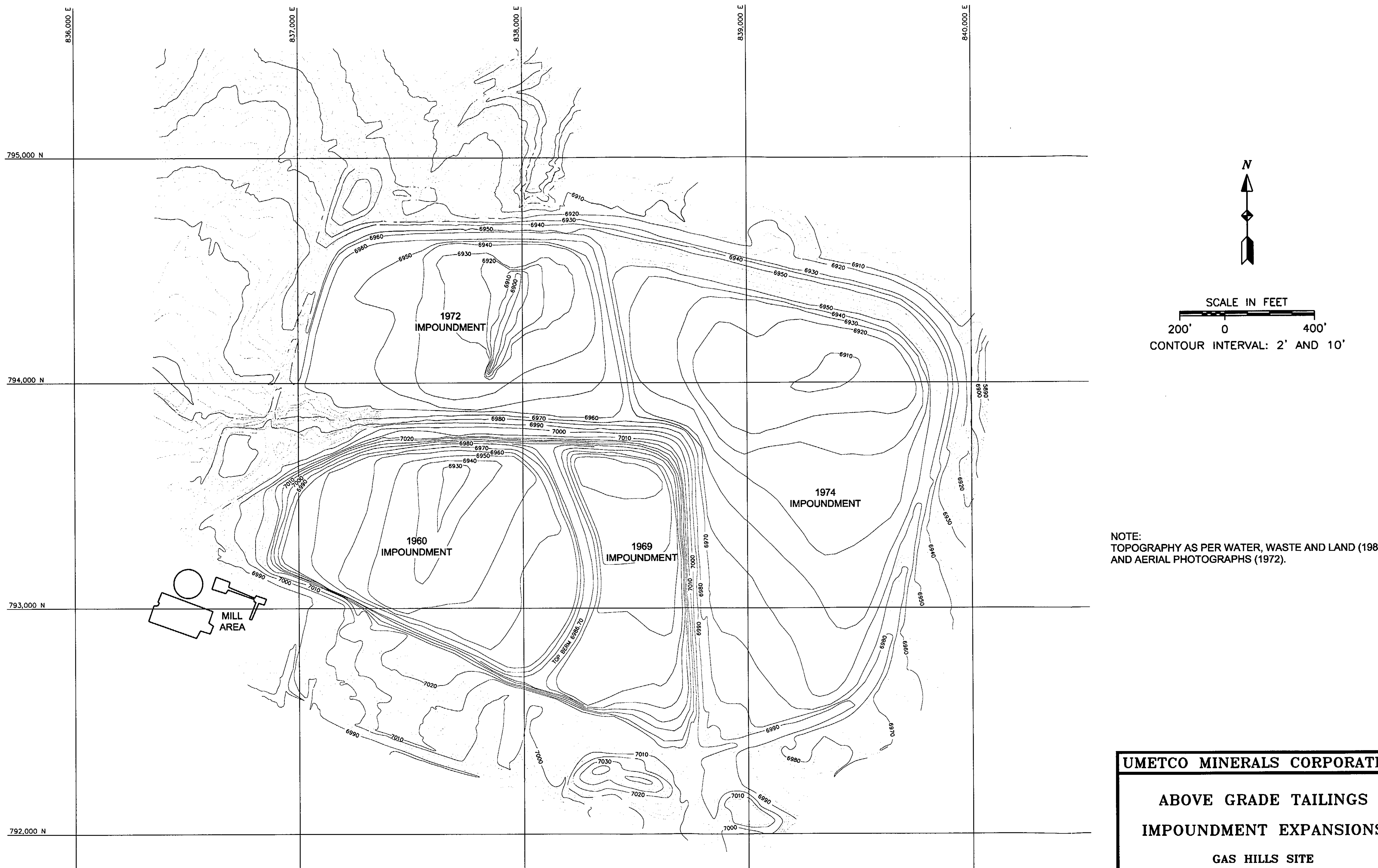
FIGURE 2.5

FIG2-5R.DWG

C-13



NOTE:
TOPOGRAPHY AS PER WATER, WASTE AND LAND (1984) AND AERIAL PHOTOGRAPHS (1972).

UMETCO MINERALS CORPORATION

ABOVE GRADE TAILINGS IMPOUNDMENT EXPANSIONS

GAS HILLS SITE

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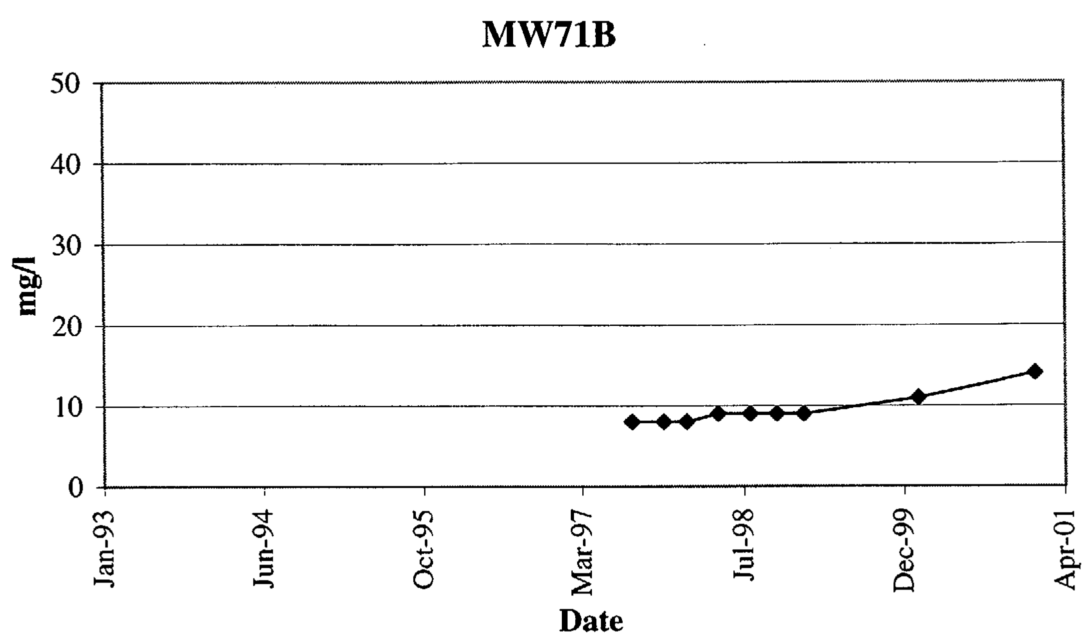
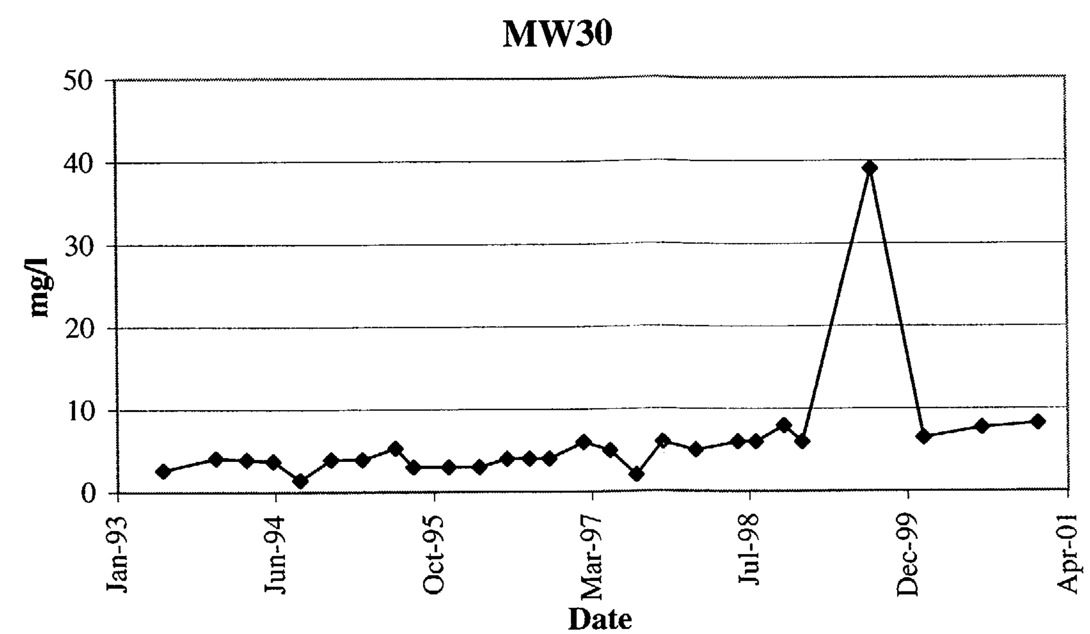
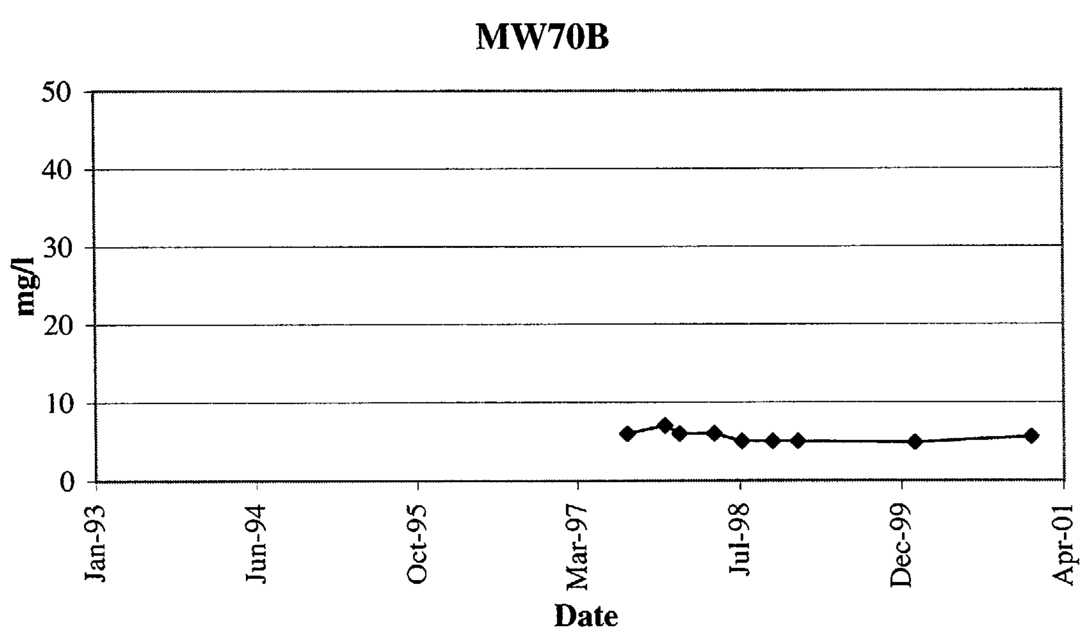
FIGURE 2.6

