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FEB - 7 2002

Title I
WM-58

Mr. Melvyn Leach
U.S. Nuclear Regulatory Commission
Two White Flint North
11545 Rockville Pike
Mail Stop T7J8
Rockville, MD 20852-2747

Subject: Draft *Shiprock Ground Water Compliance Action Plan*

Dear Mr. Leach:

The draft *Ground Water Compliance Action Plan* (GCAP) for the Shiprock, New Mexico, site is being distributed with a copy of this letter to Ken Hooks and Bill Von Till of your staff.

This draft GCAP describes the compliance strategies for both the terrace and floodplain areas. However, DOE is still evaluating modeling results of the site to determine the full remediation technology for the floodplain (i.e., installation of the slurry wall). The DOE is moving forward with construction of the remedial systems described in this draft GCAP and with the design of the slurry wall. Construction is anticipated to begin in June 2002.

The DOE is continuing to work with the Navajo UMTRA office to fully develop the remedial technology in the floodplain. The 60 percent engineering design for Phase I remedial action will follow transmittal of the draft GCAP. This document will be sent within a week or two.

In the meantime, please review this draft and call me at 970/248-7612 if you have any questions.

Sincerely,

Donald R. Metzler
Program Manager

cc w/enclosure:
K. Hooks, NRC
B. Von Till, NRC

cc w/o enclosure:
S. Marutzky, MACTEC-ERS
File Project GWSHP 1.9 (P. Taylor)

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UMTRA
Ground Water Project

Draft

Ground Water Compliance Action Plan for Remediation at the Shiprock, New Mexico, UMTRA Site

February 2002

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

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

GJO–2001–297–TAR
GWSHP1.9

Draft Ground Water Compliance Action Plan for Remediation at the Shiprock, New Mexico, UMTRA Site

February 2002

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

Project Number UGW–511–0020–28–001
Document Number U0149300

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1.0 Introduction

This Ground Water Compliance Action Plan (GCAP) for the Shiprock, New Mexico, Uranium Mill Tailings Remedial Action (UMTRA) Project site describes the scope of Phase I ground water remediation activities that are planned for the Shiprock site. Site remediation includes extraction of ground water from the terrace east area of the site, extraction of ground water from the contaminant plume on the floodplain area, monitoring of the contamination levels in the floodplain, and monitoring of water levels and contamination levels in the terrace area. In addition, a slurry wall impermeable barrier may be installed in the floodplain at the base of the escarpment as Phase II of remediation if monitoring data suggest that remedial actions on the terrace area are not lowering floodplain contaminant concentrations and modeling indicates that flushing of contaminants will not occur within 100 years.

Remediation of surface contamination was achieved when the disposal cell at the Shiprock site was completed in 1986. The Remedial Action Plan (RAP) (DOE 1985) documents the design and compliance aspects of the disposal cell. 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 (SOWP), Revision 2, for the UMTRA Project Site at Shiprock, New Mexico (DOE 2000).

The GCAP provides a brief background of the site, describes the compliance strategy, the selected remediation method, and components of the remediation. Details of the remediation components are found in the design drawings, specifications, and operational plans that are part of the project record. Section 2.0, "Site Information," summarizes contamination in the ground water, describes the terrace and floodplain ground water systems and their interaction with surface water in the area, and discusses the extent of contamination of the terrace and floodplain systems. 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 1996) was used to select the compliance strategies at the Shiprock 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 monitoring plan for the ground and surface water on the terrace and floodplain areas is included as Appendix A.

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2.0 Site Information

2.1 Site Location and Information

The Shiprock UMTRA site is located within the Navajo Nation in San Juan County in the northwest corner of New Mexico, approximately 28 miles (mi) west of Farmington (Figure 2–1). The UMTRA site is accessible by Uranium Boulevard, which extends from U.S. Highway 666 eastward about 0.5 mi to the Navajo Engineering and Construction Authority (NECA) facility. The site of the former uranium mill is on the NECA facility. The UMTRA disposal cell, which covers 76 acres, is immediately east of the NECA facility. From the center of the town of Shiprock at the junction of U.S. Highways 64 and 666, the disposal cell on the site is about 1 mi to the south, on an elevated, gravel and cobble-covered terrace overlooking the northwest-flowing San Juan River and its floodplain. The site area is south of the San Juan River and extends from the disposal cell about 1 mi to the southeast and 1.5 mi to the northwest.

The UMTRA site lies at an elevation of approximately 5,000 feet (ft). The desert climate has an average annual precipitation of about 7 inches. Almost half of this precipitation falls in the form of brief, intense downpours during the Southwest monsoonal storms that occur during months of July through October. Average snowfall is less than 10 inches per year. The arid climate and relatively thin air result in diurnal temperature variations of about 35 °F. Summer maximum and minimum Fahrenheit temperatures average in the 90's and 50's, respectively, while winter maximum and minimum Fahrenheit temperatures average in the 40's and the teens. The all-time record high is 109 °F, and the record minimum is –26 °F.

The disposal cell and adjacent former millsite area are located on an elevated terrace overlooking the floodplain of the San Juan River. The terrace is trisected by two minor north-northeast drainages, Bob Lee Wash and Many Devils Wash. At the northeast edge of the terrace, an escarpment 50 to 60 ft high forms the boundary between the San Juan River floodplain and the terrace area to the south. The crescent-shaped floodplain area immediately north of the disposal cell extends southeast upstream from the U.S. Highway 666 bridge to a point about 1,500 ft downstream from Many Devils Wash confluence. The horizontal distance from the disposal cell to the San Juan River is about 600 ft. The site and vicinity are shown in Figure 2–2.

A layer of gray Mancos Shale forms the bedrock underlying the entire site. Ground water in the floodplain is hydrologically connected to the San Juan River and receives inflow from an artificial ground water system in the terrace. In the northwest part of the site west of U.S. Highway 666, a distributary channel (former river channel) of the San Juan River is adjacent to the escarpment. The south edge of the site area is marked by the appearance of weathered Mancos Shale that forms a subtle upland area. In the subsurface, this boundary is abrupt in the form of a buried bedrock escarpment that marks the south edge of terrace alluvial material deposited by the ancestral San Juan River.

In this high desert environment, vegetation is sparse in the nonirrigated areas of the terrace and in the upland, and sparse to thick in the riparian environment in the San Juan River floodplain. Some agriculture occurs on the terrace in the northwest part of the site where irrigation is supplied by the Helium Lateral Canal system.

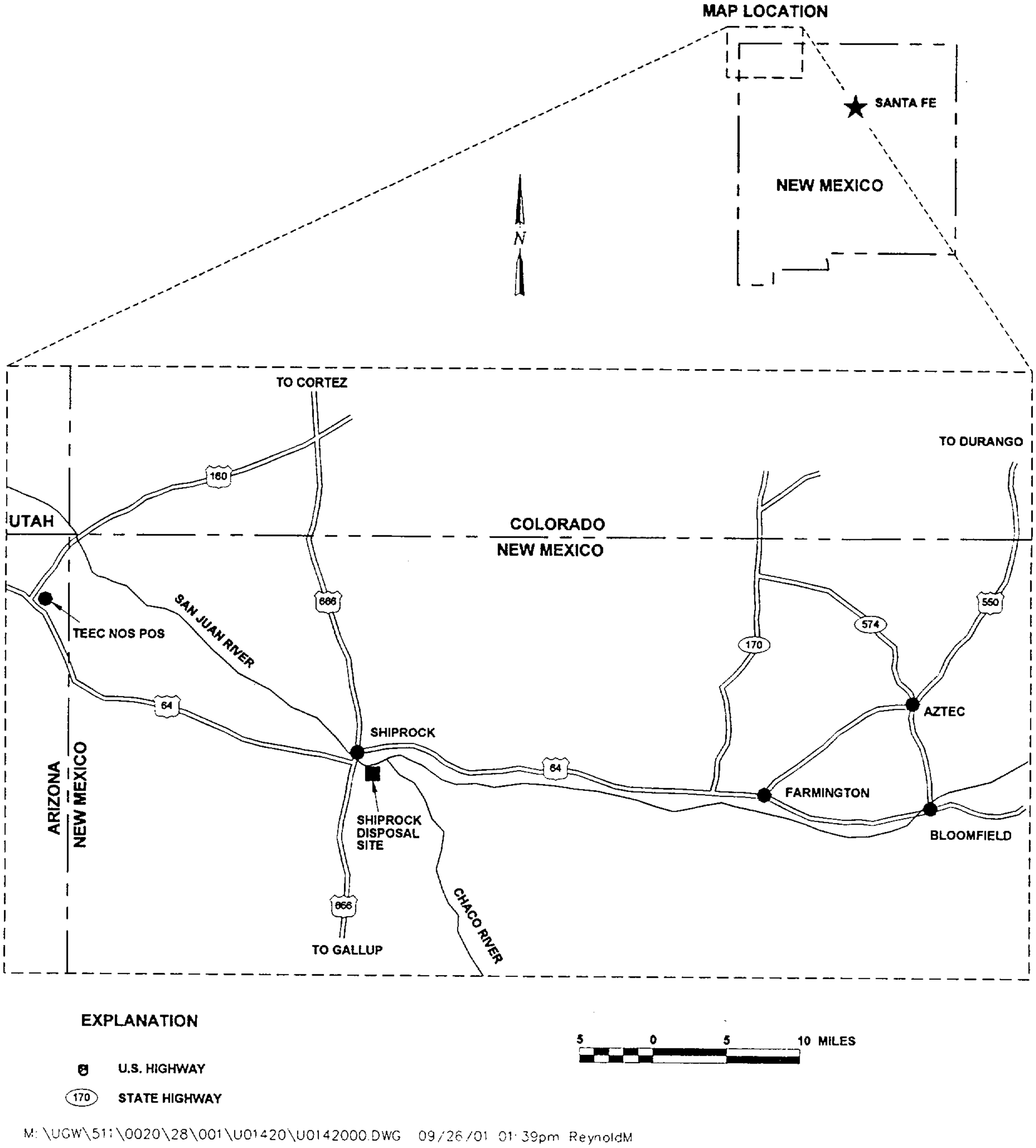

Figure 2–1. Site Location Map

Several thousand people live in the site area south of the San Juan River in the south part of the sprawling unincorporated community of Shiprock. Land use is varied across the site area. Grazing of a few sheep, goats, and cows occurs in the open lands southeast of the NECA gravel pit and in the upland area south of the disposal cell. The only perennial source of surface water available for these animals is the San Juan River. Grazing of some cows and horses also occurs in the fields irrigated by water from the Helium Lateral Canal in the northwest part of the site. No grazing is allowed in the floodplain area immediately north of the disposal cell.

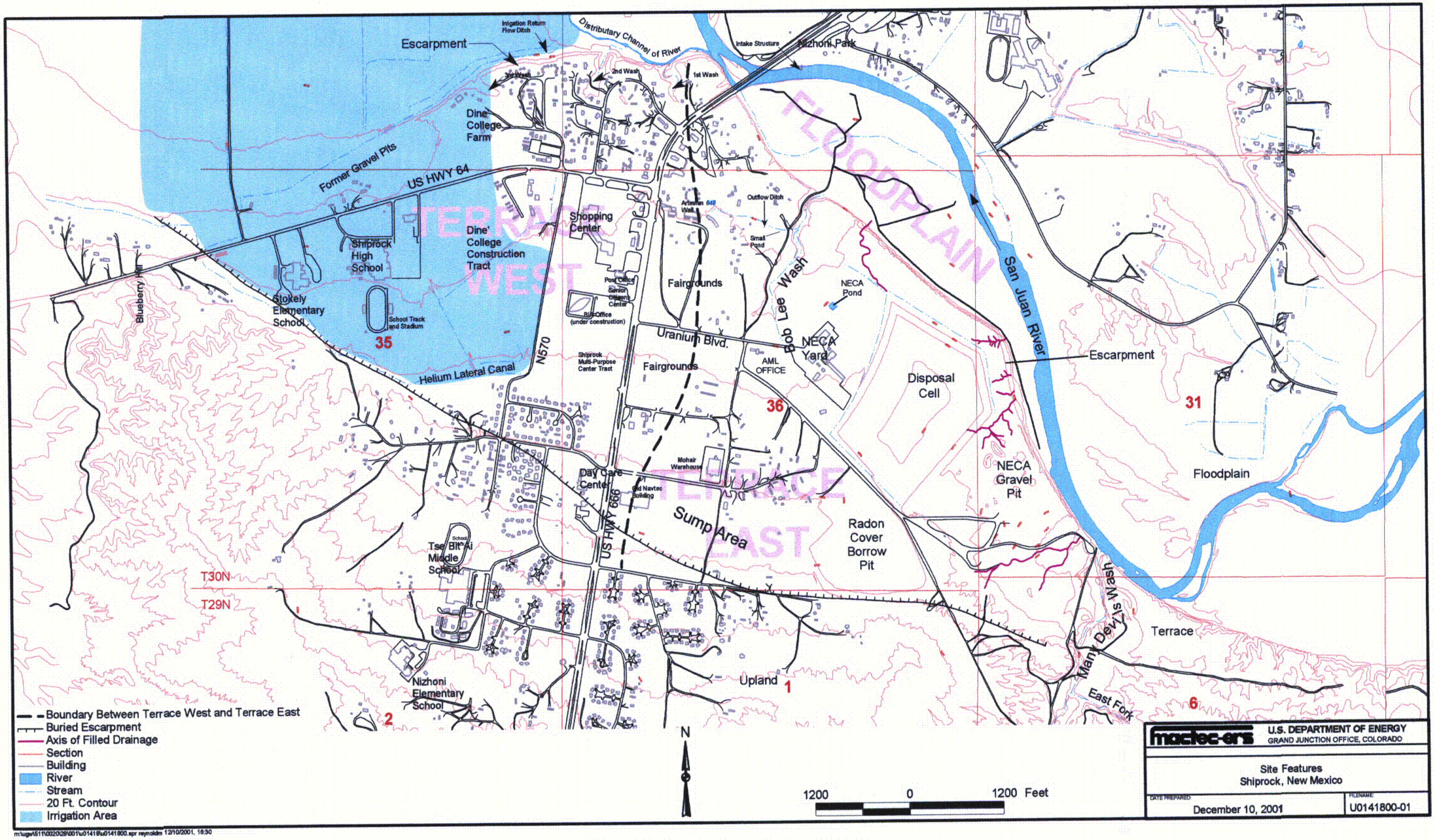

Figure 2–2. Shiprock Site and Surrounding Area

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Commercial and administrative developments and various housing areas are about 0.5 to 1 mi west of the disposal cell. An elementary school, a high school, and a new site for Dine College (under construction) are just more than 1 mi to the west. No ground water from the floodplain is being used in the site area. The only known ground water use from the terrace area is at the high school property where a well is used for irrigating the school grounds, and about 0.5 mi northwest of the disposal cell where water from a deep artesian well is infrequently used for livestock watering.

The terrace is further divided into terrace west and terrace east areas for compliance strategy purposes, reflecting different amounts of contamination and a different balance of ground water recharge. The boundary between the two areas of the terrace is shown in Figure 2–2.

2.2 History

The uranium-vanadium mill, known as the Navajo Mill, operated from 1954 to 1968. The site had been leased from the Navajo Nation, and control reverted to the Nation when the leases expired in 1973. During its operating lifetime, the mill processed about 1.5 million tons of ore, producing about 7.9 million pounds of U_3O_8 and 35.4 million pounds of V_2O_5. The mill was initially designed for an acid cure process, in which ore was allowed to "cure" by soaking in a sulfuric acid solution for 12 hours or longer. The acid cure process is designed primarily to recover vanadium. A decrease in the vanadium market about one year after the plant opened led to its conversion to an agitation leach process, with recovery of uranium only, in 1955. Shortly thereafter, a solvent extraction process was added to supplement, and eventually to replace, the original fixed-bed ion exchange process. By 1957, the solvent extraction process had been modified into a two-stage process that included vanadium recovery with a strong acid solution. The two solvent extraction processes used di(2-ethylhexl) phosphoric acid (EHPA) and tributyl phosphate (TBP) in a base of high flash-point kerosene. Alcohol was probably added as a modifying agent, nitrate and ammonium complexes were added as ion exchange strippers to concentrate uranium, and ammonia was used for pH adjustment of the slurry (Merritt 1971).

Tailings from the washing circuit were pumped to ponds on the two tailings piles. Raffinate from the solvent extraction operation was allowed to evaporate in up to ten unlined raffinate ponds that covered approximately 20 acres just south and southwest of the tailings piles. Water for the milling process was pumped from the San Juan River at an intake about 0.6 mi east-southeast of the mill.

The Shiprock mill was shut down in 1968. Between 1968 and 1973, when the lease on the millsite reverted to the Navajo Nation, some of the mill buildings and most of the equipment were dismantled and placed in the west tailings pile. Shortly after the Navajo Nation assumed control of the site in 1973, the Navajo Tribal Chairman asked officials from the U.S. Environmental Protection Agency (EPA) and other federal agencies for assistance in stabilizing the tailings piles. EPA subsequently surveyed the site and recommended decontaminating the site and stabilizing the tailings. Decontamination work under EPA guidance began in January 1975 and continued until 1980.

Uranium Mill Tailings Radiation Control Act (UMTRCA) legislation in 1978 specified significant changes to remedial action criteria for former uranium millsites compared with the decommissioning work that had already taken place at the Shiprock site. A series of surface and ground water characterization studies were performed in the early 1980s for preparation of the RAP in 1985. The U.S. Department of Energy (DOE) conducted surface remedial actions in late 1985 and 1986 consisting of removing windblown and water-transported contaminated soils from the area surrounding the millsite and tailings piles and placing this material in an engineered disposal cell on site. The two tailings piles were consolidated and encapsulated to form the disposal cell.

A long-term surveillance plan was prepared for the disposal site in 1994. After this plan was approved, the U.S. Nuclear Regulatory Commission issued a license in September 1996 to the DOE–Grand Junction Office (GJO) for the long-term care of the site; the license also deferred site ground water cleanup to the UMTRA Ground Water Project.

2.3 Ground and Surface Water Characteristics

This section summarizes the ground water characteristics at the Shiprock site. The Shiprock SOWP presents a more complete and detailed discussion of hydrology for the site.

2.3.1 Hydrology

The hydrology of the Shiprock site consists of a number of surface water systems: San Juan River; flowing artesian well 648; numerous seeps, springs, and washes; irrigation return flow; wetlands on the floodplain at the mouth of Bob Lee Wash; and the ground water systems, both natural and artificial, on the floodplain, the terrace, and the bedrock flow system. These systems were discussed in detail in the SOWP. The following sections summarize key information about the site.

2.3.1.1 Surface Water

The San Juan River drains an area of approximately 12,900 square miles (mi^2) upstream from the town of Shiprock. The average historic flow in the San Juan River at Shiprock is 2,175 cubic feet per second (cfs). Construction of Navajo Dam, 78 mi upstream of Shiprock, in 1963 moderated the former extreme variability in flow rates; maximum and minimum flow rates since 1963 have been 80 cfs and 15,000 cfs, respectively. Navajo Dam has also reduced the average flow rate in the San Juan River to the point where the average flow at Shiprock since 1963 has been an estimated 1,000 cfs.

The San Juan River is classified as a domestic water supply for primary and secondary human contact and for other purposes. The town of Shiprock and the city of Farmington draw most of their water supplies not from the San Juan River, but from Farmington Lake, which is fed by the Animas River. However, the town of Shiprock has a secondary water inlet, used in an emergency water-supply situation, that draws from the north bank of the San Juan River, just across the river from the floodplain part of the Shiprock UMTRA site. Consequently, stringent water quality standards are applied to the San Juan River, which directly impact the remediation of the Shiprock site.

The Chaco River, which drains more than 4,000 mi^2, joins the San Juan River about 2 mi upstream of the Shiprock site. The Chaco River drains many areas in the San Juan Basin that contain coal and uranium. Flow in the Chaco River ranges from 10 to 30 cfs during non-storm periods, though much of the flow is reported to be effluent from the Four Corners Power Plant about 12 mi southeast of the Shiprock site.

Bob Lee Wash is northwest of the UMTRA site. Discharge from well 648 accounts for essentially all of the surface water in Bob Lee Wash. The discharge from this well is approximately 64 gallons per minute (gpm). A wetland of about 5 acres is on the floodplain near the mouth of Bob Lee Wash. Discharge from the wetland flows slowly northwestward along a drainage (abandoned distributary) channel on the floodplain and enters the San Juan River just upstream from the U.S. Highway 666 bridge.

