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UMTRA GROUND WATER PROJECT

Draft Ground Water Compliance Action Plan for the Monument Valley, Arizona, UMTRA Site

August 1999

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

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Prepared by
U.S. Department of Energy
Grand Junction Office
Grand Junction, Colorado

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1.0 Introduction

This Draft Ground Water Compliance Action Plan (GCAP) for the Monument Valley, Arizona, Uranium Mill Tailings Remedial Action (UMTRA) Project site describes the plan for complying with ground water standards in Title 40 of the *U. S. Code of Federal Regulations* (CFR) Part 192. Remediation of surface contamination was achieved when the tailings piles, leach areas, an evaporation pond, and contaminated surface materials were completely removed from the site in January 1994. The Remedial Action Plan (DOE 1993) documents the design and compliance aspects of the surface remediation. A summary of the site history and extent of ground water contamination are provided in this GCAP as background information. Detailed information about the site and nature and extent of contamination is in the *Final Site Observational Work Plan for the UMTRA Project Site at Monument Valley, Arizona* (SOWP) (DOE 1999).

The GCAP provides a brief background of the site and describes the compliance strategy and the selected remediation method. Section 2.0, "Site Information," summarizes contamination in the ground water, describes the ground water flow system, and discusses the extent of contamination in the aquifer. Section 3.0, "Compliance Plan," discusses the regulatory drivers and documents how the compliance strategy selection process defined in the Programmatic Environmental Impact Statement (PEIS) (DOE 1996b) was used to select the compliance strategy at the Monument Valley site. Section 4.0, "Selected Remedial Action," describes the remediation method that will be used to comply with the standards in 40 CFR 192, discusses the implementation plan for the remediation, and discusses limitations of the remediation method. The final GCAP will include documentation and engineering design of the selected remediation method.

End of current text

2.0 Site Information

2.1 Location

The Monument Valley UMTRA Project site is on the Navajo Indian Reservation (Navajo Nation) in northeastern Arizona, approximately 15 miles south of Mexican Hat, Utah (Figure 2–1). The site, which is accessible by U.S. Bureau of Indian Affairs Navajo Service Route 6440, is the location of a former uranium mill.

The former millsite is on the west side of Cane Valley, which is drained to the north by Cane Valley Wash. Figure 2–2 shows features of the site such as the former mill fence line, access roads, residences, and drainages.

The elevation along Cane Valley Wash is approximately 4,800 feet (ft) above mean sea level. Comb Ridge, a 600-ft-high escarpment of Navajo, Kayenta, and Wingate sandstones, borders the valley on the east. On the west side of the valley near the former millsite, the bedrock dips to the east at approximately 5 degrees and rises up to Yazzie Mesa at an elevation of over 5,300 ft. Cane Valley between Comb Ridge and Yazzie Mesa is filled with a reddish-yellow eolian sand and minor amounts of water-transported sand, gravel, and bedrock fragments.

The Navajo Indian community of Cane Valley consists of 12 separate housing clusters, with two to four housing units per clusters. Several residences are located directly east and south of the former millsite while the remaining are within 5 miles north of the former millsite. Most of the residents work in surrounding communities and supplement their income by raising livestock and grazing in the local area. Because of its remoteness, Cane Valley does not have any utilities such as electrical power, domestic water, or telephone supplying it.

The site is arid, receiving approximately 6.4 inches (in.) of annual precipitation. Most precipitation usually occurs during July through August and December through February. Rainfall during the summer commonly occurs in high-intensity, short-duration storms that are conducive to runoff. Precipitation during the winter, however, usually occurs during low-intensity, longer-duration storms. Annual snowfall ranges between 10 and 40 in. The two driest months are generally May and June.

2.2 History

Luke Yazzie discovered uranium in 1942 approximately one-half mile west of the former millsite. Vanadium Corporation of America (VCA) acquired mining rights for the deposit from the Office of Indian Affairs in 1943 and named the lease property Monument No. 2. VCA mined the property from 1943 to 1968 with a total production of 767,166 tons of ore. The Monument No. 2 mine has produced more uranium than any other mine in Arizona.

Before 1955, there was no mill at the site. The ore was either shipped to Metal Reserve at Monticello, Utah, or the ore was mechanically upgraded at a small plant near the Mexican Hat bridge. An upgrader was constructed at the Monument Valley site in 1955 and operated until 1964. Finer grained material was shipped off site for chemical concentration at the Durango, Colorado, mill before March 1963 and later at the VCA mill at Shiprock, New Mexico. The

coarser grained material remained on the site and was piled in the areas identified as the former mill and old tailings pile (Figure 2–3). The mechanical milling operations at the Monument Valley site continued from 1955 to 1964. A batch-leach process was used from 1964 until 1968 when the mill closed and the lease expired. Control of the site, structures, and materials reverted to the Navajo Nation at that time.

The mill buildings and milling equipment were removed after 1968. The U.S. Department of Energy (DOE) began surface remediation in 1992. The tailings piles, windblown tailings, contaminated radioactive materials, concrete foundations, and debris were removed and placed in the Mexican Hat UMTRA Project disposal cell, approximately 10 miles north of the former millsite. Relocation of these materials was completed in January 1994.

2.3 Ground Water Characteristics

This section summarizes the ground water characteristics near the Monument Valley site. The Monument Valley SOWP (DOE 1999) presents a more complete and detailed discussion of hydrology for the site.

2.3.1 Hydrology

The three main aquifers onsite are the eolian/alluvial, Shinarump, and De Chelly aquifers (in descending order), with the Shinarump and De Chelly separated by the Moenkopi Formation and its lowermost Hoskinnini Member. The eolian/alluvium is predominantly an unconfined aquifer, which is underlain by the unconfined and leaky confined Shinarump. The main confining unit is the Upper Moenkopi, which overlies the leaky confined Hoskinnini and De Chelly. The Hoskinnini and De Chelly appear to be hydrologically connected, and are described as a single unit in some of the earlier boring logs. In the region of the site containing the quaternary paleochannel, the Shinarump and Upper Moenkopi Formation have been eroded away, providing a direct hydrological connection between the alluvial and De Chelly aquifers.

Eolian/Alluvial Aquifer

The eolian/alluvium (hereinafter referred to as alluvium or alluvial) consists mainly of windblown fine- to medium-grained sand deposits, which vary in thickness from 0 ft near the former millsite to 120 ft approximately 2 miles downgradient from the site. There is a broad range of the depth to ground water in the alluvial aquifer across the site. The depth to alluvial ground water generally ranges from 10 ft near the site to 30 ft below the ground surface at the downgradient leading edge of the nitrate (as NO_3) plume.

Alluvial ground water generally flows north in the site vicinity. Historically, since 1985, the horizontal gradient has been 0.011. Hydraulic conductivity ranged from 0.30 to 19 feet per day (ft/day). Assuming an effective porosity of 0.25 and a hydraulic gradient range of 0.007 to 0.012, the ground water velocity ranges from 0.6 to 1.0 ft/day.

Recharge to the alluvial aquifer is the result of the infiltration of precipitation and from upward leakage from the underlying aquifers. This area receives approximately 6.4 in. of precipitation annually, with the majority of the precipitation resulting from isolated thunderstorms during the late summer and early fall. An estimated 1.6 in. of the annual 6.4 in. is available for recharge and runoff on a yearly basis, however, only a fraction of the annual precipitation actually enters the

