DOE/AL/62350-209
REV. 1

BASELINE RISK ASSESSMENT OF GROUND WATER CONTAMINATION AT THE URANIUM MILL TAILINGS SITE NEAR MAYBELL, COLORADO

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Prepared for
U.S. Department of Energy
Grand Junction Projects Office

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CITIZENS' SUMMARY

The U.S. Department of Energy (DOE) Uranium Mill Tailings Remedial Action (UMTRA) Project consists of the Surface Project (Phase I) and the Ground Water Project (Phase II). Under the UMTRA Surface Project, tailings, contaminated soil, building foundations, and materials associated with the former processing of uranium ore at UMTRA Project sites are placed into disposal cells. The cells are designed to reduce radon and other radiation emissions and to prevent further contamination of ground water. One UMTRA Project site is near Maybell, Colorado. Surface cleanup at this site began in 1995 and is scheduled for completion in 1996. The tailings are being stabilized in place at this site. The disposal area has been withdrawn from public use by the DOE and is referred to as the permanent withdrawal area.

The Ground Water Project evaluates the nature and extent of ground water contamination resulting from past uranium ore processing activities. The Ground Water Project at this site is in its beginning stages. This report is a site-specific document that will be used to evaluate current and future potential impacts to the public and the environment from exposure to contaminated ground water. The results presented in this document and other evaluations will determine whether any action is needed to protect human health or the environment.

A risk assessment describes a source of contamination, how that contamination reaches the environment, the amount of contamination to which people and ecological communities (which are the receptors) may be exposed, and the health or environmental effects that could result from that exposure. This assessment differs from other UMTRA Project site baseline risk assessments because a quantitative assessment of human health and ecological risks is not included. The rationale for not performing a quantitative risk assessment is presented in this document.

RISK SUMMARY

Currently, no points of exposure (i.e., access to the contaminated ground water) and no receptors of contaminated ground water have been identified at the Maybell site. Therefore, there are no current human health and ecological risks associated with exposure to contaminated ground water. Furthermore, if current site conditions and land- and water-use patterns do not change, it is unlikely that contaminated ground water would reach people or the ecological communities in the future.

GROUND WATER QUALITY AND USES

Background ground water quality

The Maybell uranium district contains many uranium deposits. Because the area was widely mined in the past, the potential for natural and other non-site-related sources of uranium mineralization and related constituents in the vicinity of the Maybell site is great.

Background ground water quality is defined as the quality of ground water that would be present at the site if uranium milling activities had not taken place. In the vicinity of the Maybell site, background ground water quality is naturally poor due to uranium deposits and, therefore, of limited use.

Site-related ground water quality

The uppermost aquifer beneath the Maybell site is the Browns Park Formation aquifer. Water used in the uranium processing activities at the Maybell site (from 1957 to 1964) moved down through the tailings and added inorganic chemicals and radionuclides to the aquifer. The flow of contaminated ground water beneath the site is generally toward the southwest.

Site-related constituents were determined by comparing background concentrations to concentrations of constituents in ground water directly beneath the tailings pile and processing site. The constituents with concentrations above background are aluminum, ammonium, cadmium, calcium, chloride, copper, fluoride, iron, magnesium, manganese, molybdenum, nitrate, phosphate, potassium, selenium, sodium, strontium, sulfate, uranium, zinc, lead-210, polonium-210, radium-226, and thorium-230.

Ground water quality in areas next to the tailings, both inside and outside the permanent withdrawal area, was also compared to background concentrations. These comparisons indicate that the levels of constituents that were added to ground water by uranium milling activities fall off sharply in areas next to the site. Concentrations of site-related constituents outside of the permanent withdrawal area fall within the range of background levels. It has been almost 40 years since the milling operations began and more than 30 years since they ceased. Based on existing data, ground water chemical and physical reactions may be responsible for the absence of site-related contamination beyond a few hundred feet from the tailings pile. Ground water contamination has not moved beyond the immediate vicinity of the mill site and tailings pile since the processing began.

If current ground water conditions do not change, there is no reason to believe that the constituents will be detected outside of the permanent withdrawal area at levels above background concentrations in the future. However, certain activities at the Maybell site could cause site ground water conditions to change. The surface cleanup construction activities (e.g., compaction and consolidation of the tailings pile) could affect current ground water conditions by short-term addition of water to the aquifer. The result of this is that contaminated ground water could move outside of the permanent withdrawal area and increase the contaminant concentrations in the aquifer. Wells have been installed to monitor ground water downgradient of the disposal cell within the permanent withdrawal area.

Currently, no residential, industrial/commercial, municipal, or agricultural wells have been identified within a 3 mile (5 kilometer) radius of the site. However, livestock wells no longer extant, have been known to be located in the area of the site. The closest surface water body to the Maybell site is Rob Pit. Rob Pit is a former uranium open pit mine. The water in the pit is fed by ground water. Because the pit is near uranium deposits, radionuclides are naturally high in the ground water. The potential exists for surface water conditions to change in the future. That is, the additional water added to the aquifer because of construction activities could cause ground water from the site to move in the direction of the pit and constituent concentrations could exceed background levels.

CONCLUSIONS

Currently, no human health or ecological risks are associated with the use of contaminated ground water at the Maybell site. This will continue if the use of water and land at the site, and current ground water conditions do not change. That is, if ground water contaminants from the site do not move outside of the permanent withdrawal area in concentrations above background levels, and no exposure pathways are completed.

If the water added to the aquifer because of construction activities causes contaminated ground water from the site to move in the direction of Rob Pit in the future, current ambient levels of constituents (for example, uranium) could increase or other constituents from the ground water plume could discharge to the surface water. Nonetheless, because of the ground water conditions at the Maybell site (no off-site contamination has been observed) and the uncertainty associated with predicting future site ground water conditions, a quantitative risk is not presented. Assessing future scenarios using current information would not necessarily represent future site conditions. However, in order to assure that human health and the environment is adequately protected in the future, monitoring of the ground water should continue so that any changes in ground water conditions can be evaluated.

The environmental evaluation of the UMTRA Project Maybell site is ongoing. This risk assessment and future investigations will be used to determine how to comply with UMTRA ground water standards.

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LIST OF ACRONYMS

Acronym	Definition
ANOVA	analysis of variance
BLM	Bureau of Land Management
DOE	U.S. Department of Energy
LTSP	long-term surveillance plan
MCL	maximum concentration limit
MSL	mean sea level
RAP	remedial action plan
RRM	residual radioactive material
UMTRA	Uranium Mill Tailings Remedial Action
UMTRCA	Uranium Mill Tailings Radiation Control Act

1.0 INTRODUCTION

The former uranium mill tailings processing site near Maybell, Colorado (hereafter referred to as the Maybell site) is one of the designated uranium mill tailings sites that are undergoing surface remediation in accordance with the requirements of the *Uranium Mill Tailings Radiation Control Act* (UMTRCA) (42 USC §7901 *et seq.*) under the oversight of the U.S. Department of Energy (DOE) Uranium Mill Tailings Remedial Action (UMTRA) Project. The designated site is the area that included the actual mill site and the tailings pile, and includes the potential source area for residual radioactive material (RRM).

The UMTRA Project consists of the Surface Project and the Ground Water Project. Under the UMTRA Surface Project, tailings, radioactive contaminated soil, building foundations, and materials associated with the former processing of uranium ore at UMTRA sites are stabilized in disposal cells. The cells are designed to reduce radon and other radiation emissions and to prevent further contamination of ground water. Construction activities for surface remediation at the Maybell site began in the spring of 1995 and the disposal cell is scheduled to be completed during 1996. The tailings are being stabilized on the site. The permanent withdrawal area for the Maybell disposal site is comprised of 251 acres (ac) (101 hectares [ha]) and will be fenced, establishing a government-controlled area that will be inaccessible to the public. The size of the permanent withdrawal area is larger than the designated site in order to incorporate design features of the disposal cell.

The Ground Water Project evaluates the nature and extent of ground water contamination resulting from past uranium ore processing activities. Ground water underneath the tailings pile at the Maybell site was contaminated by the leaching of inorganic chemicals and radionuclides from the tailings pile. The DOE was authorized to conduct ground water remediation by Congress and will determine site-specific ground water compliance strategies for each site. This report is one of the first Ground Water Project site-specific documents that provides information to assist the DOE in determining the site-specific ground water compliance strategy for the Maybell site and will support decisions made for the UMTRA Ground Water Project. Additional detail on the site is available in the surface remedial action plan (RAP) (DOE, 1994).

The purpose of this baseline risk assessment is to determine whether the contaminated ground water at the Maybell site could adversely affect human health or the environment. This assessment differs from other UMTRA site baseline risk assessments because a quantitative assessment of human health and ecological risks is not presented. The determination to not quantitatively evaluate potential risks is based on the geochemical and hydrogeological evaluation of the ground water contamination at this site, as well as the absence of current complete exposure pathways and the unlikeliness of a complete exposure pathway to occur in the future.

This document presents the rationale to support the decision not to perform a quantitative risk assessment. In Section 2.0 the hydrogeologic setting of the Maybell site is presented.

Section 3.0 presents the geochemical and statistical evaluation of the analytical data associated with the site, and Section 4.0 discusses the site conceptual model of potential exposure at the Maybell site, as well as the limitations and identified data gaps of this assessment.

2.0 SITE DESCRIPTION

This section describes the history of the milling operations at the Maybell site, the regional climate, the physiography of the immediate area around the site, and key aspects of the geology and hydrogeology of the site that relate to ground water flow and contaminant transport. A brief description of surface waters and drainage features near the Maybell site is presented. An understanding of these elements provides the basis for this risk assessment.

2.1 SITE LOCATION AND HISTORY

The Maybell site is located 25 miles (mi) (40 kilometers [km]) west of Craig, Colorado, in Moffat County, in the northwestern part of the state. The unincorporated town of Maybell is located 5 mi (8 km) southwest of this site (Figure 2.1).

Uranium deposits were discovered in the Maybell uranium district in 1953 (Chenoweth, 1986). The Trace Elements Corporation established the Maybell, Colorado mill site in 1955 and 1956. The Union Carbide Corporation assumed control of the site and began operating the mill in 1957. Umetco Minerals Corporation, a wholly-owned subsidiary of the Union Carbide Corporation, holds the radioactive materials license for the tailings site and continues as the operational controller. Uranium ore was obtained from nearby open pit mines. During 7 years of operation, the mill processed approximately 2.6 million tons (2.4 million metric tons) of ore, having a grade of 0.098 percent uranium oxide. The ore was processed using a resin-in-pulp acid leach method. An upgrader circuit at the processing plant treated low-grade ore prior to leaching. Water for the mill operations came from the Yampa River. It is estimated that about one million gallons of water were used per day for the operations (Merritt, 1971). In the early 1960's, three settling ponds were constructed along the south edge of the tailings pile (Figure 2.2). All concentrate produced was sold to the U.S. Atomic Energy Commission.

There is insufficient detailed information about milling activities to determine the exact locations of contaminant sources. Mill effluent may have been placed on the tailings piles or may have been collected in the ponds close to the former mill buildings. Monitor well coverage around the former mill buildings and near the settlement ponds, which are possible contaminant sources, does not reveal specific contaminant source locations.

After the mill shut down in November 1964, Umetco dismantled it and, in 1971, started stabilizing the tailings in accordance with the state of Colorado regulations. The remaining features include the tailings pile, foundation materials at the former mill processing site area, open pit mines, and overburden piles. The uranium milling processes used at this site are described in detail in Section 3.0.