Many Devils Wash is southeast of the UMTRA site. Surface water in Many Devils Wash is confined largely to the northernmost 1,800 square feet of the channel. The source of water in the wash is quite likely derived from the artificially saturated terrace alluvium and underlying weathered Mancos Shale to the west. Discharge at the mouth of Many Devils Wash has been measured at 0.3 gpm, which flows into the San Juan River.

Three additional washes drain the terrace area west of the U.S. Highway 666 bridge. These washes, which have no formal name, are designated 1st, 2nd, and 3rd Washes, east to west, respectively. Estimates of the rate of discharge in winter 1999 were 1.5 gpm in 1st Wash and about 0.2 gpm in 2nd Wash. No flow has been seen in 3rd Wash. These washes discharge to the distributary channel of the San Juan River west of the U.S. Highway 666 bridge.

The escarpment along the San Juan River west of the mouth of Many Devils Wash contains numerous active seeps and springs that issue from the Mancos Shale. The seepage flow is very low, normally visible as damp zones along the cliff face. White efflorescent crust at other locations along the cliff face suggests that seepage has been more common in the past than it is today. Spring-fed flow has been measured at 1 gpm at seeps 425 and 426; spring flow at location 935 has been estimated at 1.5 gpm near the mouth of 1st Wash, and the spring at location 786 under the U.S. Highway 666 bridge has a comparable flow. Numerous springs and ponds are north of Shiprock High School. Surface flows from these locations enter the irrigation return flow ditch and ultimately discharge to the San Juan River via the distributary channel.

2.3.1.2 Ground Water

The floodplain alluvial aquifer is north of the disposal cell in the millsite floodplain area between the San Juan River and the base of the escarpment. It consists of unconsolidated medium- to coarse-grained sand, gravel, and cobbles that are in direct hydrologic communication with the San Juan River. The SOWP presented hydrographs showing that the aquifer responds to fluctuations in San Juan River levels. The other boundary of the floodplain system is at the contact with the base of the escarpment, where the flux is dependent on the head. A portion of the surface water from Bob Lee Wash (discharged from well 648) is being channeled from the outflow ditch into a small pond, which leaks considerably and discharges onto the floodplain just west of the mouth of Bob Lee Wash. Also, some flow from well 648 continues in the outflow ditch eastward from the small pond and into Bob Lee Wash.

The contribution from Bob Lee Wash is the major source of water to the floodplain and dominates the hydrodynamics of the floodplain. Table 4–5 in the SOWP presented the water balance on the floodplain, showing that the discharge from Bob Lee Wash constituted about 56% of the total inflow for the floodplain alluvial aquifer. The other sources of inflow to the floodplain were the San Juan River and the terrace via the Mancos Shale, which each contributed 16% of the total inflow, and recharge of precipitation and runoff, which contributed 12% of the total. (The total inflow shown in Table 4–5 in the SOWP is incorrect. The actual total inflow is 22,120 cubic feet [ft^3] per day.) The total volume of water in the floodplain alluvial aquifer is estimated at 20.1 ft^3 or 150 million gallons.

The terrace ground water system occupies a buried ancestral river channel that eroded a swale in the Mancos Shale. The system consists of unconsolidated alluvial and windblown sediments overlying the Mancos Shale. A buried escarpment defines the southern boundary of the terrace system. Water flow in the system moves to the northwest, as shown in the piezometric surface map of the site in Figure 2–3, along the axis of the channel toward the area irrigated by the Helium Lateral Canal.

Aerial photographs of the future millsite area taken in 1935 show no surface water or surface-water-dependent vegetation in the terrace, and no evidence of seepage along the escarpment. No ground water has been found in any of the test wells 1 to 2 mi east-southeast of the disposal cell in a similar terrace area that receives no recharge from irrigation. Therefore, all of the ground water in the terrace system is assumed to be anthropogenic.

In the SOWP, the terrace water balance estimated that the total infiltration into the terrace system from milling activities was about 308 million gallons. The present volume of water in the terrace east system was estimated as 38 million gallons. Comparison with present day conditions suggests that infiltration of water during the period of milling operations was sufficient to create the terrace east ground water system, and that natural recharge is insufficient to sustain a natural aquifer. Ground water modeling performed subsequent to the final SOWP indicates that the net recharge of the terrace east ground water system is significantly lower than the estimates in the SOWP. The total annual inflow and outflow on terrace east (excluding the infiltration of irrigation water in the northwest area of the terrace that is confined to the terrace west area) is presently estimated at about 2.2 million gallons. This inflow disperses radially in all directions, and approximately 25% of the total annual inflow, or approximately 600,000 gallons per year, recharges the terrace east system. This would be sufficient to create a natural aquifer. However, assuming that the same percentage of total water produced during the milling operation infiltrated the terrace east system, this would yield a net infiltration of 80 to 85 million gallons into that system during the years of milling. This amount is more than enough to have created the 38-million-gallon terrace east system.

Initial numerical modeling of contaminant concentrations suggested that drainage from the disposal cell was about 4.2 million gallons per year. A recent piezocone investigation on the disposal cell has indicated that the saturated volume of the disposal cell is probably inadequate to support the quantity of drainage estimated from the initial numerical modeling. More accurate estimates of the drainage volume will be prepared using data from the monitoring program and from additional modeling.

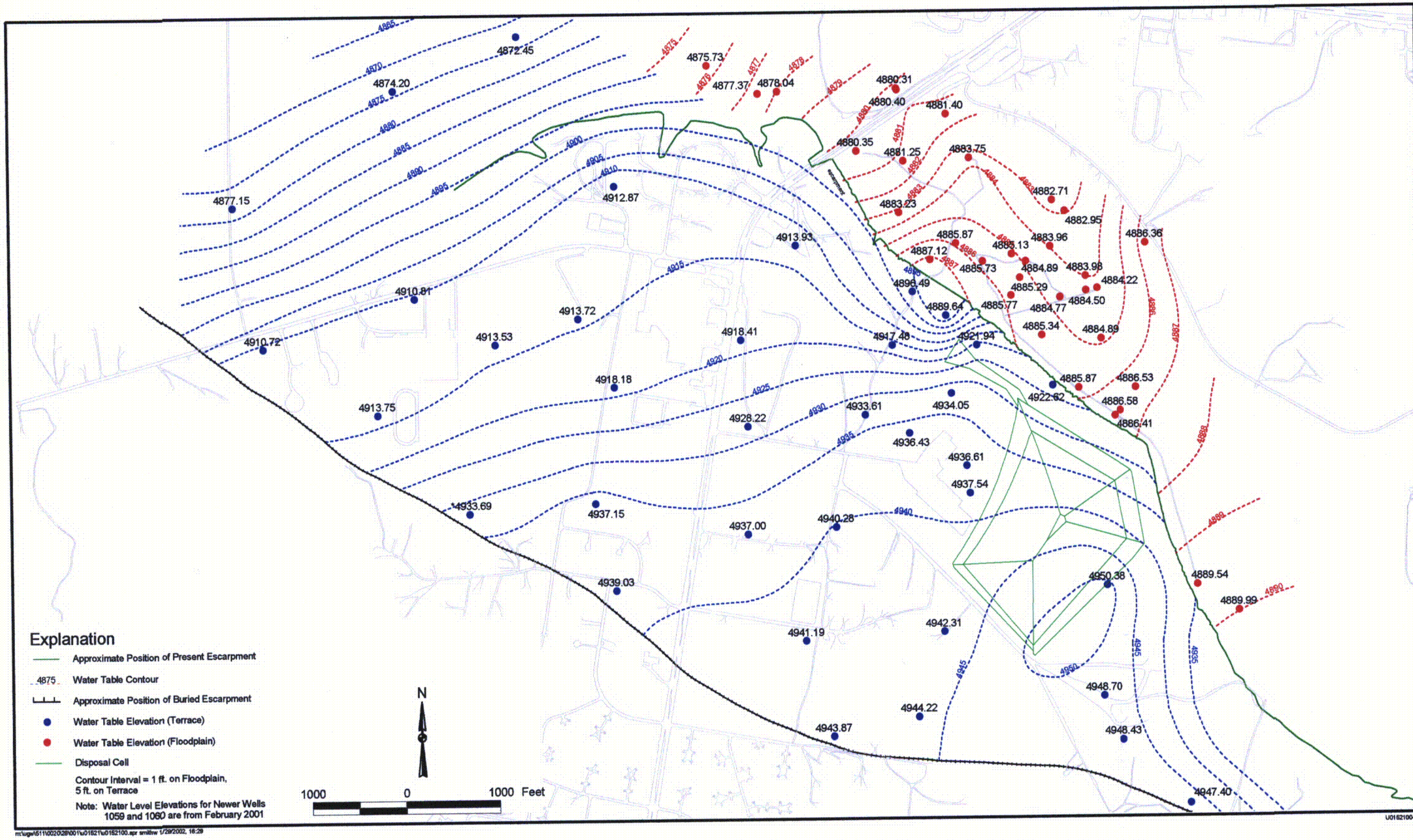

Figure 2–3. Approximate March 1999 Contours of Piezometric Surface for Both Floodplain Alluvial Aquifer and the Terrace Ground Water System

2.3.2 Water Quality of the San Juan River

Table 2–1 presents results of water quality monitoring performed by DOE at sample locations 940, at the edge of the floodplain along the south bank of the San Juan River, and 956, on the north bank of the river in the vicinity of the emergency intake for the water supply of the town of Shiprock. This table also shows the flow rate of water in the river on the day that sample was taken. The river flow rates were measured at the U.S. Geological Survey gauge 09368000 at the emergency intake structure. With only one exception, the concentrations of the selected analytes are below the standards for domestic and primary human-contact designated uses in the surface water quality standards of the Navajo Nation (Table 2–2). The exception is the uranium concentration from water sampled at location 940 in February 2000; this concentration exceeded both the Navajo Nation surface water quality standard and the EPA ground water MCL of 0.044 milligrams per liter (mg/L). In general, the results indicate that millsite-related contaminants do not pose a threat to the quality of the water in the San Juan River. However, the fact that one analysis has indicated a potential threat under certain conditions shows that continued monitoring will be required.

Table 2–1. Surface Water Quality in San Juan River

South Bank of San Juan River (Location 940)							
Date	**Flow, cfs**	**Arsenic (mg/L)**	**Nitrate (mg/L)**	**Selenium (mg/L)**	**Sulfate (mg/L)**	**TDS (mg/L)**	**Uranium (mg/L)**
06/06/1999	7,030	<0.001	0.513	<0.001	41	158	0.00032
02/03/2000	835	<0.0004	22.5	<0.001	504	1020	0.0469
06/20/2000	674	0.00045	0.781	0.0006	138	362	0.0035
07/14/2000	295	0.00094	0.102	0.00047	142	400	0.0021
11/16/2000	526	0.00032	1.42	0.0007	169	435	0.0021
02/08/2001	524	NA	3.18	0.00055	211	497	0.0055
North Bank of San Juan River (Location 956)							
Date	**Flow, cfs**	**Arsenic (mg/L)**	**Nitrate (mg/L)**	**Selenium (mg/L)**	**Sulfate (mg/L)**	**TDS (mg/L)**	**Uranium (mg/L)**
06/16/2000	938	0.0004	0.394	0.00041	102	297	0.0015
07/12/2000	427	0.00045	0.109	0.00052	139	378	0.002
11/17/2000	942	0.00036	1.53	0.00078	160	408	0.002
02/13/2001	801	NA	1.73	0.00074	176	430	0.0019

NA = Not analyzed

Table 2–2. Navajo Nation Surface Water Quality Standards for Domestic Purposes for Selected Constituents

Constituent	Surface Water Quality Standards, in mg/L
Arsenic	0.05
Total Nitrogen	10
Selenium	0.05
Sulfate	NS
TDS	NS
Uranium	0.035

NS = No standard exists

2.4 Ground Water Contamination

The contaminants of concern (COCs) that have been identified for the Shiprock site are ammonium, manganese, nitrate, selenium, strontium, sulfate, and uranium.

During active uranium and vanadium milling, water with tailings from the washing circuit and from yellow-cake filtration was pumped to the disposal area. Although excess solutions were recycled to the plant during the winter months, raffinate was also disposed of by evaporation in separate holding ponds. The milling operations, as noted above, used large amounts of sulfuric acid and ammonia, as well as smaller amounts of organic solvents, which were transported to the tailings and raffinate ponds (Merritt 1971). Ground water contamination at the site is believed to have resulted from infiltration of the milling fluids, and leaching of ore and uranium mill tailings constituents by mill water and rainwater. Using data from Merritt (1971) for the average flow to the tailings ponds, site evaporation rates calculated from pan evaporation data to estimate losses from the ponds to evaporation, and an estimate of total runoff to the floodplain alluvium from a U.S. Department of Health, Education, and Welfare (1962) study, the SOWP estimated that the cumulative volume of water infiltrated into the terrace alluvium during the 14 years of milling operations was approximately 308 million gallons.

Water has been added to the terrace area of the site from sources other than the Navajo Mill. From 1944 through the 1950s, water was used in a helium-processing plant built by the U.S. Bureau of Mines at the present site of the Shiprock Shopping Center (Figure 2–2). In the late 1950s, irrigation water was brought to the terrace west area by a siphon from the Hogback Canal; this siphoned water was distributed into the Helium Lateral Canal system for agricultural use. In 1961 an oil and gas test hole was drilled on the terrace about 0.5 mi northwest of the disposal cell area. This hole, drilled to a depth of 1,850 ft into the Morrison Formation, was not capped. Artesian flow from this hole, now known as site well 648, has continued since 1961 and is currently flowing at a rate of about 64 gpm across the terrace into Bob Lee Wash, which drains to the floodplain and eventually to the San Juan River. This flow has been beneficial in flushing milling-related contamination from the northwest part of the floodplain.

2.4.1 Terrace

The boundary between terrace west and terrace east areas roughly parallels U.S. Highway 666 as it passes through the town of Shiprock south of the San Juan River (Figure 2–2). The disposal cell and former millsite are in the terrace east system. Saturated thicknesses of the alluvial material in the terrace east system north of the sump area, shown in Figure 2–4, are thin to nonexistent, whereas saturated thicknesses in the terrace west system increase from essentially zero at the boundary between the two areas to more than 16 ft in the area near the escarpment to the west of 1st Wash.

Section 4.4.2.2 of the SOWP describes the terrace contamination in detail. Table 2–3 shows the concentrations of COCs in the terrace ground water system. No background concentrations are listed because no water has been detected at any of the wells that have been drilled in terrace locations upgradient from the site. The minimum concentrations shown for the various constituents in Table 2–3 are not uniformly concentrated in the same area, so no "background" area can be identified. For example, only one well, 836, showed a nitrate concentration at the detection limit of 0.01 mg/L. Nitrate levels at all other wells are 3.9 mg/L or higher. However, the strontium concentration of the water at well 836 is 6.39 mg/L and the sulfate concentration is 2,240 mg/L, both of which are higher than levels at a number of other wells.

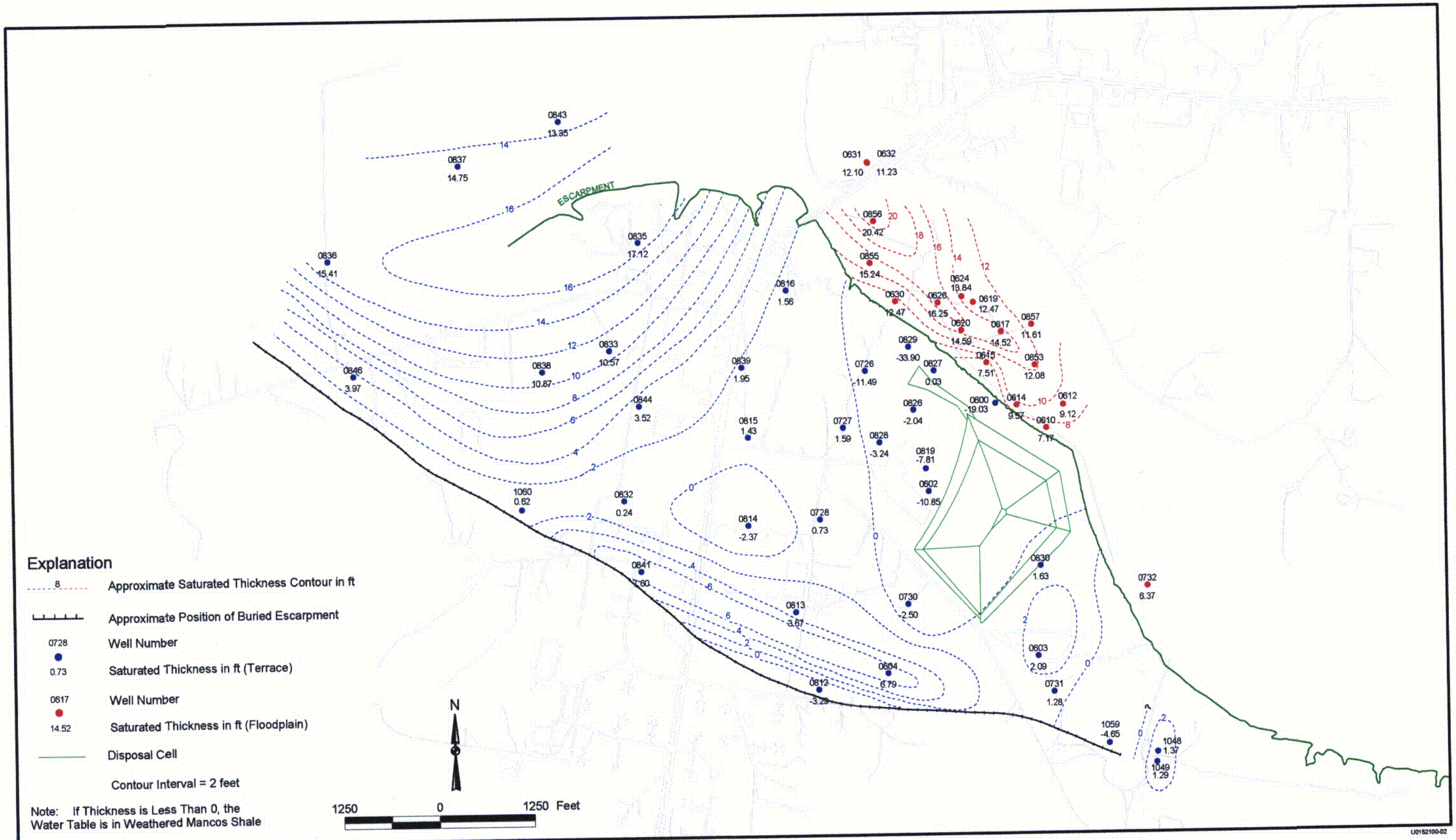

Figure 2–4. Saturated Thickness in Alluvial Material for Floodplain Alluvial Aquifer and Terrace Ground Water System

Table 2–3. Terrace Ground Water Data Summary

Terrace Contaminant	Frequency of Detection	Range mg/L	Mean mg/L
Ammonium	16/28	<0.0066 – 1,740	25
Manganese	24/28	<0.0006 – 31.4	2.54
Nitrate	28/28	0.01 – 8,790	1,618
Selenium	25/28	<0.0006 – 6.52	0.836
Strontium	28/28	2.75 – 18.3	8.14
Sulfate	28/28	1,300 – 17,800	7,359
Uranium	28/28	0.0021 – 3.08	0.247

The distribution of contaminants on the terrace is shown in the plume maps, Figures 2–5 through 2–11. There is no detectable pattern of contamination shown by the various contaminant concentrations. Uranium concentrations are highest adjacent to the northwest corner of the disposal cell, manganese concentrations peak along the southernmost corner, and highest selenium concentrations occur at some distance from the cell. All contaminants except uranium show very high concentrations along the southern boundary of the terrace system in the sump area adjacent to the buried escarpment.

2.4.2 Floodplain

Section 4.4.2.1 of the SOWP describes the floodplain contamination in detail. Table 2–4 compares concentrations of the COCs to background levels based on the sampling data from June 1999 and February 2000, including the concentration ranges, frequency of detection, and means. The background concentrations are based on samples from three monitor wells (850, 851, and 852) in a floodplain area about 1 mi upstream of the millsite floodplain.