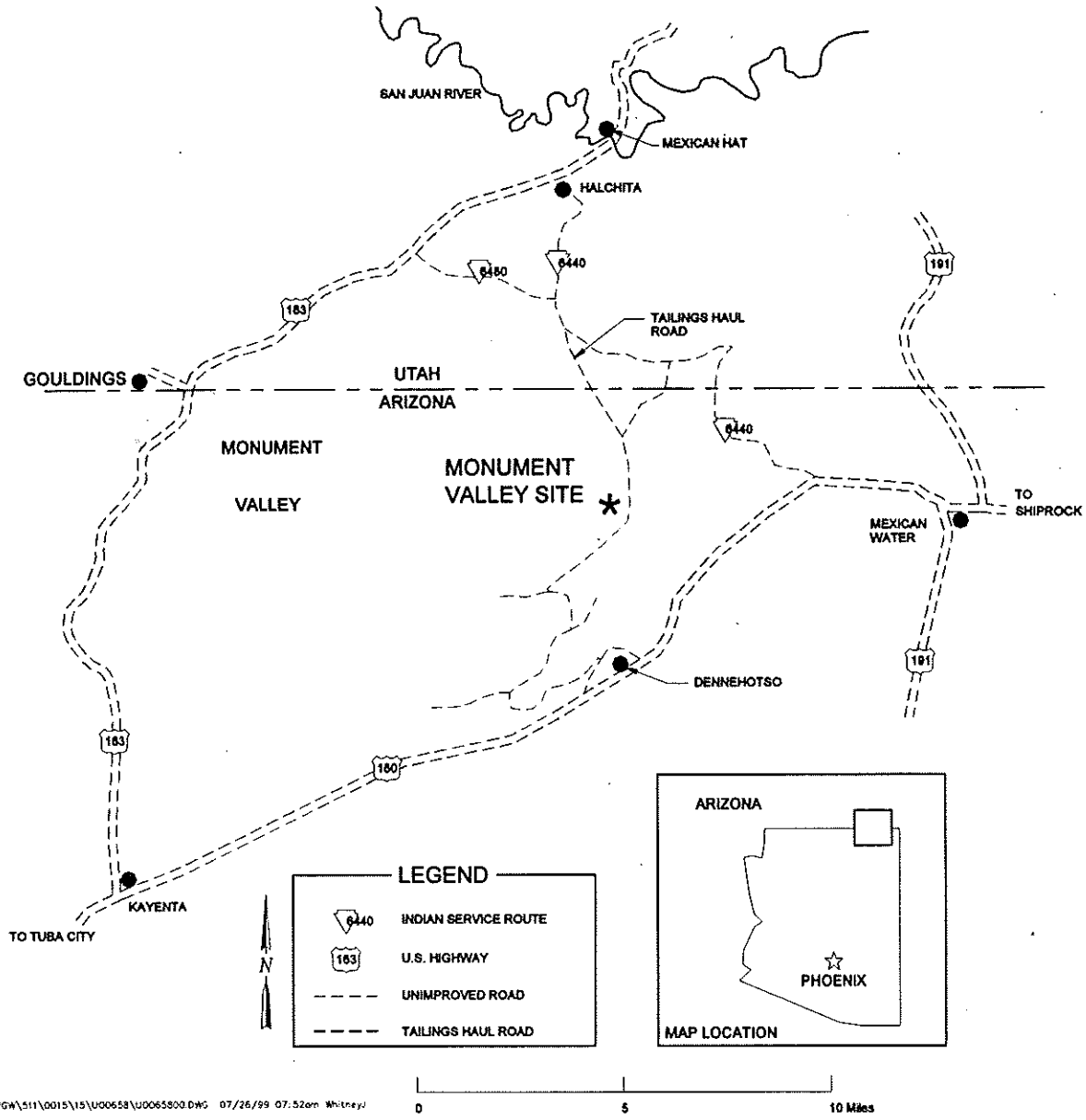

Figure 2–1. Location of the Monument Valley Site

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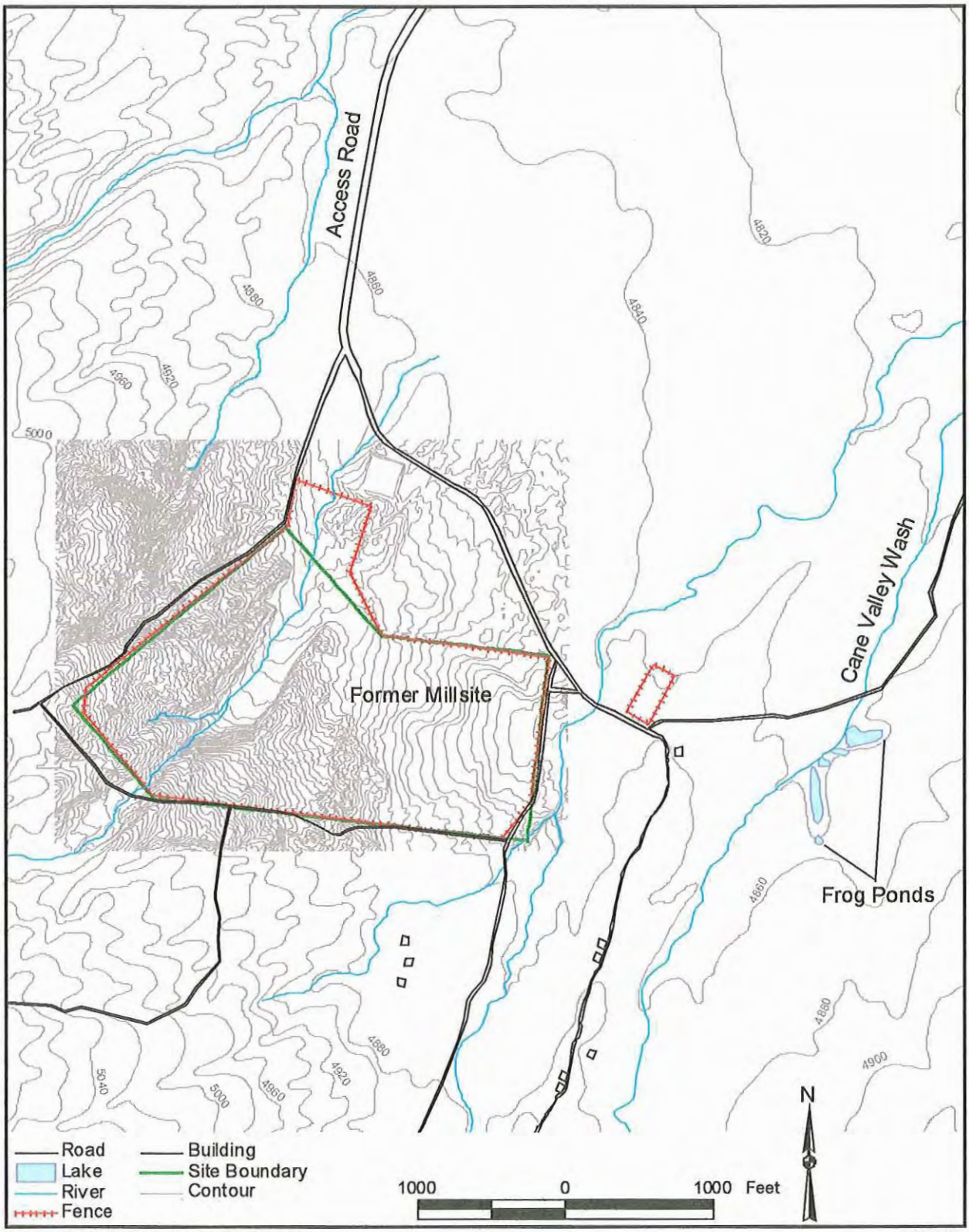

Figure 2–2. Cane Valley Area near the Former Millsite

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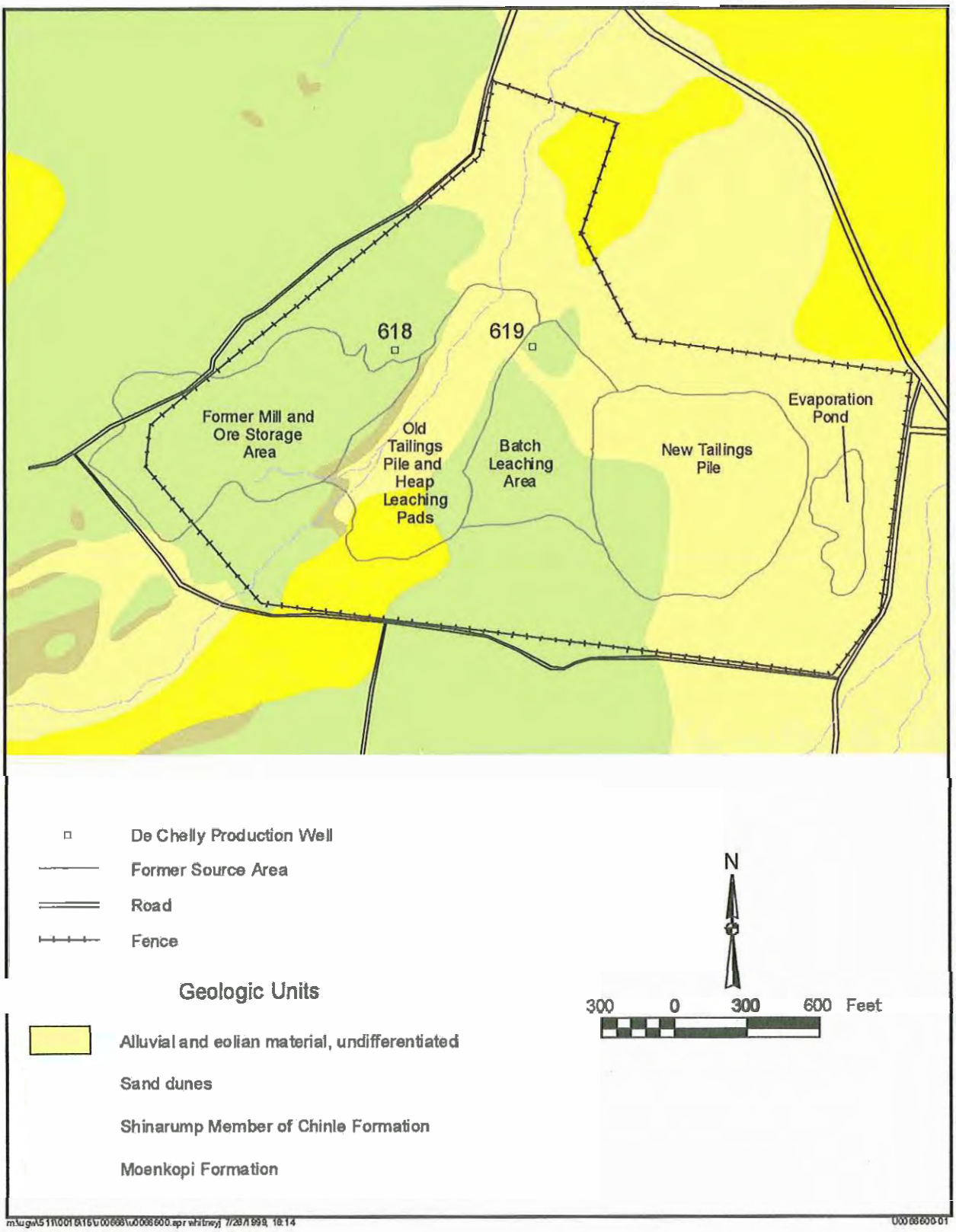

Figure 2–3. Former Mill and Ore-Storage Area, Tailings Piles, Heap-Leach Pads, and Evaporation Pond

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aquifer due to loss from evaporation and plant uptake. Discharge from the alluvial aquifer is primarily the result of evapotranspiration and evaporation.

De Chelly Aquifer

The De Chelly aquifer consists of fine-grained sandstone that is approximately 500 ft thick in the site area. Ground water is generally semiconfined, and may be unconfined in areas where the main confining unit, the overlying Upper Moenkopi, has been eroded. The potentiometric surface elevation of the De Chelly aquifer is higher compared to the ground surface elevation along portions of the eastern boundary, resulting in artesian conditions in certain wells. The maximum depth to De Chelly ground water at other areas of the site is approximately 165 ft.

Similar to the alluvial and Shinarump aquifers, the De Chelly ground water flow direction is towards the north. There is a higher hydraulic gradient at the south part of the site (0.018) that decreases to the north (0.011). The average horizontal gradient across the area historically has been 0.014. Hydraulic conductivity ranges from 2 ft/day to 6 ft/day. Using these two values as the range, the ground water Darcian velocity ranges from 0.19 to 0.56 ft/day. These calculations were based on an assumed effective porosity of 0.15 and the average hydraulic gradient of 0.014.

Recharge to the De Chelly is mainly a function of precipitation in the vicinity of the site. Outcrops of De Chelly Sandstone located to the west and south of the site tend to enhance recharge into the aquifer. Discharge is the result of vertical leakage into overlying units and by domestic and stock use.

2.3.2 Water Quality

Table 2–1 presents background ground water quality in the three aquifers near the site. The only constituents presented are nitrate, sulfate, and uranium since they are the constituents of concern (COCs). Further discussion on COCs is in Section 2.5.2 of this document. Water samples for the three aquifers were collected from 1985 through 1987. Background water quality data for the alluvial aquifer is from water samples collected at six upgradient monitor wells and four upgradient private wells. Background water quality data in the Shinarump Member is from water samples collected from two upgradient monitor wells. Background water quality data for the De Chelly Sandstone aquifer is from water samples collected from four upgradient monitor wells.

Table 2–1. Background Water Quality of the Aquifers

Constituent	Concentration (Range mg/L)	
	Alluvium Aquifer	De Chelly Aquifer
Nitrate (as NO_3)	<0.044–47	.66–22
Sulfate	12.7–668	11.6–66.3
Uranium (total)	<0.001–0.021	0.0004–0.0096

2.4 Surface Water

The only permanent surface water present in the vicinity of the project area occurs east of the former mill site in what is referred to as the Cane Valley frog ponds (Figure 2–2). The frog ponds consist of two man-made ponds constructed during the 1950s and 1960s when the mill was in operation. The ponds are situated roughly in a north to south direction along the drainage axis of Cane Valley Wash. Water was supplied by a concrete-lined cistern at the southern pond. The sides of the northern pond were lined with wooden planks braced by ore from the mines. The wooden planks, ore from in and around the northern pond, and evidence of the concrete cistern at the southern pond were subsequently removed during completion of the surface remediation activities at the former mill site in April 1994.

Presently, the southern pond is contained in a long, narrow, and deep bulldozer cut in a large sand dune. The bulldozer cut intersects the alluvial ground water, which provides some recharge to both ponds throughout the year. Geochemical similarities between the pond water and ground water from the De Chelly bedrock aquifer water suggest the ponds may also be receiving recharge through former uranium exploration boreholes that penetrated the artesian bedrock aquifer in the immediate area. The exploration boreholes were probably not properly abandoned, thereby allowing artesian flow from the De Chelly aquifer into the alluvium.

Most of the surface flow along Cane Valley Wash and other small drainage channels in the vicinity of the site are ephemeral (flows briefly only in direct response to precipitation) in the immediate location. Natural scours created by ephemeral flows (i.e., channel of these surface flows are at all times above the water table) along Cane Valley Wash are common. Small pools, which may contain standing water for prolonged periods of up to several weeks or more, are occasionally present. In response to evaporation and transpiration, the pools get smaller and eventually go dry. These small intermittent pools have been observed to occur just upstream of the frog ponds and downstream for several miles.