Figure 2.1
Tailings Site Location Map
Maybell, Colorado

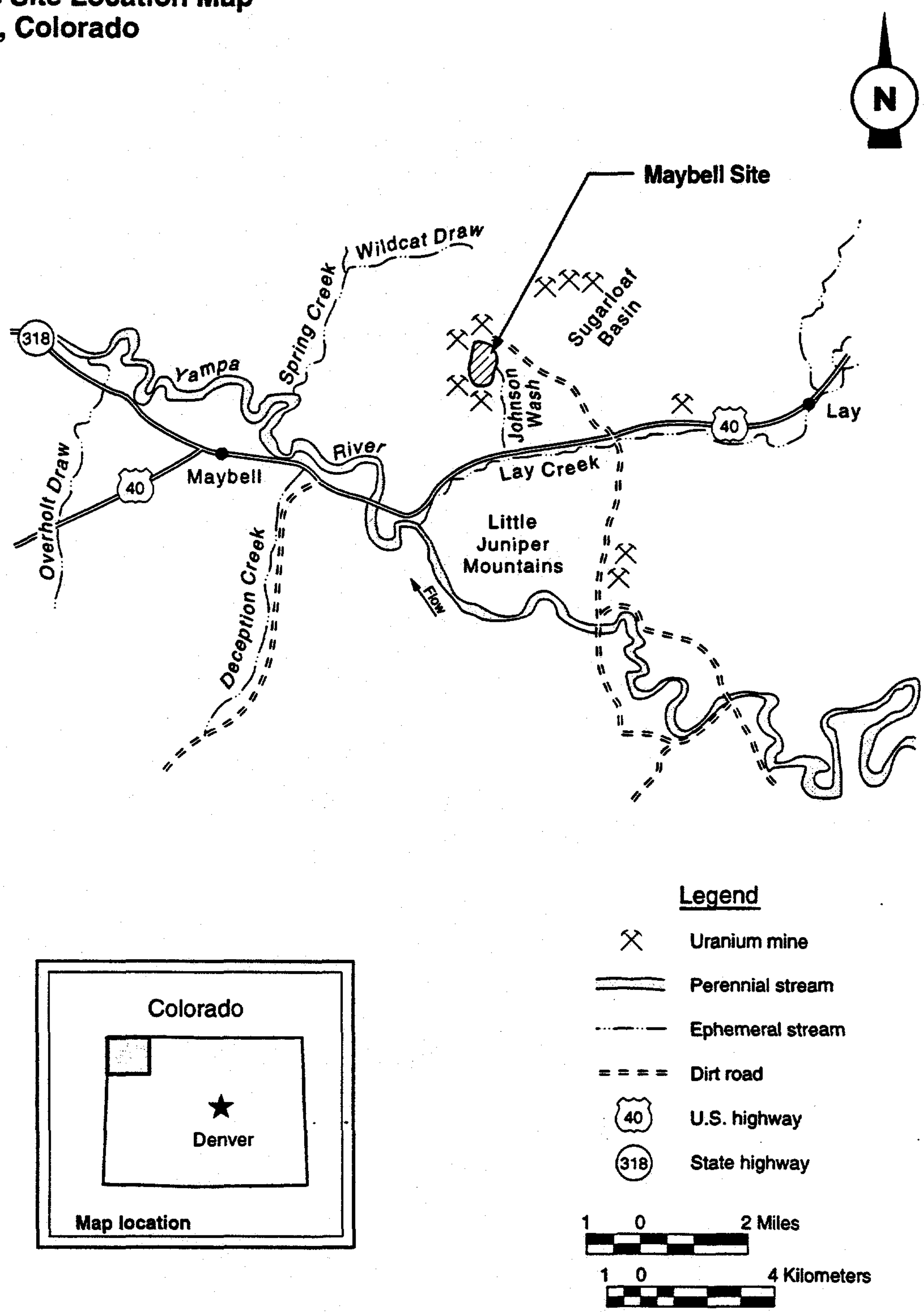

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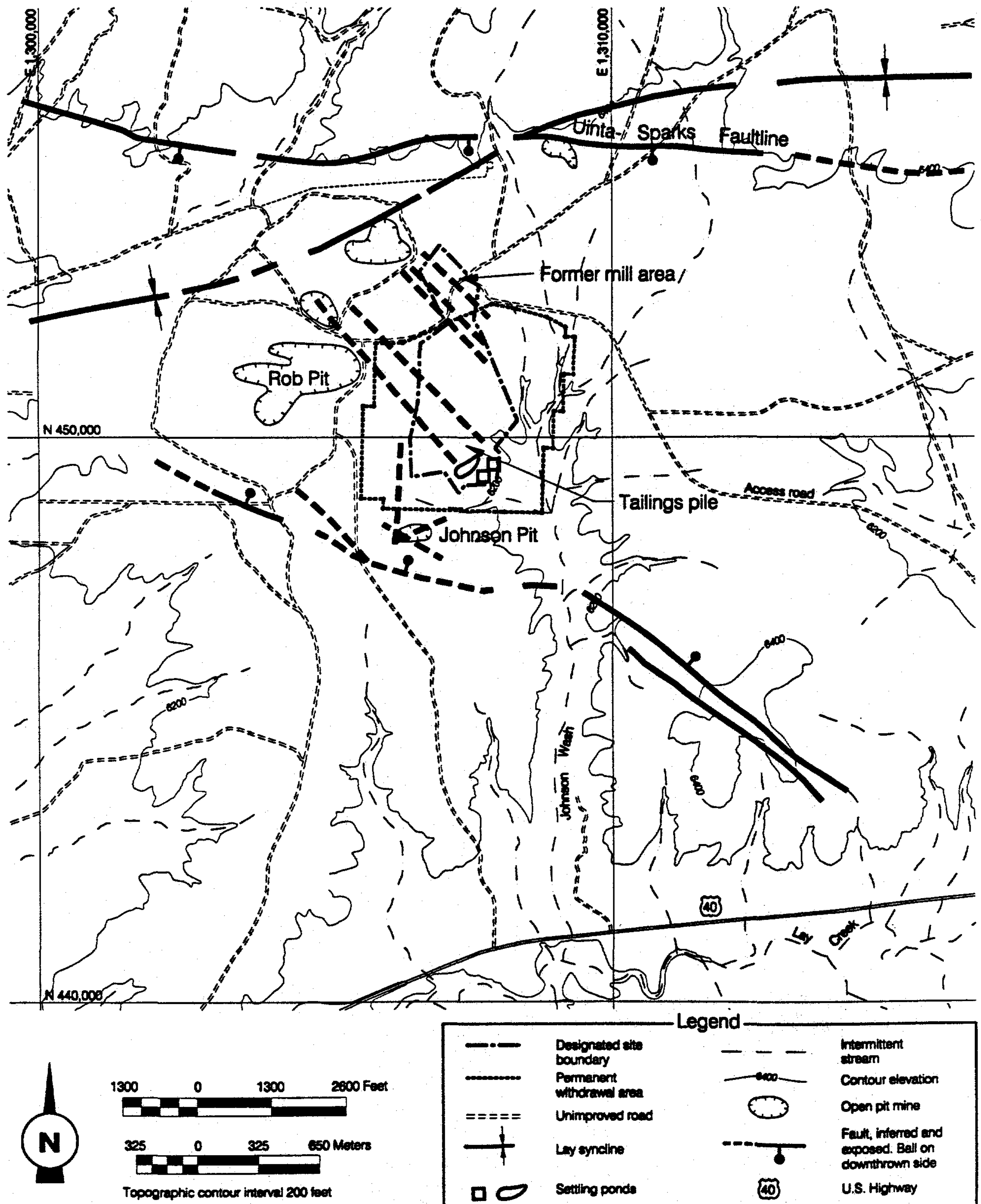
Figure 2.2
Site Boundaries, Topography, Mine Locations and Geologic Structures
Maybell, Colorado, Site



The designated site area, shown in Figure 2.2, covers approximately 110 ac (45 ha) and consists of a tailings pile and rubble from the demolition of the mill buildings buried in the former mill area. The site is situated between Johnson Wash to the east and Rob Pit to the west. Several reclaimed and unclaimed mines are in the immediate vicinity. Contaminated materials at the Maybell site include the tailings pile, which has an average depth of 20 feet (ft) (6 meters [m]) and contains 2.8 million cubic yards (yd^3) (2.1 million cubic meters [m^3]) of tailings. The former mill processing area is on the north side of the site and contains 20,000 yd^3 (15,000 m^3) of contaminated demolition debris. Off-pile contamination is present and includes areas adjacent to the tailings pile, as well as contamination dispersed by wind and surface water runoff. The volume of off-pile contamination to be placed in the disposal cell is 550,000 yd^3 (420,000 m^3). The total volume of contaminated materials to be disposed of as part of the remedial action is estimated to be 3.4 million yd^3 (2.6 million m^3).

2.2 CLIMATE

From 1959 through 1994, the average annual precipitation at the town of Maybell was 11.7 inches (29.7 centimeters [cm]) and was distributed relatively uniformly throughout the year (WRCC, 1995). The snowfall accumulation is approximately 65 inches (170 cm) per year and generally does not result in rapid runoff. Based on conditions at the airport in Craig, Colorado, the prevailing winds are from the west southwest, and to a lesser degree from the east northeast. The prevailing wind at the tailings pile is toward the east and to a lesser degree north and south along Johnson Wash (URS Company, 1976).

The average maximum temperature in July is 86 degrees Fahrenheit (°F) (30 degrees Celsius [°C]); the average minimum temperature in January is 1°F (-17°C). Extreme temperatures recorded east of the site in Lay, Colorado, range from 101°F to -47°F (38°C to -44°C) (URS Company, 1976). Average annual pan evaporation in the area is 48 inches (122 cm) (NOAA, 1968).

2.3 PHYSIOGRAPHIC SETTING

The Maybell site is located in a small valley that is approximately 2.4 mi (3.8 km) long east to west and 2.0 mi (3.2 km) wide north to south. The center of this valley where the tailings pile is located is at an elevation of about 6200 ft (1900 m) mean sea level (MSL). Hill tops around the valley reach elevations of as much as 400 ft (120 m) above the center of the valley. This valley is drained by Johnson Wash (an ephemeral stream) and its tributaries to Lay Creek (Figure 2.2).

2.4 GEOLOGY

At the Maybell site surficial deposits consist of colluvium mantled slopes and narrow alluvial deposits in gullies that feed Johnson Wash. These colluvial and alluvial deposits are up to 25 ft (8 m) thick. Alluvial deposits are also present along Johnson Wash, Lay Creek and the Yampa River (DOE, 1994).

The Maybell site is underlain by the Tertiary Browns Park Formation of Miocene age, which unconformably overlies truncated rocks of the Cretaceous Mancos Shale. The beds of the Browns Park Formation generally dip less than 10 degrees to the north toward the east-west trending axis of the Lay Syncline, located north of the site (Figure 2.2). In this area, the Browns Park Formation consists of fluviolacustrine (river and lake deposited) and eolian (windblown) sandstones overlying a basal conglomerate (Chenoweth, 1986). The lower conglomerate unit ranges in thickness from 0 to 150 ft (0 to 45 m). The upper sandstone unit (approximately 1000 ft [300 m] thick) consists of tan to gray, fine- to medium-grained sandstone with minor interbeds and lenses of conglomerate, chert, siltstone, marlstone, and volcanic ash and pumice (commonly altered to clay). The tan sandstones, typical of the oxidized zone, are commonly stained with limonite/hematite and jarosite. The unoxidized gray sandstones contain finely divided pyrite. Depth to the top of the gray sandstones ranges from 40 to 240 ft (12 to 73 m), which corresponds approximately to the first occurrence of ground water. The sandstone is generally very weakly cemented above the water table, and is generally friable and uncemented below the water table. Occasional thin lenses are moderately hard with calcite, silica, and clay cementation.

Uranium mineralization generally occurs in the upper sandstone unit of the Browns Park Formation. The source of the uranium is believed to be volcanic ash beds in the Browns Park Formation. Hydrocarbons escaping from underlying Cretaceous formations and migrating upward through faults into the Browns Park Formation are postulated to have been important in creating reducing conditions necessary for precipitation of uranium (Chenoweth, 1986). The Maybell District contains widespread low-grade uranium mineralization, where a number of open pit uranium mines supplied the Maybell site. These include Johnson Pit to the south, Rob Pit to the west, and several pits to the north and northeast (upstream/upgradient) of the millsite/tailings pile (Figure 2.2). The mineralized trend also extends south of U.S. Highway 40 and Lay Creek (Figure 2.1), with several open pit uranium mines (and prospects) in this area. The Maybell district has been extensively disturbed by exploration drilling and mining activities from the 1950s until the 1970s. Therefore, there is a potential for natural and other non-site-related sources of uranium and related constituents to impact ground water in the vicinity of the Maybell site.

2.5 HYDROGEOLOGY

Ground water occurs in the upper sandstone unit of the Browns Park Formation (uppermost aquifer) under unconfined conditions beneath the Maybell site. Water levels measured in monitor wells in the vicinity of the site range from 35 to over 300 ft (11 to 92 m) beneath the surface. Seasonal fluctuations of ground water elevations were generally less than 2 ft (0.6 m) (from lowest to highest ground water elevation) during a period of measurement of over 3 years. These minor fluctuations are in response to temporal and spatial variation in precipitation and subsequent recharge of the aquifer.

Ground water also occurs in the alluvium associated with the Yampa River and Lay Creek. Ground water in the Yampa River Valley alluvium is unconfined and ranges in depth from 10 to 20 ft (3 to 6 m) below land surface. Based upon ground water elevations projected from the potentiometric surface of the Browns Park Formation, it appears that the Yampa River Valley alluvium is recharged by ground water from the Browns Park Formation.

Ground water beneath the Maybell site is recharged from a limited upslope catchment basin. Recharge is principally from precipitation.

The potentiometric surface map of the upper Browns Park Formation aquifer indicates that ground water flow direction is generally toward the southwest beneath the site, with a hydraulic gradient of approximately 0.02 (Figure 2.3; DOE, 1994). Water level data and computer modeling of wastewater seepage from milling activities indicate that a ground water mound exists beneath the tailings pile. At the edges of the mound, the hydraulic gradient is steeper than the regional hydraulic gradient. A cross section with surface topography and the potentiometric surface shows this apparent ground water mound near the tailings pile (Figure 2.4).

Water levels are approximately 35 ft (11 m) higher than would be expected in monitor wells located near the center of the ground water mound and are steadily decreasing over time. Water levels in monitor well 649 have decreased approximately 7 ft (2 m) from December 1987 to November 1992. (Note: All well locations at this site are numbered MAY-01-0xxx. This reports uses the last three numbers to identify well location.)