Table 2–4. Floodplain Alluvial Ground Water Data Summary

Floodplain Contaminant	Frequency of Detection	Background mg/L	Range mg/L	Mean mg/L
Ammonium	32/32	0.045	0.009 – 70.38	13.14
Manganese	32/32	1.24	0.0014 – 10.4	3.2
Nitrate	32/32	0.12	0.01 – 3.48	593
Selenium	28/32	<0.001	<0.0002 – 1.04	0.084
Strontium	32/32	2.26	0.51 – 20.1	7.82
Sulfate	32/32	1,432	138 – 26,300	6,533
Uranium	32/32	0.007	0.0025 – 3.77	0.756

The distribution of COCs on the floodplain is shown in the plume maps (Figures 2–12 through 2–18). Contaminant concentrations are generally low in the southeastern portion of the floodplain adjacent to the San Juan River, because of the diluting effect of recharge from the river. Concentrations are highest at the base of the escarpment, particularly in the area nearest the disposal cell.

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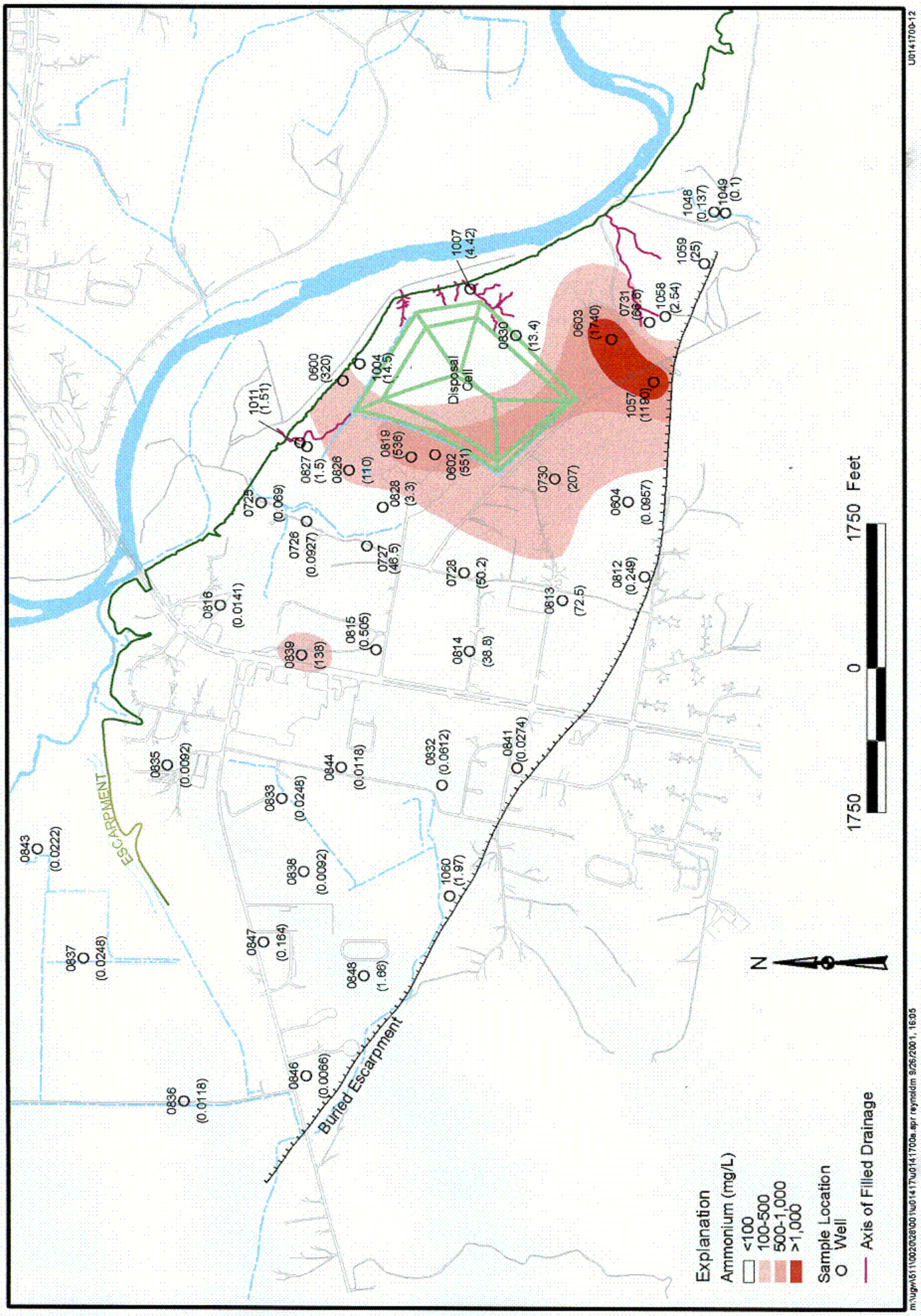

Figure 2–5. Ammonium Concentrations in Terrace Ground Water (March 1999 through April 2000 data)

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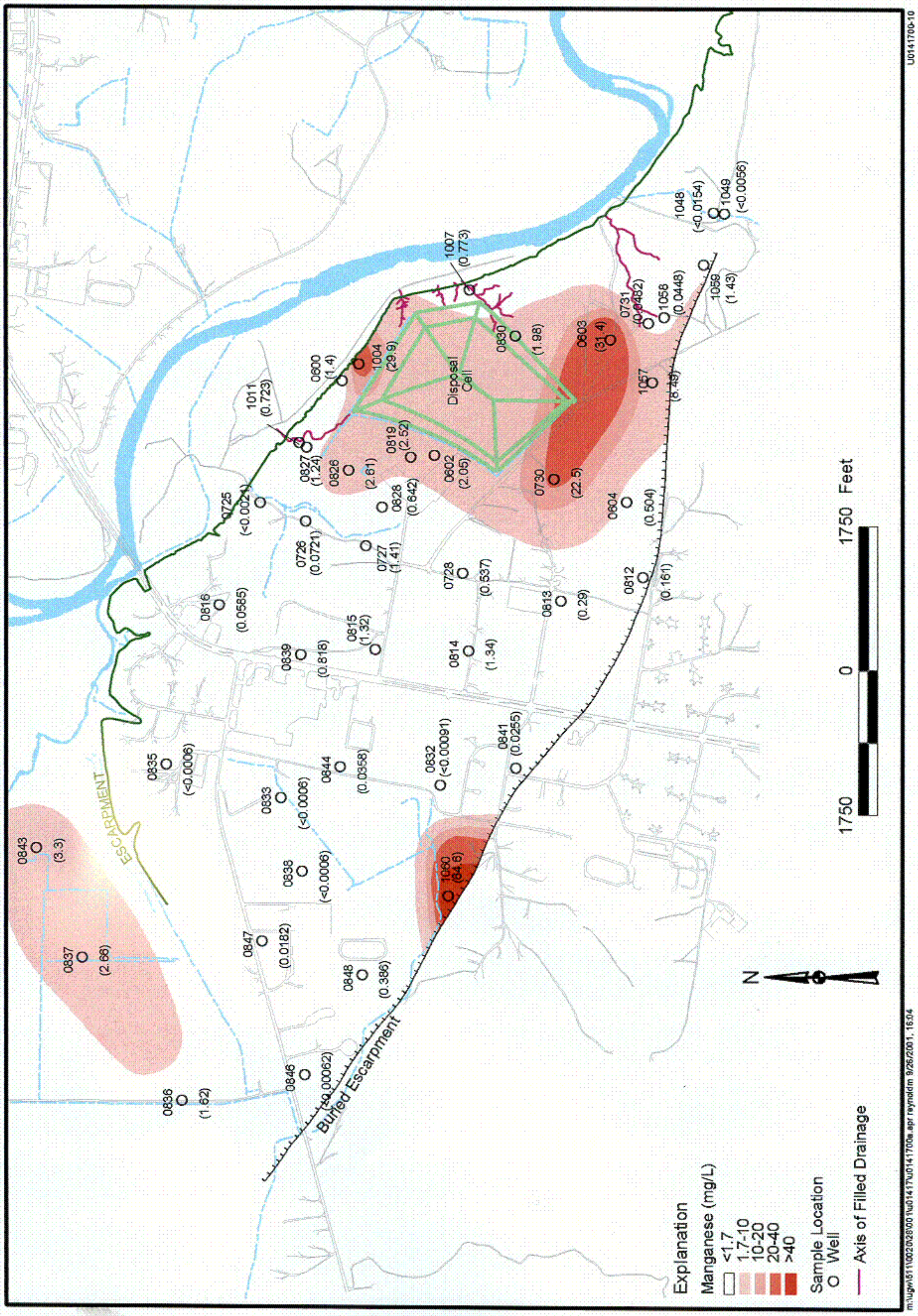

Figure 2–6. Manganese Concentrations in Terrace Ground Water (March 1999 through April 2000 data)

C05

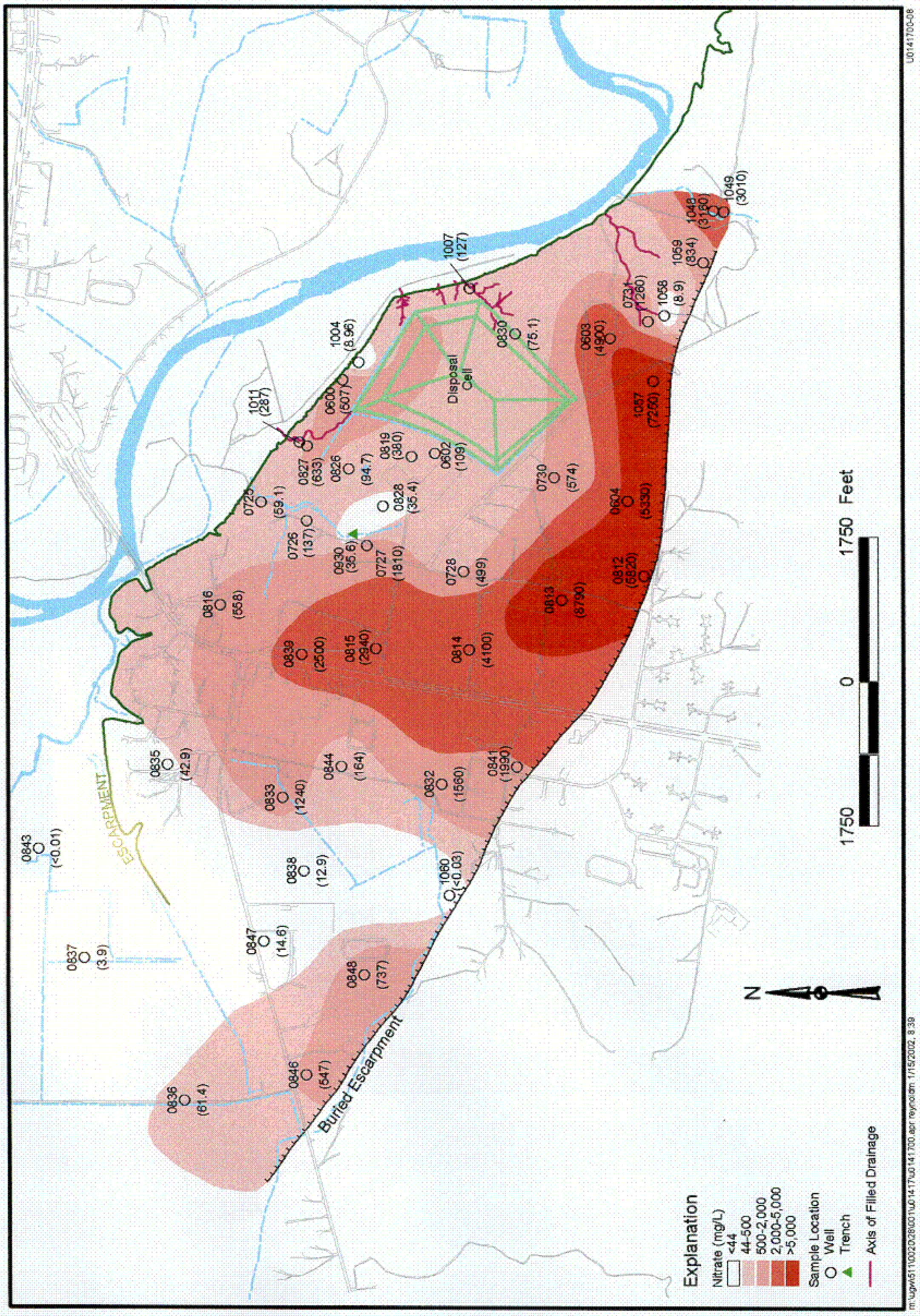

Figure 2–7. Nitrate Concentrations in Terrace Ground Water (March 1999 through April 2000 data)

C06

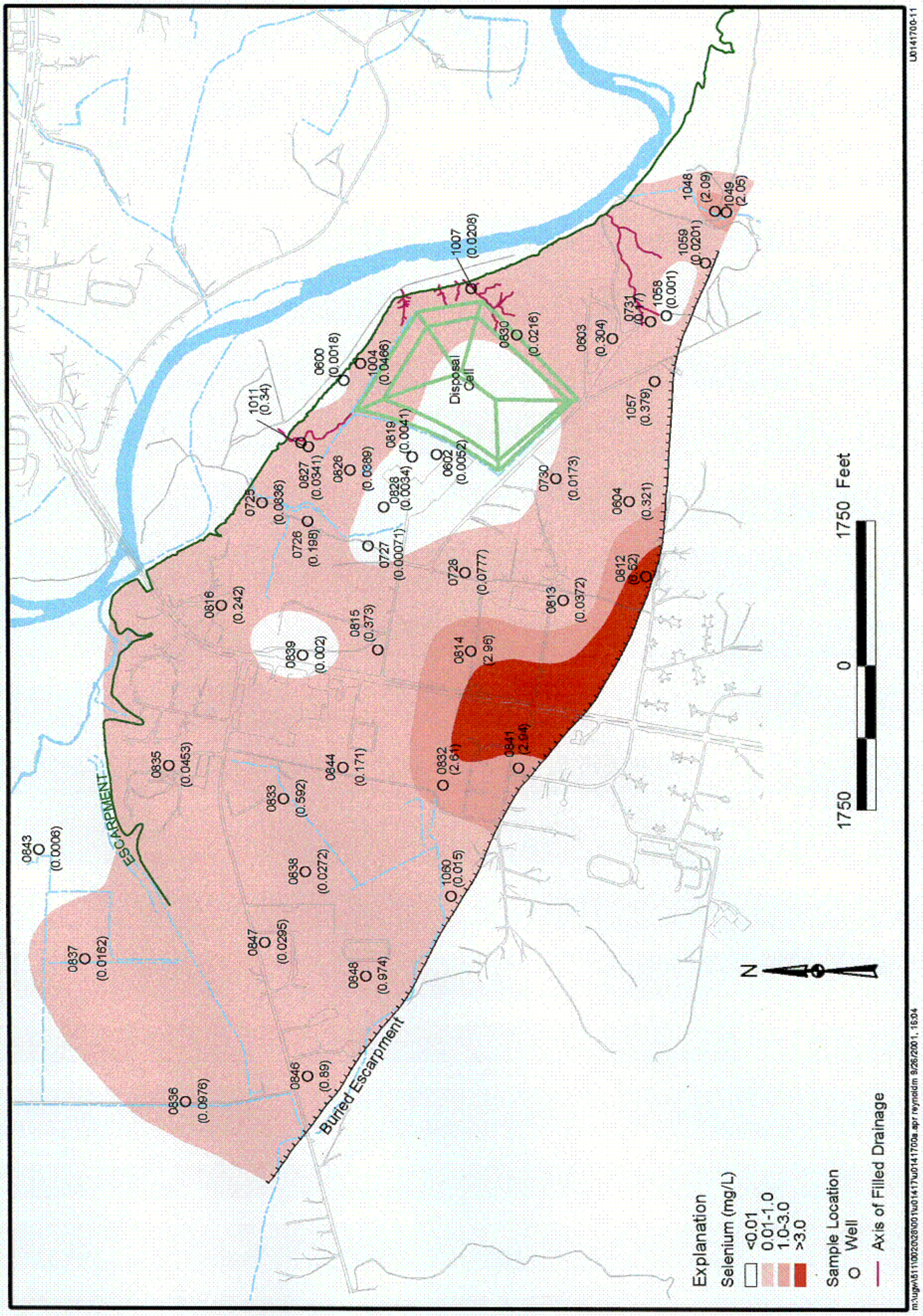

Figure 2–8. Selenium Concentrations in Terrace Ground Water (March 1999 through April 2000 data)

C07

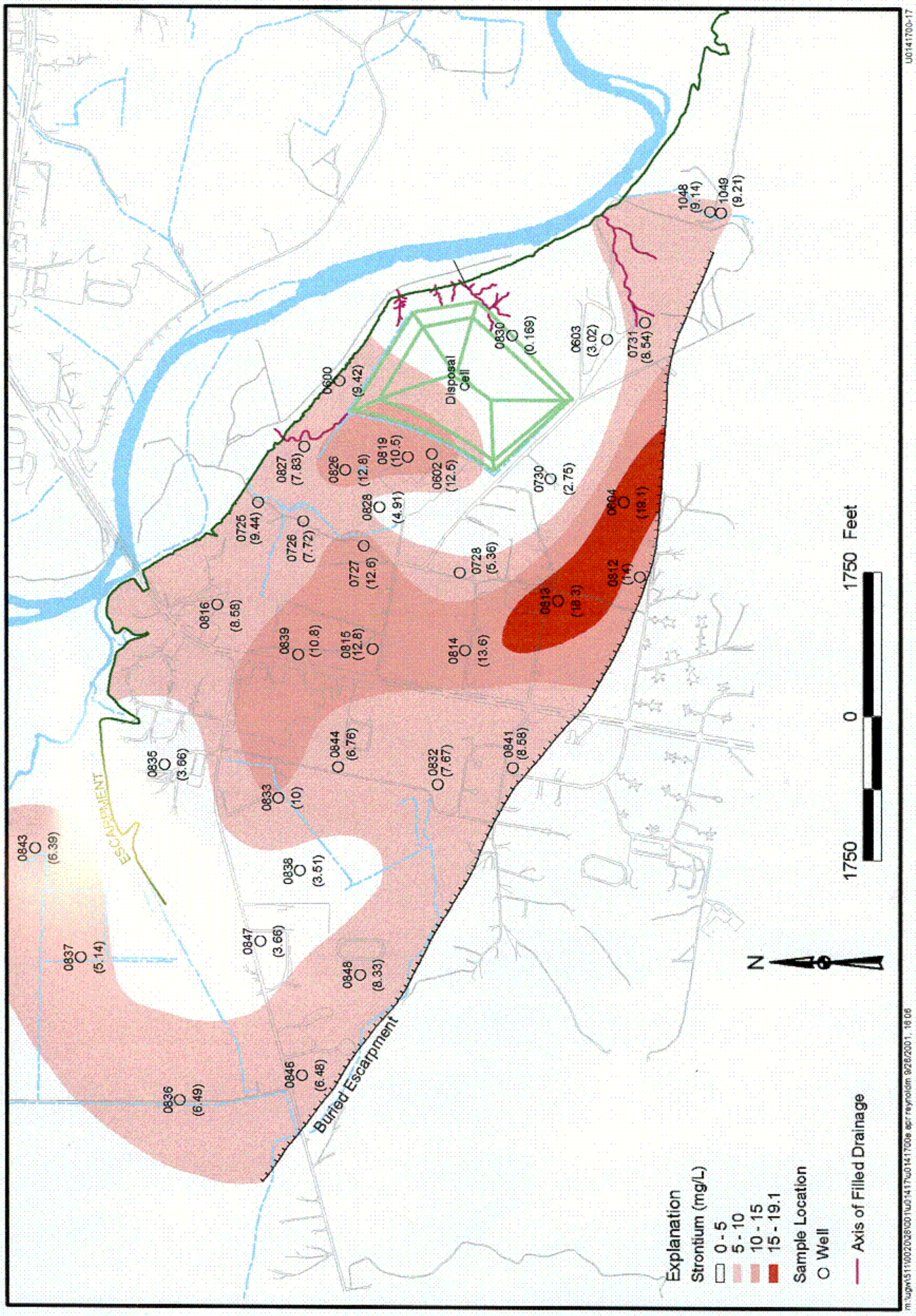

Figure 2–9. Strontium Concentrations in Terrace Ground Water (March 1999 through April 2000 data)