Surface water in Cane Valley Wash (when present) and the frog ponds is a potential source of water for livestock and wildlife, although the extent of use is undetermined. There is no indication that the surface water in the area is used for domestic consumption or long-term irrigation. Surface water samples collected from intermittent pools along Cane Valley Wash have naturally occurring high sulfate-to-chloride ratios. Cane Valley Wash and the frog ponds appear to be unaffected by site-related contaminants.

2.5 Ground Water Contamination

2.5.1 Source of Contamination

Three former source areas of potential ground water contamination exist at the site: (1) the old tailings pile and heap-leach area, (2) the new tailings pile, and (3) the evaporation pond. The locations of these former source areas are shown in Figure 2–3. In addition, a potential continued source area is the subpile soils. The old tailings pile was composed of the sand tailings that were a residual product of the mechanical upgrading of ore. The upgrading process used water that contained a minor amount of flocculents but no other processing chemicals. Thus, tailings solutions in the old pile basically were water-equilibrated to minerals in the ore. Heap leaching of these old tailings occurred in the area where they were stored. Old tailings were placed on the heap-leach pad and sulfuric acid was added to the tailings. Heap-leach pads were lined to collect

the leachate, which contained sulfuric acid. By contrast, the new tailings pile contained sand tailings and processing solutions. The processing solutions contained sulfate, nitrate, and ammonium from the processing chemicals. The evaporation pond was probably used to retain seepage from the new tailings pile.

Old Tailings Pile

Water in contact with the former old tailing pile probably contained primarily calcium, sulfate, and several metals and trace constituents including aluminum, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, uranium, and vanadium. These constituents were probably derived from the dissolution of ore-associated minerals in the tailings, including gypsum (calcium sulfate), uranyl vanadates, and minor amounts of copper-bearing minerals. The dissolution of the mineral gypsum (hydrous calcium sulfate) may explain the predominance of both calcium and sulfate in the old tailings leachates.

New Tailings Pile

Pore fluid from the new tailings pile can be characterized as an ammonium-nitrate and calcium-sulfate solution, reflecting the presence of gypsum in the ores, the dissolution of other calcium-bearing minerals in the ores, and the addition of sulfuric acid and ammonium nitrate to the processing solutions. The new tailings fluids were also acidic as indicated by the relatively low pH (4.3). Chloride levels are notably low in these solutions and about the same as in background ground waters. Metals and trace elements include aluminum, barium, chromium, cobalt, copper, iron, manganese, molybdenum, nickel, strontium, uranium, vanadium, and zinc. These elements were derived from the dissolution of the ores. In general, concentrations of site-related constituents in the pore-fluid solutions associated with the new tailings pile increased with increasing depth in the pile, reflecting seepage of the solutions from the base of the pile, and infiltration of precipitation into the top of the pile.

Evaporation Pond

Solutions beneath the evaporation pond area differ from those in the new tailings pile. Notably, the acidity of the solutions has been reduced by reactions with carbonate minerals in the subsoil. Also, the ammonium and sulfate concentrations decreased while the sodium concentrations increased. These changes reflect reactions of the tailings fluids with the subsoil resulting in a calcium-sodium-nitrate-sulfate solution. As with the tailing pore fluids, the chloride concentrations are notably low (45 milligrams per liter [mg/L]) and are also within the range observed in natural background alluvial ground water. The metals and trace elements that are present in the tailings solutions are also present in the evaporation pond area.

Overall, the former tailings and evaporation pond solutions contain much greater proportions of ammonium, calcium, nitrate, potassium, and sulfate than are present in background ground waters. Trace elements including manganese, uranium, and vanadium are also present above background concentrations. Thus, these are the constituents most likely to be present in the subpile soils and dispersed in the ground water downgradient from the former source areas.

Subpile Soils

The Monument Valley site had several periods of uranium milling activities. During these activities, mill tailings, heap-leach residues, and various processing chemicals were stored in unlined ponds. Any tailings and residuals in the soils that exceeded 15 picocuries per gram (pCi/g) radium-226 were removed from the site during the surface remediation which was completed in 1994. However, site-related inorganic constituents (non radiometric with the exception of uranium) detected in relatively high concentrations in pore fluid samples collected from the former source areas suggest that some of these constituents may have leached into the soils below the storage ponds and gone undetected during the radiometric assessment for the tailings removal. Samples of the soils directly beneath the former sources areas were collected and analyzed for manganese, nitrate, strontium, sulfate, uranium, and vanadium, all of which were identified in the Baseline Risk Assessment (BLRA) (DOE 1996a) as the most significant site-related constituents occurring in the alluvial aquifer to determine if these areas are likely to be continuing sources of ground water contamination. Ammonium was also analyzed because it is present in ground water and will oxidize to NO_3.

2.5.2 Extent of Contamination

Nitrate, sulfate, and uranium are the COCs at the Monument Valley site because they exceed either U.S. Environmental Protection Agency (EPA) or Navajo Nation cleanup goals. EPA standards are established as maximum concentration limits (MCLs) under 40 CFR 192 for nitrate (44 mg/L) and uranium (0.044 mg/L). Because an EPA standard has not been established for sulfate, DOE has agreed to set a cleanup goal of 250 mg/L as requested by the Navajo Nation.

Alluvial Aquifer

Ammonium and nitrate provide the greatest contrast to natural background concentrations in the alluvial ground water. The maximum ammonium concentration of 254 mg/L detected in ground water collected at monitor well MON–606 is 423 times the upper range in natural background. The maximum nitrate concentration of 1,030 mg/L, also detected in ground water collected at MON–606, is 22 times the upper range in natural background. Maximum concentrations detected for uranium occur at levels that are less than 5 times the upper range in natural background. The maximum uranium was detected in water from monitor well MON–774. Nitrate and uranium are the only site-related constituents that exceed a MCL. Nitrate frequently exceeds the 44 mg/L MCL while uranium only slightly exceeds the 0.044 mg/L MCL at one isolated location (MON–774).

Nitrate is especially useful as an indicator chemical to discriminate site-related contaminated ground water from alluvial background waters because it occurs in relatively low concentrations in background ground water, is associated in relatively high concentrations with the former tailings pore fluids, and is highly mobile in alluvial ground water under almost all conditions, thus it is a conservative estimate of the extent of site-related contamination. The MCL allowable for nitrate contamination at a DOE facility of 44 mg/L is considered to be representative of the boundary of contamination and is considered sufficient for use in defining the maximum extent of site-related contamination in the alluvial aquifer as discussed in the Monument Valley SOWP (DOE 1999).

It is apparent from the 44 mg/L nitrate boundary delineated in Figure 2–4 that the leading edge of the plume has migrated approximately 4,500 ft (0.85 miles) north of the former mill site covering an area measuring approximately 11.2 million square feet, or about 260 acres. The northerly direction of plume migration is consistent with the direction of the ground water flow in the alluvial aquifer. A linear ground water flow velocity of 150 ft/year is estimated assuming nitrate contamination first entered the alluvial aquifer at the start of the 1967 milling operation (4,500 ft/30 years).

A mass of relatively high nitrate is delineated by concentrations greater than 500 mg/L, which begins near the former new tailings pile and extends approximately 2,600 ft (0.5 miles) downgradient. Thus, the primary source of nitrate contamination in the alluvial aquifer appears to be related to process fluids draining from the former new tailings pile with lesser amounts of contamination contributed by leakage from the evaporation pond to the east and from the former old tailings pile and heap-leach areas to the west. The boundary of the nitrate plume is defined by the most recent sampling data collected in August 1998 as shown in Figure 2–5.

Nitrate concentrations tend to gradually increase as a function of depth in the most downgradient area of the plume. The alluvial ground water from the entire saturated section located between the former new tailings area at MON–606 (approximately 10 ft in thickness) to downgradient monitor well MON–653 (approximately 50 ft in thickness) is contaminated above the 44 mg/L nitrate MCL.

Sulfate concentrations in the alluvial aquifer exhibit a similar geochemical dispersion pattern as nitrate. The 1997 sulfate plume, revealed by concentrations greater than 600 mg/L (Figure 2–6), also appears to originate near the downgradient edge of the former new tailings area. Changes in sulfate concentrations also show a trend similar to the nitrate concentrations, with sulfate levels increasing downgradient and decreasing near the former source area.

Uranium also tends to be mobile in the alluvial ground water under the conditions at the site, as indicated by its respective downgradient concentrations presented in Figure 2–7. Similarly, ammonium concentrations (Figure 2–8) exhibit a downgradient dispersion pattern, however the dispersion is less extensive, reflecting the removal of ammonium from solution by adsorption on the aquifer matrix.

Estimates of the volume of contaminated ground water in the alluvial plume are based on the areal and vertical distribution of nitrate concentrations discussed previously. Separate estimates are presented for (1) the mass of relatively high nitrate concentrations delineated by the 500 mg/L boundary which begins near the former new tailings pile and extends approximately 2,600 ft (0.5 miles) downgradient, and (2) nitrate concentrations between 500 mg/L and the 44 mg/L MCL. Assumptions used in the calculations are presented with the estimated contaminant volumes in Table 2–2.

Table 2–2. Estimated Volume of Contamination in the Alluvial Aquifer

Nitrate (mg/L)	Area (ft^2)	Average saturated thickness (ft)	Contaminated saturated thickness (percent)	Estimated porosity (percent)	Estimated volume (gal)
44 to 500	8.8×10^6	34	75	25	420×10^6
500 and greater	2.4×10^6	27	100	25	120×10^6
				Total	540×10^6

De Chelly Bedrock Aquifer

Ground water samples collected from the De Chelly aquifer do not exhibit wide spread site-related contamination. Sampling data demonstrate that concentrations of site-related constituents such as ammonium, nitrate, potassium, strontium, vanadium, radium-226, and radium-228 do not exceed the upper range in natural background at any on-site or downgradient location. Other constituents such as magnesium and sulfate occur in one instance at concentrations only slightly above the upper limit of natural background.

Calcium and uranium are the only site-related constituents that occur frequently above natural background in the De Chelly aquifer.

Uranium is present at concentrations above the upper limit in natural background in ground water collected in 1997 at MON–664, –657, –619, and –776. However these maximum values only slightly exceed the 0.044 mg/L uranium MCL.

In summary, production well MON–619 can be considered an isolated point source for the elevated uranium concentrations observed in the De Chelly aquifer. Uranium concentrations in ground water collected at MON–619 during the period 1985 through 1998 have declined significantly since the well was pumped during an aquifer test in 1993, indicating that the De Chelly aquifer is diluting the concentrations by naturally flushing the uranium downgradient. Uranium observed in downgradient well MON–657 exhibit a similar pattern of decreasing uranium concentration versus time. Uranium concentrations in the De Chelly are expected to continue to decrease with time as the aquifer dilutes and flushes the uranium downgradient.

Continued impact to the De Chelly ground water is not expected since well 619 is no longer being pumped for production. In addition, dedicated low-flow bladder pumps were installed at the end of the 1997 field characterization to prevent contaminated alluvial water to be actively drawn into the De Chelly through the erosional window located in the adjacent paleovalley when the well is sampled for water quality. The most recent sampling results obtained in 1998 suggest that natural flushing is working. For example, uranium concentrations at well 657 have decreased to levels below the MCL, thereby reducing the areal extent of the plume.