Aquifer pumping tests were conducted in four monitor wells (662, 663, 665, and 672) to measure hydraulic parameters of the upper portion of the Browns Park Formation at the Maybell tailings pile (DOE, 1994). Results of Theis and Jacob analyses indicated unconfined conditions with delayed yield during the latter stages of the tests. Calculations based on data from 17 pumping tests of the four monitor wells indicate an arithmetic mean for transmissivity of 92 square feet (ft^2) per day (0.99 square centimeters [cm^2] per second) and a range of transmissivity values of 1.8 ft^2 per day (0.02 cm^2 per second) to 392 ft^2 per day (4.2 cm^2 per second). The range of hydraulic conductivity values is 0.05 ft per day (1.8×10^{-5} cm per second) to 6.6 ft per day (2.3×10^{-3} cm per second). The average hydraulic conductivity of the upper sandstone unit was estimated to be 1.7 ft per day (6.0×10^{-4} cm per second). Aquifer testing of the Browns Park Formation conducted in 1959 by Trace Elements Corporation yielded hydraulic conductivity values between 11.4 ft per day (4.0×10^{-3} cm per second) and 17.0 ft per day (6.0×10^{-3} cm per second) (Dames and Moore, 1975). These values are in the upper range of hydraulic conductivity values for a sandstone (Freeze and Cherry, 1979).

Figure 2.3
Potentiometric Surface Map for the Browns Park Formation Aquifer Maybell, Colorado, Site

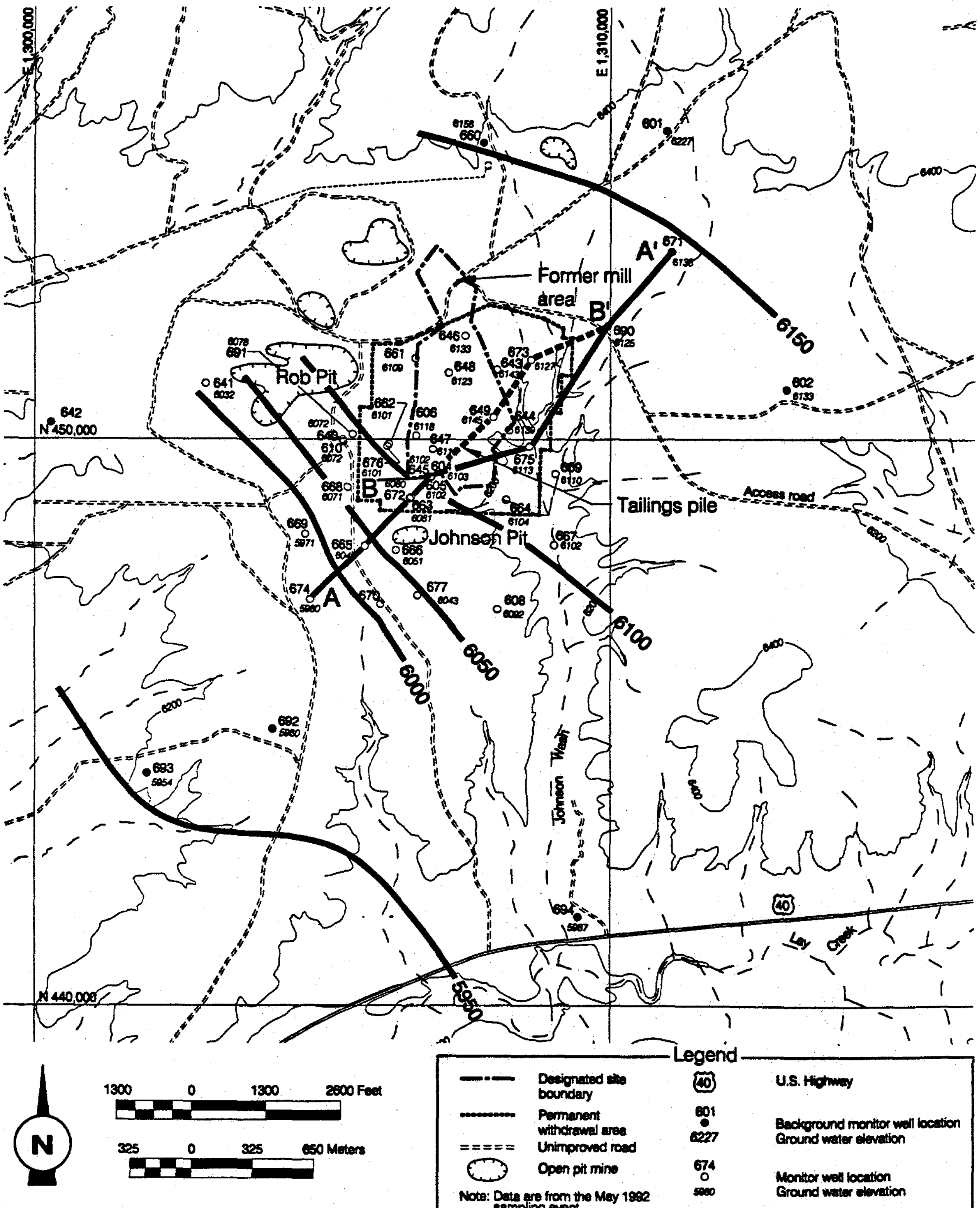


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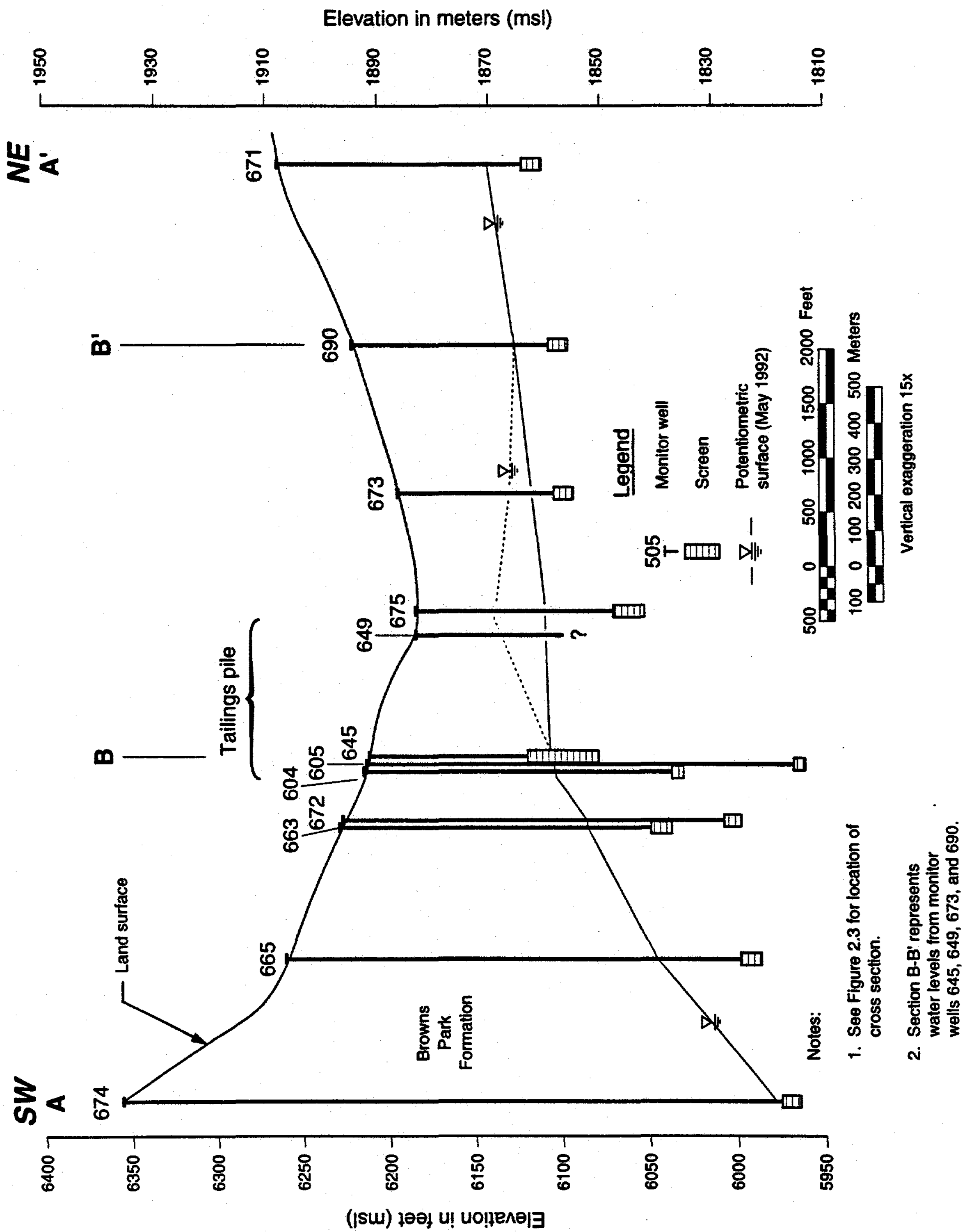
Figure 2.4
Cross Section of Land Surface and Potentiometric Surface Maybell, Colorado, Site



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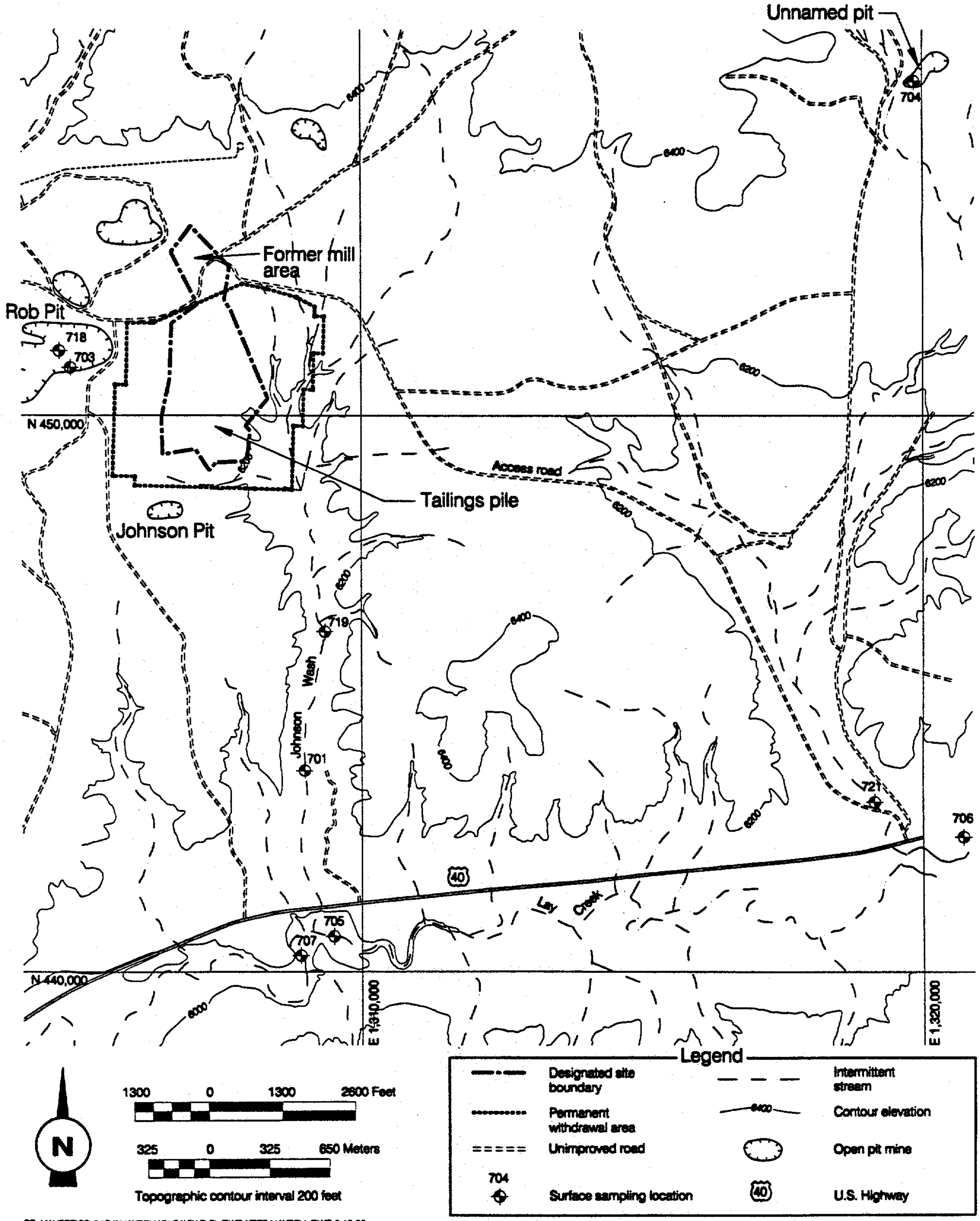
The average linear ground water velocity in the upper sandstone unit of the Browns Park Formation was estimated based on the most representative values (generally averaged) available from hydrogeologic characterization data for the site. Estimated values for linear ground water velocities range from 0.005 to 0.66 ft per day (0.002 to 0.20 m per day). The average linear ground water velocity was 0.17 ft per day (6 x 10^{-5} cm per second), based on an average hydraulic conductivity of 1.7 ft per day (6 x 10^{-4} cm per second) (derived from pumping test data), an average hydraulic gradient of 0.02 ft/ft (0.6 cm/cm) (from potentiometric surface map), and an effective porosity of 0.20 (Freeze and Cherry, 1979) (Calculation MAY-11-93-14-07-00 from DOE, 1994). Using a value of 0.17 ft per day (6 x 10^{-5} cm per second), or 62.0 ft per year (18.9 m per year), for an average linear ground water velocity, ground water could have moved horizontally downgradient, horizontally about 56 ft (17 m) to 7500 ft (2300 m) or a mean value of 1900 ft (580 m) since 1964 when the mill was shut down.