C08

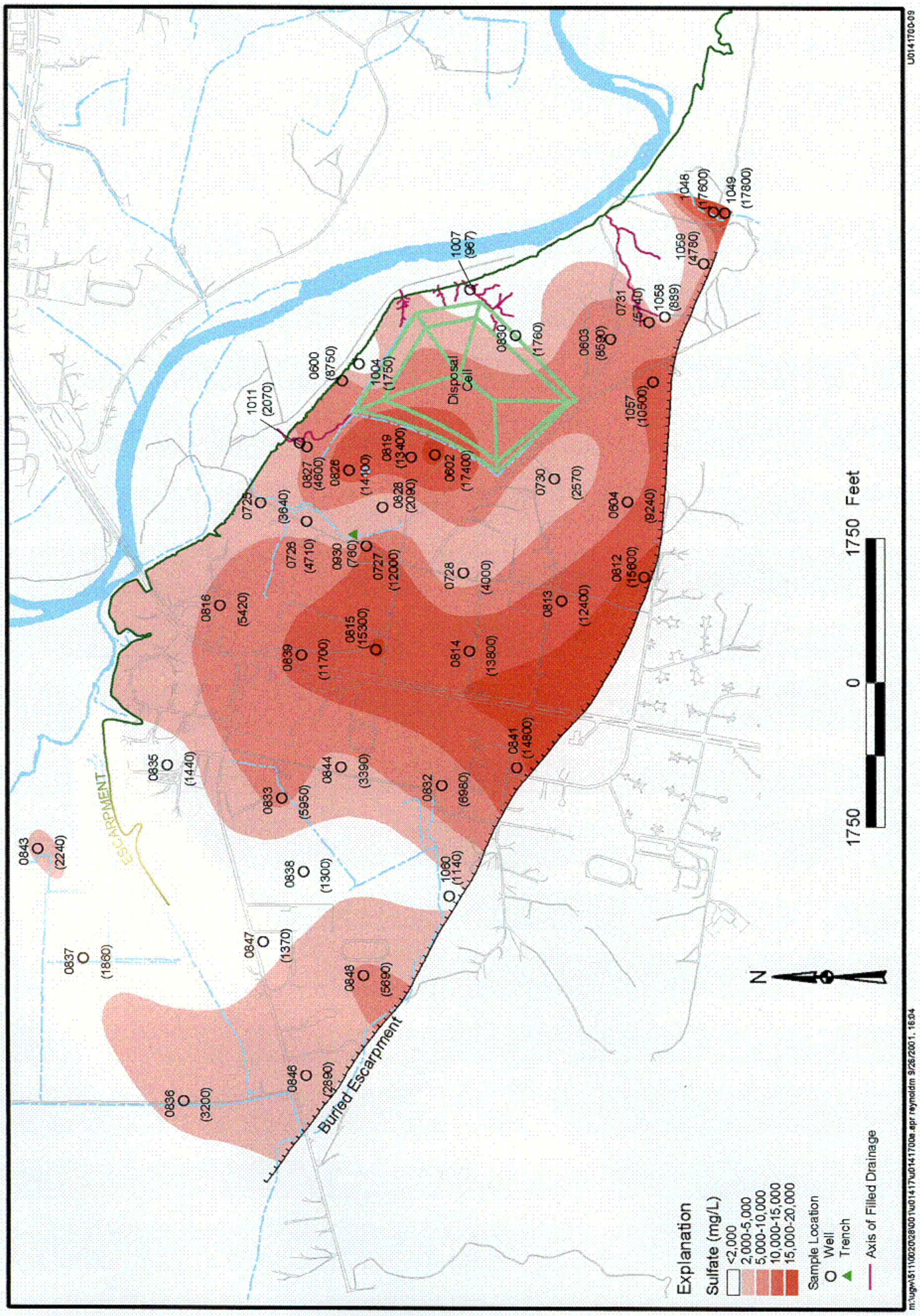

Figure 2–10. Sulfate Concentrations in Terrace Ground Water (March 1999 through April 2000 data)

C09

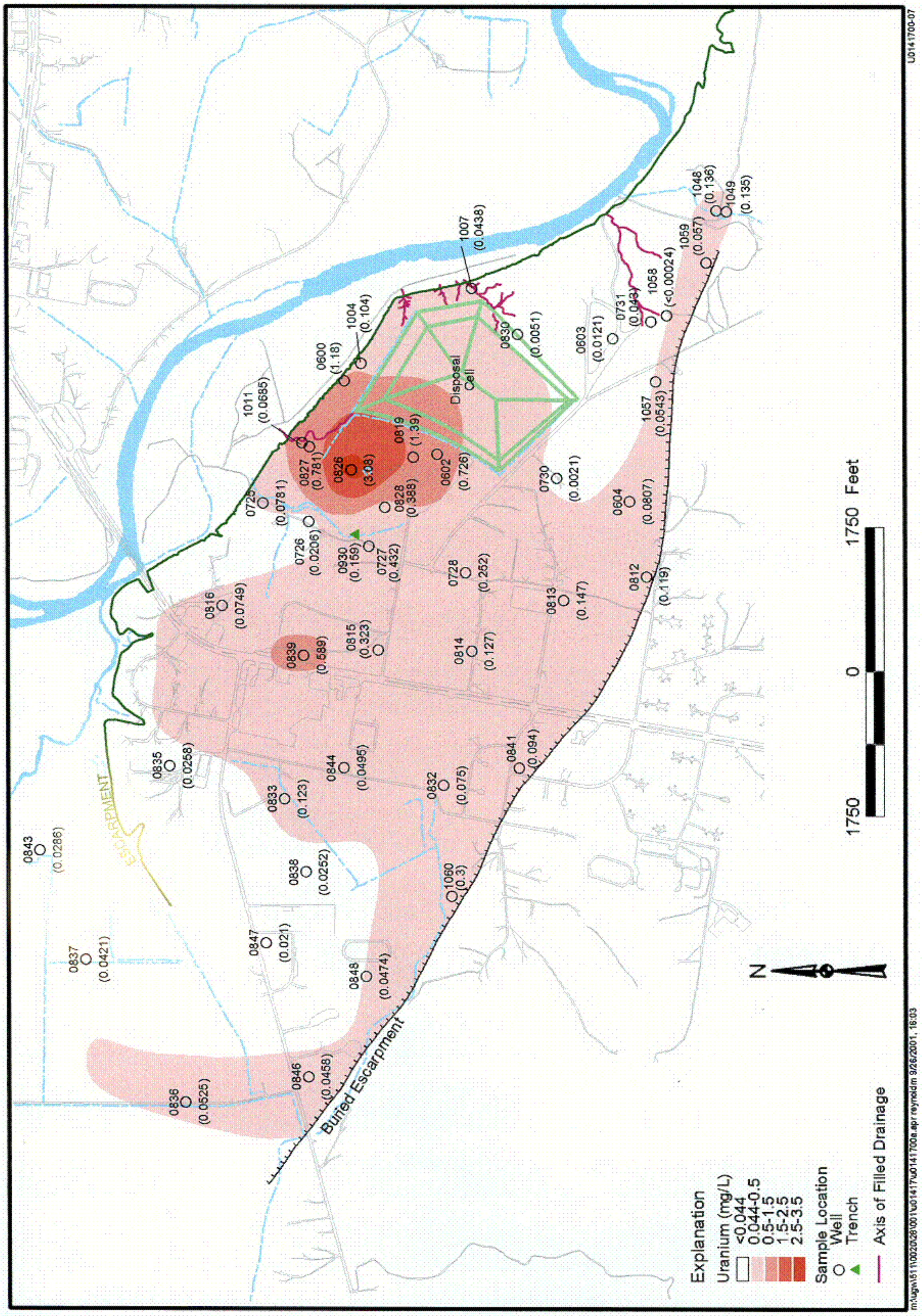

Figure 2–11. Uranium Concentrations in Terrace Ground Water (March 1999 through April 2000 data)

C10

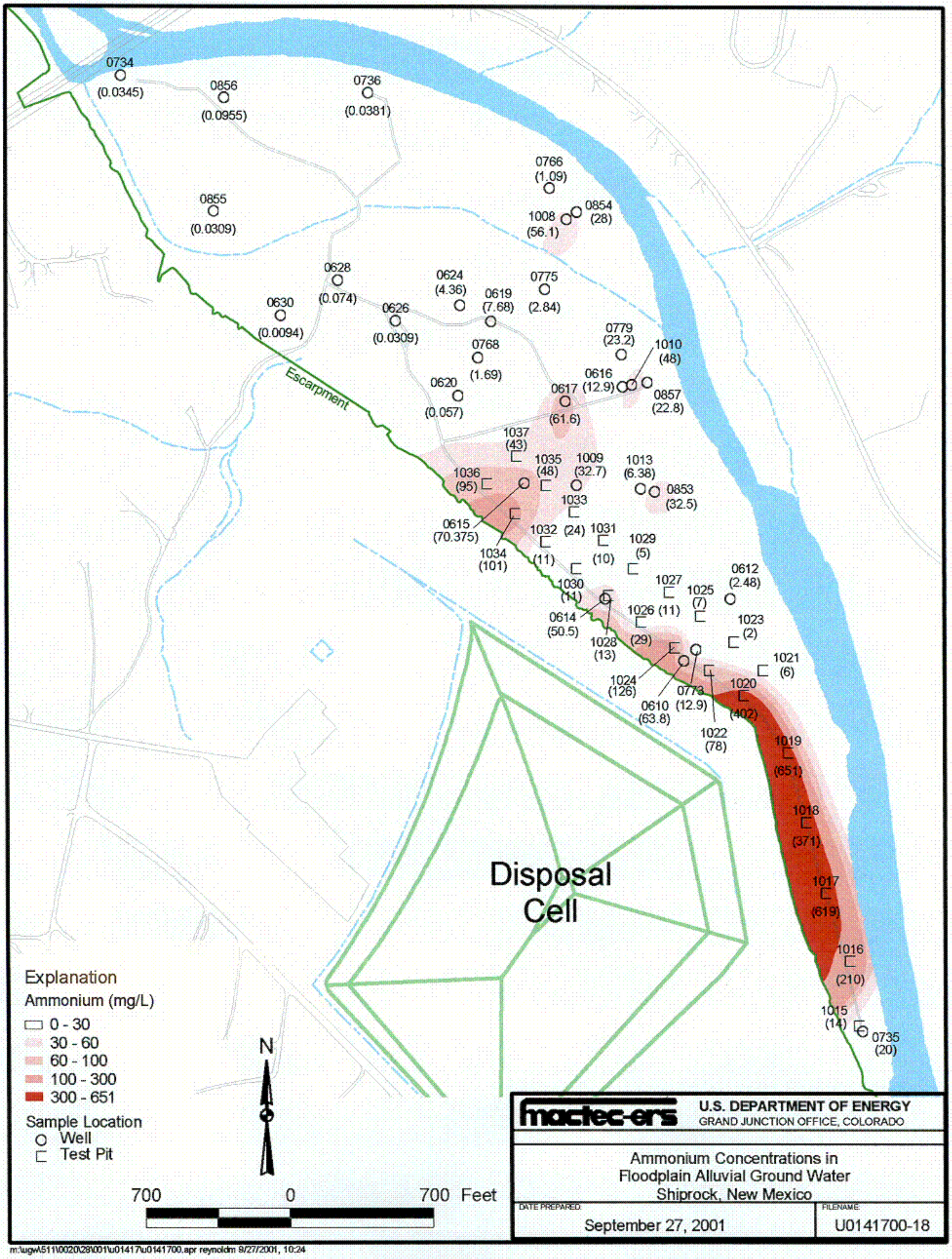

Figure 2–12. Ammonium Concentrations in Floodplain Ground Water (March 1999 through April 2000 data)

C11

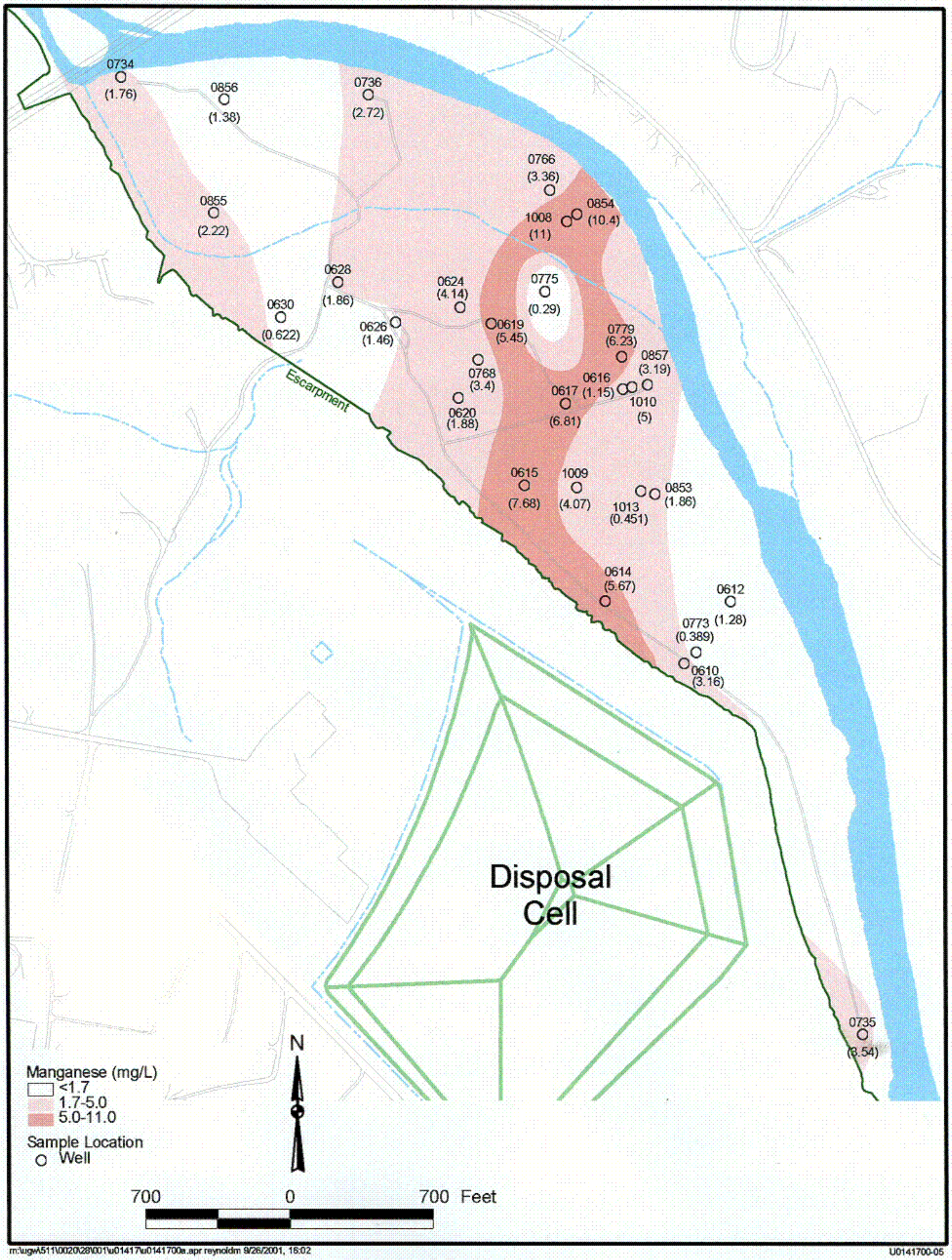

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Figure 2–13. Manganese Concentrations in Floodplain Ground Water (March 1999 through April 2000 data)

C12

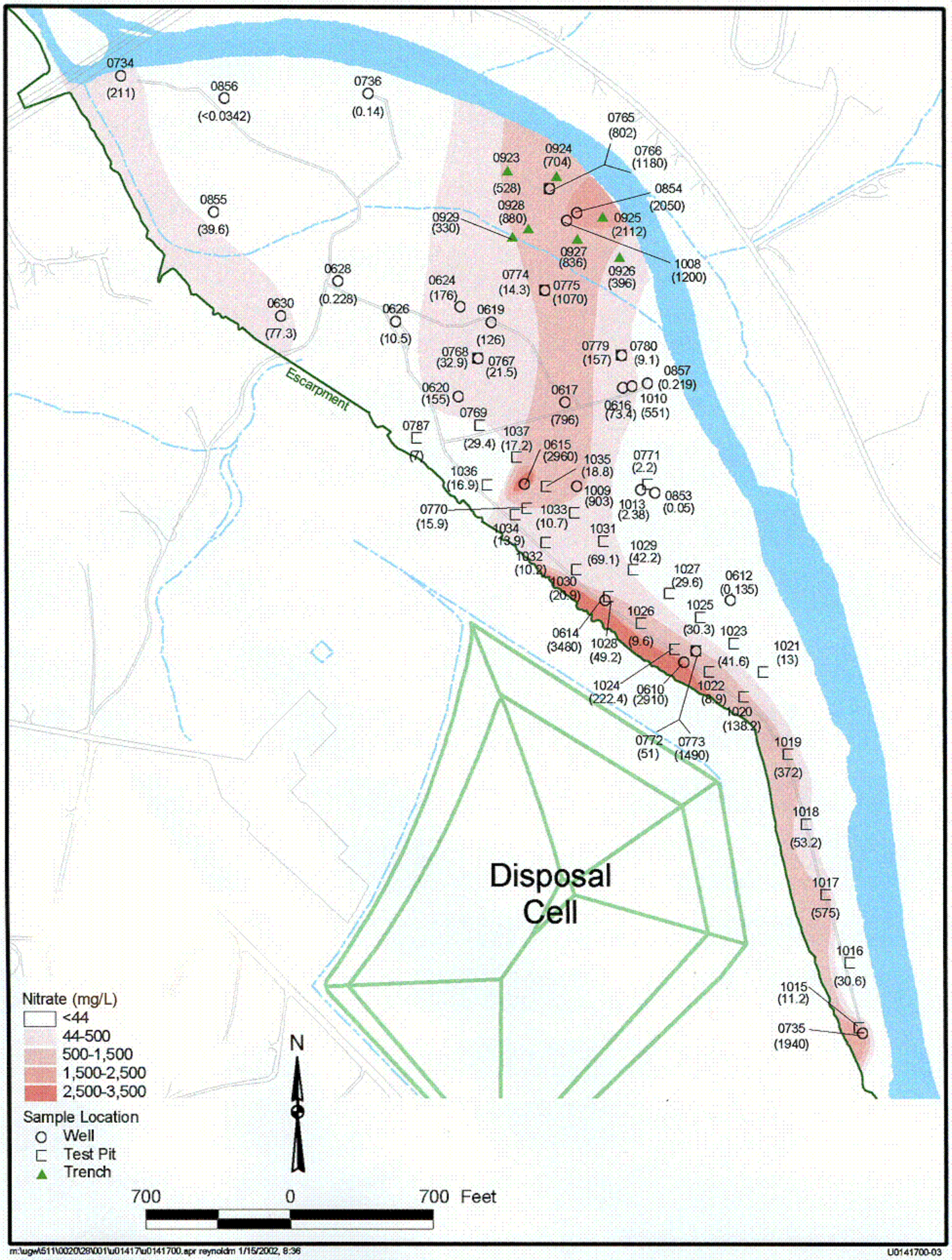

Figure 2–14. Nitrate Concentrations in Floodplain Ground Water (March 1999 through April 2000 data)