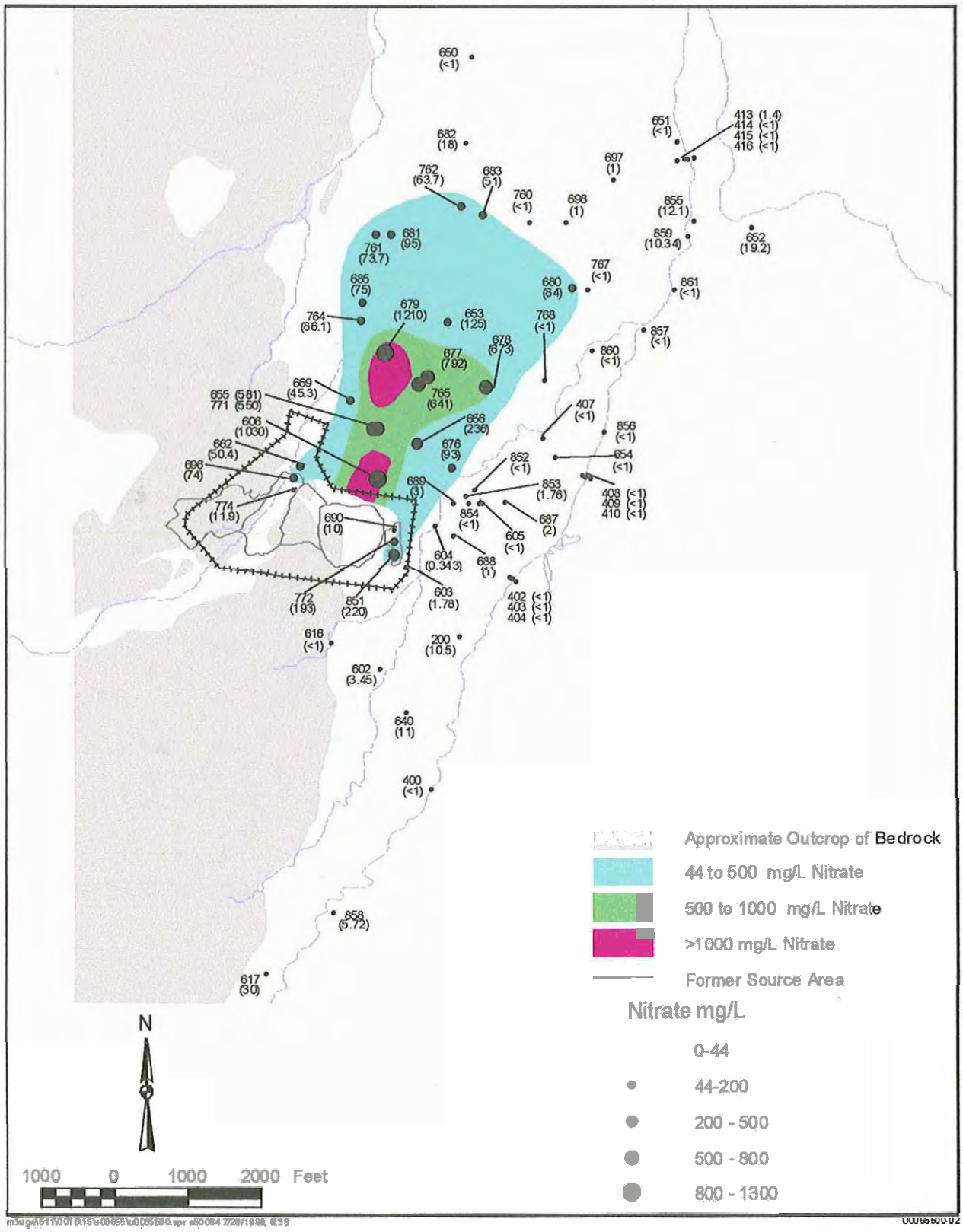

Figure 2–4. Distribution of Nitrate Concentrations in the Alluvial Aquifer—Data through September 1997

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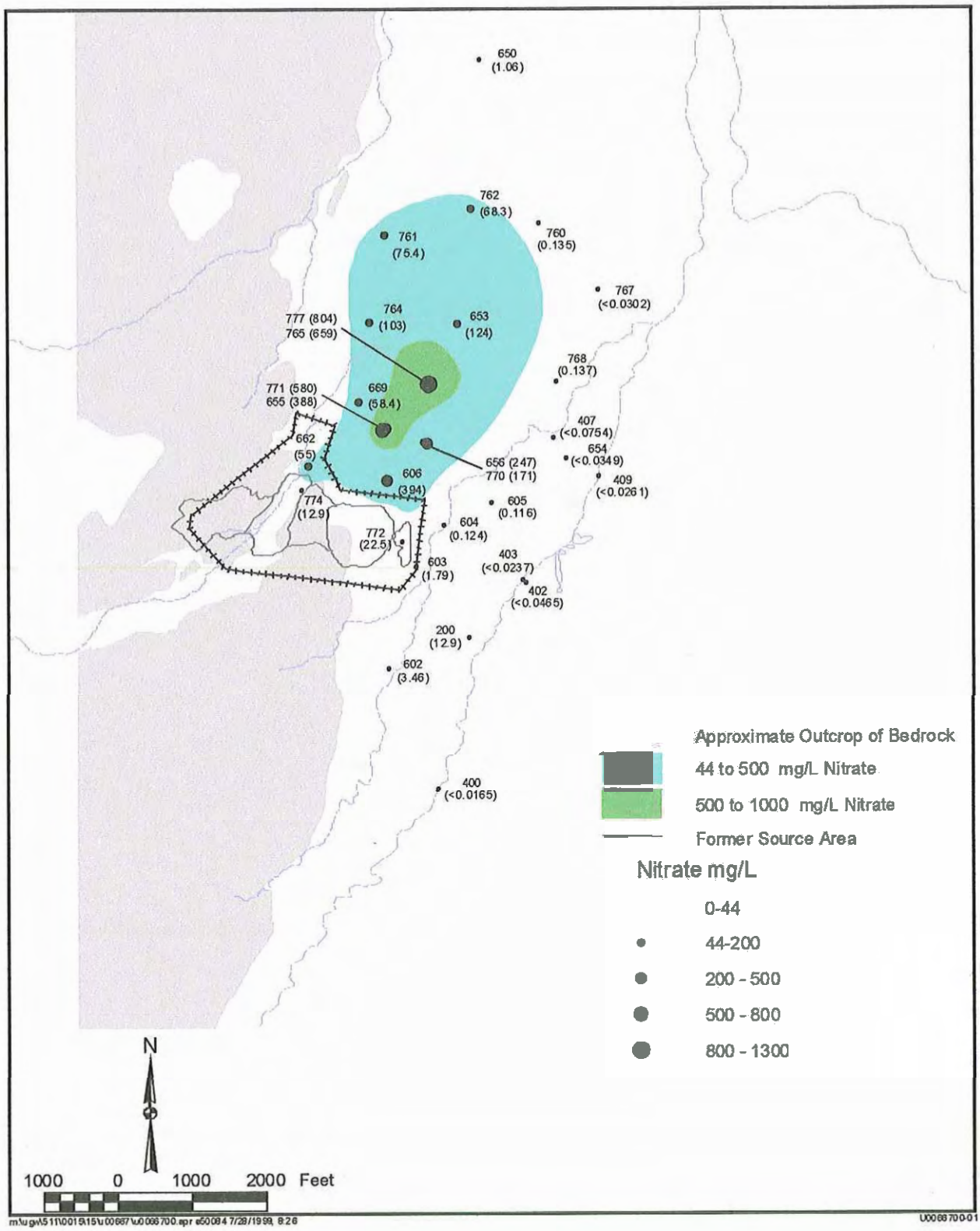

Figure 2–5. Distribution of Nitrate Concentrations in the Alluvial Aquifer—August 1998

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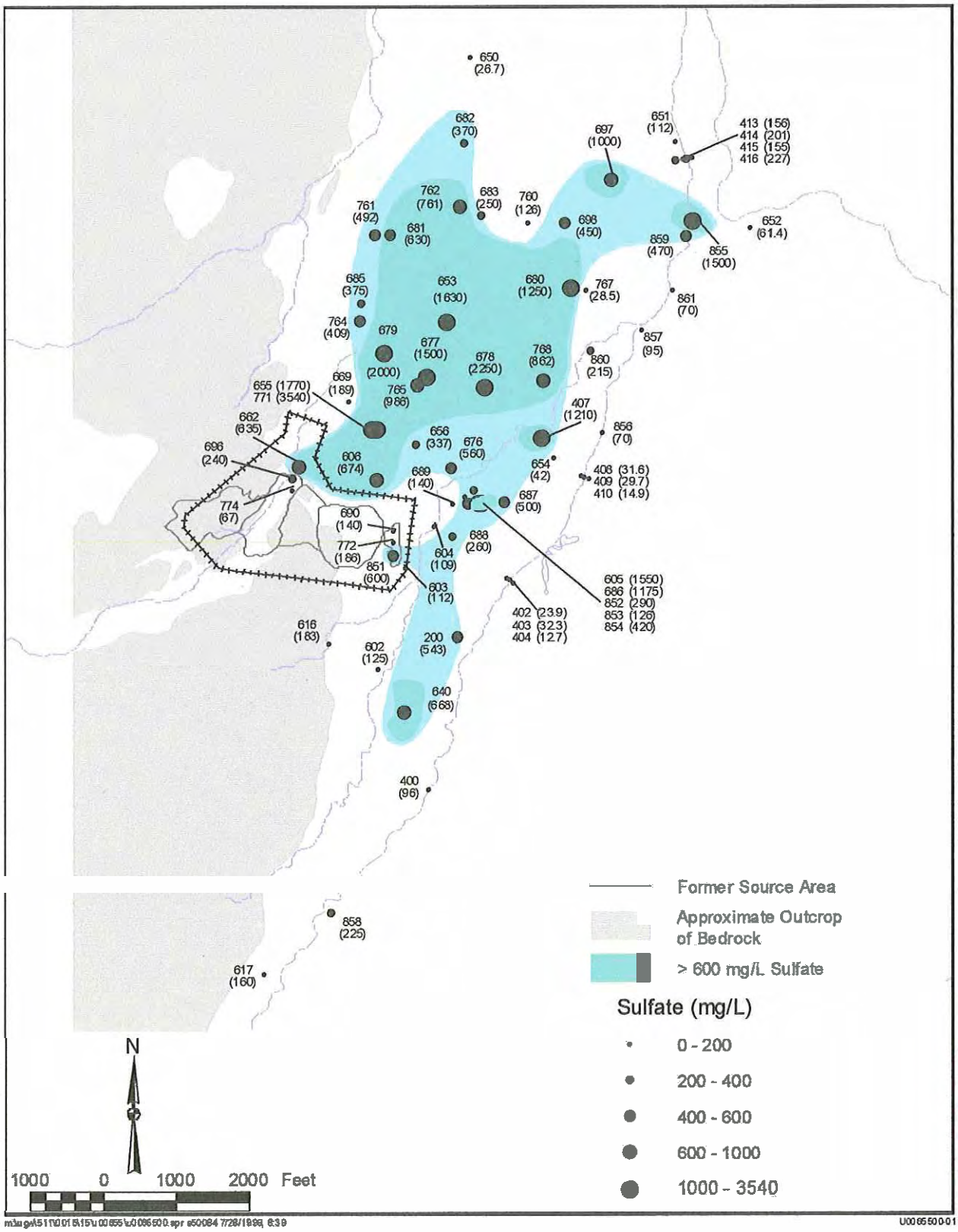

Figure 2–6. Distribution of Sulfate Concentrations in the Alluvial Aquifer—Data through September 1997