2.6 SURFACE WATER

Johnson Wash, an ephemeral stream, drains the Maybell site and nearby areas and flows only during major runoff events. Johnson Wash is a tributary to Lay Creek, which is another ephemeral stream. The confluence of Johnson Wash with Lay Creek is 1.5 mi (2.4 km) south of the site and 200 ft (60 m) lower in elevation than the base of the tailings pile (Figure 2.5). The bottom of Johnson Wash could intersect the water table at certain intervals. A seep (701) in Johnson Wash about 1000 ft (300 m) north of Lay Creek is very likely an expression of ground water. Seep 719, farther up the wash, may be the result of surface runoff that has infiltrated into the alluvium, but is perched above the more impermeable Browns Park Formation. Because of the distance of these seeps from the tailings pile and direction of ground water flow across the site, it is not likely that contamination in ground water beneath the tailings pile could reach the surface through these seeps.

The surface body of water nearest the Maybell site is in the bottom of Rob Pit, approximately 0.3 mi (0.5 km) west of the tailings pile. Rob Pit is a former open pit mine. The water surface elevation in the pit corresponds to the water table elevation in the area. Because ground water flows radially away from the ground water mound beneath the tailings pile, there is some component of flow from the mound toward Rob Pit. It is possible that constituents in ground water beneath the tailings pile could eventually reach Rob Pit. Surface water also occurs in the bottom of another open pit mine near Sugarloaf Basin approximately 2 mi (3 km) east of the Maybell site. The relationship of water in this pit to the ground water table is not known.

Figure 2.5
Surface Water Features and Sampling Locations
Maybell, Colorado, Site



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3.0 MAGNITUDE AND EXTENT OF CONTAMINATION

The purpose of this section is to delineate the area where processing-related ground water contamination exists, to identify constituents above background, and to estimate the amount of contamination that exists in ground water as a result of former uranium processing activities at the Maybell site. This information is used to develop the conceptual site model of exposure for the Maybell site.

3.1 DATA SOURCES AND STATISTICAL METHODS

Ground water quality data from the Maybell site collected from 1986 to 1995 were used to characterize the magnitude and extent of contamination (DOE, 1996). Figure 2.3 presents a map of the Maybell site showing the DOE monitor well network. Table 3.1 gives the sampling history and screen interval for each well. All wells were completed in the Browns Park Formation.

Data from filtered ground water samples were used to evaluate site-related ground water contamination because only one round of data from unfiltered ground water samples is available for the Maybell site. In August 1992, both filtered and unfiltered ground water samples were collected from some of the monitor wells at the site and analyzed for a limited number of inorganic constituents. The 1992 results suggest that the following constituents may be higher in unfiltered than in filtered ground water: aluminum, iron, lead, manganese, silica, uranium, vanadium, and zinc.

In 1988 and 1989, ground water from three monitor wells (643, 645, and 648) at the Maybell site was screened for organic constituents listed in Appendix IX to 40 CFR Part 264. There were no organic constituents detected in 1988. In 1989 small amounts of carbon disulfide and toluene (18 and 19 micrograms per liter respectively) were detected in ground water from monitor well 643, directly beneath the pile. There is no information to indicate that these chemicals were used during uranium processing at the site.

Statistical methods were employed to identify constituents in ground water that are elevated above ambient levels as a result of contamination added to the ground water from former uranium processing activities at the site (DOE, 1996). Concentrations of constituents in ground water from nine monitor wells completed directly beneath the tailings pile and processing site (locations 606, 643, 644, 646, 647, 648, 649, 661 and 673) were compared to concentrations of constituents found in eight background ground water wells (locations 601, 602, 660, 671, 690, 692, 693, and 694). Well locations are found on Figure 2.3. Measurements from the selected wells were ranked from 1 = smallest to N = largest, and then the average rankings of the wells were compared using analysis of variance (ANOVA). The results of the procedure approximate those of the Kruskal-Wallis nonparametric test when applied to data sets with more

Table 3.1 Monitor well information, Maybell, Colorado, site

Monitor well ID	Years sampled	Number of sampling rounds	Screen interval (ft)
Background wells			
Upgradient			
MAY-01-0601	86-92, 94	9	147-152
MAY-01-0602	86-92, 94-95	12	156-161
MAY-01-0660	89-92, 95	6	280-290
MAY-01-0671	89-92	5	140-150
MAY-01-0690	87-92, 94-95	9	115-125
Farther downgradient			
MAY-01-0692	87-90, 92	6	340-350
MAY-01-0693	87-92	7	281-296
MAY-01-0694	87-92	7	61-76
Inside withdrawal area			
Tailings-area wells			
MAY-01-0606	86-92, 94-95	11	122-137
MAY-01-0643	86-92	9	48-88
MAY-01-0644	86-92	9	43-83
MAY-01-0646	86-92	9	98-138
MAY-01-0647	86-92	9	NA
MAY-01-0648	86-90, 92	8	NA
MAY-01-0649	86-92	9	NA
MAY-01-0661	89-92, 94-95	7	140-150
Adjacent to the site			
MAY-01-0604	86-92, 94-95	12	177-182
MAY-01-0605	86-92, 94-95	12	242-247
MAY-01-0662	89-92	5	180-190
MAY-01-0663	89-92, 94-95	7	180-189
MAY-01-0664	89-92	5	130-139
MAY-01-0672	89-92	5	220-230
MAY-01-0673	89-92, 94-95	7	90-100
MAY-01-0675	89-92, 95	6	100-110
MAY-01-0676	89-92, 94-95	7	150-159
MAY-01-0695	94-95	2	130-150
MAY-01-0696	94-95	2	148-168

Table 3.1 Monitor well information, Maybell, Colorado, site (Concluded)

Monitor well ID	Years sampled	Number of sampling rounds	Screen interval (ft)
Outside withdrawal area			
Immediately outside			
MAY-01-0609	86-92	9	103-113
MAY-01-0610	86-92	9	185-200
MAY-01-0640	86-88, 92	4	NA
MAY-01-0665	90-92, 94	6	260-270
MAY-01-0666	89-92	5	230-240
MAY-01-0667	89-92, 95	6	80-89
MAY-01-0668	89-92	5	220-229
MAY-01-0669	90-92	4	330-350
MAY-01-0691	87-87-90, 92	6	160-170
Farther outside			
MAY-01-0608	86-92	9	225-245
MAY-01-0641	86-92	8	NA
MAY-01-0642	86	1	220-230
MAY-01-0670	90, 92	3	400-420
MAY-01-0674	90-92, 95	6	380-390
MAY-01-0677	90-92	5	254-263

NA – not available.

than 30 observations (EPA, 1989). Data sets analyzed for the Maybell site typically have 100 or more observations per constituent. The 0.10 level of significance was applied for each evaluated constituent.

The hypothesis was tested that all background and tailings-area wells access ground water with the same average concentration. Rejection of the hypothesis implies that at least one well in the group differs from the others. In such cases, individual follow-up tests were conducted comparing the average concentration of each of the nine tailings-area wells to the average background concentration. In order to control the probability of incurring one or more false positive results among the nine tests at approximately 0.10, individual tests were evaluated at the 0.10/9 = 0.011 level of significance. The statistical comparison procedures involved 24 constituents in the ground water at the Maybell site. Table 3.2 presents these constituents and indicates which of the nine tailings-area wells have average concentrations statistically above average background.

3.2 BACKGROUND WATER QUALITY SUMMARY

Background water quality is defined as the quality of ground water that would be present at the site if uranium milling activities had not taken place. Background monitor wells 601, 602, 660, 671, 690, 692, 693, and 694 are located sufficiently upgradient or downgradient from the tailings pile to not be affected by tailings leachate. Domestic well 650 was included in previous characterizations of background ground water quality in the Browns Park Formation (DOE, 1994), but was omitted for this assessment because of its distance from the site (more than 5 mi [8 km]).

Background ground water is locally variable and generally poor in the vicinity of the Maybell site. Large amounts of low- to intermediate-grade, sub-economic mineralized material are present in the Browns Park Formation. It is estimated that the Maybell area could contain at least 200 million pounds (90 million kilograms [kg]) of uranium oxide in intermediate-grade resources (Chenoweth, 1986). These unmined intermediate-grade deposits are a natural source for uranium and other ore-related constituents, such as arsenic and selenium, in the ground water. In addition, several open pit mines are located hydraulically upgradient of the Maybell site. The Gertrude, Sage, and an unnamed strip mine located just northeast of the Maybell site are open pit mines that represent additional potential sources of contamination for ground water at the Maybell site. Portions of the Browns Park Formation have become oxidized through mining activities, resulting in mobilization of arsenic, cadmium, molybdenum, lead, radium, selenium, and uranium, to levels above EPA ground water standards maximum concentration limit (MCL) in some background wells (40 CFR Part 192). Thus, constituents in ground water may be derived from both natural (mineralized zones) and other (exploration drilling and open pit mining) independent of the uranium milling activities that took place at the Maybell site. On the basis of widespread ambient contamination in the region from uranium ore deposits, background ground water at the site is classified as limited use ground water (DOE, 1994).

Table 3.2 Constituents above background concentrations under or near the tailings pile, Maybell, Colorado, site

	Well location								
Constituent	606	643	644	646	647	648	649	661	673
<u>Inorganic</u>									
Aluminum	X	X				X	X		
Ammonium				X					
Cadmium	X								
Calcium	X	X	X	X	X	X	X	X	X
Chloride	X		X	X	X	X	X	X	X
Copper		X	X		X	X	X		
Fluoride	X	X	X	X		X	X		
Iron	X								
Magnesium	X	X	X	X	X	X	X	X	X
Manganese	X	X		X					
Molybdenum	X			X		X			
Nitrate	X	X	X	X	X	X	X	X	X
Phosphate		X	X	X	X	X	X		
Potassium	X	X	X	X	X	X	X	X	
Selenium	X	X	X	X	X	X		X	X
Sodium	X	X	X	X		X	X	X	X
Strontium		X	X	X	X	X	X	X	X
Sulfate	X	X	X	X	X	X	X		X
Uranium	X	X	X	X	X	X	X	X	X
Zinc	X	X							
<u>Radionuclides</u>									
Lead-210	X	X	X		X	X	X		
Polonium-210		X			X				
Radium-226	X	X	X	X		X	X		
Thorium-230						X	X		

X – constituent concentration statistically is above average background.

Because these natural and man-made sources are nonuniformly distributed in the area, background ground water quality is spatially highly variable. In addition, it has been hypothesized that hydrocarbons derived from underlying Cretaceous formations entered the Browns Park Formation along steeply dipping faults and created a reducing environment favorable for the precipitation of uranium (Chenoweth, 1986). Resulting ore bodies are local vein-like and tabular deposits adjacent to faults. Consequently, redox conditions (redox [Eh] representing a major class of chemical reactions, is the tendency for electron transfer reactions to occur) are variable on a scale of a few hundred feet. The wide variation in Eh measurements observed at the site (105 to 573 millivolts [mV]) is accompanied by a similar spatial variability in concentrations of redox sensitive constituents like iron and manganese.

In general, the background ground water is classified as a calcium bicarbonate/sulfate type (Figure 3.1). The pH of these waters tends to be near neutral (6.8 to 7.2) but, again pH is locally variable. For example, the pH of ground water in monitor well 601 is acidic (near pH 5) as a result of localized sulfide oxidation within the ore zones at the site. Total dissolved solids range from 257 to 4940 milligrams per liter (mg/L) in background ground water and alkalinity (as mg/L $CaCO_3$) ranges from 4 to 566.