C13

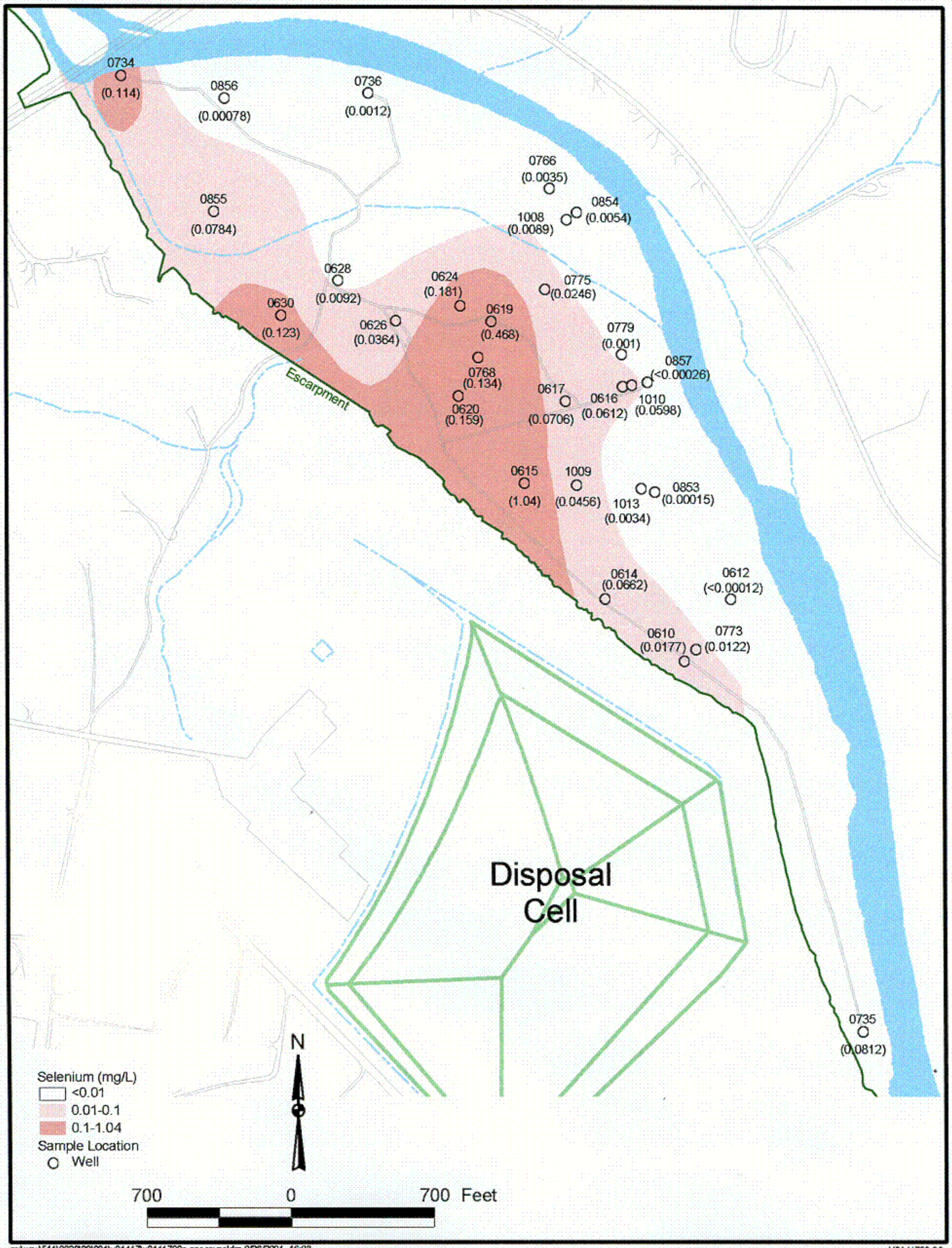

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Figure 2–15. Selenium Concentrations in Floodplain Ground Water (March 1999 through April 2000 data)

C14

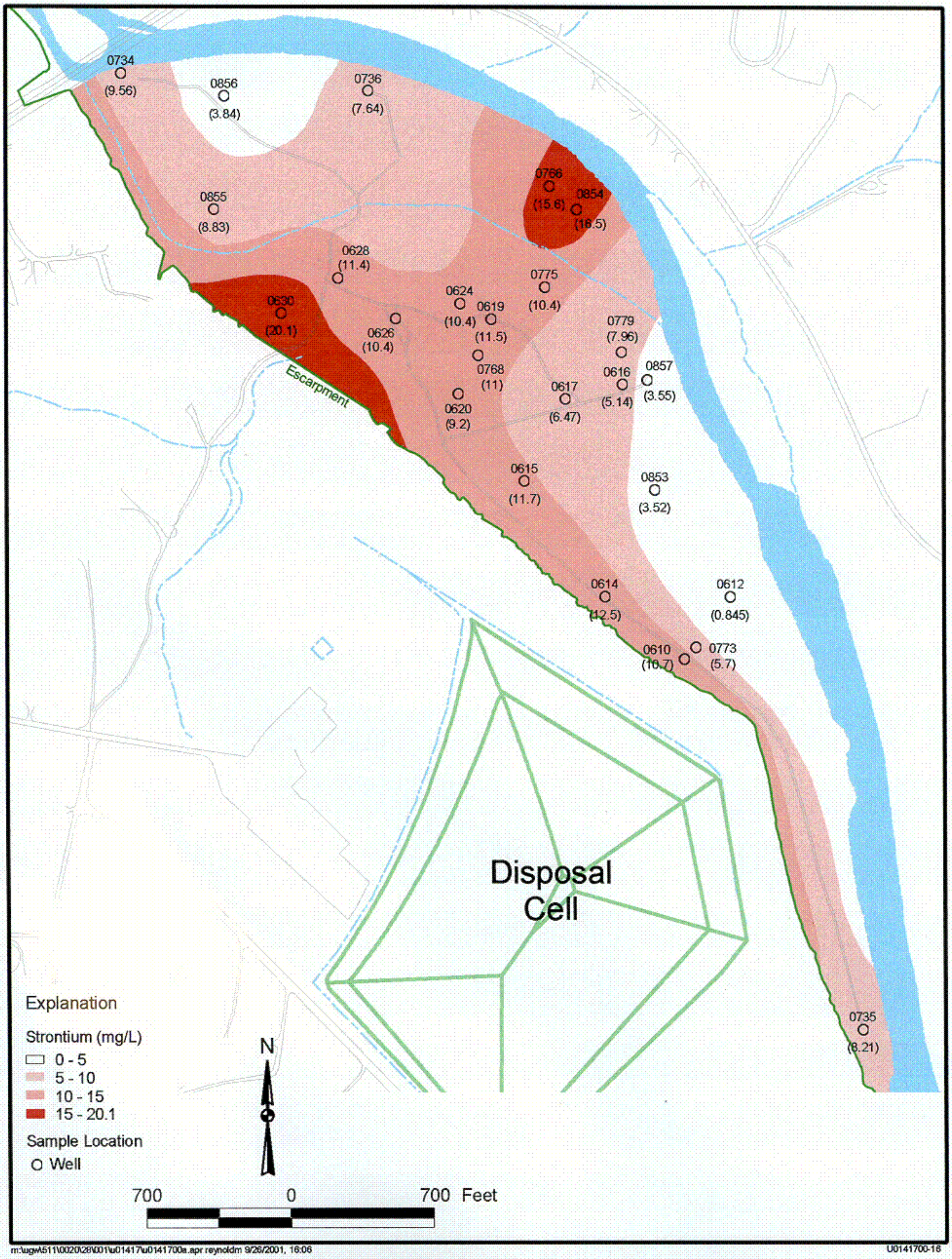

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Figure 2–16. Strontium Concentrations in Floodplain Ground Water (March 1999 through April 2000 data)

C15

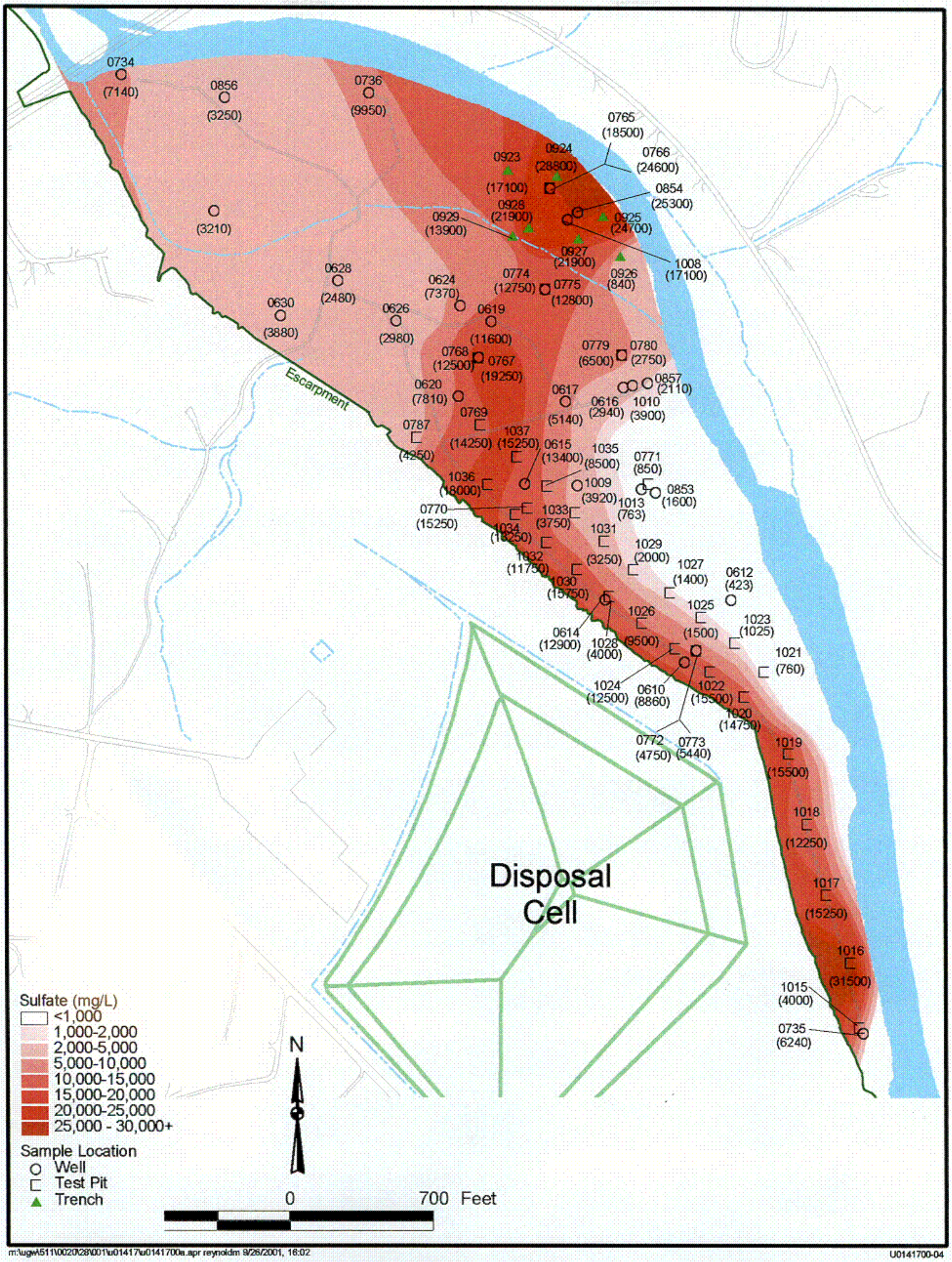

Figure 2–17. Sulfate Concentrations in Floodplain Ground Water (March 1999 through April 2000 data)

C16

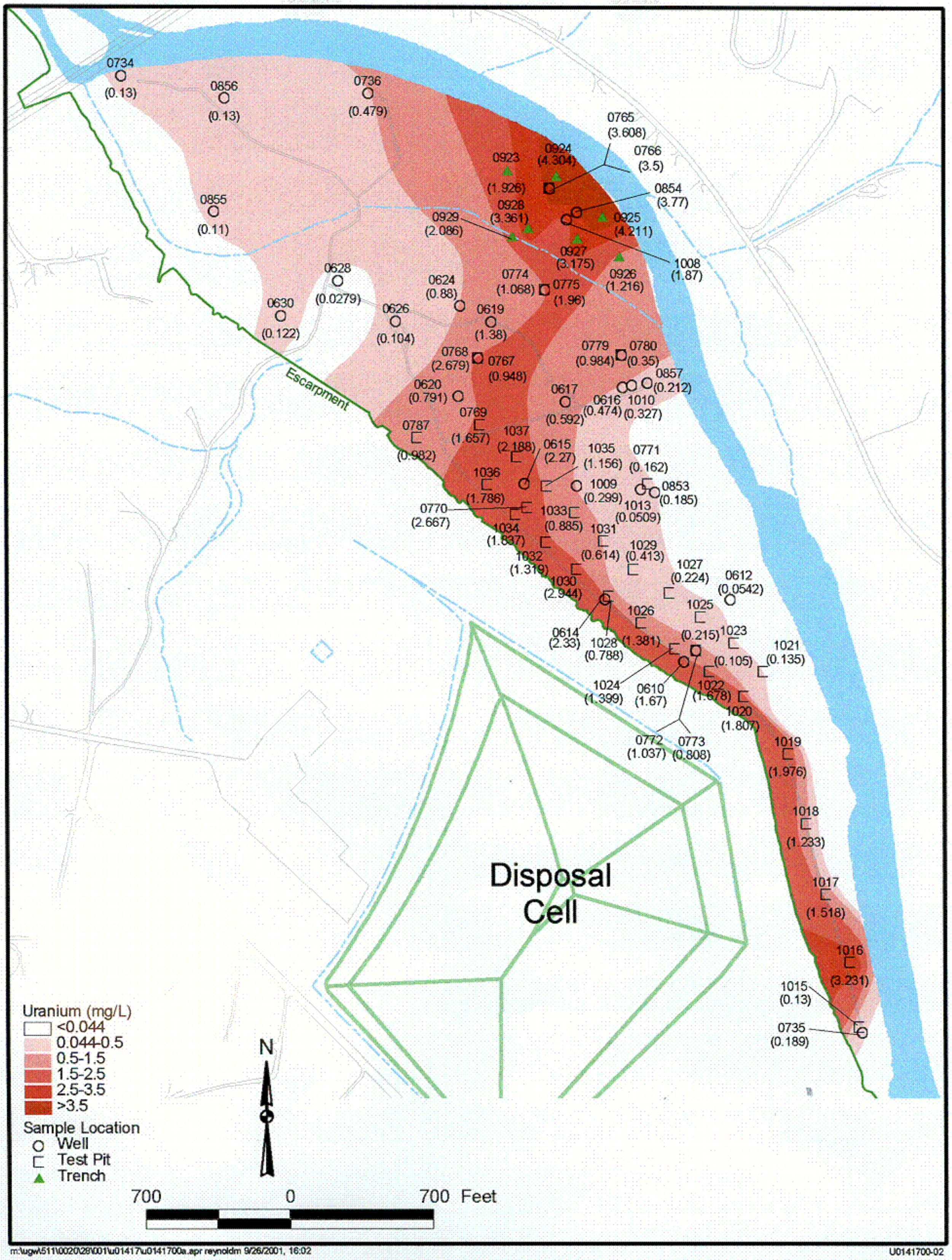

Figure 2–18. Uranium Concentrations in Floodplain Ground Water (March 1999 through April 2000 data)

C17

3.0 Ground Water Compliance Strategy

This section describes the proposed ground water compliance strategy for remediation of contaminants at the Shiprock UMTRA site that are attributable to milling activities. Ground water compliance decisions at the Shiprock site were made by using the compliance selection framework described in Section 3.1 and shown in Figure 3–1. This compliance selection framework is documented in Section 2.0 of the PEIS (DOE 1996) and is supported by the PEIS Record of Decision (62 FR 81). The Environmental Assessment of Ground Water Compliance at the Shiprock Uranium Mill Tailings Site (EA) (DOE 2001) details the selected compliance strategy and environmental impacts. Appendix B lists those aspects of the compliance and remediation strategy for which commitments to various agencies and stakeholders were listed in the EA.

3.1 UMTRA Ground Water Compliance Selection Process

The framework defined in the PEIS governs selection of the strategy to achieve compliance with EPA ground water standards, which are listed in Table 3–1 for the COCs at the Shiprock site. The framework takes into consideration human health and environmental risk, stakeholder input, and cost. The PEIS outlines a step-by-step approach that results in the selection of one of these three general compliance strategies listed below.

Table 3–1. Ground Water COCs for the Shiprock Site and EPA MCLs

Contaminant	MCL (40 CFR 192)
Ammonium	NA
Manganese	NA
Nitrate (as N)	10 mg/L (equivalent to 44 mg/L as NO_3)
Selenium	0.01 mg/L
Strontium	NA
Sulfate	NA
Uranium (234 + 238)	30 pCi/L (equivalent to 0.044 mg/L assuming secular equilibrium)

Notes: NA means that the contaminant does not have a MCL in 40 CFR 192.
pCi/L – picocuries per liter

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

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

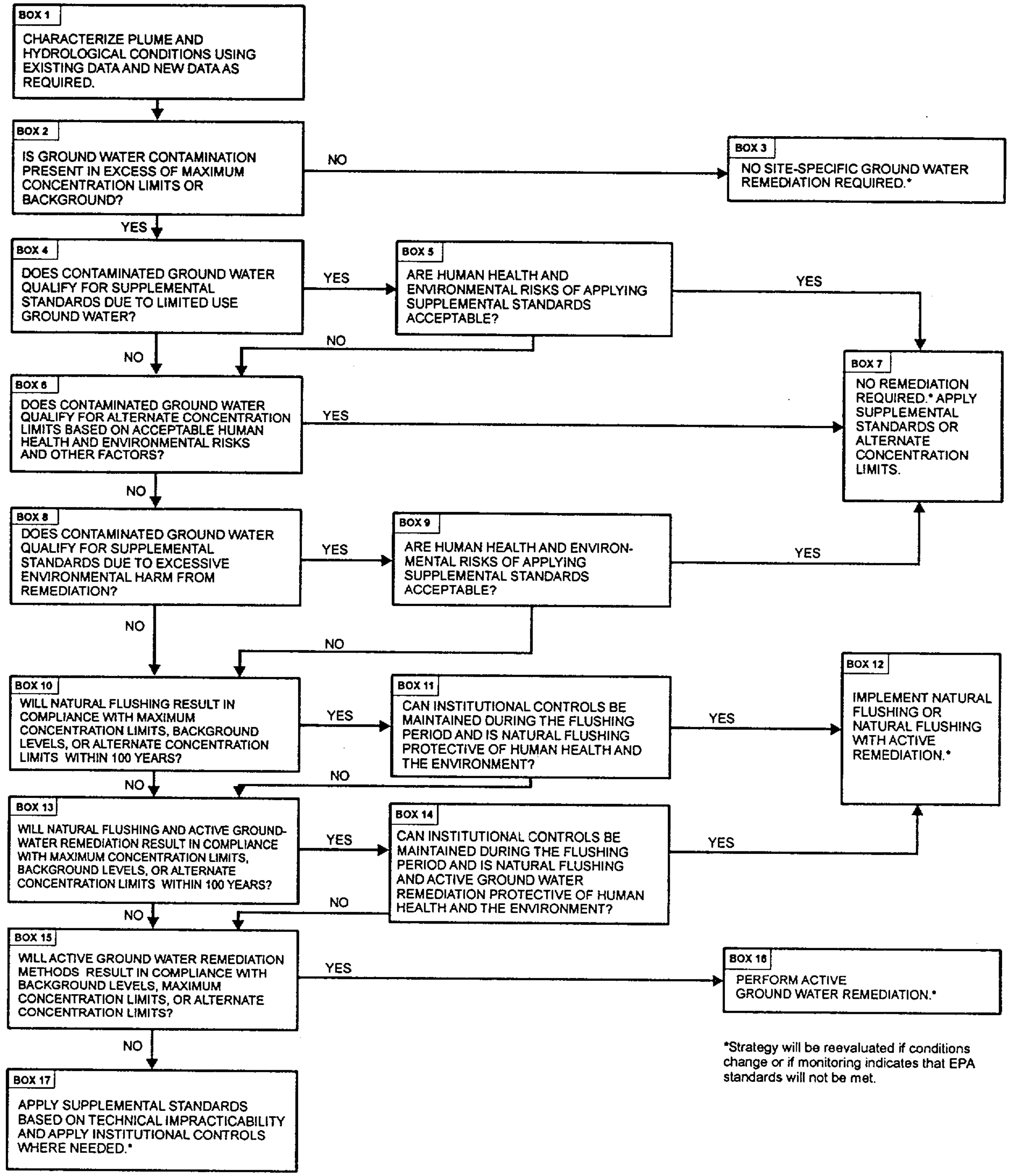

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Figure 3–1. Compliance Selection Framework

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

The general compliance strategy for Shiprock incorporates each of these strategies in the various areas of the Shiprock site. The process of developing the compliance strategy for Shiprock was described in the SOWP. This discussion will cover the results of the evaluation process described in the SOWP, including the revisions that have been made to the compliance strategy since the SOWP was issued in fall 2000.

3.2 Shiprock Ground Water Compliance Strategies

Because the Shiprock site is divided physiographically and hydrologically into two regions, the compliance strategies for each region, the terrace ground water system and the floodplain aquifer, are considered separately. In addition, the terrace system is subdivided into two areas, terrace east and terrace west. Interim actions, described in Section 3.3, necessary to protect humans and ecological receptors from contaminated terrace ground water that surfaces at several seeps and washes, were completed in 2000. The compliance strategies proposed for the two areas in the terrace are described in Section 3.4 and the compliance strategy for the floodplain is described in Section 3.5.

3.3 Interim Actions

Contaminated ground water from the terrace system discharges to the surface in upper Bob Lee Wash, lower Many Devils Wash, and seeps 425 and 426. To minimize potential risks to human health and ecological receptors from this exposure pathway, DOE completed several interim actions. The interim actions included covering pools of water in the washes with geotextile and large rock, fencing around the washes to prevent livestock access, and fencing and netting around the seeps to prevent bird access. Repairs and modifications will be made as necessary to these interim actions as determined by inspections conducted at least annually.