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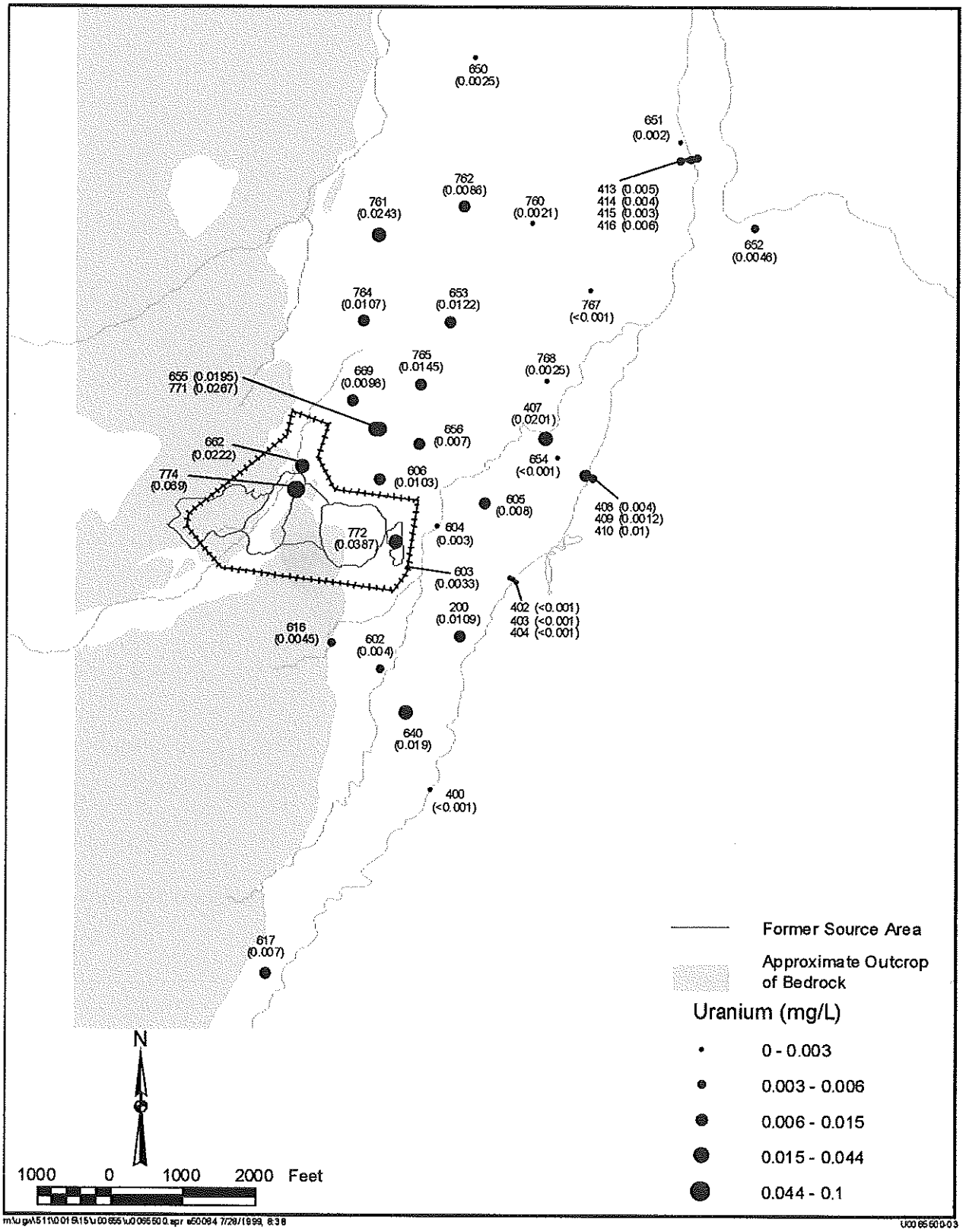

Figure 2–7. Distribution of Uranium Concentrations in the Alluvial Aquifer—Data through September 1997

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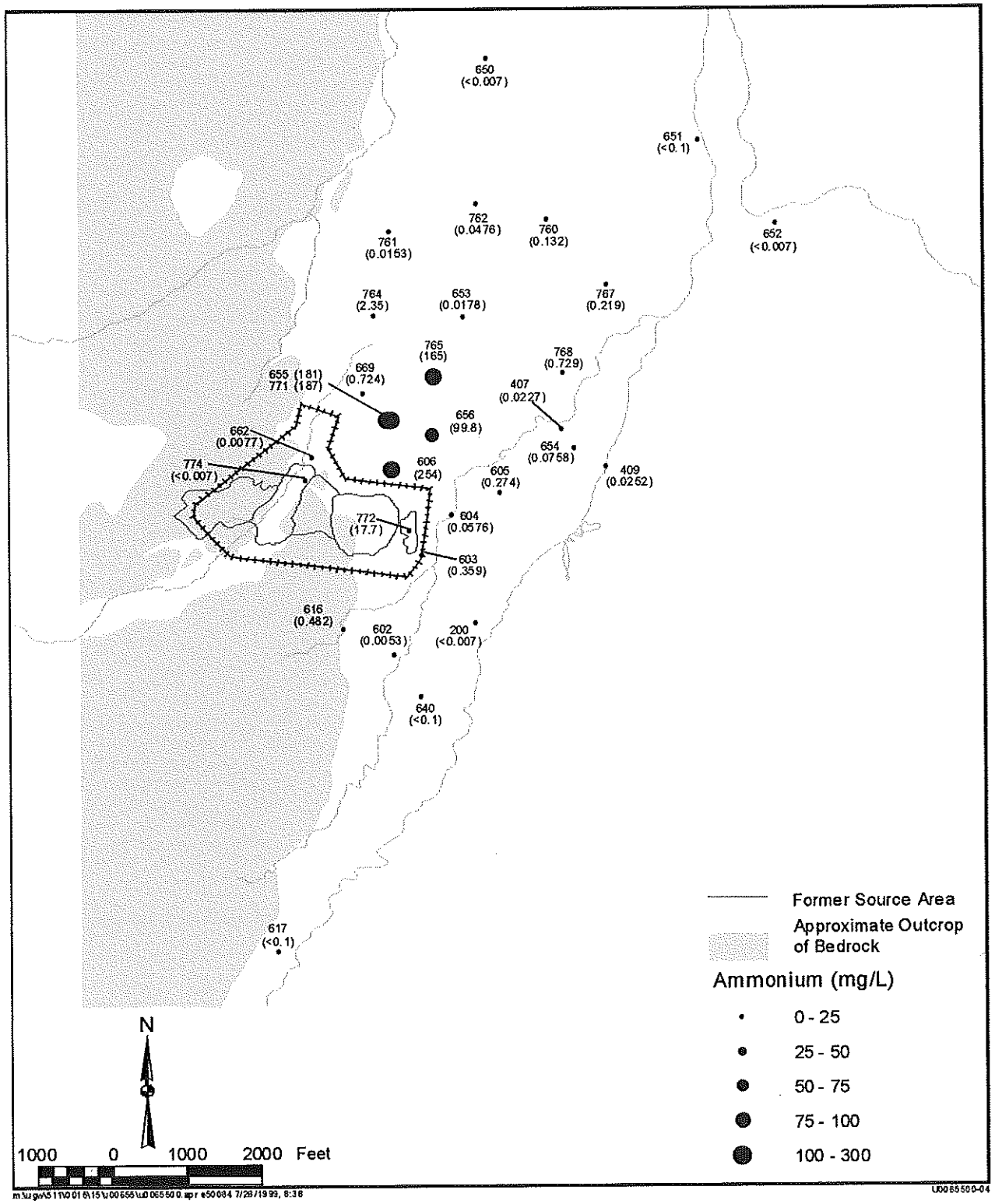

Figure 2–8. Distribution of Ammonium Concentrations in the Alluvial Aquifer—Data through September 1997

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3.0 Compliance Plan

This section describes the proposed ground water compliance strategy for contaminants in the ground water that are attributable to milling activities. It also explains the application of site-specific data to the ground water compliance selection framework. Ground water compliance decisions at the Monument Valley site were made by using the compliance selection framework shown in Figure 3–1. This compliance selection framework is documented in Section 2.0 of the PEIS (DOE 1996b) and is supported by the PEIS Record of Decision (DOE 1997).

3.1 UMTRA Ground Water Compliance Strategies

The PEIS framework used to determine the appropriate ground water compliance strategy for the Monument Valley site is summarized in the flow chart provided as Figure 3–1. The framework takes into consideration human health and environmental risk, stakeholder input, and cost. A step-by-step approach is followed until one, or a combination of one or more, of three available compliance strategies is selected. The three compliance strategies are:

- *No remediation*—Compliance with the EPA ground water protection standards would be met without altering the ground water or cleaning it up in any way. This strategy could be applied at the Monument Valley site for those contaminants at or below MCLs or background levels or for those contaminants above MCLs or background levels that qualify for supplemental standards or ACLs.

- *Natural flushing*—Allows natural ground water movement and geochemical processes to decrease contaminant concentrations to regulatory limits within a period of 100 years. The natural flushing strategy could be applied at the Monument Valley site if ground water compliance can be achieved within a 100 years or less, where effective monitoring and institutional controls can be maintained, and where the ground water is not and is not projected to be a drinking water source.

- *Active ground water remediation*—Requires application of engineered ground water remediation methods such as gradient manipulation, ground water extraction, treatment, land application, phytoremediation, and in situ ground water treatment to achieve compliance with the standards.

3.2 Monument Valley Compliance Strategy

DOE is required by the PEIS to follow the ground water compliance selection framework summarized in Figure 3–1 in selecting the appropriate compliance strategy to clean up the ground water aquifers affected by former processing activities at the Monument Valley site. Three aquifers are known to exist at the site. Site-specific characterization data were used in combination with the PEIS flow chart presented in Figure 3–1 to select an appropriate compliance strategy for the alluvial aquifer and the De Chelly aquifer. DOE has determined that no remediation strategy is appropriate for the Shinarump aquifer because ground water contamination is not present in excess of MCLs and no COCs were identified. A detailed discussion of the selected compliance strategy, and how the strategy was determined, is