FIG2-6R.DWG

**Figure 2.7 Chloride Concentrations, Deep Well Completions, Gas Hills Site
Umetco Minerals Corporation, Grand Junction, Colorado**







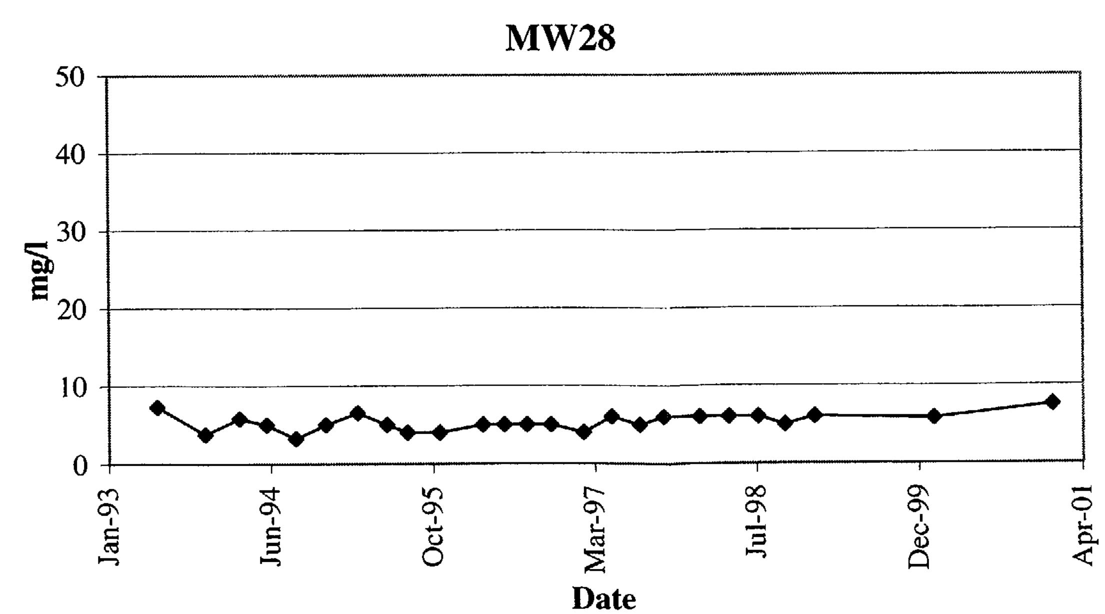
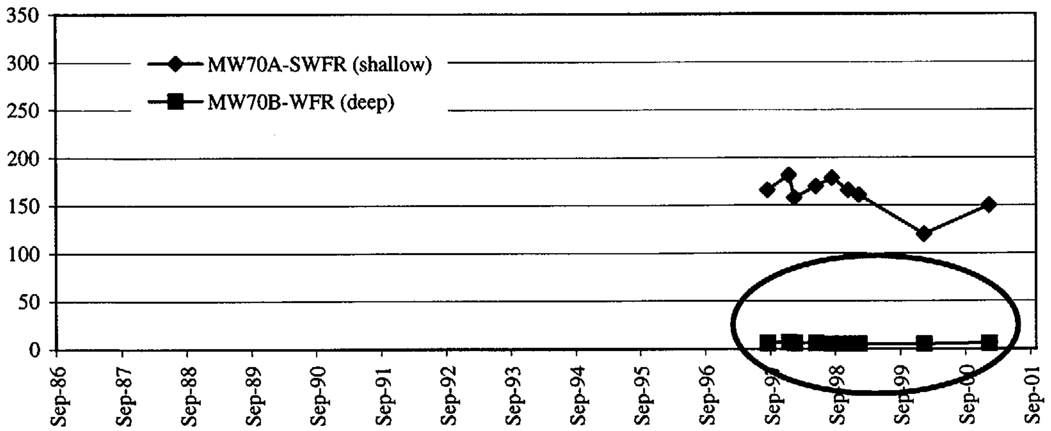
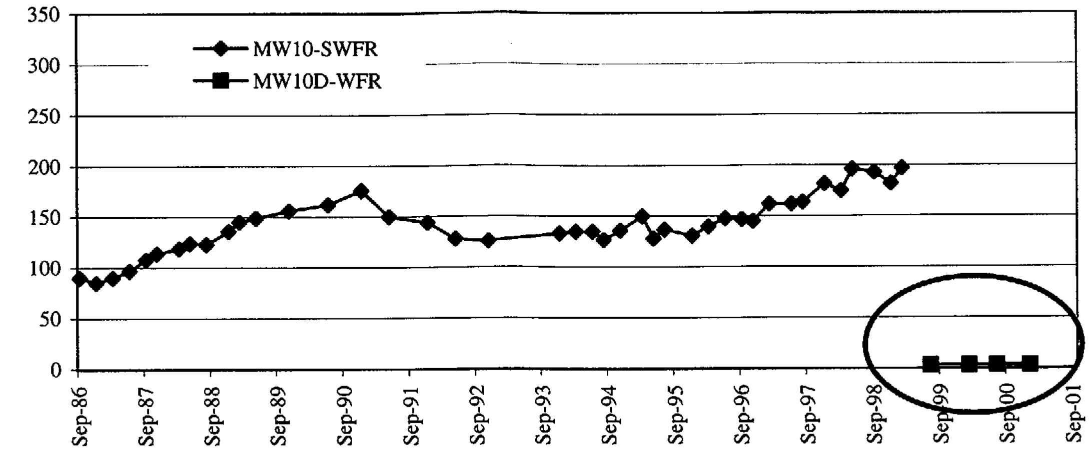