3.4 Terrace Compliance Strategies

3.4.1 Terrace East Compliance Strategy

The proposed compliance strategy for terrace east is active remediation until potential risks to humans and the environment have been eliminated. Specifically, milling-related water from the anthropogenic ground water system will be pumped from extraction wells and collected in french drains along the washes. Collectively, the removal of water by the wells and french drains will dry the seeps and curtail surface expression of ground water in Many Devils and Bob Lee Washes. The extracted water would be piped to a pond on the terrace and evaporated. The objective of this action is to eliminate the current exposure pathways at the washes and seeps. It will also reduce or eliminate the flow of ground water from the terrace to the floodplain. As noted in Section 7.2.2.1 of the SOWP, cleanup standards such as MCLs are irrelevant to a remediation strategy that adopts this objective. The terrace east ground water is not an aquifer and represents relict water emplaced by milling and other anthropogenic processes. Modeling indicates that a pumping duration of approximately 7 years will be required to reduce ground water levels sufficiently to hydrologically isolate contaminated ground water from seeps in the washes and dry up flow paths onto the floodplain.

3.4.2 Terrace West Compliance Strategy

After pumping in the terrace east system for a period of approximately 7 years, the terrace east ground water system will be cut off from the terrace west system. As determined by modeling, the boundary between the two systems after this period is shown in Figure 2–2.

The proposed compliance strategy for the terrace west ground water system is application of supplemental standards with monitoring. Supplemental standards is justified because the terrace west system qualifies as limited use ground water (that is not a current or potential source of drinking water), based on the existence of widespread ambient contamination not related to milling activities that cannot be cleaned up using treatment methods normally used in public water systems.

Contamination in the ground water west of U.S. Highway 666 results partly from millsite processing activities and partly from leaching of uranium, sulfate, and selenium from underlying Mancos Shale bedrock by irrigation water. Nitrate and ammonium, other COCs that occur west of U.S. Highway 666, may also be derived from sources other than milling activities, such as fertilizers and septic systems. These conclusions have been verified by uranium isotope analysis, which established that the terrace west part of the ground water system is influenced by Mancos Shale. The uranium isotopic ratios from ground water west of U.S. Highway 666 and other geochemical studies of ground water associated with Mancos Shale support the hypothesis that this marine shale of Late Cretaceous age is being leached and that COCs in this region may never be reduced to MCL levels. This further supports the application of supplemental standards.

Irrigation water will continue to provide a source of ground water recharge to terrace west after it is separated from the terrace east system after approximately 7 years of active remediation, which will lower the ground water surface. After this time, some flushing of contaminants from the terrace west system may occur. However, as discussed in Section 4.4.8 of the SOWP, it is highly probable that some constituents in the system—notably uranium, selenium, and sulfate—are derived from leaching of Mancos Shale, and standards may never be achieved for this region. A cost analysis study for ground water in the Grand Junction, Colorado, area showed that treatment of that water, which is a similar geological and geographical setting, is economically infeasible compared with the use of alternative water sources (DOE 1999). Because other drinking water sources are readily available in the Shiprock area, it is unlikely that treatment of terrace west water for drinking water purposes would be economical. However, in areas of terrace west where water yield is sufficient, water quality is suitable for agriculture and livestock watering. Therefore, the application of supplemental standards to terrace west ground water is protective of human health and the environment.

DOE plans for monitoring (Appendix A) this area include sampling to determine if concentrations of COCs are increasing. It is anticipated that some decrease in concentrations of nitrate will occur over time as irrigation continues to flush residual milling-related contamination. Neither the milling-related nor natural contamination leaching from the Mancos Shale poses an excessive risk to humans or wildlife at this time.

3.5 Floodplain Compliance Strategy

The compliance strategy for the floodplain surficial aquifer proposed in Section 7.2.1 of the SOWP was active remediation in combination with natural flushing. This strategy was to be implemented by a combination of extraction wells located in the most contaminated part of the plume, and monitoring of the floodplain and terrace to determine the extent and nature of drainage from the disposal cell.

Subsequent to the publication of the SOWP, additional data from field investigations suggested that, although the compliance strategy was sound, the plan that was proposed in the SOWP might be excessively aggressive. Specifically, the results of a piezocone investigation conducted on the disposal cell indicated that the tailings are mostly unsaturated (DOE 2002). Saturated slimes were found in the northeast part of the disposal cell covering less than 10% of the disposal cell area. These slimes could still be the source for a small quantity of flux from the cell. Results from the piezocone investigation indicate that the rate of infiltration from the disposal cell to the floodplain is likely significantly lower than the assumed rate in the SOWP. Consequently, the high extraction rates in the floodplain proposed in the SOWP will probably not be necessary.

Note: The remedial system for the floodplain will be re-evaluated through additional modeling over the next 3 months. The following paragraphs describe the floodplain Phase I remedial system as presently planned.

The remediation strategy for the floodplain will include a period of up to 20 years of active remediation followed by natural flushing to achieve MCLs, ACLs, or background concentrations. If the continuing source of infiltration onto the floodplain is low as the piezocone investigation suggests, this extraction may end after a short period. However, additional modeling must be performed to determine whether this is a valid assumption. If extraction during this initial period does not result in the desired reduction in concentrations of COCs, a slurry wall impermeable barrier or additional extraction wells may be required to cut off the contamination from the rest of the floodplain area. Additional investigations would be performed to determine the source of terrace contamination that migrates into the floodplain. Potentially, a remedial system could be designed to intercept contamination on the terrace prior to its seeping into the floodplain.

The active remediation currently planned for Phase I will consist of the installation of two extraction wells in the most highly contaminated area of the floodplain. A sample of San Juan River water collected in February 2000 that contained a high concentration of uranium (Table 2–1) indicated that the ground water contaminant plume in the adjacent floodplain could pose a potential risk to aquatic life. Hydrologic modeling has indicated that this risk can be alleviated by placement of a single extraction well in the floodplain, located at the point of convergence of the contaminant flow lines. The minimum extraction rate for this well will be 7 gpm initially until the evaporation pond is adequately filled. The well can be pumped at higher rates if necessary. A second well, only about 150 ft away from the first well, was added to ensure that the evaporation pond fills quickly at the beginning of remediation. During the initial early remediation period when the pond is filling, the extraction rate for each well will average between 7 and 10 gpm. After the pond is sufficiently filled, these wells will discharge to the evaporation pond at a combined extraction rate of between 7 and 10 gpm for the duration of the initial period of active remediation, currently estimated to be 7 years. At the end of this period, the progress of the remediation will be reviewed to determine what additional actions may be

necessary to reach treatment standards in the floodplain. If additional extraction wells are required, their installation and operation would constitute Phase II of remediation.

Once active pumping has ended, the remediation strategy for the floodplain will then be natural flushing to remove remaining contamination. DOE will monitor water levels and ground water chemistry for the duration of the remediation according to the monitoring plan described in Appendix A.

The COCs for human health on the millsite floodplain are manganese, nitrate, selenium, sulfate, and uranium. Plume maps for these contaminants are in Section 2.0. Compliance standards and cleanup goals for the human health COCs are in Table 3–2. For uranium and nitrate, compliance standards are their respective UMTRA standards of 0.044 and 44 mg/L. For manganese, the cleanup objective is the maximum background concentration, which is currently 2.74 mg/L. This value may change if higher background concentrations are found in future sampling.

Table 3–2. Compliance Standards and Cleanup Goals for Floodplain Human Health COCs

Contaminant	Compliance Standard or Cleanup Goal
Uranium	0.044 mg/L (UMTRA standard)
Nitrate	44 mg/L (UMTRA standard)
Manganese	2.74 mg/L (maximum background concentration)
Sulfate	Approximately 2,000 mg/L (maximum background concentration or concentration in ground water from artesian well 648)
Selenium	0.05 mg/L (proposed ACL using Safe Drinking Water Act standard)

The EPA is currently reviewing toxicity data for sulfate, so the final Shiprock cleanup goal for sulfate is uncertain. The background sulfate concentrations currently range up to 1,920 mg/L; therefore, floodplain sulfate concentrations may never drop below this value. In addition, sulfate is constantly being added to the floodplain aquifer from the outflow of ground water from artesian well 648 and from leaching of sulfate from weathered Mancos Shale bedrock. Sulfate concentration in water from well 648 ranges up to 2,340 mg/L, so concentrations around the mouth of Bob Lee Wash are not expected to decrease below this value (or approximately 2,000 mg/L) in the floodplain aquifer as long as the well is flowing.

The relatively high concentrations of selenium in the millsite floodplain aquifer make it unlikely that the UMTRA standard of 0.01 mg/L can be met within the statutory limit of 100 years. Therefore, as noted in the SOWP, DOE proposes that an ACL value of 0.05 mg/L from the Safe Drinking Water Act be adopted as the cleanup standard for Shiprock.

3.5.1 Institutional Controls

Institutional controls on the floodplain to minimize the potential for risk to human health and the environment include:

1. Grazing restrictions for a 7-year period during the initial remediation in which affected grazing allottees will be compensated.

2. DOE and Navajo Nation control of access to the floodplain area.

3. A DOE-Navajo Nation agreement to prohibit drilling of new wells or other use of ground water in the floodplain until remediation is completed.

4. Assurance from the Navajo Water Code Administration that artesian well 648 will be allowed to continue flowing into Bob Lee Wash and onto the floodplain. Flow from the well for the past 40 years has flushed contaminants from much of the floodplain and the success of the proposed remediation depends on its continued flow.

The DOE is required to obtain approval from the New Mexico State Engineer's Office if it is determined that water rights in the San Juan River could be affected by ground water removed during operation of one or more extraction wells. The office has determined that a permit will be necessary for water consumed in the remediation process.

End of current text

4.0 Selected Remedial Action

This section describes the remediation components, treatment technologies, and implementation plan that will be used to meet the compliance strategies for the Shiprock site.

4.1 Overview

The remediation method for the terrace east area at the Shiprock site is containment of risk by diversion of contaminated water away from the existing seeps into a french drain collection system, thereby eliminating the risk associated with exposure to, or ingestion of, the contaminated water. Remediation of the terrace east also will include extraction of water from wells in the sump area south of the disposal cell to further reduce ground water flowing toward the washes and seeps. The extracted ground water from the terrace will be treated in a solar evaporation pond in the south part of the radon cover borrow pit. The remediation method for the floodplain will be an initial period of up to 20 years of active extraction of contaminated ground water, followed by natural flushing to reduce concentrations of contaminants in the floodplain to below compliance standards and cleanup goals. This GCAP discusses only the initial, or Phase I, scope of remediation involving two extraction wells on the floodplain. The extraction rate on the floodplain may be increased after the completion of the 7 year Phase I active remediation period on the terrace.

4.2 Development of Remediation Approach

The Shiprock SOWP documented the evaluation process that was used to develop remediation and treatment alternatives for the Shiprock site. The alternatives evaluation involved a qualitative review of all available treatment technologies to determine those that would be suitable for the site. This alternatives evaluation was used as a basis for discussions between DOE and the stakeholders. As a result of these discussions, a remediation and treatment system was developed that included the following components:

- Installation of french collection drains along Bob Lee Wash and Many Devils Wash
- Installation of five extraction wells in the terrace east area
- Installation of two extraction wells in the floodplain
- Construction of an 11-acre solar evaporation pond to evaporate the water captured by the french collection drains and the extraction wells
- Monitoring of ground and surface water and contaminant concentrations on the floodplain and terrace areas

Figure 4–1 shows the location of all these components of the remediation system.

4.3 Remediation System Components

4.3.1 Drain System—Terrace East

Seepage along Bob Lee Wash and Many Devils Wash will be collected in subsurface french drains. The drains will be offset from the centerline of each wash to minimize infiltration of surface water. These drains incorporate a perforated pipe surrounded by drain rock and are lined

with impermeable geomembrane and geotextile filter fabric. Drain locations are shown in Figure 4–1, and Figure 4–2 shows a cross section of the drain construction.

The single drain in Bob Lee Wash will discharge to a pipeline that will flow northward along the wash to a collection sump. Water from this collection sump will be pumped northward across a short section of terrace to intersect the pipeline carrying water from the floodplain wells. This combined water will then be piped southeastward on the terrace along the north and east sides of the disposal cell to intersect the short pipeline carrying water from the extraction well (1074) in the filled drainage. All this collected water will then be routed to the southwest to the evaporation pond. The drains in Many Devils Wash will be discharged to a sump, and this water will be pumped through a pipeline northwest to the evaporation pond.

4.3.2 Extraction System – Terrace East

The extraction system for the terrace east area consists of five vertical extraction wells, which are shown in Figure 4–1. Four of the wells (1070 through 1073) are in the sump area west and northwest of the radon cover borrow pit, and the fifth well (1074) is just east of the disposal cell in a drainage that flowed from the terrace to the floodplain and was later filled.

The design of these wells will be similar to that of terrace well 818, which was used for pumping tests. The design of well 818 is shown in Appendix A of the SOWP. Well 818 was drilled by the casing advance method using an air rotary hammer, and the terrace east extraction wells will likely be drilled with a similar method. The depth of the terrace wells in the sump area will be approximately 40 to 60 ft from ground surface. The saturated thickness in the area of these wells is approximately 10 ft. The depth of the extraction well in the filled drainage will be between 40 and 50 ft; saturated thickness in the area of that well is less than 5 ft. The five extraction wells are expected to have a combined capacity of 10 to 12 gpm. The water from the four extraction wells in the sump area will be collected in a pipeline and sent eastward to the evaporation pond. The water from the extraction well just east of the disposal cell will join the pipeline that collects water extracted from the drain system in Bob Lee Wash and the floodplain wells.

4.3.3 Extraction System—Floodplain

Note: The complete remedial system will be developed during a 3-month evaluation period.

The initial extraction system for Phase I remediation on the floodplain consists of two vertical extraction wells. The design of these wells will be similar to that of floodplain well 858. The design of well 858 is shown in Appendix A of the SOWP. Well 858 was drilled by the casing advance method using an air rotary hammer, and drilling of the floodplain wells will probably utilize the same method. The depth of the wells will be approximately 20 ft. The saturated thickness on the floodplain is approximately 13 to 15 ft.

Floodplain extraction wells are shown in Figure 4–1. Ground water pumped from the extraction wells will be piped to the evaporation pond. The floodplain extraction wells will operate at the rate required to maintain a minimum liquid level in the evaporation pond. This combined extraction rate after initial pond filling is expected to be from 7 to 10 gpm for the Phase I remediation period. This extraction rate may increase during later remediation to compensate for less ground water being present on the terrace.

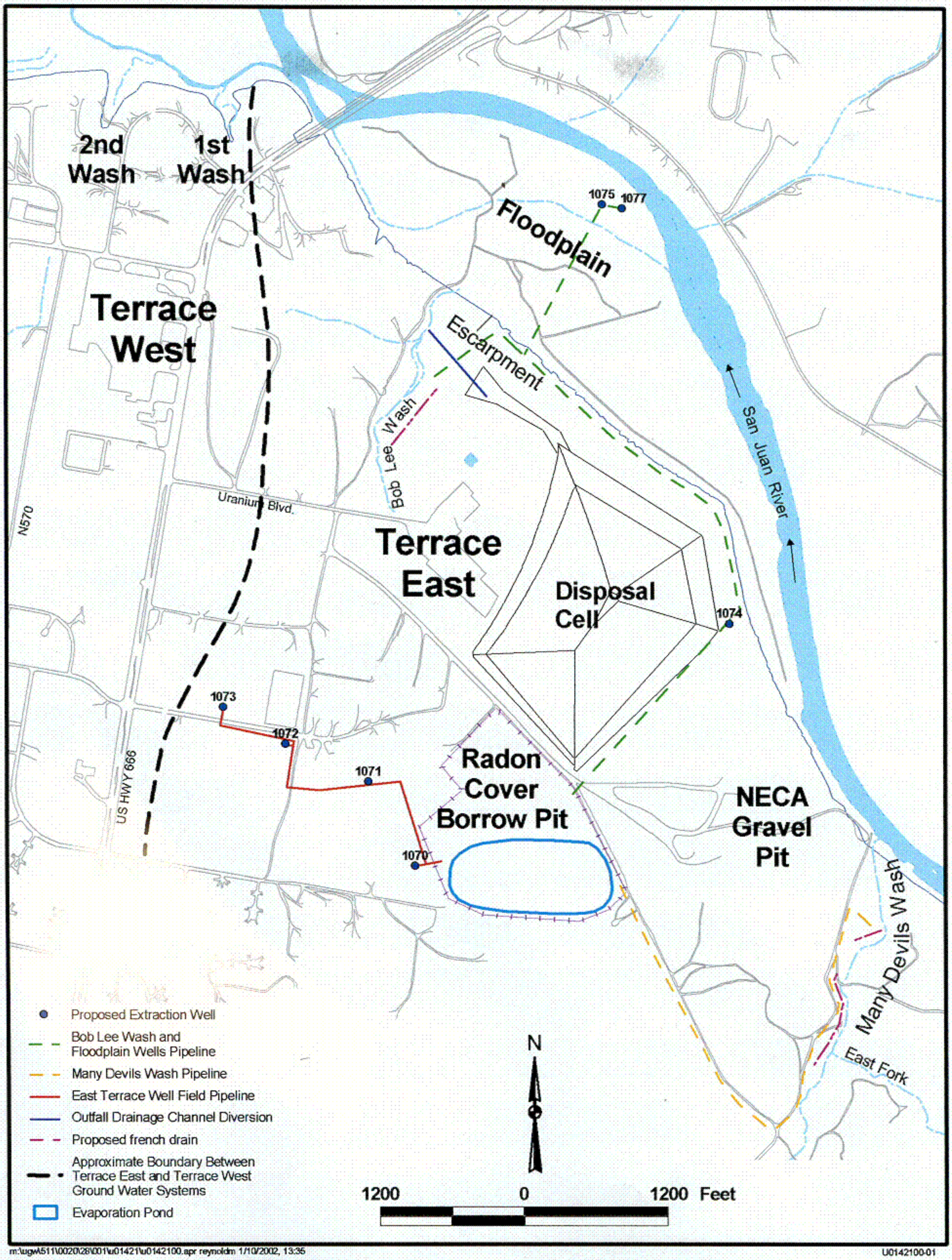

Figure 4–1. Remediation System Components at the Shiprock Site

C18

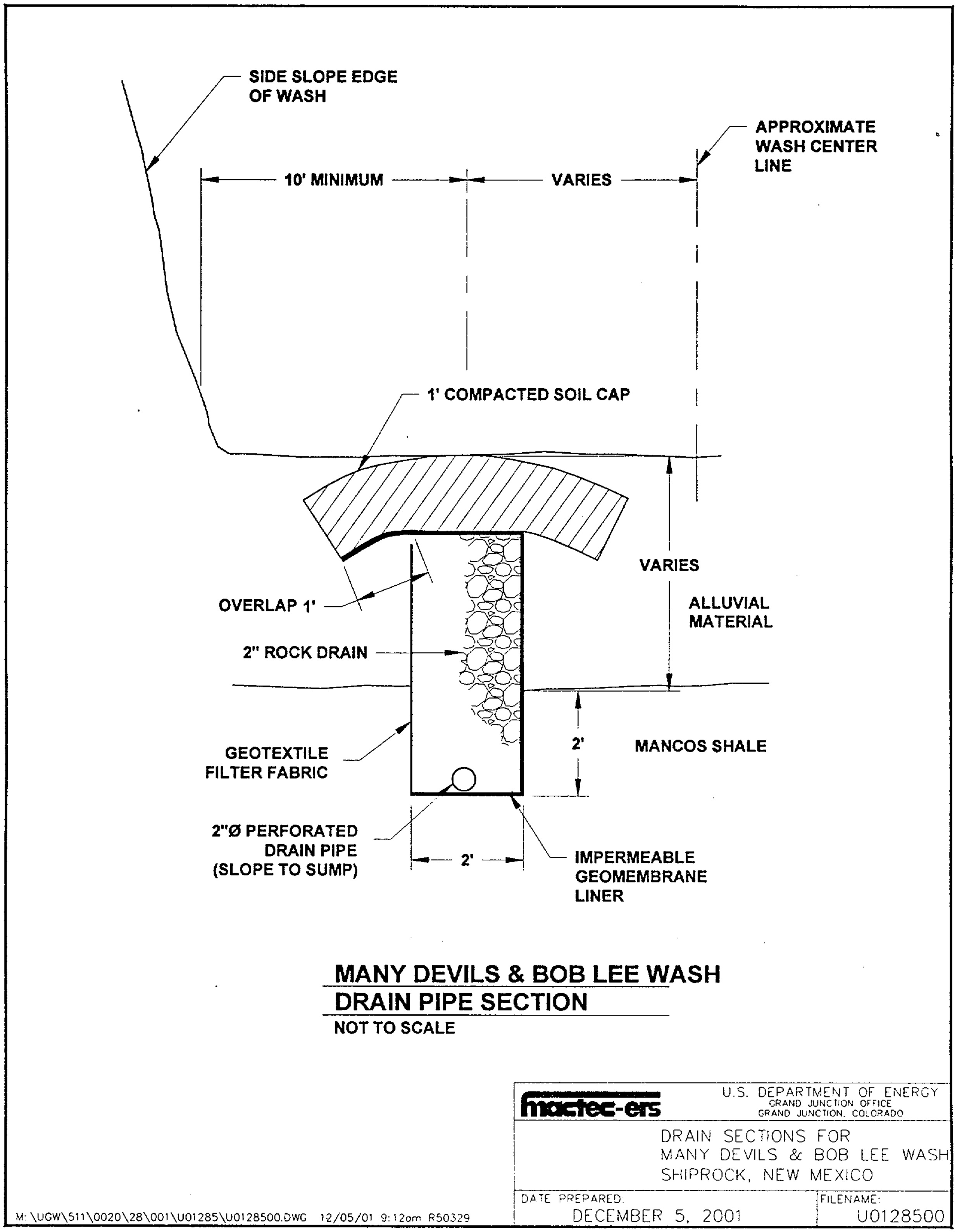

Figure 4–2. Cross Section of the French Drain Construction in Bob Lee and Many Devils Washes

4.3.4 Evaporation Pond

The selected method for treating the extracted ground water from the french drains and extraction wells is solar evaporation. The contaminated water will be pumped to an evaporation pond that will be constructed in the south part of the radon cover borrow pit area. Preliminary plans call for use of a single-lined pond with a prepared soil sub-base. In-situ soils are fine-grained loess that can be conditioned to provide a practically impermeable sub-base, obviating the need for a second liner layer. The liner material will be selected during the detailed design. Consideration will be given to constructability and longevity. Provision will be made for testing of the liner at the end of construction. Any leaks discovered will be repaired prior to placing the pond in service. A leak detection system will be included in the pond design.