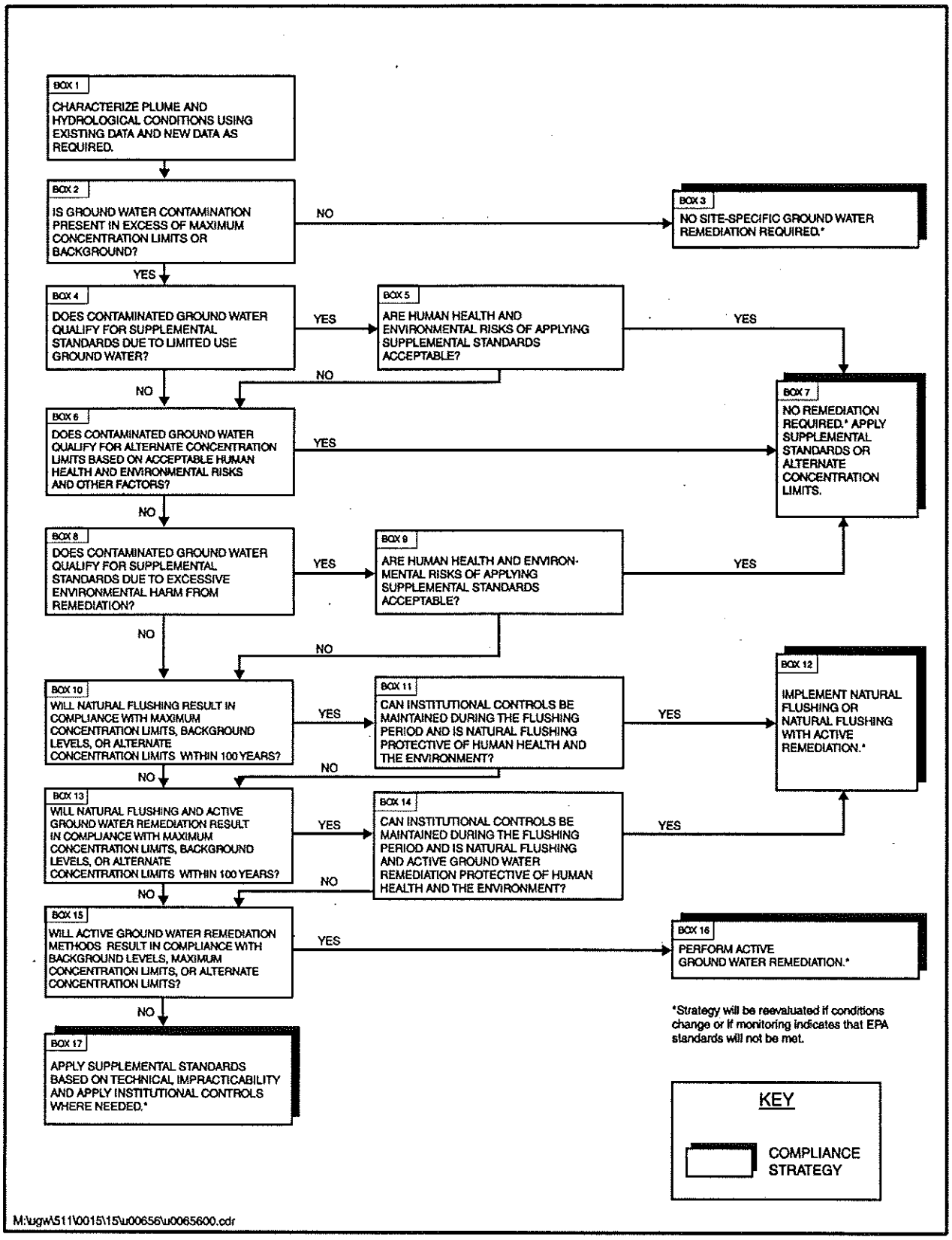

Figure 3–1. Compliance Selection Framework

presented in the Monument Valley SOWP (DOE 1999) and is summarized below for the alluvial and De Chelly aquifer systems.

3.2.1 Alluvial Aquifer Compliance Strategy

DOE has determined that active remediation for nitrate and sulfate and natural flushing for uranium, which are identified as COCs, is the appropriate strategy for the alluvial aquifer. Uranium occurs at one isolated location near the former source area at a concentration that only slightly exceeds the MCL. Because the source has been removed and the uranium concentration is near the MCL, natural flushing is expected to reduce uranium to the MCL within 20 years. Section 4.0 describes the remedial action method for nitrate and sulfate.

3.2.2 De Chelly Aquifer Compliance Strategy

DOE has determined that natural flushing to reduce uranium concentrations below the MCL is the appropriate strategy for the De Chelly aquifer. Uranium occurs at one isolated location near the former source area at a concentration that only slightly exceeds the MCL. Because the source has been removed and uranium concentration is near the MCL, natural flushing is expected to reduce uranium to the MCL within 20 years. No other COCs were identified in the De Chelly aquifer.

3.3 Remediation Standards and Goals

The general requirements for contaminant levels in the ground water at UMTRA sites are specified in 40 CFR 192.04, Table 1. The COC at the Monument Valley site that have standards specified in 40 CFR 192 are nitrate and uranium. The regulation does not specify ground water restoration standards for other contaminants of concern that exceed background concentrations.

Sulfate is the only COC that exceeds background concentrations but does not have an MCL. The Navajo Nation has requested a cleanup goal for sulfate to be 250 mg/L. DOE has agreed to treat sulfate in the contaminant plume to 250 mg/L, or to background concentration, whichever is greater. A sulfate-to-chloride ratio less than 10 is indicative of background.

Cleanup levels for the aquifer were divided into aquifer restoration standards (requirements of 40 CFR 192) and aquifer restoration goals (cleanup goals requested by the Navajo Nation but not required by 40 CFR 192). The restoration standards and goals for the aquifer are listed in Table 3–1.

Table 3–1. Aquifer Restoration Standards and Goals

Contaminant	Cleanup Level	Concentrations in the Plume
Aquifer Restoration Standards (required by 40 CFR 192)		
Nitrate	10 mg/L as N (44 mg/L as NO_3)	<.014–1030 mg/L
Uranium	30 pCi/L (0.044 mg/L) U-234 and &-238	<.001–.069 mg/L
Aquifer Restoration Goals (requested by the Navajo Nation)		
Sulfate	250 mg/L or sulfate-to-chloride ratio <10	26.7–3540 mg/L

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4.0 Selected Remedial Action for the Alluvial Aquifer

The preferred method to clean up the contamination in the alluvial aquifer at the Monument Valley site was selected after evaluation of several remediation alternatives (DOE 1999). For ease of evaluation, each potential alternative was divided into two components (1) a ground water extraction and disposal alternative, and (2) a ground water treatment alternative.

Two pumping alternatives were proposed to address the extraction and disposal of the ground water. Both alternatives consisted of vertical pumping wells to extract the contaminated ground water. The first pumping alternative proposed to use the elevated nitrate concentrations in the extracted ground water as fertilizer to grow native plants and potentially non-native plants, via a surface irrigation system as the disposal component. The second pumping alternative considered vertical injection wells to return treated ground water to the aquifer as the disposal option.

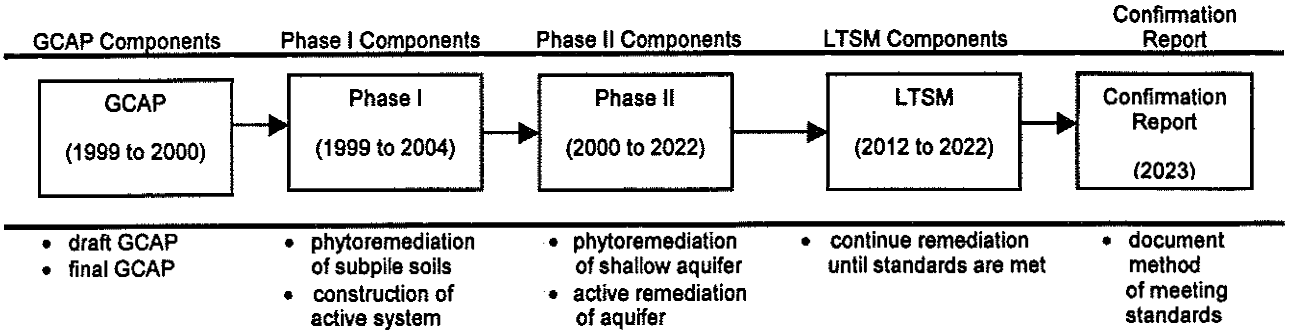
Four treatment alternatives (1) native plant farming, (2) distillation, (3) chemical treatment with biological denitrification, and (4) reverse osmosis, were developed for evaluation. In addition, all of the treatment alternatives incorporated phytoremediation of the subpile soil ammonia in the vicinity of the former tailing piles as well as phytoremediation of shallow portions of the aquifer using plantings of black greasewood. In this document, "phytoremediation" is used to refer to a passive system, which depends solely on the action of plant root systems in the treatment of soils and shallow ground water contamination.

The remediation method that was selected for restoration of the deeper portions of the contaminated alluvial aquifer at the Monument Valley site combines the pumping alternative that uses extraction and injection wells and/or infiltration trenches with the treatment alternative that uses distillation. Phytoremediation was the final treatment method selected to cleanup the subpile soils and the shallow portions of the aquifer. After evaluation, these pumping and treatment alternatives had the best balance of effectiveness, implementability, and cost.

4.1 Implementation of Remediation Approach

A conceptual plan to implement the selected alternatives is presented in Figure 4–1. The remediation is scheduled in two phases. Phase I will consist of phytoremediation of subpile soil ammonium located inside the former millsite fenced area. Residual ammonium in soils and substrates where the tailings piles were removed (subpile soils) may be a continuing source of ground water nitrate. DOE will implement Phase I remediation in the summer of 1999 and will continue until remediation is complete, which is estimated in approximately 5 years.

Phase II remediation will consist of passive phytoremediation of shallow portions of the alluvial aquifer and an active remediation system consisting of extraction wells, distillation treatment, and reinjection wells and/or trenches to return the treated ground water to the aquifer. Phase II phytoremediation is planned to start in the spring of 2000, and is expected to require up to 20 years to complete the remediation of the shallow aquifer.



1. Time periods and components are estimates and may change due to funding constraints or technical considerations.
2. LTSM components refer only to ground-water remediation activities. LTSM at the site will continue for 200 to 1,000 years.
Key: GCAP = ground-water compliance action plan; LTSM = long-term surveillance & maintenance;
LTSP = long-term surveillance plan; O&M = operation and maintenance

Figure 4–1. Conceptual Implementation Plan

Construction of the Phase II well field, distillation system, and site infrastructure will be initiated in the year 2000. The active remediation system is expected to be operational in 2001. After approximately 10 years of operation the Phase II remediation will be transferred to DOE's Long-Term Surveillance and Maintenance Program. The active system will continue to operate until cleanup levels are met or the remediation method is shown to be no longer effective. A confirmation report will then be prepared to document that the standards in 40 CFR 192 were met (i.e., that cleanup standards were met, cleanup goals were met, ACLs were developed, or technical impracticability was implemented).

4.2 Proposed Remediation Method

The proposed remediation incorporates (1) phytoremediation of subpile ammonia using fourwing saltbush, (2) phytoremediation of shallow portions of the aquifer using black greasewood and potentially non-native plants that would have beneficial use to the community, and (3) active remediation of the deeper portions of the aquifer using a pump and treat system. The active portion of the remediation alternative consists of a well field extraction system, a distillation system, and a reinjection system to return the treated ground water to the aquifer. Portions of the alluvial aquifer and the subpile soils that are proposed to be remediated by phytoremediation are illustrated in Figure 4–2. Also illustrated in Figure 4–2 is the location of a conceptual well field configuration and distillation system.