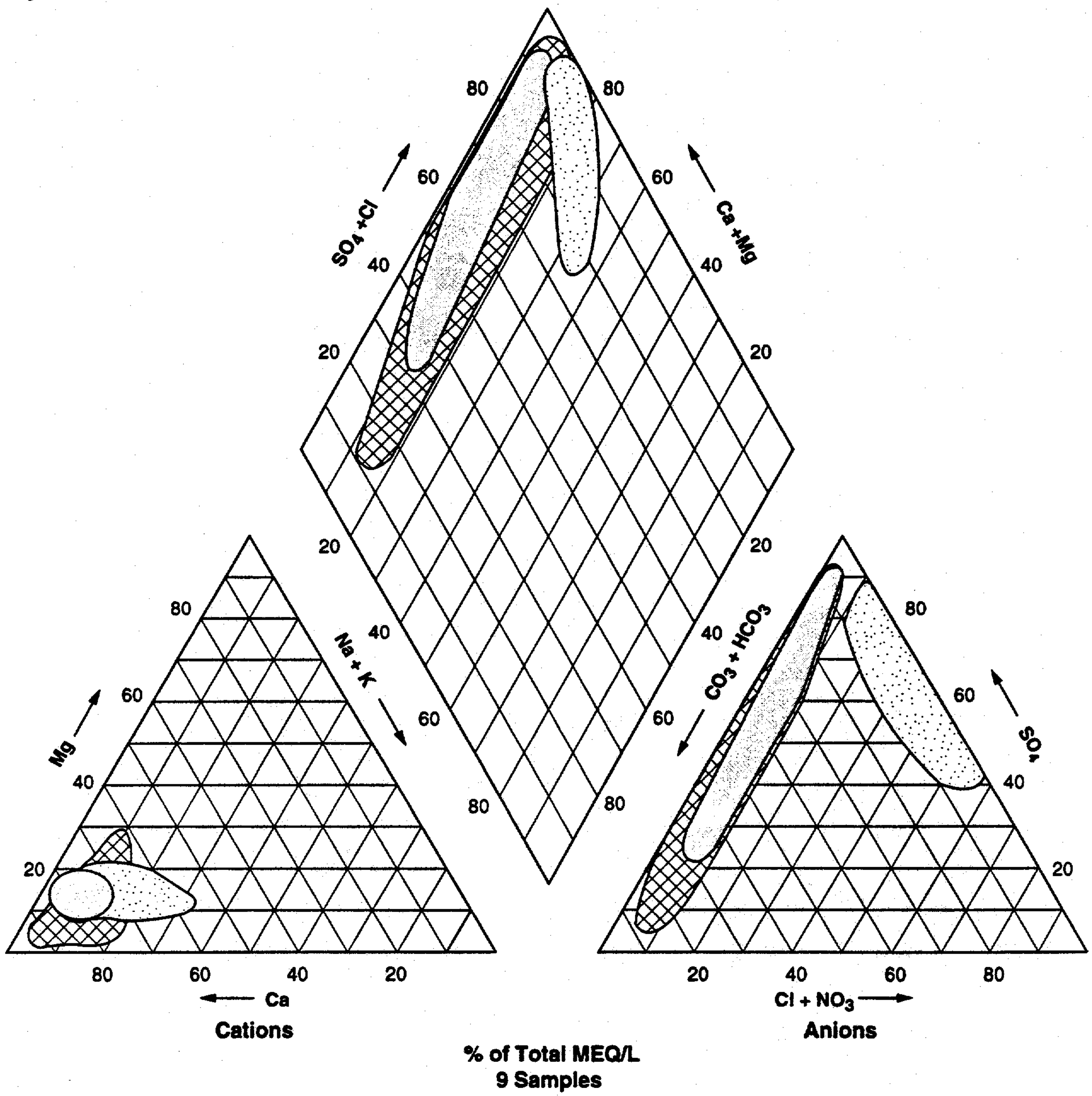
Table 3.3 summarizes the background ground water quality data for monitored constituents at the site. For each background well, the median concentration of a constituent from multiple sampling rounds was computed. The background wells were then ranked from lowest to highest on the basis of their medians. Table 3.3 shows the median concentration of the background well with the lowest ranking, the middle ranking, and the highest ranking. This table arrangement was selected to illustrate the high degree of geographic variation in concentration between background wells.

3.3 MAGNITUDE OF SITE-RELATED GROUND WATER CONTAMINATION

Acid leaching, followed by resin-in-pulp ion exchange extraction of uranium ores contributed sulfuric acid and ammonium nitrate to the tailings pile, and, thus, to the ground water at the Maybell site. Additionally, sodium chlorate was used as an oxidant. Therefore, indicators of contamination that might be expected in downgradient wells are the ammonium, nitrate, sulfate, and chloride ions. Contaminants that can be expected in association with the uranium ores themselves include arsenic, molybdenum, selenium, uranium, and vanadium (Evans, 1987).

A map showing the highest observed concentrations of nitrate and uranium in monitor wells at the site is presented in Figure 3.2. These two constituents are among the most mobile constituents derived from uranium processing at the site. Therefore, levels of these constituents above ambient background define the maximum extent of processing related contamination. Because background conditions are so variable, the exact edge of the contaminant plume is not well

Figure 3.1
Trilinear Plot Showing Major Ion Concentrations in Ground Water Monitor Wells Maybell, Colorado, Site



Background monitor wells	Millsite/ tailings-area monitor wells	Monitor wells just outside permanent withdrawal area
601	606	609
602	643	610
660	644	640
671	646	665
690	647	666
692	648	667
693	649	668
694	661	669
	673	691

Legend

- Background wells
- Millsite/tailings-area wells
- Downgradient wells

Data from October/November 1992.

MAC: SITE/MAYBELL/BLRA/TRILINEAR PLOT

Table 3.3 Background ground water quality in the Browns Park Formation, Maybell, Colorado, site

Constituent well group	Median concentration[a] (mg/L)		
	Lowest well	Middle well	Highest well
Aluminum			
Background	<0.05	<0.10	0.21
Tailings-area	<0.05	0.20	1.57
Adjacent	<0.05	0.08	<0.10
Outside PWA	<0.05	<0.10	0.20
Ammonium			
Background	<0.1	0.2	0.5
Tailings-area	<0.1	<0.1	84
Adjacent	<0.1	<0.1	<0.1
Outside PWA	<0.1	<0.1	0.2
Antimony			
Background	<0.003	<0.003	0.004
Tailings-area	<0.003	<0.003	0.014
Adjacent	<0.003	<0.003	<0.003
Outside PWA	<0.003	<0.003	<0.003
Arsenic			
Background	<0.008	0.01	0.05
Tailings-area	0.007	0.01	0.20
Adjacent	<0.008	<0.01	0.07
Outside PWA	<0.010	<0.01	0.03
Barium			
Background	<0.1	<0.1	0.2
Tailings-area	<0.1	<0.1	<0.1
Adjacent	<0.1	<0.1	<0.1
Outside PWA	<0.1	<0.1	<0.1
Beryllium			
Background	<0.005	<0.005	<0.01
Tailings-area	<0.008	<0.008	<0.01
Adjacent	<0.005	<0.008	<0.01
Outside PWA	<0.005	<0.008	<0.03
Boron			
Background	<0.1	<0.1	0.6
Tailings-area	<0.1	<0.1	0.1
Adjacent	<0.1	<0.1	<0.1
Outside PWA	<0.1	<0.1	0.2
Cadmium			
Background	<0.001	<0.001	0.002
Tailings-area	<0.001	<0.001	0.002
Adjacent	<0.001	<0.001	<0.001
Outside PWA	<0.001	<0.001	<0.001

Table 3.3 Background ground water quality in the Browns Park Formation, Maybell, Colorado, site (Continued)

Constituent well group	Median concentration[a] (mg/L) Lowest well	Middle well	Highest well
Calcium			
Background	63	262	659
Tailings-area	273	728	1080
Adjacent	44	420	566
Outside PWA	68	117	414
Chloride			
Background	6.1	13	32
Tailings-area	10	48	142
Adjacent	2.8	13	297
Outside PWA	8.4	12	13
Chromium			
Background	<0.01	<0.01	<0.01
Tailings-area	<0.01	<0.01	<0.03
Adjacent	<0.01	<0.01	<0.01
Outside PWA	<0.01	<0.01	0.03
Cobalt			
Background	<0.05	<0.05	<0.05
Tailings-area	<0.04	<0.05	<0.05
Adjacent	<0.04	<0.05	<0.05
Outside PWA	<0.04	<0.05	<0.05
Copper			
Background	<0.02	<0.02	<0.02
Tailings-area	<0.02	<0.02	0.04
Adjacent	<0.02	<0.02	<0.02
Outside PWA	<0.02	<0.02	<0.02
Cyanide			
Background	<0.01	<0.01	<0.01
Tailings-area	<0.01	<0.01	<0.01
Adjacent	<0.01	<0.01	<0.01
Outside PWA	<0.01	<0.01	<0.01
Fluoride			
Background	0.1	0.2	0.6
Tailings-area	0.2	0.3	0.7
Adjacent	0.1	0.2	0.4
Outside PWA	<0.1	0.2	0.4
Iron			
Background	0.03	0.17	2.2
Tailings-area	<0.03	0.11	9.1
Adjacent	<0.03	0.39	4.2
Outside PWA	<0.04	0.07	0.2

Table 3.3 Background ground water quality in the Browns Park Formation, Maybell, Colorado, site (Continued)

	Median concentration[a] (mg/L)		
Constituent well group	Lowest well	Middle well	Highest well
Lead			
Background	<0.005	<0.01	<0.01
Tailings-area	<0.005	<0.01	<0.01
Adjacent	<0.003	<0.005	<0.01
Outside PWA	<0.008	<0.01	<0.01
Magnesium			
Background	5	19	93
Tailings-area	19	89	160
Adjacent	5	34	57
Outside PWA	7	12	41
Manganese			
Background	0.05	0.19	5.2
Tailings-area	0.02	0.18	4.2
Adjacent	<0.01	0.18	0.7
Outside PWA	<0.02	0.04	0.2
Mercury			
Background	<0.0002	<0.0002	<0.0002
Tailings-area	<0.0002	<0.0002	<0.0002
Adjacent	<0.0002	<0.0002	<0.0002
Outside PWA	<0.0002	<0.0002	<0.0002
Molybdenum			
Background	<0.01	<0.02	0.06
Tailings-area	<0.01	<0.05	0.09
Adjacent	<0.01	0.02	0.09
Outside PWA	<0.01	0.02	0.04
Nickel			
Background	<0.04	<0.04	<0.04
Tailings-area	<0.04	<0.04	<0.05
Adjacent	<0.04	<0.04	<0.04
Outside PWA	<0.04	<0.04	<0.04
Nitrate			
Background	<1.0	<1.7	9
Tailings-area	<1.0	950	1650
Adjacent	<1.0	3.7	22
Outside PWA	<1.0	2.6	5
Phosphate			
Background	0.1	0.5	1.1
Tailings-area	<0.1	1.9	5.0
Adjacent	<0.1	<0.1	0.2
Outside PWA	<0.1	<0.1	<0.5

Table 3.3 Background ground water quality in the Browns Park Formation, Maybell, Colorado, site (Continued)

	Median concentration[a] (mg/L)		
Constituent well group	Lowest well	Middle well	Highest well
Potassium			
Background	2.1	4.9	28
Tailings-area	5.1	16	35
Adjacent	1.7	7.0	13
Outside PWA	2.6	4.3	5
Selenium			
Background	<0.005	<0.005	1.1
Tailings-area	<0.005	0.79	1.4
Adjacent	<0.005	<0.005	<0.02
Outside PWA	<0.005	<0.005	0.02
Silica			
Background	27	48	84
Tailings-area	22	50	57
Adjacent	23	39	52
Outside PWA	25	40	58
Sodium			
Background	15	49	323
Tailings-area	18	153	423
Adjacent	7.0	22	33
Outside PWA	9.5	13	32
Silver			
Background	<0.01	<0.01	<0.01
Tailings-area	<0.01	<0.015	0.02
Adjacent	<0.01	<0.01	<0.01
Outside PWA	<0.01	<0.01	<0.03
Strontium			
Background	0.2	1.3	3.2
Tailings-area	0.9	2.7	3.8
Adjacent	0.2	1.0	2.9
Outside PWA	0.5	0.7	1.6
Sulfate			
Background	16	684	2120
Tailings-area	610	1580	1840
Adjacent	17	785	1570
Outside PWA	44	137	1010
Thallium			
Background	<0.01	<0.01	<0.01
Tailings-area	<0.01	<0.01	<0.03
Adjacent	<0.01	<0.01	<0.01
Outside PWA	<0.01	<0.01	<0.03

Table 3.3 Background ground water quality in the Browns Park Formation, Maybell, Colorado, site (Continued)

Constituent well group	Median concentration[a] (mg/L) Lowest well	Middle well	Highest well
Tin			
Background	<0.005	<0.005	0.019
Tailings-area	<0.005	0.012	0.030
Adjacent	<0.005	<0.005	0.011
Outside PWA	<0.005	<0.005	<0.005
Uranium			
Background	0.002	0.004	0.083
Tailings-area	<0.003	0.39	7.0
Adjacent	0.002	0.022	0.10
Outside PWA	<0.003	<0.003	0.039
Vanadium			
Background	<0.01	0.02	0.03
Tailings-area	<0.01	0.03	<0.05
Adjacent	<0.01	0.03	0.04
Outside PWA	0.01	0.02	0.04
Zinc			
Background	<0.005	0.009	0.046
Tailings-area	<0.005	0.026	0.14
Adjacent	<0.005	0.008	0.014
Outside PWA	<0.005	0.005	0.019
Radionuclides			
Lead-210			
Background	0.0	0.6	2.8
Tailings-area	0.2	2.3	7.4
Adjacent	0.6	0.8	2.7
Outside PWA	0.0	0.7	37
Polonium-210			
Background	0.1	0.2	0.7
Tailings-area	0.1	0.4	1.1
Adjacent	0.1	0.4	0.7
Outside PWA	0.0	0.2	2.5
Radium-226			
Background	0.0	0.4	3.1
Tailings-area	0.0	0.8	1.8
Adjacent	0.1	0.2	0.3
Outside PWA	0.0	0.5	15
Radium-228			
Background	0.1	0.5	1.3
Tailings-area	0.3	0.9	1.7