The amount of water that can be evaporated in the pond was calculated by determining the annual evaporation rate at the site, and modifying this value by introduction of correction factors that adjust laboratory measurements based on real-world considerations. Annual evaporation rates are usually reported as *pan evaporation*, collected by allowing water to evaporate from a shallow pan over an extended period of time. Because the pan allows heat conduction along the sides and the bottom, pan evaporation rates overstate actual evaporation that can be achieved in a lake or pond in which the sides and base do not conduct heat. Also, pan evaporation studies use water of negligible salinity. The presence of dissolved salts significantly inhibits the evaporation rate. Reported pan evaporation rates must be corrected for pan effects, salinity, and natural precipitation.

Annual pan evaporation at the Shiprock site is approximately 65 inches per year, and the pan evaporation factor, which corrects pan evaporation rates to pond and shallow lake evaporation is 0.72 (NOAA 1982). Thus, the corrected annual evaporation at the Shiprock site is 46.8 inches. The annual precipitation in Shiprock is approximately 7 inches.

Evaporation rates are adjusted for the inhibiting effect of salinity using a correction factor called the *activity*. Pure water has an activity of 1.00, and activity decreases as salinity increases. An independent consultant working on the Tuba City, Arizona, UMTRA ground water remediation project determined that the activity of the brine in the evaporation pond at the site will vary from a maximum of 1.00 during periods of low evaporation, when the pond contents are being diluted by inflow, to a minimum of about 0.63 during periods of high evaporation when the dissolved salts content is highest. The formulas to calculate brine activity from salt content that were derived for the Tuba City site were also applied to Shiprock, which has a similar ground water contaminant profile.

The surface area of the pond will be approximately 11 acres, measured at the top. Assuming an average reliability of 95% for the extraction system, a pond with an area of 11 acres and a depth of approximately 10 ft can treat a total influent rate of up to 25 gpm for up to 7 years, or up to 20 gpm for 40 years. The design depth of 10 ft will provide a freeboard of 2 ft and a final solids depth of 2 ft. The extraction wells on the floodplain can be operated at a variable rate sufficient to maintain a minimum liquid depth of at least 6 inches for dust control.

During detailed design, an evaluation will be made of the best way to compact the sub-base material so as to achieve the lowest hydraulic conductivity for a brine leachate. This will involve

stringent quality assurance/quality control of moisture conditioning and compaction specifications.

4.3.5 Monitoring

Monitoring of ground and surface water in the terrace and floodplain areas during remediation planned for the scope of Phase I is presented as the monitoring plan in Appendix A. This plan would be modified depending on the results of additional modeling over the next 3 months and the decision of whether to install a slurry wall impermeable barrier on the floodplain. These additional remedial measures would constitute Phase II of the remediation.

4.4 Implementation Plan

DOE's main criterion in implementing the Shiprock remediation is to reach the remediation goals for each area of the site. The implementation will use the observational approach, employing capture-zone analysis, optimization modeling studies, and monitoring, to track the progress of the remediation and make adjustments to the placement and number of extraction wells and evaporation capacity as needed.

Work on the detailed design of the Shiprock remediation is in progress. A number of issues remain to be worked out before the design requirements can be finalized. The detailed design of the remediation system will be completed in fiscal year 2002, and the construction will be completed in fiscal year 2003. The system is planned to be operational by the end of calendar year 2003.

Extraction in the terrace east area is expected to continue for 7 years. During this time, the condition of the terrace will be continuously re-evaluated to determine if the goals of the extraction—drying the seeps and curtailing surface expression of the ground water at washes—have been achieved. Operation of any particular extraction well may be discontinued at any time if it is determined that continued extraction of contaminated water in its vicinity is no longer practical. However, the extraction will not be terminated at any location as long as sources of exposure remain in that area. Thus, extraction from a particular well may be terminated earlier than 7 years, or it may continue after that period if it is necessary. At the conclusion of extraction on the terrace, a confirmation report will be produced to demonstrate that the remediation of the terrace has alleviated the threats to human and animal health posed by leakage of millsite-related contaminants from seeps and washes.

Monitoring of contaminant concentrations on the floodplain will continue, in accordance with the plan presented in Appendix A, for the 7-year duration of pumping on the terrace. During this time, contaminant concentrations will be compared with the predictions of the hydrologic modeling. At the end of the 7-year terrace ground water extraction period, the progress of remediation on the floodplain will be reviewed. Adjustments to the rate of active remediation on the floodplain, possibly including the installation of additional extraction wells, will be made at that time if the results of the monitoring and modeling effort indicate that such adjustments are required. The requirements for this additional active extraction will be documented in a revised GCAP.

Once active extraction on the floodplain and terrace east has been terminated, responsibility for monitoring concentrations and water levels, to confirm that terrace seeps and ground water

surface expressions remain curtailed and that the progress of the natural flushing process is satisfactory, would be transferred to DOE's Long-Term Surveillance and Maintenance Program (LTSM). The LTSM Program will be responsible for producing the final confirmation report for the floodplain. The final confirmation report for the floodplain will not be issued until the final compliance standards and cleanup goals have been met by natural flushing.

4.5 Uncertainties and Contingencies

The chief uncertainties in the Shiprock remediation are whether the planned terrace extraction will decrease the amount of ground water it to the extent of stopping flow from the seeps and the washes; and whether there is a major continuing source of infiltration from the terrace onto the floodplain and, if so, what is the nature of that source. The monitoring plan is designed to assess the extent of both of these areas of uncertainty.

A number of contingency measures designed to achieve compliance with ground water standards are available for implementation in the event that concentrations of COCs do not drop rapidly enough to achieve compliance with compliance standards and cleanup goals by the end of the treatment duration. These measures include:

- Increasing the flow of contaminated ground water from the terrace east area by installing additional extraction wells
- Increasing the flow of contaminated ground water from the floodplain by installing additional extraction wells or operating the existing wells at higher rates
- Installing an infiltration trench along the base of the escarpment that would use water diverted from the San Juan River to accelerate flushing of the floodplain
- Installing a slurry wall impermeable barrier on the floodplain to contain infiltration of contaminated water from the terrace
- Pumping ground water from the area of the disposal cell if significant quantities of such water are found
- Increasing the capacity of the evaporation pond through enhanced evaporation methods

Should any of these measures be required, they would be documented in a revised GCAP.

As documented in the SOWP, initial hydrologic modeling suggested that effective remediation of the Shiprock site could require a combined extraction rate, from the terrace and floodplain systems, of 100 gpm or higher. The remediation plan described in this GCAP uses a much lower extraction rate. The observational approach will be utilized to determine whether the current planned extraction rates are adequate to remediate the site ground water. Should it become apparent that higher rates are required, the results of the observations will be used to calibrate the ground water flow and transport model to determine the actual required extraction rates.

Implementation of higher extraction rates in either ground water system would require increasing the site evaporation capability. This could be done by constructing additional solar evaporation ponds, by installation of a spray evaporation pond, or by converting the existing solar

evaporation pond to a spray system. Preliminary calculations suggest that the evaporation capacity of the solar evaporation pond could be increased by as much as ten times by adding a suitable spray enhancement system. The operation of such a spray system would require monitoring of air quality and radiation levels around the periphery of the pond to verify that radionuclides and other contaminants are not being carried outside the containment area.

The use of an infiltration trench along the base of the escarpment, to increase the hydraulic head on the floodplain and accelerate the rate of flushing, was considered for the pumping plans presented in the scenarios developed in the SOWP. Although the selected remediation process does not incorporate the infiltration trench, observation of the progress of remediation may indicate that such a method will be required to accelerate the pace of contaminant removal in order to meet the remediation objectives.

The observational approach will be used during the remediation planned in this draft GCAP to further evaluate the rate of leakage from the disposal cell. The model will be adjusted based on analyses of water drawn from the extraction and monitor wells. Ultimately, if concentrations of contaminants in ground water from floodplain wells along the base of the escarpment are not clearly decreasing after 7 years of extraction on the terrace east, construction of a slurry wall impermeable barrier along the base of the escarpment may be necessary.

The use of a slurry wall impermeable barrier was investigated during the GCAP preparation as a means to intercept infiltration of contaminants migrating from the terrace to the floodplain. The slurry wall would be an effective barrier to infiltration of contaminants onto the floodplain; however, results from the piezocone investigation (DOE 2002) suggest that the rate of infiltration may not be high enough to warrant installation of a slurry wall impermeable barrier. This system is expensive to install and requires continuous maintenance while it is in service. The decision on whether to install a slurry wall impermeable barrier will be made over the next 3 months based on results of additional modeling, which includes as an input the results of the piezocone investigation.

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Appendix A

Ground and Surface Water Monitoring Plan
Shiprock, New Mexico, Site

Contents

Figure

Tables

Attachment

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1.0 Introduction

Topographic and hydrologic features divide the Shiprock, New Mexico, Uranium Mill Tailings Remedial Action (UMTRA) ground water site into two regions known as the floodplain and the terrace. Contaminated surface water, an expression of ground water contamination, occurs at scattered locations around the site in both the floodplain and terrace regions. Because of different degrees of contamination and different sources of ground water recharge, the terrace is further divided into terrace east and terrace west. Active remediation using french drains and extraction wells to collect contaminated water was selected as the compliance strategy for the terrace east area. The compliance strategy selected for the terrace west area was supplemental standards with monitoring, based on limited use ground water and widespread ambient contamination derived from Mancos Shale not related to milling activities. Ground water modeling has predicted that after about 7 years of active remediation in the terrace east system, recharge from terrace east to terrace west should be hydraulically cut off, and the source of milling-related contamination will no longer affect the terrace west area. Contaminants of concern (COCs) in terrace ground and surface water are ammonium, manganese, nitrate, selenium, sulfate, uranium, and strontium. Monitoring of the terrace east ground and surface waters is necessary to evaluate the progress of the active remediation and the extent and nature of any continuing source from the disposal cell. Monitoring of the terrace west ground and surface waters would be conducted to ensure that milling-related constituents do not affect water quality and to confirm that elevated concentrations of certain constituents continue to be present as a result of leaching from Mancos Shale.

The compliance strategy for the floodplain is natural flushing with monitoring supplemented by some active remediation from two wells, which would extract ground water from the most contaminated part of the floodplain plume for at least 20 years. The floodplain ground and surface water COCs are the same as for the terrace. Compliance standards and cleanup goals for human health COCs in the floodplain are listed in Table A–1. Monitoring of ground and surface water is necessary for the first 7 years to evaluate success of the active remediation phase both on the floodplain (from the two wells) and on terrace east. Success would be seen in decreasing concentrations of milling-related constituents resulting from mass-removal from the plume and from reduction in the amount of water in the terrace east system (less water available to migrate down to the floodplain system). Monitoring on the floodplain after 7 years would evaluate the success of contaminant removal from the two extraction wells and the efficiency of natural flushing over the rest of the floodplain. This plan describes the monitoring and sampling approach for the terrace and floodplain.

Table A–1. Compliance Standards and Cleanup Goals for Floodplain Human Health Contaminants of Concern

Contaminant	Compliance Standard or Cleanup Goal
Uranium	0.044 mg/L (UMTRA standard)
Nitrate	44 mg/L (UMTRA standard)
Manganese	2.74 mg/L (maximum background concentration)
Sulfate	Approximately 2,000 mg/L (maximum background concentration or concentration in ground water from artesian well 648)
Selenium	0.05 mg/L (Proposed ACL using Safe Drinking Water Act standard)

2.0 Purpose and Scope

A brief site background is provided first in this plan. More detailed descriptions of the site are in the *Final Site Observational Work Plan for the Shiprock, New Mexico, UMTRA Project Site* (SOWP; DOE 2000a). The monitoring plan is then described and includes a discussion of the monitoring network, analytes, sampling methods and procedures, and quality assurance/quality control (QA/QC) measures. Data evaluation and an evaluation of the progress of natural flushing are also discussed. Lastly, environmental compliance issues are addressed.

3.0 Site Background

The Shiprock site lies south of the San Juan River and is centered around the disposal cell, which is about 1 mile (mi) south of the center of the town of Shiprock at the junction of U.S. Highways 64 and 666. The disposal cell contains the uranium-mill tailings that were stabilized in place from two former tailings piles and raffinate ponds associated with the former millsite buildings immediately adjacent to the west. This disposal cell and millsite are on a broad terrace about 50 to 60 feet (ft) above the San Juan River floodplain. An escarpment separates the terrace from the floodplain below.

Ground water is present at depths of about 5 ft in alluvium of the river floodplain aquifer. Ground water below the terrace surface, however, is artificial and anthropogenic. Historical photographs from the 1930s show that the terrace and the washes cutting through it were dry. Starting in the 1940s with the construction of the helium processing plant and continuing in the 1950s with the construction of the Navajo (uranium and vanadium) Mill and Helium Lateral Canal providing irrigation, the terrace ground water system was created. After milling and helium processing ended, irrigation continued, disposal cell construction occurred, and a large residential population occupied the terrace area, continuing to add water to the terrace system. No ground water has been found in a geologically similar terrace area unaffected by human developments that is 1 to 2 mi east of the Shiprock site. Therefore, a comparison of Shiprock terrace system ground water to background conditions is not possible.

Contaminants associated with milling were slurried into nearby tailings piles and raffinate ponds situated on a high point of the Mancos Shale bedrock, which is below the thin ancestral river alluvium covering the terrace surface. Over the 14 years of milling and subsequent site remediation and disposal cell construction, these milling contaminants have migrated radially across the terrace along pathways through the porous terrace alluvium and underlying weathered and fractured Mancos Shale. Contaminated ground water has traveled southeast where it emerges as seeps in Many Devils Wash, northwest where seeps occur in Bob Lee Wash and 1st and 2nd Washes, and north where seeps along the escarpment drain into the floodplain. Ecological risk concerns are present where this contaminated ground water reaches the surface as seeps and contributes to surface flows. Ground water also traveled southwest where it resides in alluvium on a shallow bedrock swale (or sump area) formed by the ancestral San Juan River channel. The bedrock swale is abruptly bounded to the south by a buried bedrock (Mancos Shale) escarpment that forms the boundary of the terrace system. The terrace and floodplain features of the site are shown in Figure A–1. Although water supplied by milling and reclamation activities is no longer being added to the terrace system, some saturated slimes are still present in the unlined disposal

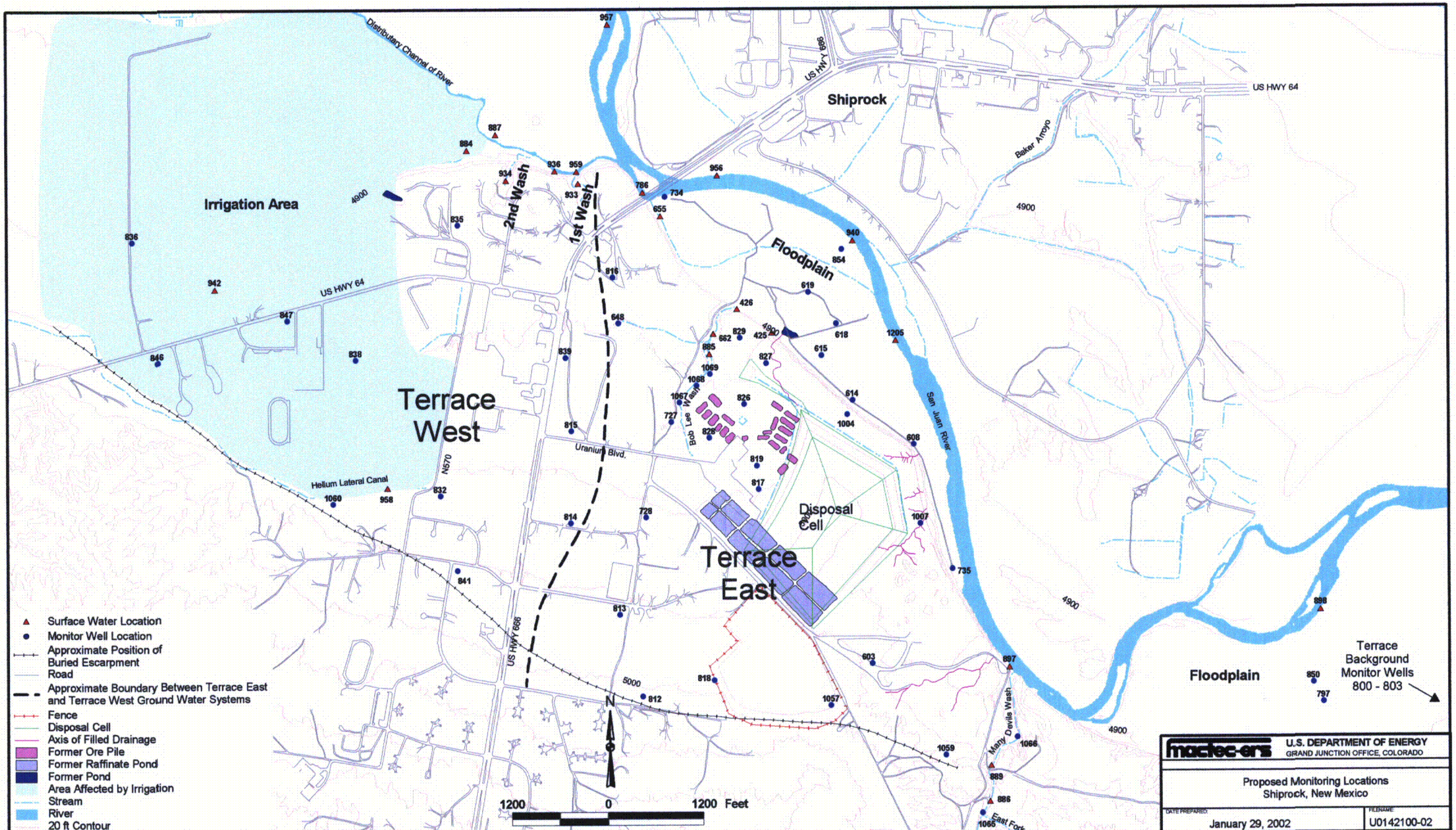

Figure A–1. Proposed Monitoring Locations for the Shiprock Site

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cell and water from precipitation on the cell may be contributing to continued movement of contaminants across the terrace and down to the floodplain.