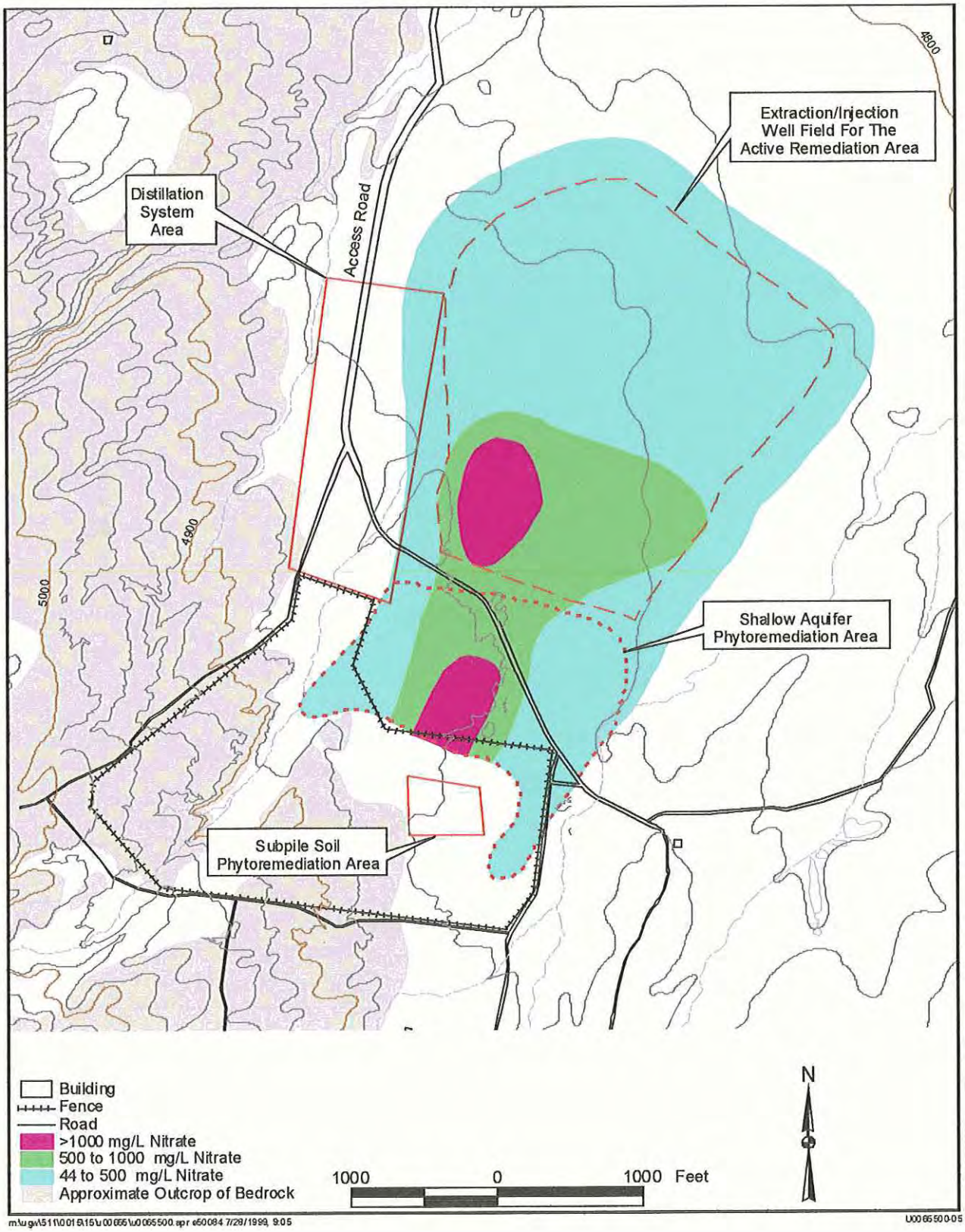


Figure 4–2. Conceptual Location of the Phytoremediation, Well Field, and Distillation System for the Remediation of the Alluvial Aquifer at Monument Valley

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4.2.1 Phytoremediation

Phytoremediation is a type of ground water remediation process, which relies on the natural affinity of plants for nitrates and other nitrogen species. Nitrate and ammonia in the ground water are taken up by the plant roots and assimilated into plant tissues. Nitrate is then reduced in the leaves and roots of the plant to ammonia or ammonium ion, which in turn is converted to amino acids. Amino acids are the building blocks for complex nitrogenous compounds, which are essential for maintenance and growth of plant cells. In this document, "phytoremediation" will be used to refer to passive systems, which depend solely on the action of plant root systems in the treatment of soils and shallow ground water contamination zones.

4.2.1.1 Proposed Phytoremediation of the Subpile Soils

The phytoremediation process will be used for treatment of the ammonia-contaminated soils in and around the former location of the tailings piles. The principal species that will be used for phytoremediation process of the subsurface ammonia-contaminated soils at Monument Valley is fourwing saltbush, *atriplex canescens,* which is a halophyte, or salt-tolerant plant. Approximately 5 acres will be planted and it is estimated that it will take 5 years to complete remediation. The proposed area is shown on Figure 4–2.

4.2.1.2 Proposed Phytoremediation of the Shallow Aquifer

Phytoremediation can also be used for treatment of the uppermost, or shallowest, portion of the alluvial aquifer. In this mode, roots of phreatophyte plants extending down into the upper portion of the water table will draw contaminated water without the need for irrigation. (An irrigation system might be required for the first one or two growing seasons to allow the plants to establish themselves. Once the roots have extended into the aquifer, irrigation would no longer be required and the system could be shut down.) The principal phreatophyte species that will be used for aquifer phytoremediation at Monument Valley is black greasewood, *sarcobatus vermiculatus.* Approximately 60 to 80 acres will be planted and it is estimated that it will take 20 years to complete remediation. The proposed area is shown on Figure 4–2.

4.2.2 Proposed Extraction System

The selected pumping method has two primary objectives: (1) extract contaminated ground water from the aquifer at a rate that will generate two pore volumes of the nitrate plume within 20 years, and (2) contain the contamination to an area within the existing plume. Extracting two pore volumes of the nitrate plume (i.e., 2 times 540 million gallons) within 20 years requires a continuous extraction rate of approximately 100 gallons per minute (gpm). The anticipated extraction rate for the selected pumping method will be approximately 100 gpm once the system reaches its maximum capacity. Containment of the plume can be achieved by injecting treated ground water along the edges of the plume to control its downgradient migration and redirect uncontaminated ground water around the plume. Alternatively, plume containment may be achieved by locating a series of extraction wells along the inside leading edge of the plume to reverse or maintain a neutral ground water flow gradient.

An example of how the well field will be configured is shown in Figure 4–2 for a fully implemented system. The actual well field configuration will be determined by optimization modeling as part of the design. Optimization modeling determines the optimal well placement

and pumping rates, for both pumping and injection wells based on particle capture. The optimal design will be constrained to maximize mass removal and 2 pore volumes of plume water within 20 years and to contain the plume from spreading. Extraction wells may be concentrated along the leading edge of the plume as well as in the most contaminated area of the plume. Injection wells or trenches may be located in areas to enhance the sustainable extraction rates or in areas outside the area of the nitrate plume to stop downgradient movement.

The extraction system will consist of extraction wells, varying in depth up to a maximum of approximately 90 ft, depending on the depth of the alluvial aquifer at the particular location. The expected flow rate per well may vary from 3 to 30 gpm, giving the extraction system a peak capacity of 100 gpm once all wells are in service.

A typical extraction-well design for the Monument Valley site would consist of a 10-in. diameter borehole completed with either a 5 or 6-in. diameter wire-wrapped stainless-steel screen and blank polyvinyl chloride (PVC) casing. The section of the well containing the well screen will be completed with an appropriately-sized sand pack. The final design of the well and the size of the pump will be optimized based on field conditions.

4.2.3 Proposed Distillation Treatment System

The extraction wells will be installed at selected locations across the nitrate plume, within an area measuring approximately 5.8 million square feet, or about 133 acres. The water pumped from these wells must be collected from across this substantial area and delivered to the treatment facility. Each pump will discharge into a PVC outlet pipe. These outlet pipes will be directed into a series of headers, which in turn will connect to a main PVC extraction system discharge pipe, which is routed to the feed tank. The feed tank will be equipped with a level control system with full instrumentation and controls. From the feed tank, contaminated water is pumped directly to the distillation system, which will consist of one self-contained unit with a feed capacity of 100 gpm. The unit will be instrumented to permit continuous operation with remote monitoring capability. The conceptual location of the distillation system is shown in Figure 4–2.

The concentrated brine from the distillation unit, which is expected to average less than 2 percent of the total feed, will be pumped to a solar evaporation pond for final concentration. This pond will be sized to hold all of the sludge produced during the lifetime of the remediation project. The dry sludge from this pond will be removed at the end of the project. The conceptual location of the sludge pond is shown in Figure 4–2.

The treated water from the distillation system, expected to average 98 percent or more of the total feed, will be pumped to a distillate tank having a capacity of approximately 10,000 gallons. This will provide holding capacity so that the injection system can continue to operate during short shutdowns in the distillation system. Figure 4–3 shows a typical process flow diagram for a distillation unit.

The capacity of the treatment system will be sized to match the extraction rate from the well field, estimated at 100 gpm. One treatment unit is planned to meet the treatment needs of all the extraction system phases. The actual flow rate (i.e., extraction rate and required treatment rate) for an implementation phase may be different from the planned flow rate. Deviations from the

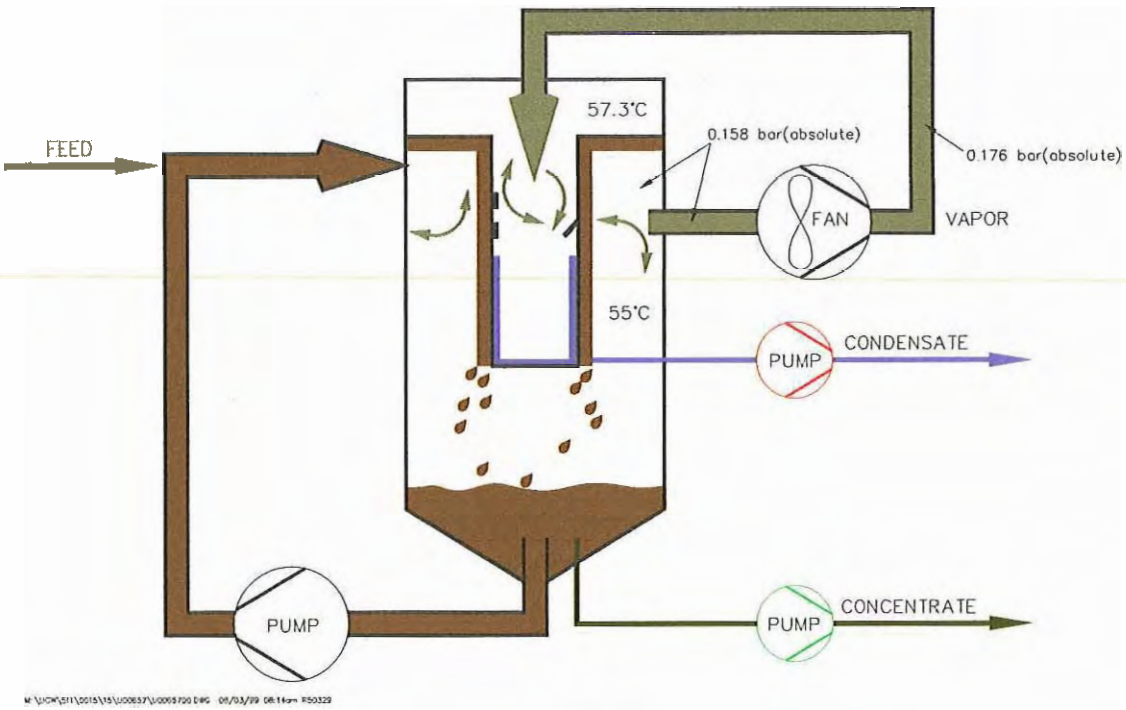

Figure 4–3. Distillation Process Flow Diagram

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planned flow rate may be due to funding constraints or the ability to extract ground water and, therefore, the size of the treatment system actually installed may differ from this plan.

4.2.4 Proposed Injection System

Water from the distillate tank is pumped continuously to the injection system. This will consist of injection wells and/or infiltration trenches with the wells, varying in depth to a maximum of approximately 90 ft. The actual placement of the injection wells and trenches shown in Figure 4–2 will be determined by optimization modeling during the design. The expected flow rate from the well field will deliver the injection system a peak capacity of 100 gpm once all wells are in service. The construction of the injection wells is similar to that of the extraction wells, except that no pump or discharge piping is used. The infiltration trenches will have drainage pipe located along the bottom to evenly disperse the distillate along the trench.