Table 3.3 Background ground water quality in the Browns Park Formation, Maybell, Colorado, site (Concluded)

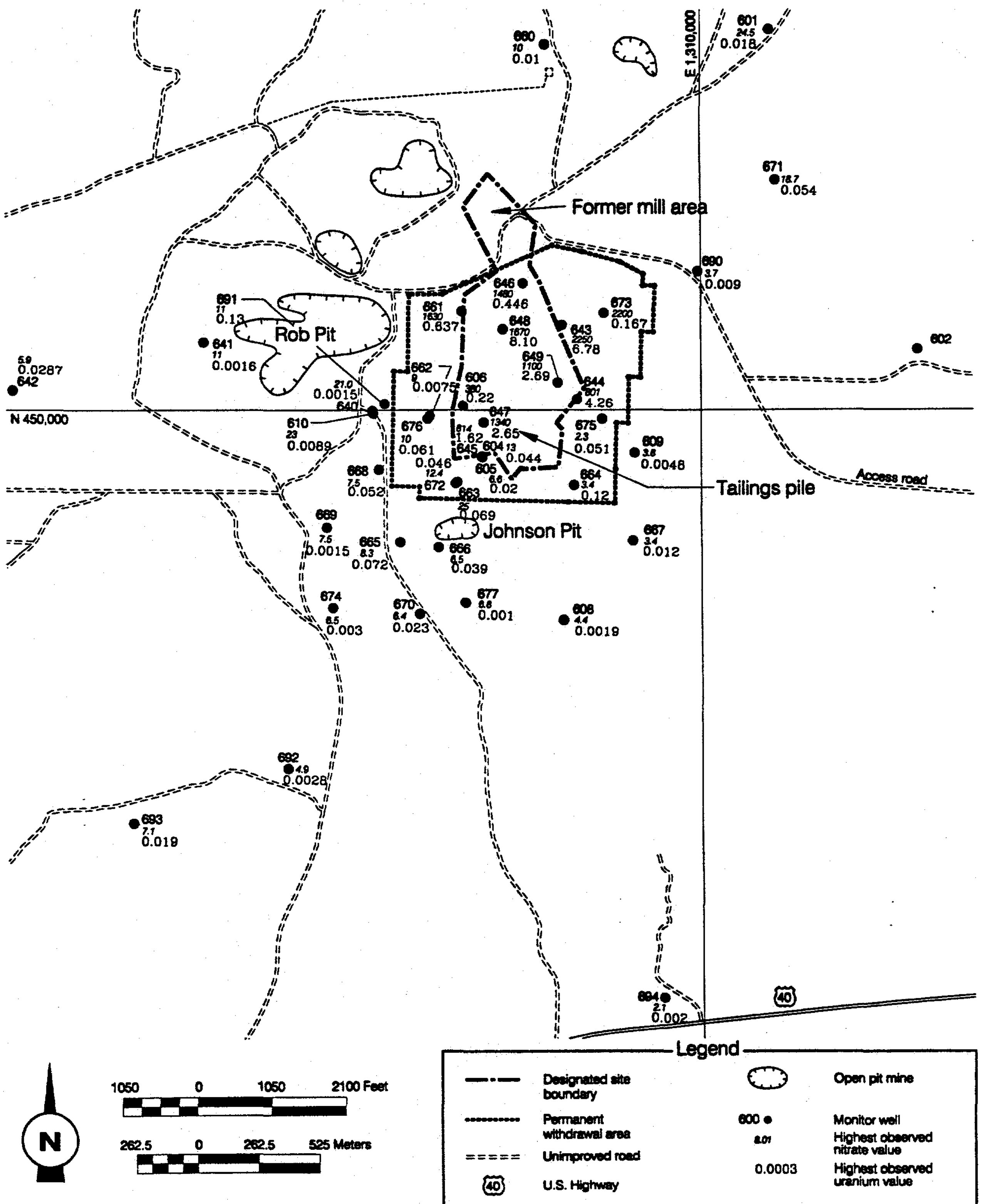
Constituent well group	Median concentration[a] (mg/L) Lowest well	Middle well	Highest well
Radium-228 (continued)			
Adjacent	0.0	0.4	1.1
Outside PWA	0.0	0.5	1.5
Thorium-230			
Background	0.0	0.1	0.3
Tailings-area	0.0	0.3	0.8
Adjacent	0.0	0.1	0.8
Outside PWA	0.0	0.2	0.6

[a]The median concentration/activity for any well is found by listing the concentration/activity data *for the well from lowest to highest. The median is the middle number in the ordered list.* Medians from the different wells within the same well group are then ordered from smallest to largest. August 1986 through April 1995 filtered ground water samples were used.

Notes:
1. Background monitor wells: 601, 602, 660, 671, 690, 692, 693, and 694.
2. Tailings-area monitor wells: 604, 605, 606, 643, 644, 646, 647, 648, 649, 661, and 673 (well 673 is included among on-site wells due to high nitrate concentrations).
3. Adjacent monitor wells (outside the tailings areas, but inside the boundary for the permanent withdrawal area): 662, 663, 664, 672, 675, 676, 695, 696.
4. Outside permanent withdrawal area monitor wells (directly outside the boundary of the permanent withdrawal area): 609, 610, 665, 666, 667, 668, and 691.

PWA – permanent withdrawal area.

Figure 3.2
Highest Observed Nitrate and Uranium Concentrations in Monitor Wells Maybell, Colorado, Site



PC: H:\USERS\SUNIGA\MAYBELL\BLRA\HONUC-MW.DWG XREF:MAYBELL.DWG 2-19-96 defined. However, Figure 3.2 indicates that contamination in ground water has not extended more than a few hundred feet from the tailings pile.

Table 3.3 provides for a comparison of background ground water quality to water quality in the tailings area, in areas adjacent to the site and inside the permanent withdrawal area, and immediately outside of the permanent withdrawal area. These data indicate that levels of constituents that were added to ground water by uranium milling activities (shown in Table 3.2) fall off sharply in areas adjacent to the site. All constituents are within the range of background levels in monitor wells that are located outside of the permanent withdrawal area, with the exception of certain radiological constituents, discussed later in this section. The correspondence between the composition of background ground water quality and downgradient water quality is shown graphically in Figure 3.1. Note also that anions contained in contaminated ground water directly beneath the tailings pile plot in a distinctly different field from background and downgradient ground water on this trilinear diagram of major ion species.

Many process- and ore-related constituents are attenuated in the unsaturated zone between the bottom of the tailings pile and the water table. Water levels measured in the vicinity of the site indicate that the unsaturated zone is from 35 to over 300 ft (11 to 90 m) thick. Chemical reaction with plentiful calcite in the tailings subsoil neutralize acidic tailings leachate and precipitate gypsum, removing sulfate from the infiltrating water (DOE, 1994). High concentrations of ferrous iron are stable in acidic tailings leachate (up to 560 mg/L) but ferric iron oxyhydroxides are the stable iron species in more neutral environments (Brookins, 1988). Thus, abundant iron oxyhydroxides were precipitated in the tailings sub-soil during neutralization of tailings leachate (DOE, 1994). Iron oxyhydroxides have a strong affinity for many contaminant species and the precipitation of these iron-rich phases enhance the adsorption of arsenic, molybdenum, selenium, uranium, and other contaminant species present in contaminated pore water, mitigating concentrations of these species in ground water beneath the site.

Notwithstanding these attenuation processes, several site contaminants have traveled through the unsaturated zone and are present in ground water directly beneath the tailings pile at the site. Several mechanisms may be responsible for the lack of ground water contamination more than a short distance downgradient of the tailings pile. The process of gypsum and iron oxyhydroxide precipitation may continue in ground water beneath the site, causing some attenuation of trace metals downgradient of the tailings pile (DOE, 1994). In addition, some nitrate may be removed by biologically mediated denitrification processes as suggested by microbiological studies conducted at the site (Thompson and Associates, 1990). It is unlikely, however, that these mechanisms completely remove all contamination downgradient of the site. Other possible mechanisms include: no ground water contamination (the apparent contamination is due to leaky wells drilled through the tailings); or, very slow ground water movement (local flow conditions in the Browns Park Formation are variable or the estimated average ground water velocity of 60 ft per year is an overestimate). Regardless of the reason, ground water contamination has not moved beyond the immediate vicinity of the mill site and tailings pile in the almost 40 year period since the milling operations began.

Concentrations of radionuclides lead-210 and radium-226 are above ambient background levels in a few monitor wells located outside the permanent withdrawal area, most notably in monitor well 668. However, the elevated levels are not the result of processing-related contamination. Lead-210 and radium-226 are both extremely insoluble in ground water and their movement is strongly retarded relative to more mobile constituents such as nitrate or uranium. Yet, for monitor well 668, concentrations of both nitrate and uranium fall within the range of background in ground water, whereas radium-226 activity measured in ground water from the well is an order of magnitude higher than radium-226 activity measured in ground water directly beneath the tailings pile.

Redox conditions in ground water in monitor well 668 are reducing (Eh commonly in the -65 to 0 mV range), probably as the result of ore-forming conditions present nearby. Uranium concentrations are low in this ground water (commonly in the range of 0.002 to 0.004 mg/L) because under reducing conditions any uranium in ground water would be precipitated as uraninite. Thus, uranium is being concentrated in the aquifer matrix and the local area around monitor well 668 is likely one of the many zones of intermediate grade mineralization in the Maybell area. Lead-210 and radium-226 are daughter products of the uranium decay series. An atom of uranium is stable in the crystalline structure of uraninite but when an atom of uranium decays to another element, the resulting atom may be unstable in the structure and will have a tendency to be released to ground water. Consequently, high levels of lead-210 and radium-226 in these downgradient monitor wells are not indicators of processing-related contamination; but, instead, these constituents are signs of uranium ore formation. This process also applies to other members of the uranium decay chain.

To summarize the results of geochemical analysis presented in this section; uranium processing-related constituents have not migrated more than a few hundred feet from the tailings pile and there is no evidence that ground water outside the permanent withdrawal area has been contaminated by former uranium processing activities at the Maybell site. High levels of radionuclides in a few off-site wells are the result of ore-forming processes.

3.4 SURFACE WATER

Surface water near the Maybell site is limited to ponded water in Rob Pit, two seeps in Johnson Wash, and locations along the intermittently flowing Lay Creek. Current data show no indication that contaminated ground water has impacted any surface water in the vicinity of the Maybell site. Levels of uranium ore-related constituents that have been detected in surface water are primarily due to naturally occurring mineralization in the Maybell area.

Surface water sampling locations are shown in Figure 2.5. Table 3.4 indicates the years each location was sampled and the number of rounds of data available from each location. An unnamed pit northeast of Sugarloaf Basin and an intermittent stream draining Sugarloaf Basin have been sampled to represent background locations for Rob Pit and Johnson Wash, respectively.

Table 3.5 summarizes the results of analyses of surface water samples in Johnson Wash and Lay Creek for several constituents that are indicators of contamination. Section 2.6 concludes that because of the distance of the seeps in Johnson Wash and the sampling locations along Lay Creek from the tailings pile and the direction of ground water flow across the site, it is not likely that contamination in ground water beneath the tailings pile could reach the surface through these seeps. A Bureau of Land Management (BLM) well (656) adjacent to Johnson Wash surface seep location 701 was sampled to test whether contamination in seep 701 is derived from ground water or surface sources. Results demonstrate that contamination is related to surface sources. For example, uranium values of <0.001 mg/L in well 656 are considerably lower than those found in the surface seep (0.124 mg/L) less than 100 ft (30 m) away.

A number of open pit uranium mines affect surface locations in Johnson Wash. Some are upstream/upgradient from the Maybell site and several open pit uranium mines (and prospects) are located south of U.S. Highway 40, with the mineralized trend extending south across the highway and Lay Creek.

Consequently, there is significant naturally occurring mineralization in the region that results in elevated concentrations of potentially hazardous constituents expected to be related to uranium ore. Sources of constituents include dissolution of near-surface mineralization, surface runoff from mines, overburden piles, and ore stockpiles, and accumulations of materials in alluvial stream sediments.

Johnson Wash was also the locus of routine discharge of tailings effluent during the early period of operation of the uranium mill at Maybell (Smart, 1960). In addition, an unplanned discharge of tailings occurred into the wash in 1961 (Cromer, 1961). Thus, it is possible that some of the materials that are located at the bottom of the wash are related to milling.

Therefore, levels of uranium ore-related constituents in surface water samples from Johnson Wash and Lay Creek are derived from mineralization in both the Johnson Wash and Lay Creek drainage areas and could potentially be attributed, in part, to release of contaminated material from the millsite. Current data do not allow discrimination between these two sources. Because contaminated ground water is not the source of these constituents, the possible surface contamination is addressed under the UMTRA Surface Project.

Table 3.4 Years sampled and number of data rounds available for surface sampling locations, Maybell, Colorado, site.