Figure 2.8 Comparison of Water Quality in Deep Versus Shallow Well Completion

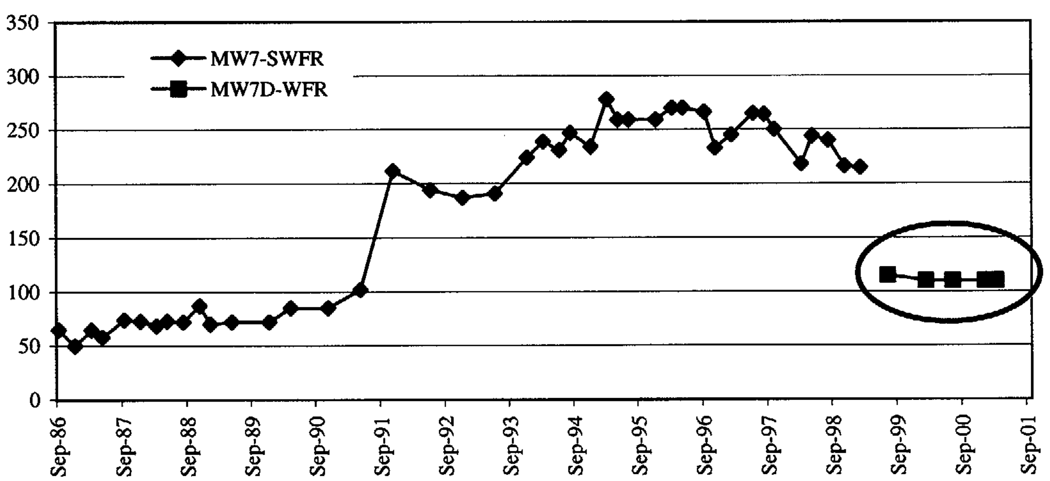
MW70A and MW70B-Chloride



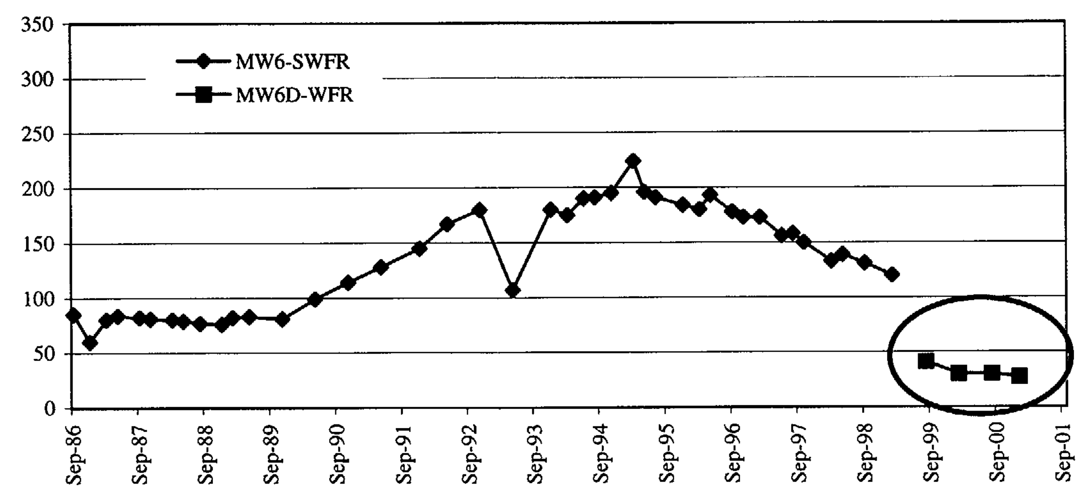
MW10 and MW10D-Chloride



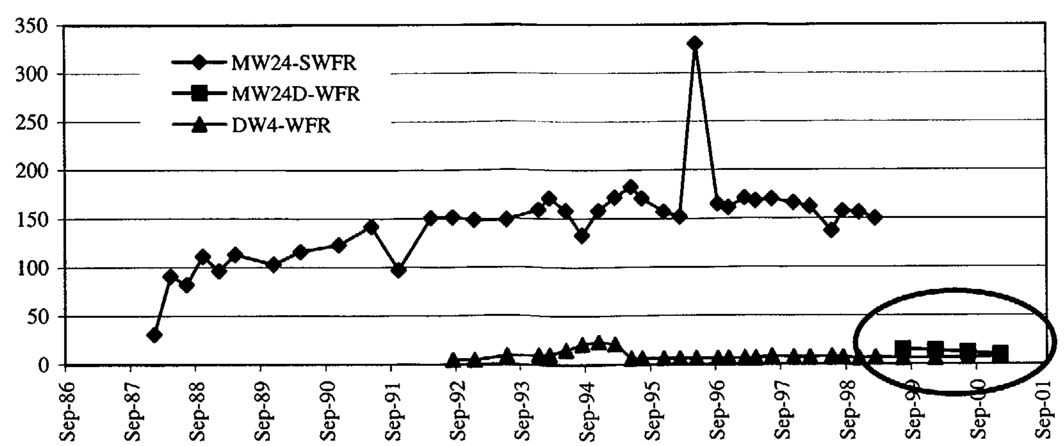
MW7 and MW7D-Chloride



MW6 and MW6D-Chloride

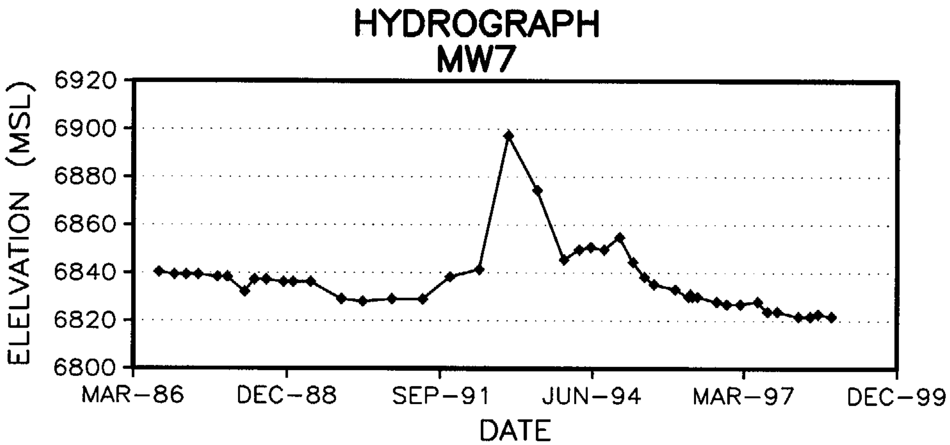


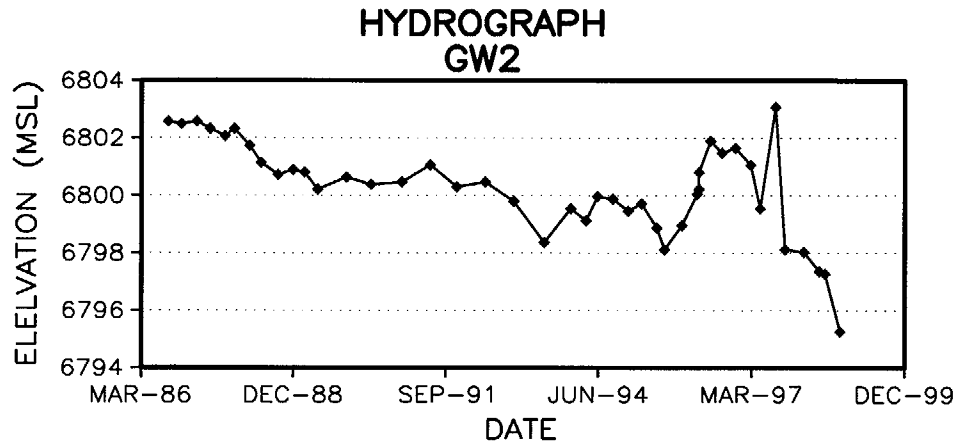
MW24, MW24D and DW4-Chloride

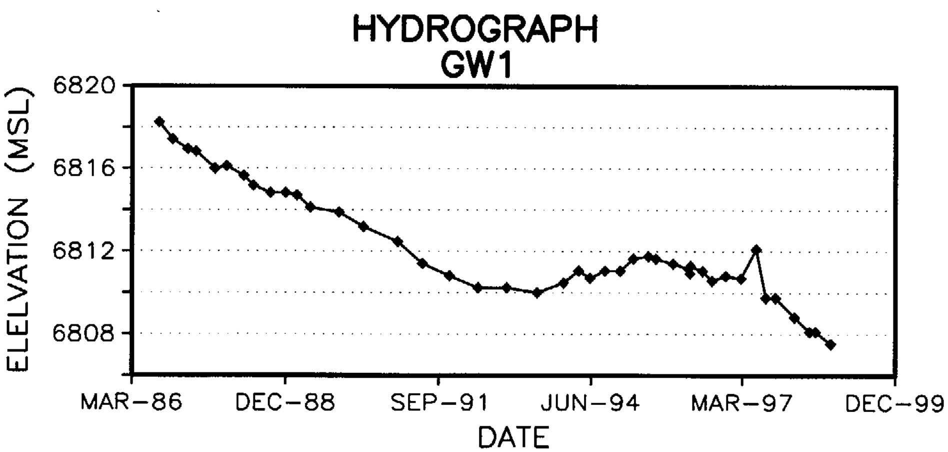


SWFR-Southwestern Flow Regime (formerly known as the Upper Wind River Aquifer)
WFR-Western Flow Regime (formerly known as the Lower Wind River Aquifer)