4.3 Limitations of the Selected Remediation

Although the selected remediation method (i.e., ground water extraction and treatment, also known as pump and treat) is the best method to meet cleanup goals in the aquifer, the effectiveness of pump-and-treat systems has been limited. Few sites with contaminated ground water have ever been restored to drinking water standards (Travis 1990; EPA 1996), primarily because of limitations of the extraction systems. Hydraulic inefficiencies, heterogeneity of the aquifer, and sorption of the contaminants to the aquifer material are the main factors that limit the effectiveness of ground water extraction systems.

Hydraulic inefficiencies account for the diffusion of contaminants into low-permeability areas and hydrodynamic isolation (stagnation points) within a well field. Heterogeneities of the aquifer (e.g., changes in the hydraulic conductivity and effective porosity) affect the ability to extract ground water from all areas of the aquifer. The sorption of contaminants to the aquifer material retards the movement of the contaminants in the ground water. The more a contaminant sorbs to the aquifer matrix, the more ground water must be extracted to remove the contaminant.

Hydraulic inefficiencies and heterogeneities of the aquifer are expected to be the main factors that limit the effectiveness of the extraction system at the Monument Valley site. Sorption of contaminants is not expected to be significant for nitrate and sulfate.

A common occurrence with almost all pump-and-treat systems is "tailing." Tailing is when there is only a small reduction in the concentration of contaminants in a well over long periods of pumping. It is caused by both sorption of contaminants to the aquifer material and aquifer heterogenieties. Aquifer heterogenieties (i.e., different permeabilities within the same area) cause tailing because contaminants are removed first from the most permeable areas where there is the highest ground water velocity. After contaminants have been removed from the most permeable areas, the slow advection and diffusion of contaminants from the less permeable areas to the more permeable areas govern the rate of contaminant removal. Contaminants in the less permeable areas slowly mix with clean water in the more permeable areas, creating a low concentration in the extracted ground water that tends to stay relatively constant with time. This causes a tailing effect on the curve that plots time on the x-axis and concentration of a contaminant on the y-axis.

Also, physical properties of the fine-grained material that compose the alluvial aquifer, primarily low hydraulic conductivity and low effective porosity, will limit the ability to extract ground water. Another technical difficulty expected during construction is flowing sands in the subsurface that may hamper installation of new wells.

If active remediation cannot achieve the cleanup levels, other methods of protecting human health would be pursued. A provision in 40 CFR 192 allows the use of alternate concentration limits (ACLs) that would be set at a higher concentration than the current cleanup goals but that would still be protective of human health. The use of ACLs may require that the area within the fence surrounding the former mill site be extended to incorporate areas of the plume that could not be remediated to the cleanup levels. Using ACLs and extending the fenced area would only be considered if active remediation could not effectively reduce contaminant levels in the aquifer to the cleanup standards. A determination that active remediation was no longer effective would be based on a period of operation that demonstrated the remediation system was not able to reduce contaminant concentrations in the aquifer.

4.4 Institutional Controls

Active remediation will take approximately 20 years while natural flushing is estimated to take place within that time frame. During this time, ground water will be unavailable for human consumption.

4.4.1 Ground Water Use Restrictions

Because of the remediation activities planned, DOE and the Indian Health Services (IHS) will enter into an Interagency Agreement (IA) with a Memorandum of Understanding (MOU) being a part of it. As required by the IA and MOU, IHS and the Navajo Nation will agree not to use ground water from the site for any purpose and not to construct wells or any other means of exposing contaminated ground water within the plume boundary during the remediation period. In order to implement this restriction, DOE will provide an alternate water supply, which is further discussed in Section 4.4.2.

4.4.2 Alternate Water Supply System

The Alternate Water Supply System will provide a clean water system for residents located at the Cane Valley site. DOE's goal is to provide a new water source to replace the shallow wells currently used by some residents near the site.

Monitoring well 625 is an artesian well presently used by the local residents on a consistent basis for their water supply and as a water source for livestock grazing within Cane Valley. It is believed that this well was installed to provide a water supply for the ore-processing operations. Documentation regarding the installation of this well (boring or well completion logs) is not available but it is believed that it is completed within the De Chelly aquifer. Monitoring well 625 is upgradient of the contamination plume and is the only well in the area used for human consumption.

DOE will design and construct the water system as part of the remediation phase. Upon completion of the project; operation and maintenance responsibilities will be assigned to the

Navajo Tribal Utility Authority (NTUA). The water supply and delivery facilities will consist of the following:

1. Water well with water pump to supply the system.
2. Construction of a pump house complete with plumbing, electrical controls, and chemical treatment equipment at the new domestic water well.
3. Construction of approximately 26,400 ft of 4-inch PVC water main distribution system.
4. Construction of two 25,000 gallon water storage tanks with appropriate foundations.
5. Construction of three haul water fill points on the distribution system.

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5.0 Compliance and Performance Monitoring

5.1 Monitoring Requirements to the Alluvial Aquifer

Monitoring activities will include placing data loggers in wells along the perimeter of the site to evaluate pre-pumping trends and the trends associated with hydraulic head as pumping continues. Ground-water samples will also be collected from each pumping well to monitor concentration of contaminants as pumping continues. Samples will be analyzed for contaminants and field parameters that could suggest what geochemical processes are occurring. The existing UMTRA ground water monitoring program will be used to establish the pre-pumping baseline and to collect samples to monitor ground water concentrations.

Monitoring also will be used to evaluate the performance of the phytoremediation and the extraction and injection system. A monitoring plan will establish technical criteria to evaluate the success of the remediation and will also propose the steps that might be taken if contaminant concentrations show significant "tailing," that is, an absence of continued improvement in ground-water quality with time.

System performance monitoring and evaluation will continue during Phase II remediation. The performance of the well field will be maximized by using phased installation of additional wells, pulsed pumping techniques, and adaptive pumping strategies, if necessary. Pulsed pumping techniques permit part of the well field to recover periodically, and adaptive pumping strategies are used to induce the movement of ground water from stagnation zones. DOE anticipates that the planned location for wells and number of wells will change because the actual site conditions encountered during remediation will be different from the conditions estimated with the flow model that was used for the initial evaluation of the well field.

Most of the future monitoring efforts will be concentrated on the alluvial aquifer because it is the ground-water system most affected by site-related contamination. A list of 25 proposed alluvial wells to be monitored, and the associated analytical and sampling frequency requirements, are summarized in Table 5–1. Uranium, nitrate, and sulfate are the only COCs present in the alluvial aquifer. Uranium will be monitored at the one location where an isolated uranium occurrence slightly exceeds the MCL. Nitrate, sulfate, and chloride will be monitored at all the proposed sample locations. Chloride is included as an analyte to calculate a sulfate-to-chloride ratio; relatively high values are indicators of site-related sulfate contamination.

Ammonium will be monitored only at selected locations close to the former source areas where relatively high ammonium concentrations are present in the ground water and where phytoremediation of the former source area is planned. All of the proposed on-site and downgradient monitor wells will be sampled annually. Three background locations will also be sampled concurrent with each routine annual sampling event.

Table 5–1. Summary of Proposed Sample Location, Analytical Requirements, and Monitoring Frequency for the Alluvial Aquifer

Monitor Well	Monitoring Purpose	Analyte	Frequency
MON–604, –662, –669, –764, –767, and –768	lateral boundary of plume	nitrate, sulfate, chloride	annual
MON–760, –761, and –762	leading edge of plume	nitrate, sulfate, chloride	annual
MON–650	most downgradient location	nitrate, sulfate, chloride	annual
MON–655, –656, –770, –771, –765, and –777	vertical contaminant profile	ammonium, nitrate, sulfate, chloride	annual
MON–606, –772, –774	on and near site	ammonium, nitrate, sulfate, and chloride plus uranium at location MON–774	annual
Group I: MON–200, –400, and –402	natural background	nitrate, sulfate, chloride	biennial[a]
Group II: MON–403, –602, and –640	natural background	nitrate, sulfate, chloride	biennial[a]

[a]Group I and II will be alternated with each annual sampling event.

Additional or alternate sampling locations to monitor concentration reductions within the plume may be proposed at a later date when extraction wells are installed as part of the active remediation.

5.2 Monitoring Requirements for the De Chelly Aquifer

Wide spread site-related contamination as a result of the former uranium processing operations is not evident in the De Chelly aquifer. Uranium is present in a few ground water samples at concentrations that slightly exceed the 0.044 mg/L MCL, however the area of impact is small, isolated, and the concentrations appear to be decreasing with time. The slightly elevated uranium concentrations are associated with former production well MON–619 located in the area of the former old tailings pile. This De Chelly well, which is hydrologically connected to alluvial ground water in the adjacent paleovalley, was used to supply water for the milling operation. Prolonged pumping of the well drew uranium contamination from the alluvium into the De Chelly. Uranium concentrations have declined significantly in ground water monitoring samples collected from MON–619 since the well was pumped during an aquifer test in 1993. Further decreases are expected since well 619 is no longer used as a production well and dedicated low-flow bladder pumps have been installed for water quality sampling purposes.

Future ground water monitoring will include MON–619 and three other De Chelly monitor wells located in the vicinity of the former old tailings pile. The analytical and sampling frequency requirements are listed in Table 5–2. Uranium will be monitored at all the proposed sample locations on an annual basis for a period of 5 consecutive years. If at the end of the 5-year period of natural flushing the uranium concentrations are not trending lower, an alternate remediation strategy will be applied as per the PEIS. If, however, the uranium concentrations decrease below the UMTRA standard, then an additional 3 years of monitoring will be conducted to verify that the concentrations remain below the standard before the wells are abandoned.

Table 5–2. Summary of Proposed Sample Locations, Analytical Requirements, and Monitoring Frequency for the De Chelly Aquifer

Monitor Well	Monitoring Purpose	Analyte	Frequency
MON–619	location of point-source of uranium in De Chelly	uranium	annual
MON–776	upgradient of point-source	uranium	annual
MON–657	leading edge of uranium >MCL	uranium	annual
MON–775	downgradient of leading edge	uranium	annual

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6.0 References

Travis, C.C. and C. B. Doty, 1990. "Can Contaminated Aquifers at Superfund Sites be Remediated?" *Environmental Science and Technology*, **24**(10): 1464–1466.

U.S. Department of Energy, 1993. *Remedial Action Plan for the Codisposal and Stabilization of the Monument Valley and Mexican Hat Uranium Mill Tailings at Mexican Hat, Utah,* prepared by the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico, February.

———, 1996a. *Baseline Risk Assessment of Ground Water Contamination at the Monument Valley Uranium Mill Tailings Site, Cane Valley, Arizona* DOE/AL/62350-43, Rev.2, U.S. Department of Energy, Albuquerque, New Mexico.

———, 1996b. *Final Programmatic Environmental Impact Statement for the Uranium Mill Tailings Remedial Action Ground Water Project*, DOE/EIS–0198, prepared by the U.S. Department of Energy, UMTRA Project Office, Albuquerque Operations Office, Albuquerque, New Mexico, October.

———, 1997. *Record of Decision, Uranium Mill Tailings Remedial Action Ground Water Project*, 62 *Federal Register* 22913–22916, April 28.

———, 1999. *Final Site Observational Work Plan for the UMTRA Project Site at Monument Valley, Arizona*, MAC–GWMON1.1, prepared by U.S. Department of Energy, Grand Junction Office, April.

U.S. Environmental Protection Agency, 1996. *Pump and Treat Groundwater Remediation, A Guide for Decision Makers and Practitioners*, EPA/625/R–95/005, July.

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