Location ID	Location	Years sampled	Number of rounds
MAY-01-0701	Johnson Wash	86, 94-95	4
MAY-01-0703	Rob Pit	86-88	3
MAY-01-0704	Sugarloaf Basin pit	86-88	4
MAY-01-0705	Lay Creek at confluence with Johnson Wash	86-88,94-95	8
MAY-01-0706	Lay Creek upstream of Johnson Wash	86-88, 94-95	8
MAY-01-0707	Lay Creek downstream of Johnson Wash	86-88, 94-95	8
MAY-01-0718	Rob Pit	89-91, 94-95	6
MAY-01-0719	Johnson Wash	89-90, 94	3
MAY-01-0721	Wash draining Sugarloaf Basin	94-95	2

Table 3.5 Results of analyses of surface water samples in Johnson Wash and Lay Creek for nitrate, sulfate, and uranium, Maybell, Colorado, site

	Location description	Frequency of detection[a]	Minimum	Mean	Maximum
Nitrate					
Background					
MAY-01-0721	Sugarloaf Drainage	0/2	<1.0	-	<1.0
Downstream					
MAY-01-0701	Johnson Wash	0/4	<1.0	<1.0	<1.0
MAY-01-0719	Johnson Wash	0/2	<1.0	-	<1.0
Background					
MAY-01-0706	Lay Creek	0/7	<1.0	<1.0	<1.0
Downstream					
MAY-01-0705	Lay Creek	0/7	<1.0	<1.0	<1.0
MAY-01-0707	Lay Creek	0/5	<1.0	<1.0	<1.0
Sulfate					
Background					
MAY-01-0721	Sugarloaf Drainage	1/1	-	1320	-
Downstream					
MAY-01-0701	Johnson Wash	3/3	1000	1050	1110
MAY-01-0719	Johnson Wash	2/2	1100	-	1150
Background					
MAY-01-0706	Lay Creek	7/7	972	1308	1550
Downstream					
MAY-01-0705	Lay Creek	7/7	985	1426	1880
MAY-01-0707	Lay Creek	7/7	985	1473	1910
Uranium					
Background					
MAY-01-0721	Sugarloaf Drainage	2/2	0.003	-	0.029
Downstream					
MAY-01-0701	Johnson Wash	4/4	0.050	0.138	0.271
MAY-01-0719	Johnson Wash	3/3	0.086	0.141	0.206
Background					
MAY-01-0706	Lay Creek	8/8	0.003	0.006	0.010
Downstream					
MAY-01-0705	Lay Creek	8/8	0.005	0.023	0.103
MAY-01-0707	Lay Creek	8/8	0.004	0.072	0.271

[a]Frequency of detection/number of sampling rounds analyzed.

Note: Units are measured as milligrams per liter (mg/L).

Concentrations of constituents in surface water samples from Lay Creek are dependent on the amount of stream flow and vary according to the time of year sampled. During periods of low flow, evaporation of standing water in ponds would tend to yield higher concentrations than when the water is actively flowing. This is indicated by results of the June 1995 sampling (a period when Lay Creek was actively flowing) from locations 705 and 707 when concentrations of uranium were 0.009 and 0.011 mg/L respectively. In contrast, uranium values observed in results from the July 1994 sampling (Lay Creek was not flowing) were 0.103 and 0.271 mg/L for locations 705 and 707, respectively.

As discussed in Section 2.6, it is possible that constituents in ground water beneath the tailings pile could reach Rob Pit. However, concentrations of constituents associated with uranium mineralization in the Rob Pit surface water samples are expected because the water is in contact with naturally occurring intermediate-grade mineralization adjacent to and beneath the pit. Similar elevated concentrations of uranium in water samples from the pit near Sugarloaf Basin have also been observed. This pit is located upgradient from the Maybell site and represents background conditions. Water in Rob Pit represents an expression of ground water (water table). However, in the semi-arid climate of western Colorado, all bodies of standing water are subject to strong evaporation effects. Consequently, concentrations of constituents that enter these features have could build up over time in both surface water and sediments.

A comparison between the background pit and Rob Pit water quality is presented in Table 3.6. The Sugarloaf Basin pit contains equal or higher concentrations of all constituents except calcium, fluoride, sulfate, and radium-226. The Sugarloaf Basin pit is clearly unimpacted by UMTRA processing-related contamination, and yet, key indicator parameters associated with uranium ores are much higher in the Sugarloaf Basin pit than in Rob Pit. Uranium, for example, averages an order of magnitude higher in the Sugarloaf Basin pit than in Rob Pit (3.0 mg/L compared to 0.38 mg/L in Rob Pit). This demonstrates that there are not enough background locations to capture the true variability of ground water and surface water conditions at the site. Concentrations of constituents that are higher in Rob Pit than in the Sugarloaf Basin pit are consistent with the range of concentrations of those same constituents found in background ground water (Table 3.3). Lower concentrations of uranium and higher concentrations of radium-226 in Rob Pit most likely indicate the nearby presence of current ore forming conditions. Thus, there is no geochemical evidence that Rob Pit has been contaminated by past UMTRA-related uranium milling processes.

Table 3.6 Comparison of water quality in the unnamed background pit to Rob Pit, Maybell, Colorado, site

Constituent	Location	Number of samples[a]	Median	Maximum detected
Inorganics				
Aluminum	Background	4	0.29	0.30
	Rob Pit	6	<0.13	0.28
Ammonium	Background	4	<0.10	0.30
	Rob Pit	7	<0.10	0.10
Cadmium	Background	4	<0.003	0.011
	Rob Pit	9	<0.001	0.001
Calcium	Background	4	311	351
	Rob Pit	9	581	770
Chloride	Background	4	52	58
	Rob Pit	8	25	30
Copper	Background	4	0.03	0.03
	Rob Pit	6	<0.02	0.03
Fluoride	Background	4	0.15	0.18
	Rob Pit	6	0.79	1.0
Iron	Background	4	0.08	0.10
	Rob Pit	8	<0.06	0.12
Magnesium	Background	4	74	93
	Rob Pit	9	67	87
Manganese	Background	4	0.13	0.46
	Rob Pit	9	0.04	0.64
Molybdenum	Background	4	0.13	0.19
	Rob Pit	9	<0.01	0.14
Nitrate	Background	4	3.6	6.6
	Rob Pit	10	<1.0	8.0
Phosphate	Background	4	<0.2	2.8
	Rob Pit	10	<0.1	0.3
Potassium	Background	4	12	16
	Rob Pit	8	14	19
Selenium	Background	4	0.011	0.013
	Rob Pit	9	<0.005	0.036
Sodium	Background	4	71	200
	Rob Pit	8	39	135

Table 3.6 Comparison of water quality in the unnamed background pit to Rob Pit, Maybell, Colorado, site (Concluded)

Constituent	Location	Number of samples[a]	Median	Maximum detected
Strontium	Background	4	2.7	3.1
	Rob Pit	6	2.4	3.1
Sulfate	Background	4	1115	1250
	Rob Pit	8	1825	2110
Uranium	Background	4	3.0	3.5
	Rob Pit	8	0.38	0.67
Zinc	Background	4	0.020	0.033
	Rob Pit	6	<0.007	0.010
Radionuclides (pCi/L)				
Lead-210	Background	4	5.0	10
	Rob Pit	6	1.0	17
Polonium-210	Background	4	5.1	9.4
	Rob Pit	6	1.2	2.7
Radium-226	Background	4	0.2	0.7
	Rob Pit	7	2.2	3.2
Thorium-230	Background	4	0.7	3.3
	Rob Pit	6	0.3	17

[a]Filtered surface water quality from August 1986 through April 1995 was used for this evaluation.

Note: Units are measured in milligrams per liter (mg/L) unless otherwise noted.

pCi/L – picocurie per liter.

4.0 CONCEPTUAL SITE MODEL OF EXPOSURE

This section discusses the conceptual site model of potential exposure to people and the ecological environment from constituents in the ground water at the Maybell site.

A complete exposure pathway can occur only if there are a source of contamination, a mechanism of chemical release, a transport medium, an exposure point, and an exposure route. At the Maybell site, because of leaching (mechanism of chemical release) of the tailings pile (source), ground water is contaminated beneath the site with inorganic chemicals and radionuclides. Therefore, ground water is identified as the transport medium for constituents at this site. An exposure point is defined as the location of potential contact between receptor (e.g., people or livestock) and constituent (e.g., a well placed in the contaminated ground water). If no exposure points can be identified then, an exposure route (e.g. ingestion of ground water as drinking water) to a receptor cannot be completed.

The conceptual site model of potential exposure for the Maybell site is presented in Figure 4.1. This model is based on the following discussion of current and future land- and water-use patterns and the evaluation of the geochemical and hydrogeological conditions of the contaminated ground water at the Maybell site.

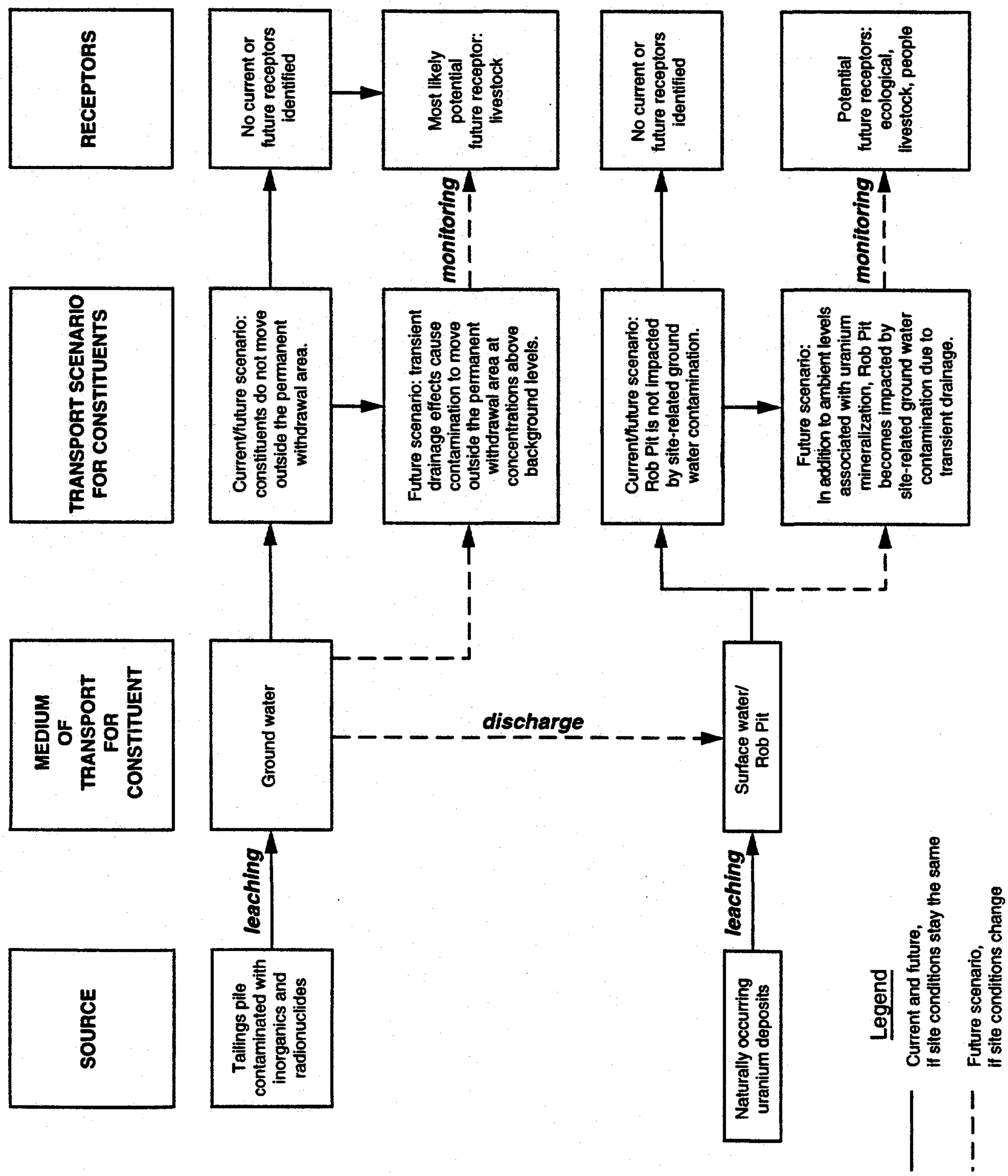
4.1 CONSTITUENT TRANSPORT SCENARIOS

As discussed in Sections 2.0 and 3.0, several mechanisms (for example, adsorption, denitrification, precipitation, neutralization processes, and a slow ground water velocity) may be responsible for the absence of site-related contamination beyond a few hundred feet of the tailings pile in the almost 40 year period since milling operations began. Regardless of the reason, ground water is not currently a medium of transport for constituents beyond the permanent withdrawal area. If ground water geochemical and hydrogeological conditions do not change in the future, ground water will continue not to be a medium of transport for constituents outside of the permanent withdrawal area. However, current ground water conditions at the Maybell site have the potential to change in the near future because of surface remedial actions.

4.1.1 Potential impacts of surface remediation on ground water

Construction activities for surface remediation at the Maybell site began in the spring of 1995 and are scheduled to be completed during 1996. Consolidation of the tailings during disposal cell construction may affect existing ground water conditions. A short-term amount of contaminated water, termed transient drainage, may enter the Browns Park Formation beneath the disposal cell during and after construction. The sources of this transient drainage water are tailings pore fluid, precipitation during construction, and construction water added for compaction and dust control.