FIG2-9R.DWG







UMETCO MINERALS CORPORATION

HYDROGRAPHS FOR MONITOR WELLS MW7, GW1 AND GW2

GAS HILLS SITE

APRIL 2001

FIGURE 2.9

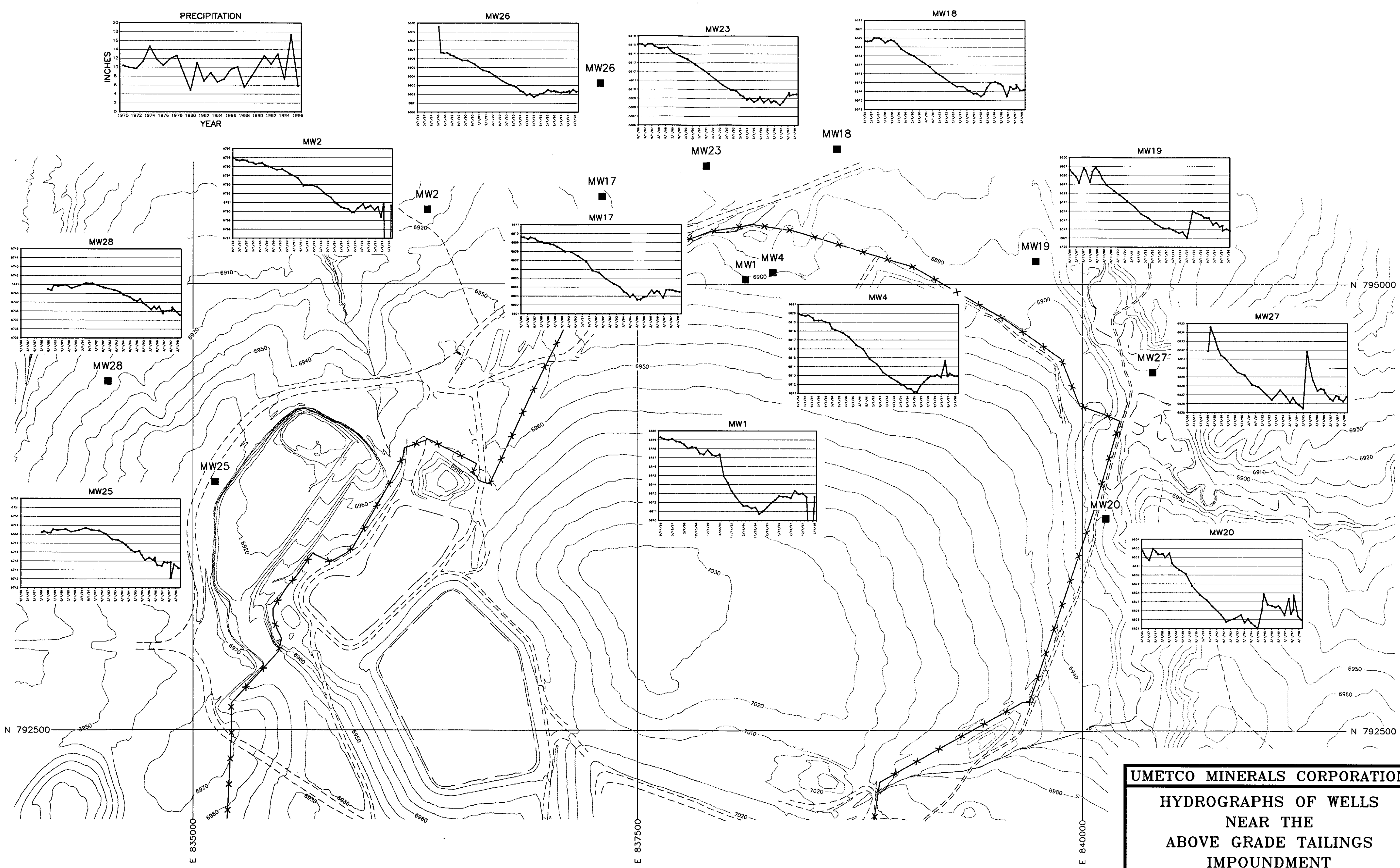
THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED:

FIGURE 2.10:
GAS HILLS, WYOMING HYDROGEOLOGIC CROSS SECTIONS

WITHIN THIS PACKAGE...OR, BY SEARCHING USING THE DRAWING NUMBER:
FIGURE 2.10

NOTE: Because of this page's large file size, it may be more convenient to copy the file to a local drive and use the Imaging (Wang) viewer, which can be accessed from the Programs/Accessories menu.



UMETCO MINERALS CORPORATION

HYDROGRAPHS OF WELLS NEAR THE ABOVE GRADE TAILINGS IMPOUNDMENT

GAS HILLS SITE

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FIGURE 2.12

FIG2-12.DWG

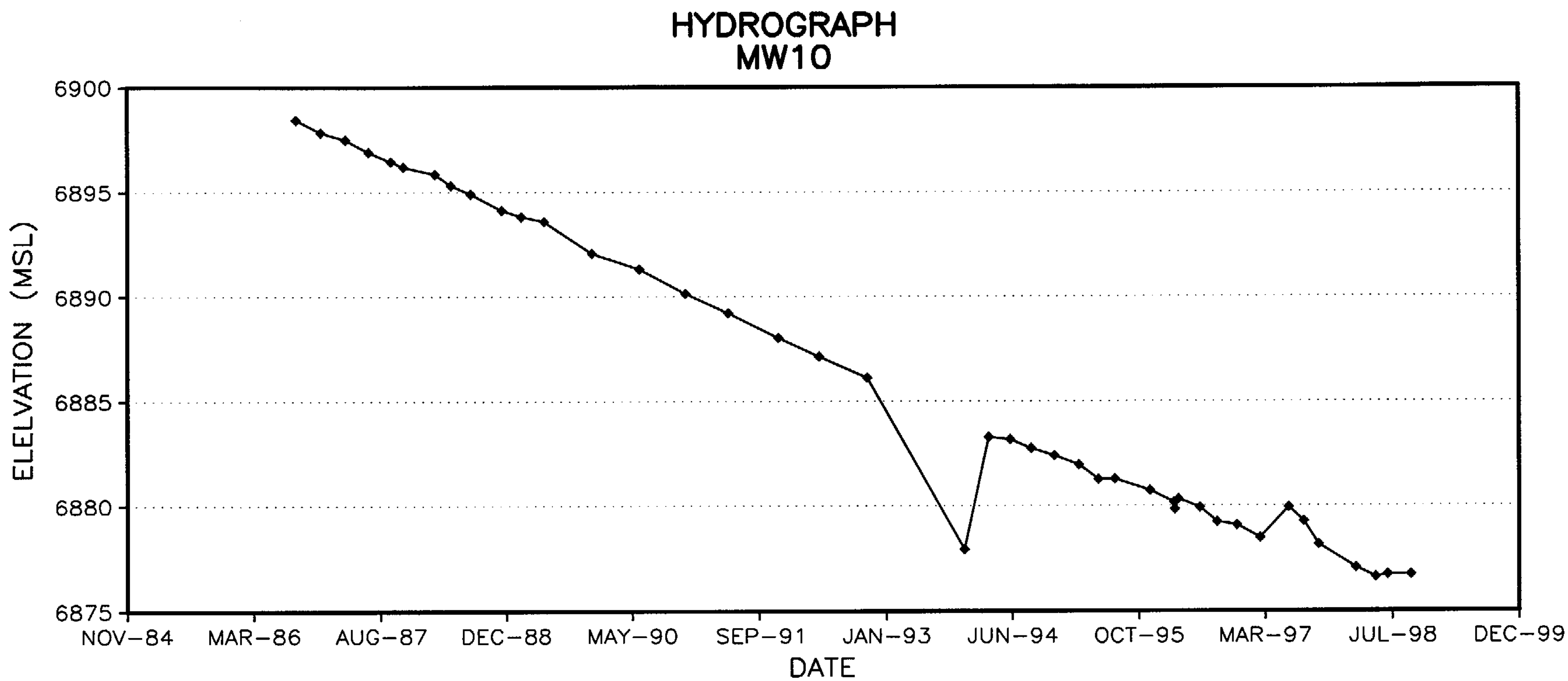
THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED:

FIGURE 2.11: WATER-LEVEL ELEVATIONS AND CONTOURS SECOND QUARTER 1996 GAS HILLS SITE

WITHIN THIS PACKAGE...OR, BY SEARCHING USING THE DRAWING NUMBER: FIGURE 2.11

NOTE: Because of this page's large file size, it may be more convenient to copy the file to a local drive and use the Imaging (Wang) viewer, which can be accessed from the Programs/Accessories menu.



UMETCO MINERALS CORPORATION

HYDROGRAPH FOR

WELL MW10

GAS HILLS SITE

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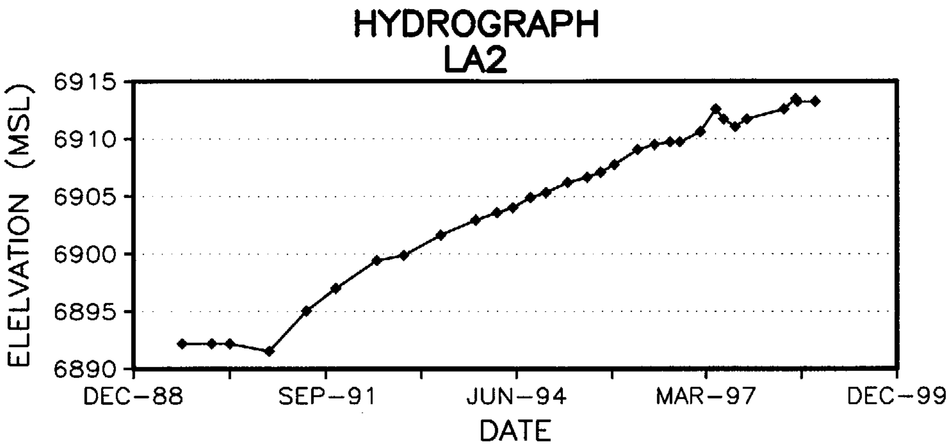
FIGURE 2.13

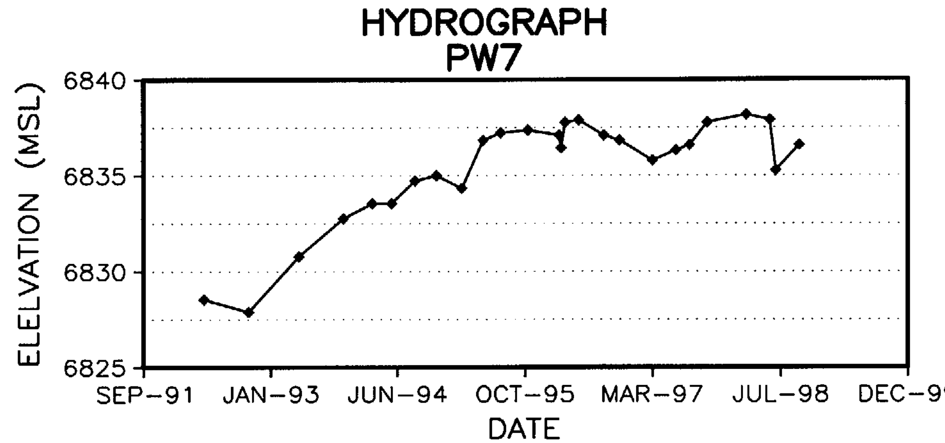
THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

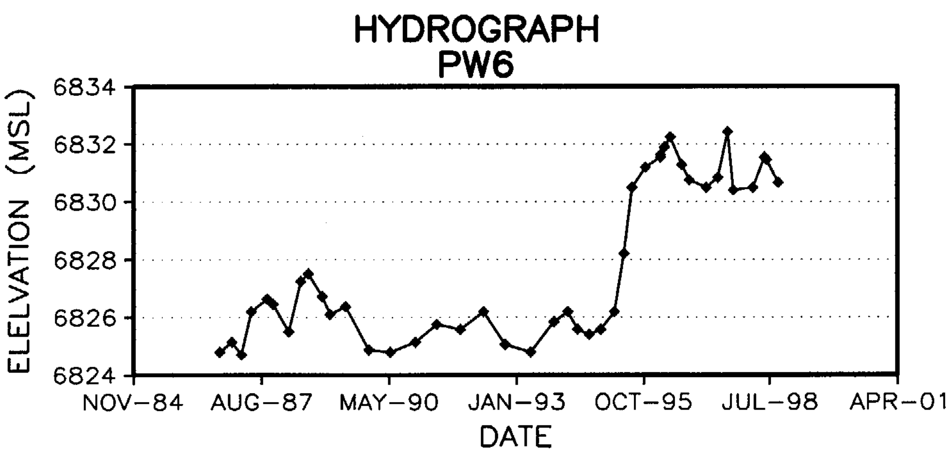
THAT CAN BE VIEWED AT THE RECORD TITLED: FIGURE 2.14: WATER-LEVEL ELEVATIONS AND CONTOURS SECOND QUARTER 1998 GAS HILLS SITE

WITHIN THIS PACKAGE...OR, BY SEARCHING USING THE DRAWING NUMBER: FIGURE 2.14

NOTE: Because of this page's large file size, it may be more convenient to copy the file to a local drive and use the Imaging (Wang) viewer, which can be accessed from the Programs/Accessories menu.