Figure 4.1
Conceptual Site Model of Exposure
Maybell, Colorado, Site



MAC: SITE/MAY/BLRA/CONCEPTL

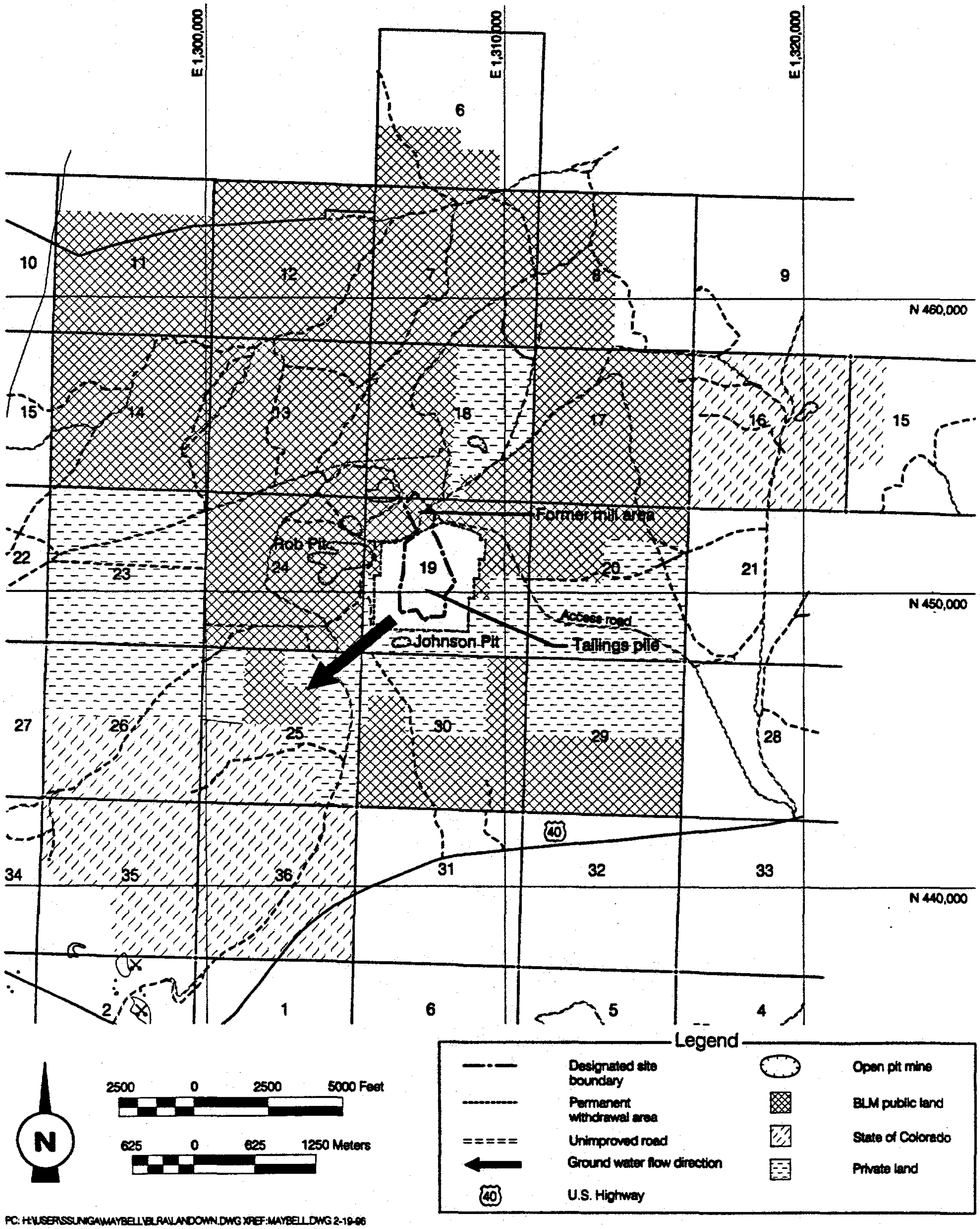
The additional water may temporarily alter the level of the ground water beneath the site, thereby, altering the hydraulic gradient of the ground water. The result of this is that contaminated ground water could move outside of the permanent withdrawal area and could increase constituent concentrations in the aquifer. Currently, the magnitude of these changes has not been estimated. Modeling of transient drainage is being conducted. The effect of the transient drainage is important for the Maybell site risk assessment because these ground water impacts could cause the contamination inside the permanent withdrawal area to migrate off-site beyond the permanent withdrawal area at concentrations above those occurring in background areas.

4.2 GROUND WATER AND LAND USE

The Maybell site is in a remote location. Historically (and currently) the primary land use in the area has been ranching as well as some recreational use (e.g., hunting and motorcycling). The land surrounding the site is owned by a few local ranchers, the BLM, and the state of Colorado (Figure 4.2). The BLM owns the northern portion of the land where the site is located. The southern portion is privately owned. The DOE has acquired all of the land within the boundary of the permanent withdrawal area and access to the public is restricted. No private ground water wells are or will be permitted within this area. After the surface remediation is complete, adjacent lands that are in temporary withdrawal (as part of the remedial action) will return to normal use; that is, grazing, recreational and agricultural uses will be permitted outside the boundary of the permanent withdrawal area. No agricultural activities requiring the irrigation of crops have been observed in the vicinity of the site. Because the area is used mainly for grazing and the water quality is naturally poor (i.e., background water quality is classified as a limited use ground water), crop propagation activities are not expected to occur near the Maybell site in the future.

Water use near the Maybell site was identified in a 1990 water use field survey by inspecting well records at the Colorado Division of Water Resources. No residential, industrial/commercial, municipal, or agricultural wells were identified within a 3 mi (5 km) radius of the site. The results of the first survey were verified by another site visit in October of 1994 (TAC, 1995). Additionally, it was determined that no new wells had been constructed within the same 3 mi (5 km) radius of the site since 1990. Because of the naturally poor water quality in the immediate vicinity of the Maybell site, people live where palatable water can be found. Several domestic wells are located in and near the town of Maybell, 5 mi (8 km) southwest of the tailings pile. These wells are located in the Yampa River Valley alluvium, with the exception of monitor well 650, which is located in the Browns Park Formation aquifer. Ground water from the Browns Park Formation has been used for limited livestock watering, as two windmill-operated wells formerly existed for this purpose. One windmill-operated well (monitor well 656) was located along Johnson Wash, approximately 1 mi (1.6 km) south of the tailings pile, but was removed between 1990 and 1992 (TAC, 1990; 1992). The second windmill-operated well (monitor well 631) was

Figure 4.2
Approximate Land Ownership Boundaries for Areas Surrounding the Maybell, Colorado, Site



PC: H:\USERS\SUNGA\MAYBELL\BLRA\LANDOWN.DWG XREF:MAYBELL.DWG 2-19-96 located approximately 2 mi (3 km) northeast of the tailings pile. Discussions with the well owner indicated that the owner had not used this windmill since 1982 (DOE, 1994). Additionally, the surface water in Rob Pit is currently used by a local rancher to water livestock

Ground water movement at the site is to the southwest. If the plume were to migrate beyond the permanent withdrawal area, the plume would reach BLM and/or private land (Figure 4.2). People are not allowed to live on BLM land and therefore a well constructed for domestic uses should not occur at any time. However, a permit to construct a well for other uses, for example, livestock watering is allowed on BLM land. Likewise, since it is unlikely that the privately owned land in the vicinity of the site will be used for any purposes other than ranching, it is unlikely that any private wells would be constructed on this land for uses other than livestock watering sources. Additionally, based on current and past land-use of the area, the population growth of the area surrounding the Maybell site is low and this is not expected to change in the future.

To summarize, no complete exposure pathways have been identified for current use of contaminated ground water near the Maybell site because ground water has not transported constituents above background levels beyond the permanent withdrawal area. Additionally, no exposure points have been identified, that is, no wells or discharges of ground water to the surface have been identified where a receptor could come into contact with contaminated ground water. Furthermore, if current hydrogeologic and geochemical conditions do not change in the future, the potential for exposure pathways to exist is not likely because of these same reasons. However, the effect of transient drainage has the potential to change current site conditions and allow ground water under the site to migrate beyond the permanent withdrawal area in concentrations that exceed background levels. If this occurs, then there is a potential for an exposure pathway to be completed. The most likely receptor for the future exposure scenario would be livestock.

4.3 SURFACE WATER

The closest surface water body to the Maybell site is in Rob Pit, approximately 0.3 mi (0.5 m) west of the site (Section 2.6). The water in this pit is fed by ground water. Rob Pit is a former open pit uranium mine and constituents have been detected in the surface water that are associated with naturally-occurring, intermediate-grade uranium mineralization (i.e., lead-210, polonium-210, radium-226, and thorium-230). As discussed in Section 3.4, water quality data indicate that surface water in this pit has not been impacted by the contaminated ground water associated with the Maybell site. If transient drainage causes hydrogeological conditions at the site to change in the future there is a potential for contaminated ground water to discharge to Rob Pit. Potential constituent concentrations in the pit (if impacted by transient drainage) cannot reasonably be estimated.

Potential pathways of exposure to constituents in Rob Pit are presented on Figure 4.1. Currently, a local rancher uses the water in the pit as a watering source for livestock. Other receptors have the potential to be exposed to constituents in Rob Pit if Rob Pit is affected by transient drainage. Aquatic life, benthic organisms, plants, and wildlife live in or have access to the surface water in the pit. Since recreational activities occur in the area, people can be exposed to constituents in Rob Pit by dermal contact with and by accidental ingestion of surface water and sediment while swimming.

If a conservative assumption is made that site-related ground water were to discharge to Rob Pit (Figure 4.1), then the potential exists that receptors could be exposed to site-related constituents.

4.4 CONCLUSIONS

Constituents are not being detected above background concentrations outside of the permanent withdrawal area. Because of the geochemical and hydrogeological conditions of the ground water and the lack of exposure points and receptors, no complete exposure pathways have been identified for current ground water use. Furthermore, based on current ground water conditions, and current and projected future land- and water-use patterns of the area, the potential for a complete exposure pathway to exist in the future is unlikely.

However, if current ground water conditions at the site changes in the future because of transient drainage, and the plume migrates beyond the permanent withdrawal area at levels which exceed background concentrations, there is a potential for an exposure pathway to be complete. In this scenario, the ground water would be the medium of transport beyond the permanent withdrawal area and ground water flow would move constituents onto land that is used for ranching. Since wells have been known to exist in the past for livestock watering, the most likely receptor(s) to contaminated ground water would be livestock.

If transient drainage affects the pit, the identified potential complete exposure pathways will exist in the future. Transient drainage effects regarding Rob Pit cannot be predicted at this time. If a conservative assumption is made that ground water from the site were to discharge to the pit, then the potential would exist that receptors could be exposed to higher concentrations of existing constituents or to other constituents contributed by discharge of contaminated ground water to the surface water in the pit.

Because of the unique ground water conditions at the Maybell site and the uncertainty associated with speculating about future site ground water conditions, a quantitative risk assessment evaluating future scenarios is not presented.

Nonetheless, in order to be assured that human health and the environment are adequately protected in the future, monitoring of the ground water should continue so that any ground water conditions that change can be evaluated. Already in place is the DOE program for monitoring ground water after the surface remediation is complete. For this program the long-term surveillance plan (LTSP) will be developed for the Maybell site in 1996. The LTSP will describe the monitoring and surveillance program for the Maybell site, including the frequency and location of any ground water monitoring that may be required for ground water protection.

4.5 LIMITATIONS OF THIS RISK ASSESSMENT

The primary limitation of this risk assessment is the inability to predict the future distribution of contamination. Several mechanisms may be responsible for the lack of downgradient contamination but there are not enough data to distinguish among them. These mechanisms are attenuation of constituents by processes of adsorption, denitrification, precipitation, neutralization processes; a slower than anticipated ground water velocity; and localized constituent sources located further upgradient from the edge of the plume than indicated by the distribution of the tailings. However, it is not clear whether one or more of these mechanisms is responsible for the lack of constituents in ground water downgradient of the site. Without this knowledge it is not possible to predict future constituent distribution including the effects of the projected transient drainage from the disposal cell.

Three areas adjacent to the site may require additional characterization has limited well coverage. These areas are the area around the former mill buildings which is possible constituent source area; the area south of the tailings pile between well cluster 604, 605, and 645, and well 664 to the east in the area of the former three settling ponds; the third area is located between the mill area and Rob Pit. The encompassing conceptual site model of the hydrogeologic and geochemical conditions will be further developed in the SOWP.

Because of the great variability of background ground water concentrations, there is some uncertainty as to whether or not the full variability of background has been captured. This uncertainty could lead to overestimation or underestimation of identifying constituents associated with former processing activities at the Maybell site.

The former mill area and the settling ponds may be locations of constituent sources. Without knowing where all various components of the ground water contamination originated, potential off-site migration of constituents in ground water may not be fully understood.

The geochemical attenuation properties of the Browns Park Formation has not been fully characterized. These properties are needed to define potential interactions of site-related constituents and attenuating processes.

5.0 LIST OF CONTRIBUTORS

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UNITED STATES CODE

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