UMETCO MINERALS CORPORATION

HYDROGRAPHS FOR MONITOR WELLS LA2, PW6 AND PW7

GAS HILLS SITE

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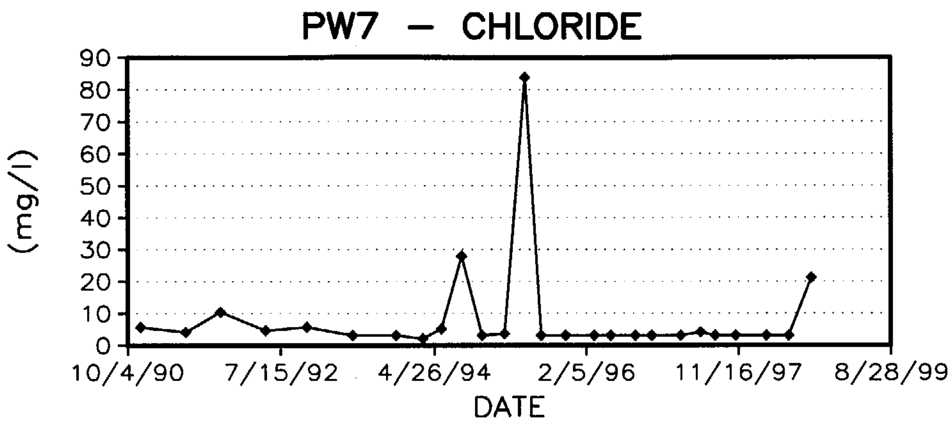
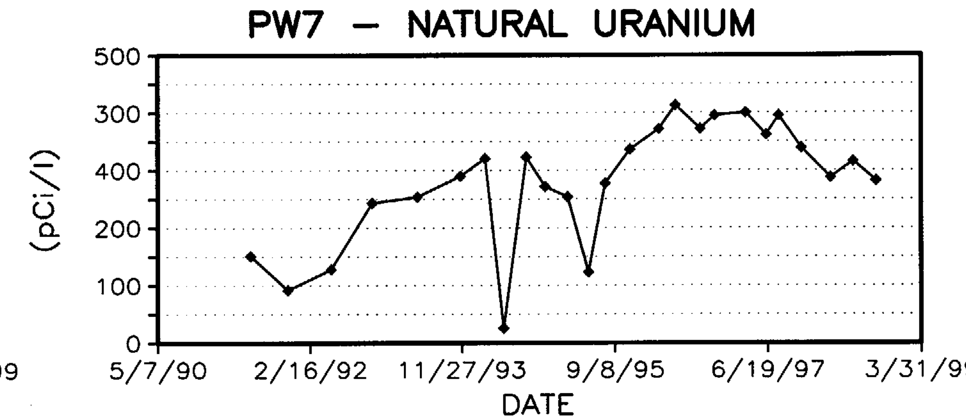
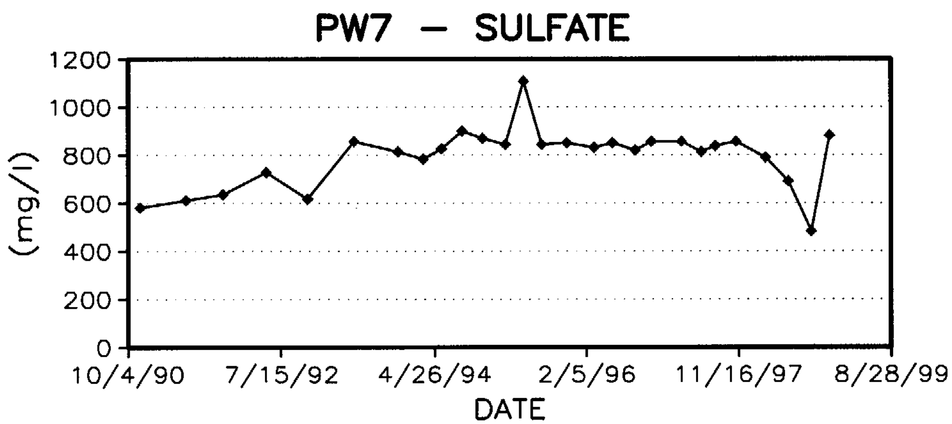
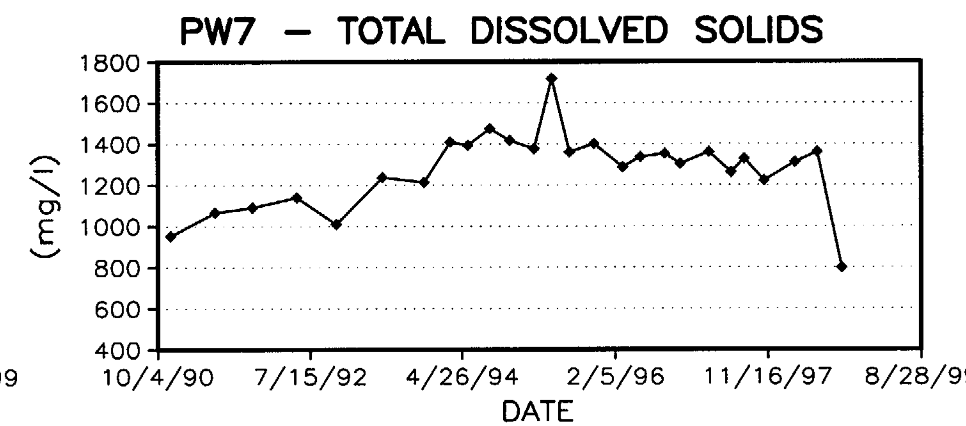
FIGURE 2.15

FIG2-16.DWG









UMETCO MINERALS CORPORATION

TIME SERIES PLOTS

MONITOR WELL PW7

GAS HILLS SITE

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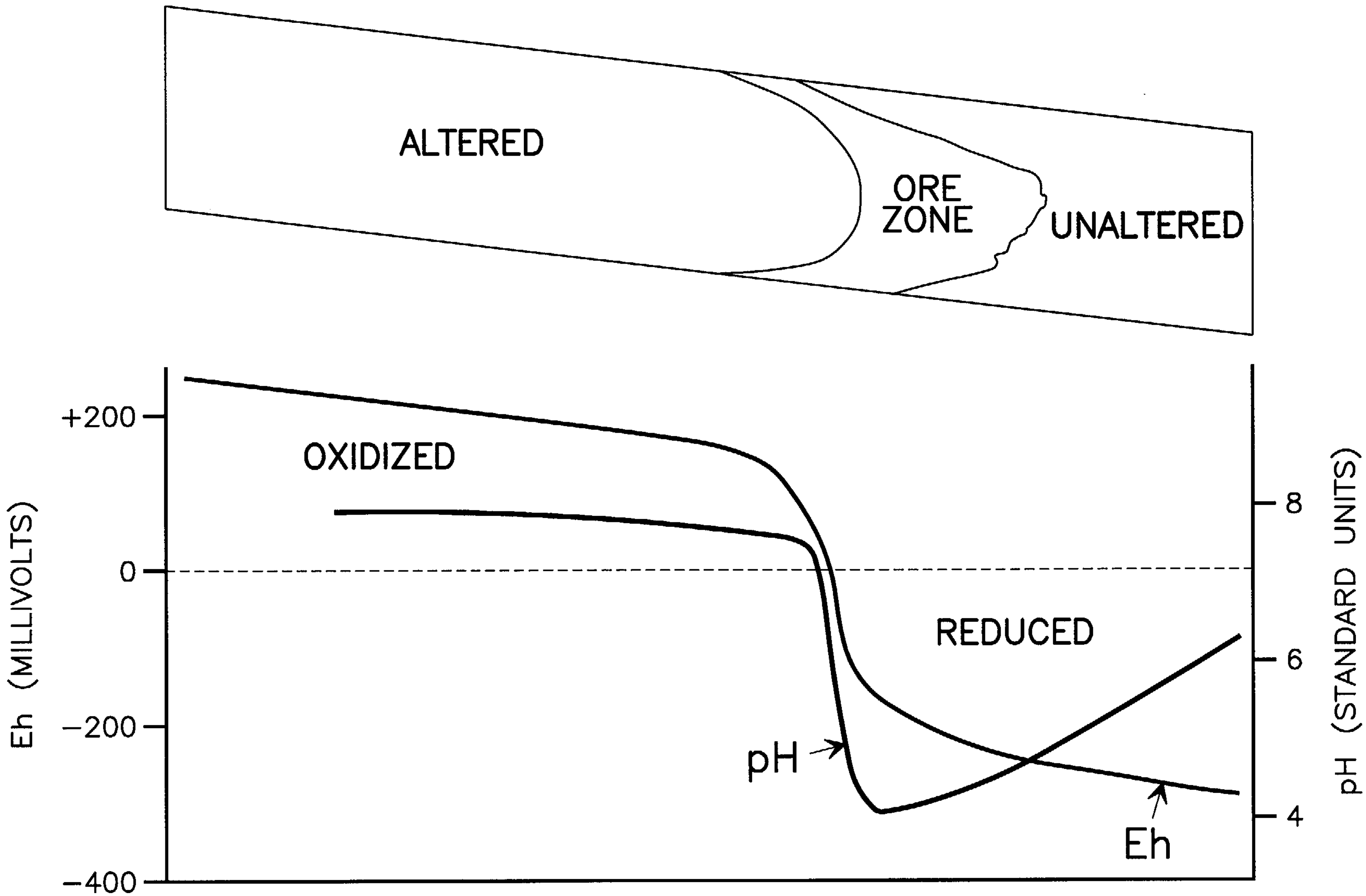
FIGURE 2.16

THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED: FIGURE 2.17: HYDRAULIC CONDUCTIVITY VALUES WIND RIVER AQUIFER GAS HILLS SITE

WITHIN THIS PACKAGE...OR, BY SEARCHING USING THE DRAWING NUMBER: FIGURE 2.17

NOTE: Because of this page's large file size, it may be more convenient to copy the file to a local drive and use the Imaging (Wang) viewer, which can be accessed from the Programs/Accessories menu.



NOTE:

CONDITIONS REPRESENTED ARE DURING TRANSPORTATION AND DEPOSITION OF URANIUM AND OTHER METALS RELATED TO A GEOCHEMICAL CELL DETERMINED BY HARSHMAN (1966).

UMETCO MINERALS CORPORATION

pH AND REDOX CONDITIONS

GAS HILLS SITE

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FIGURE 2.18

THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

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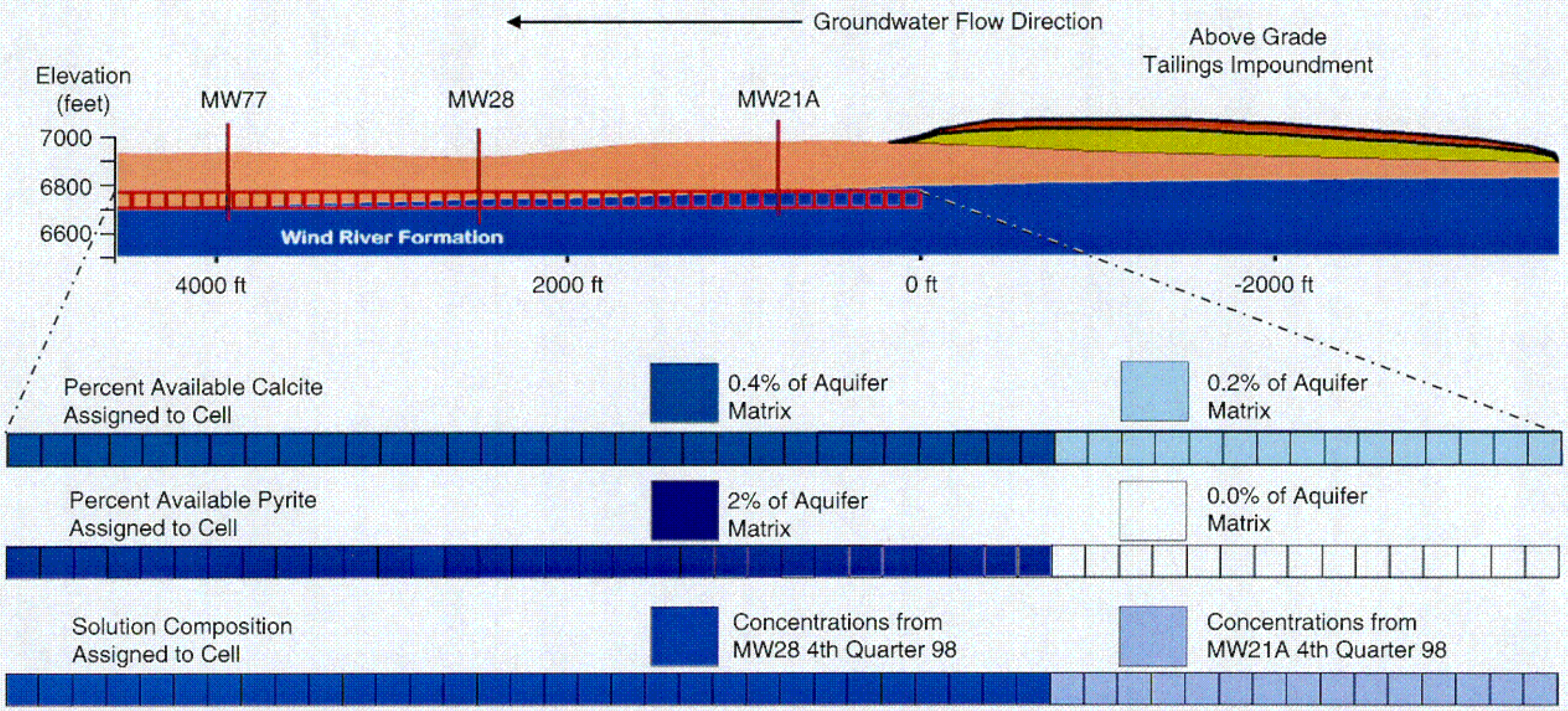
FIGURE 2.19: LOCATION OF HYDROGEN SULFIDE BEARING GROUNDWATER GAS HILLS SITE

WITHIN THIS PACKAGE...OR, BY SEARCHING USING THE DRAWING NUMBER: FIGURE 2.19

NOTE: Because of this page's large file size, it may be more convenient to copy the file to a local drive and use the Imaging (Wang) viewer, which can be accessed from the Programs/Accessories menu.

Figure 2.20 Model Grid for Western Flow Regime (Lower Wind River)



Adsorption Surface

0.2% of aquifer matrix

S_A = 600 m^2/g (ferrihydrite)

N_{s1} = 0.005 mol/mol Fe

N_{s2} = 0.02 mol/mol Fe

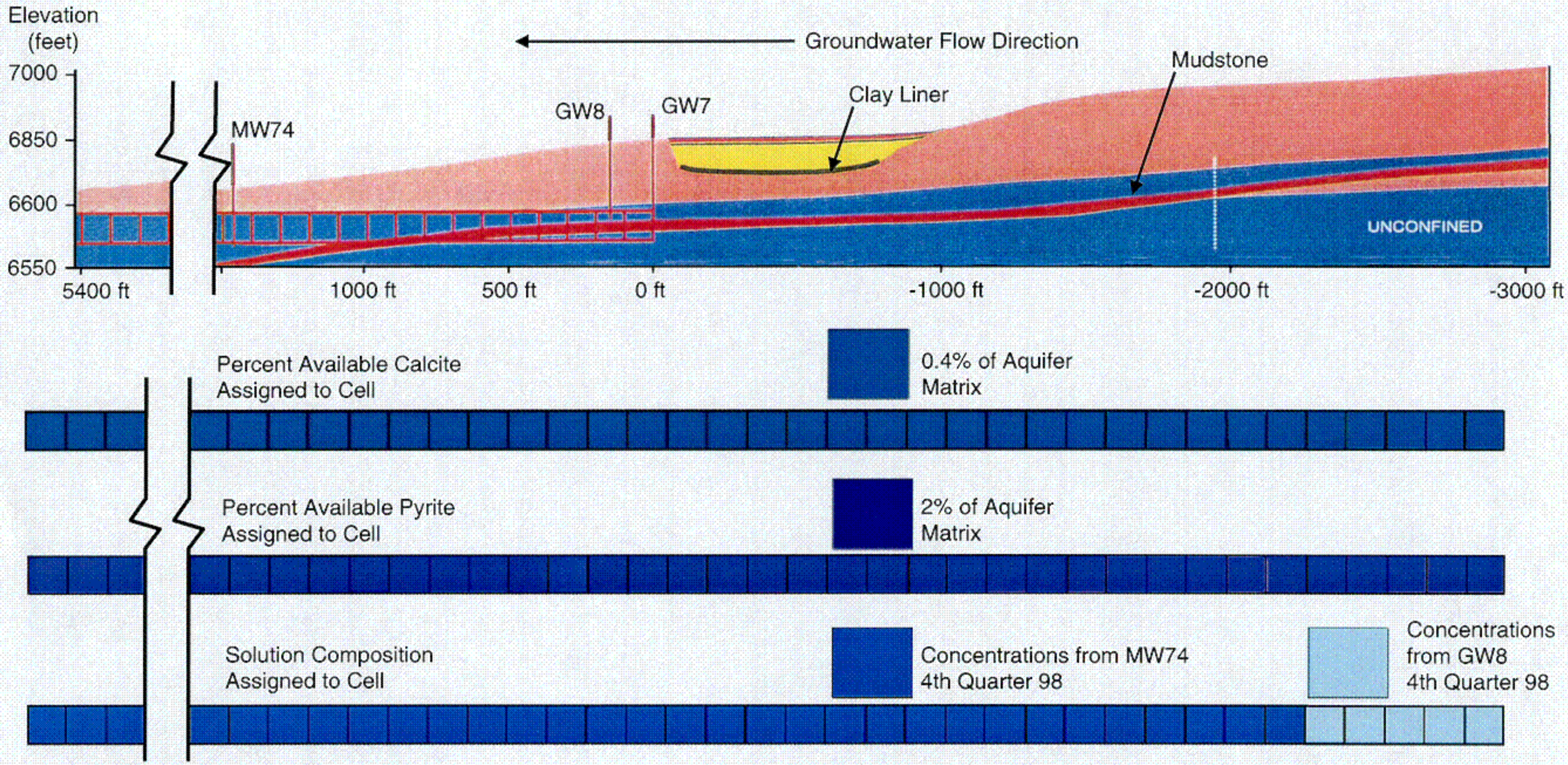
Cation Exchange Surface

CEC = 10 $cmol_{(+)}$/kg

Minerals Allowed to Precipitate

$CaCO_3$	NiS
UO_2	$Fe(OH)_3$
$USiO_4$	$NiCO_3$
FeS_2	$RaSO_4$
$FeSe_2$	$Th(OH)_4$
Se(a)	$PbSO_4$
NiSe	$CaSO_4 \cdot 2H_2O$

Figure 2.21 Model Grid for Southwestern Flow Regime (Upper Wind River)



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N_{s1} = 0.005 mol/mol Fe
N_{s2} = 0.02 mol/mol Fe

Cation Exchange Surface

CEC = 10 $cmol_{(+)}$/kg

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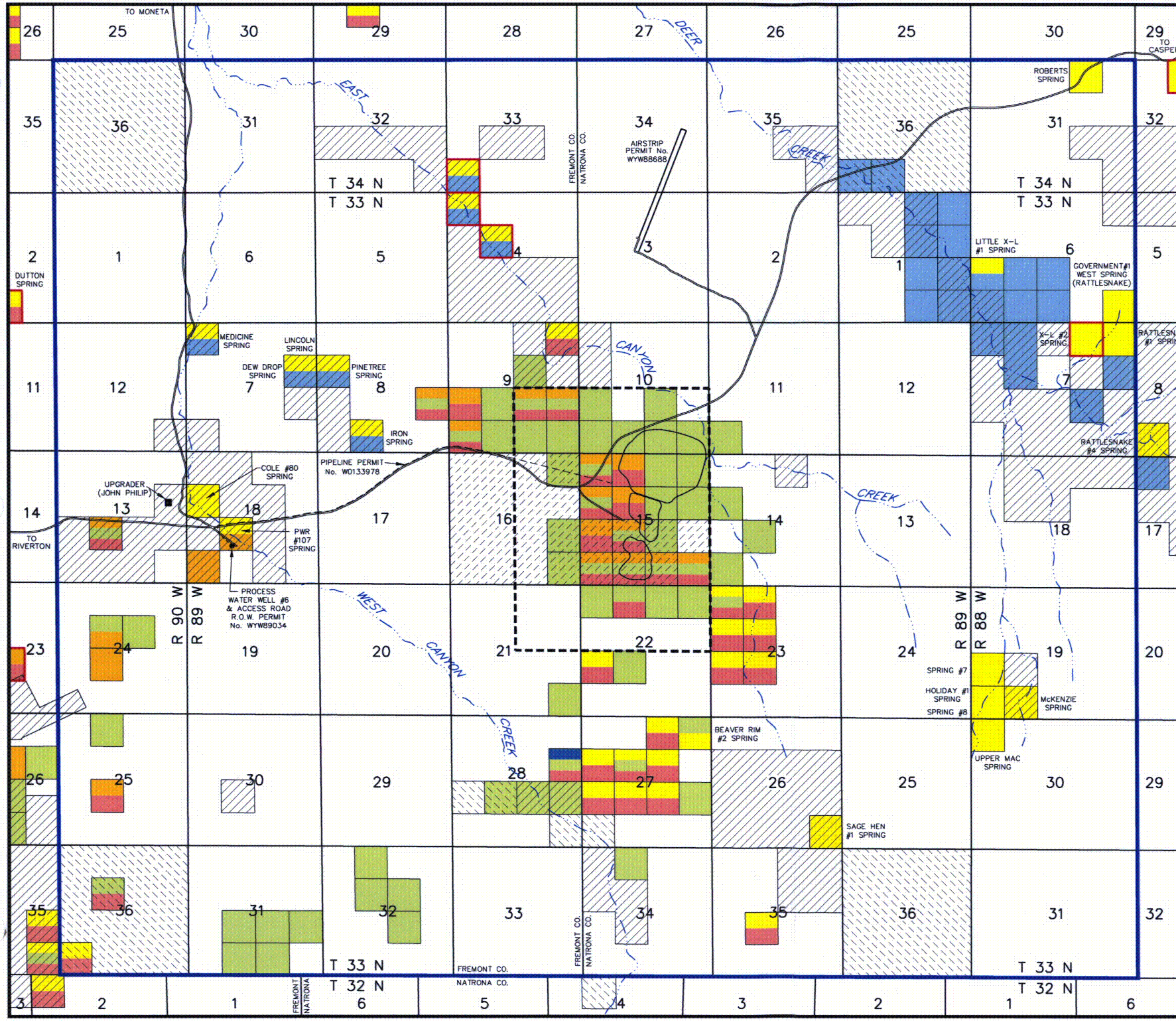
UO_2	$Fe(OH)_3$
$USiO_4$	$NiCO_3$
FeS_2	$RaSO_4$
$FeSe_2$	$Th(OH)_4$
Se(a)	$PbSO_4$
NiSe	$CaSO_4 \cdot 2H_2O$



LEGEND:

- LONG TERM CARE BOUNDARY (SEE NOTE 1)
- WATER RIGHTS SEARCH BOUNDARY
- PRIVATE LAND
- PRIVATE LAND (UMETCO)
- STATE LAND
- FEDERAL LAND (NO HATCHING)
- LIVESTOCK WATER RIGHTS
- DOMESTIC WATER RIGHTS
- IRRIGATION WATER RIGHTS
- INDUSTRIAL WATER RIGHTS
- MONITORING/MISCELLANEOUS WATER RIGHTS
- RESERVOIR WATER RIGHTS
- FLOOD CONTROL WATER RIGHTS

NOTES:

1). THE LONG TERM CARE BOUNDARY INCLUDES ALL OF SECTION 15, THE NORTH 1/2 OF SECTION 22, THE NORTHEAST 1/4 OF SECTION 21, THE EAST 1/2 OF SECTION 16, THE SOUTHEAST 1/4 OF SECTION 9 AND THE SOUTH 1/2 OF SECTION 10, ALL LOCATED IN TOWNSHIP 33 NORTH, RANGE 89 WEST OF THE SIXTH PRINCIPAL MERIDIAN. SAID LAND CONTAINS 1920 ACRES MORE OR LESS.

2). WATER RIGHT LOCATIONS AS PER DATABASE SEARCH BY THE WYOMING STATE ENGINEERS OFFICE AND LETTER DATED APRIL 18, 2001 FROM THE STATE ENGINEERS OFFICE.

UMETCO MINERALS CORPORATION

LAND AND WATER USES IN THE VICINITY

GAS HILLS SITE

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FIGURE 2.22

C-16