Milling contaminants are present in the floodplain north of the disposal cell in an arcuate plume that extends to the San Juan River. Floodplain contamination formerly was more extensive and covered the western part of the floodplain, but this area has been flushed by relatively clean ground water produced since the early 1960s by an artesian well on the terrace that has been routed to Bob Lee Wash and onto the floodplain. Flushing of milling contaminants has also occurred in the part of the terrace west area where San Juan River water in the Helium Lateral Canal system has been used for irrigation since the late 1950s.

4.0 Ground and Surface Water Sampling and Analysis

4.1 Terrace Monitoring Strategy

The monitoring strategies for the two areas on the terrace, terrace east and terrace west, are as follows:

1. Terrace east—Determine the effectiveness of active remediation (extraction wells and french drains) in cutting off recharge to terrace west and in drying up the seeps on the escarpment and in the washes.

2. Terrace west—Determine that recharge from terrace east is being cut off, resulting in drying up of seeps in washes, and that milling-related constituents do not affect the current beneficial use of the ground water.

Location numbers of ground water (from wells) and surface water sampling and measurements, along with monitoring purpose, analyses/measurements to be performed, and monitoring frequency are shown for terrace east and west in Table A–2. These monitoring locations are shown on the site map in Figure A–1. Sampling and measurements are scheduled to begin in March 2002 and repeat in September 2002 for a spring-fall semiannual frequency. Terrace ground and surface water samples will be analyzed for the seven COCs, including strontium for ecological risk concerns. These samples will also be analyzed for major-ion chemistry and field parameters (alkalinity, conductivity, oxidation-reduction potential, and pH).

Thirteen wells in terrace east and 9 wells in terrace west have been selected for semiannual water sampling for the first 7 years during active remediation. After the first 7 years, sampling would occur annually for the next 5 years, and once every 5 years thereafter. Water levels will also be measured in these wells at the time of sampling. In addition, water level measurements only will be made at the same frequency in nine additional terrace east wells and in two additional terrace west wells. Plots of water level measurements from these numerous wells should be adequate to determine if the ground water levels are decreasing, indicating the success of ground water extraction by the five wells and by the three french drains in the terrace east area. Analyses for COCs and other chemical characteristics should allow tracking of plumes of contaminated water and the effectiveness of ground water flushing by irrigation in part of the terrace west area. Annual water level measurements will be made for the next 5 years at four terrace background wells (800 through 803) about 1 to 2 mi east of the site. If water levels rise in these wells, which

has not be detected in the past 3 years, then the presence of ground water would be indicated in this terrace area unaffected by the anthropogenic water sources.

Seven surface water sample locations in terrace east and six surface locations in terrace west have been selected for sampling for the same frequency as stated above for the terrace wells. The only exception is water from location 958, which is from the siphon outlet of San Juan River water that flows into the Helium Lateral Canal system. Sampling and analysis of this water will occur once every 2 years, starting in either March or September 2003 (depending on availability of water in the system). Analysis of this water will provide characteristics of the irrigation water applied to part of the terrace west area that has been beneficial in flushing milling-related contaminants.

Table A–2. Summary of Monitoring Requirements for Terrace East and Terrace West Areas

Location	Purpose	Analyses/Measurement	Frequency
Artesian well 648	Cleanup standards for floodplain	COCs: Ammonium, manganese, nitrate, selenium, sulfate, uranium; strontium for ecological risk concerns Water chemistry: calcium, chloride, magnesium, potassium, sodium On-site field analyses: alkalinity, conductivity, oxidation-reduction potential, pH, water level	Semiannual flow measurements; sample for chemical analyses every 2 years (last sampled in February 2001)
Terrace east wells: 603, 812, 813, 816, 817, 818, 826, 827, 828, 1004, 1007, 1057, 1059 Terrace west wells: 832, 835, 836, 838, 839, 841, 846, 847, 1060	Water level and ground water chemistry		Semiannually through the 7 year extraction . period, then annually through year 12, and every 5 years thereafter
Terrace east wells: 727, 728, 819, 829, 1065, 1066, 1067, 1068, 1069 Terrace west wells: 814, 815	Monitor lowering of water levels	Water level	
Terrace east surface water: 425, 426, 662, 786, 885, 886, 889 Terrace west surface water: 884, 933, 934, 936, 942, 958	Monitor for ecological risks and lowering of water levels	COCs: Ammonium, manganese, nitrate, selenium, sulfate, uranium; strontium for ecological risk concerns Water chemistry: calcium, chloride, magnesium, potassium, sodium On-site field analyses: alkalinity, conductivity, oxidation-reduction potential, and pH Water level for 885, 886, and 889 Flow rate for 425, 426, and 786	Sample 958 for chemical analysis once every 2 years (last sampled in February 2001)
Terrace background wells: 800, 801, 802, 803	Presence of ground water in terrace background	Water level	Annually for the first 5 years

Three of the surface water sample locations (425, 426, and 786) in terrace east are seeps along the escarpment where flow rates will be measured. A decrease in flow rate (and the drying up) of these seeps will provide a measure of the efficiency of active remediation in terrace east. Measurements of water levels at three surface locations (885 in Bob Lee Wash and 886 and 889 in Many Devils Wash) in terrace east will be made from PVC casings installed in the wash

bottoms. These water level measurements will provide evidence for effectiveness of terrace east remediation and decreasing of the amount of ground water appearing in the washes. Sampling of the seeps in the terrace east area will provide chemical data to evaluate ecological risk present in the nearby floodplain toward which the seeps drain. Sampling of surface water at location 662 in lower Bob Lee Wash will provide chemical data on the mix of water from well 648 and water containing milling-related contaminants from upper Bob Lee Wash.

Sampling of the seeps in the terrace west area from 1st Wash, 2nd Wash, and an escarpment area between the washes (locations 933, 934, and 936, respectively) will provide evidence for the effectiveness of terrace east remediation in reducing the level of contamination in the seeps. Also, chemical data from sampling of these seeps will be used to evaluate ecological risk in the nearby San Juan River distributary channel toward which the seeps drains. Sampling of surface water at locations 942 and 884 (a spring flowing from terrace gravel deposits and water in the irrigation return flow ditch, respectively) will provide chemical data to assess the effectiveness of flushing in the area affected by irrigation from the Helium Lateral Canal (942) and to evaluate ecological risk in the nearby distributary channel toward which the irrigation return flow ditch (884) drains.

During the initial 7-year extraction period of semiannual sampling, results will be shared with stakeholders and regulators. These results will be reviewed after 7 years and trends will be analyzed to determine if less frequent sampling is justified.

The continued flow of relatively clean water from artesian well 648 is important to ensure the continued flushing of the northwest part of the floodplain. Flow from the well was measured at approximately 64 gallons per minute in 1999; however, the wellhead has a valve and the flow rate has been variable in the past. The flow rate will be measured semiannually to ensure that flow restrictions do not occur. The chemistry of the large volume of water from well 648 also affects the floodplain ground water and its cleanup standards. Sulfate concentration of well 648 water is elevated at approximately 2,000 milligrams per liter (mg/L). Because of this influx of well water, the floodplain ground water where influenced by the well cannot be flushed or cleaned up for sulfate to less than 2,000 mg/L. The chemistry of well 648 water will be analyzed, similar to other terrace wells, from sampling every 2 years. The next sampling of well 648 will be in March 2003.

4.2 Floodplain Monitoring Strategy

The monitoring strategy for the floodplain is designed to determine the progress of the natural flushing process in meeting compliance standards for site COCs and to determine the effectiveness of active remediation (from two extraction wells) during Phase I remediation in removing contaminants from the most contaminated part of the plume to prevent it from reaching the San Juan River.

Location numbers of ground water (from wells) and surface water sampling, along with monitoring purpose, analyses/measurements to be performed, and monitoring frequency are shown for the floodplain in Table A–3. These monitoring locations are shown on the site map in Figure A–1. Sampling and measurements are scheduled to begin in March 2002 and repeat in September 2002 for a spring-fall semiannual frequency. Floodplain ground and surface water samples will be analyzed for the seven COCs, including ammonium and strontium for ecological

risk concerns. These samples will also be analyzed for major-ion chemistry and field parameters (alkalinity, conductivity, oxidation-reduction potential, and pH).

Table A–3. Summary of Monitoring Requirements for the Floodplain

Location	Purpose	Analyses/Measurement	Frequency
Wells 608, 614, 615, 618, 619, 734, 735, 854	Compliance action levels (40 CFR 192)	COCs: Manganese, nitrate, selenium, sulfate, uranium (and ammonium and strontium based on ecological concerns) Water chemistry: calcium, chloride, magnesium, potassium, sodium On-site field analyses: alkalinity, conductivity, oxidation-reduction potential, pH, water level (in wells)	Semiannually through the first 7 year extraction period, then annually through year 12, and every 5 years thereafter
Wells 797,850	Floodplain, background		
Surface 898	San Juan River, background		
Surface 897, 940, 1205	San Juan River on site, risk		
Surface 956	Intake on north side of San Juan River, risk		
Surface 957	San Juan River, downgradient, risk		
Surface 655	Floodplain drainage channel, risk		
Surface 887	Distributary channel, risk		
Surface 959	Distributary channel, risk		

Ten wells in the floodplain have been selected for semiannual water sampling for the initial 7-year Phase I active remediation (extraction) period. After the first 7 years, sampling would occur annually for the next 5 years, and once every 5 years thereafter. Water levels will also be measured in these wells at the time of sampling.

Seven of the wells are in the contaminant plume in the floodplain just north of the disposal cell. Well 854, situated between the two extraction wells in a highly contaminated part of the plume, is designated a point of compliance well. Analyses of samples from this well will track the progress of reducing the mass of the contaminant plume by the extraction wells. After Phase I active remediation (extraction) is completed in 7 years, or when it is established from modeling that the floodplain will flush within 100 years, sampling and analysis of the seven wells will show the progress of natural flushing.

Although well 734 in the northwest corner of the floodplain is outside of the contaminant plume, it has had the highest contaminant concentrations in that part of the floodplain. Monitoring of this well will ensure that flushing continues in this part of the floodplain.

Ground water compliance standards and cleanup goals for human health COCs (manganese, nitrate, selenium, sulfate, and uranium) on the floodplain, listed in Table A–1, are as follows:

- For uranium and nitrate, the UMTRA standards of 0.044 and 44 mg/L, respectively.
- For manganese, the cleanup goal is the maximum background concentration (currently 2.74 mg/L) from sample analyses of the floodplain background wells 797 and 850.
- For sulfate, uncertain and under review by the U.S. Environmental Protection Agency, the value will likely be 2,000 mg/L or higher because of contribution from artesian well 648.
- For selenium, a proposed alternate concentration limit (ACL) using the value of 0.05 mg/L from the Safe Drinking Water Act.

Two remaining wells (797 and 850) are in the floodplain background area, approximately 1 mi upstream (east) of the disposal cell. Sampling and analyses of ground water from these wells will provide background concentrations of COCs, particularly for those contaminants such as manganese, which do not have UMTRA Project compliance standards. The cleanup goal for manganese will be the maximum concentration found in the background samples.

Nine surface water sample locations have been selected for sampling for the same frequency as stated above for the floodplain wells. Six locations are on the San Juan River, two are on the distributary channel, which receives drainage from terrace west, and one is on a drainage channel in the northwest end of the floodplain.

San Juan River sample locations upgradient (background) and downgradient are 898 and 957, respectively. River locations onsite include 897, 1205, and 940. Location 940, the site of a sample collected in February 1999 that contained uranium slightly exceeding the UMTRA ground water standard and exceeding the Navajo Nation surface water standard, is designated as a point of exposure and is where the floodplain contamination plume reaches or comes close to the river. Sample location 956 is along the north side of the river at the site of the intake for an emergency water supply for the town of Shiprock.

Analyses of samples from locations 887 and 959 in the distributary channel should provide evidence for the success of remediation in the terrace east system, which would dry up the seeps in 1st and 2nd Washes that drain into the distributary channel area. Analyses of samples from location 655 in the floodplain drainage channel will track the progress of natural flushing in the northwest part of the floodplain.

4.3 Ground and Surface Water Sampling

Ground and surface water sampling will be conducted in accordance with the "Sampling and Analysis Plan for the UMTRA Ground Water Project" (DOE 2001a) and the "Environmental Procedures Catalog, Manual 6" (DOE continually updated). Ground water samples will be collected from each of the wells and the surface water locations specified in Tables A–2 and A–3 and submitted to the Grand Junction Office (GJO) Analytical Laboratory for analysis. Sampling frequencies and analyses for FY 2002 for the Shiprock site are listed in the *FY 2002 Sampling Frequencies and Analysis* (DOE 2001b); some changes to these frequencies and analyses for the site are in this monitoring plan.

The ground water sample protocol will be based on classification of each well according to their hydraulic properties, as shown in the Sampling and Analysis Plan (DOE 2001a). Category I wells produce a minimum of 100 milliliters per minute (mL/min); most of the floodplain wells will be in this category and will be sampled using a low-flow purging method. Category II and III wells produce less than 100 mL/min and have initial water levels above and within the screened interval, respectively; most of the terrace wells will be in these categories and will be sampled using low volume purge techniques or with a bailer.

A list of specific procedures used for this sampling is found in Table 1–1 of the Sampling and Analysis Plan (DOE 2001a). These procedures are also in the *Environmental Procedures Catalog* (DOE continually updated).

4.4 GJO Laboratory Analysis

Ground water and surface water samples will be submitted to the GJO Analytical Laboratory. All procedures will be checked for accuracy through internal laboratory QC checks (e.g., analysis of blind duplicates, splits, and known standards). Sample preservation will consist of storing the samples in an ice chest with Blue Ice (or equivalent) to cool samples during field sampling, packaging, and shipping. Ground and surface water samples will be analyzed for five major ions—calcium, chloride, magnesium, potassium, and sodium; samples will also be analyzed for the seven COCs—ammonium, manganese, nitrate, selenium, strontium, sulfate, and uranium. Analytical methods to be used are detailed in *Analytical Chemistry Laboratory Handbook of Analytical and Sample Preparation Procedures* (DOE 2001c).

4.5 Quality Assurance and Quality Control

The objective of QA and QC measures is to provide systematic control of all tasks so as to maximize accuracy, precision, comparability, and completeness. Basic sampling procedures are presented in the Sampling and Analysis Plan (DOE 2001a) and *Environmental Procedures Catalog* (DOE continually updated). Deviations from these procedures will be noted in a Field Variance Log with an explanation and a description of its possible effect on data quality.

4.5.1 Sample Control

To maintain evidence of authenticity, the samples collected must be properly identified and easily distinguished from other samples. Samples collected at the Shiprock site will be identified by a label attached to the sample container specifying the sample identification number, location, date collected, time collected, and the sampler's name or initials.

Ground water and surface water samples for laboratory analysis will be kept under custody from the time of collection to the time of analysis. Chain-of-custody forms will be used to list all sample transfers to show that the sample was in constant custody between collection and analysis.

While the samples are in shipment to the GJO Analytical Laboratory, custody seals will be placed over the cooler opening to ensure that the integrity of the samples has not been compromised. The receiving laboratory must examine the seals on arrival and document that the seals are intact. Upon opening the container, the receiving laboratory will note the condition of the sample containers (e.g., broken or leaking bottles).

4.5.2 Laboratory Quality Control

Laboratory QC will be performed in accordance with the *Analytical Chemistry Laboratory Administrative Plan and Quality Control Procedures* (DOE 2001d). Quality control will include analysis of blanks, duplicates, spikes, and check samples.

5.0 Data Evaluation and Interpretation

Analyses from seven rounds of sampling (starting in December 1998) are available for most of the wells. The wells in the 600 and 700 series are older and have more than seven sampling rounds, and the 1000 series of wells are newer and have only about three sampling rounds. No contaminant concentration trends have been noticed in the floodplain or terrace well sampling data. Fewer sampling rounds (than for wells) are available for surface water samples, and no concentration trends have been noted from these data.

After the approximately 7 years of active remediation on the terrace and the floodplain, the progress of natural flushing will be monitored and analyzed from the sampling results. One method that could be used to determine the effectiveness of flushing by identifying trends is the nonparametric Mann-Kendall test. A description of this test methodology is in Attachment A–1. The following discussion of the test is from the *Ground Water Compliance Action Plan for the Old Rifle, Colorado, UMTRA Project Site* (DOE 2001e). The test does not require any particular data distribution and will accommodate missing values and data reported as less than the detection limit. Essentially it analyzes a series of data by subtracting the values of earlier collected data from later collected data. The number of resulting positive values are summed and resulting negative values are summed. The difference of these sums is determined by subtracting the number of negative values from the number of positive values. The result is the S statistic. This is compared to a probability table to determine the probability that the series of values does not represent an increasing or decreasing trend. Therefore, the smaller the probability, the greater the confidence that a real trend exists.

Use of the Mann-Kendall statistic does not assist in comparing predicted versus observed contaminant concentrations, but it does give a measure of how much significance should be attached to otherwise qualitative conclusions. If wells in critical locations at the site (e.g., plume centers) began to exhibit data that showed no clear trends, and if concentrations at those wells were unacceptably high, this could be an indication that natural flushing is not working and that the compliance strategy should be reassessed. If, on the other hand, data from critical wells continued to display decreasing trends, it could mean that natural flushing should continue to operate. Although it may not provide a clear answer, results from the Mann-Kendall test may help in the decision-making process. As each round of sampling data becomes available, the statistical calculations should be updated and results reported.

6.0 Environmental Compliance and Waste Management

6.1 Compliance Requirements

National Environmental Policy Act (NEPA): The entire area has had surveys and investigations completed. No additional cultural resources or threatened and endangered (T&E) surveys are required. DOE has categorically excluded the activities in this monitoring plan from further NEPA review.

Transportation Requirements: Transportation of hazardous materials and regulated waste will be performed in compliance with the regulatory requirements of the U.S. Department of

Transportation at 49 CFR Parts 106-180 and applicable local and state transportation requirements.

6.2 Waste Management

Investigation Derived Waste (IDW): Although few regulatory requirements exist that are directly applicable to field-generated IDW management, DOE remains committed to managing IDW in a manner that is protective of human health and the environment through the use of best management practices.

All *liquid IDW,* consisting of well purge water, will be dispersed on the ground at the well from which the water was extracted. This is according to the *Management Plan for Field-Generated Investigation Derived Waste* (DOE 2000b).

Solid IDW includes disposable sampling equipment, personal protective equipment, used field test kits, and trash. All solid IDW must be containerized in plastic bags and managed as solid waste at a permitted, licensed, or registered solid or industrial waste disposal or treatment facility. A radiological field evaluation is not required because the sampling is not being conducted in a supplemental standards area and because solid IDW that has come in incidental contact with contaminated ground water is not considered residual radioactive material.

7.0 References

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———, 2001a. *Sampling and Analysis Plan for the UMTRA Ground Water Project*, P–GJPO–2353, Rev. 5, prepared for the U.S. Department of Energy, Grand Junction Office, Grand Junction, Colorado, October.

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———, 2001c. *Analytical Chemistry Laboratory Handbook of Analytical and Sample Preparation Procedures*, U.S. Department of Energy, Grand Junction Office, Grand Junction, Colorado.

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U.S. Department of Energy, 2001e. *Ground Water Compliance Action Plan for the Old Rifle, Colorado, UMTRA Project Site*, GJO–2000–177–TAR, prepared by U.S. Department of Energy, Grand Junction Office, Grand Junction, Colorado, June.

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End of current text

Attachment A–1

Description of Mann-Kendall Test

16.3.3 Intervention Analysis and Box-Jenkins Models

If a long time sequence of equally spaced data is available, intervention analysis may be used to detect changes in average level resulting from a natural or man-induced intervention in the process. This approach, developed by Box and Tiao (1975), is a generalization of the autoregressive integrated moving-average (ARIMA) time series models described by Box and Jenkins (1976). Lettenmaier and Murray (1977) and Lettenmaier (1978) study the power of the method to detect trends. They emphasize the design of sampling plans to detect impacts from polluting facilities. Examples of its use are in Hipel et al. (1975) and Roy and Pellerin (1982).

Box-Jenkins modeling techniques are powerful tools for the analysis of time series data. McMichael and Hunter (1972) give a good introduction to Box-Jenkins modeling of environmental data, using both deterministic and stochastic components to forecast temperature flow in the Ohio River. Fuller and Tsokos (1971) develop models to forecast dissolved oxygen in a stream. Carlson, MacCormick, and Watts (1970) and McKerchar and Delleur (1974) fit Box-Jenkins models to monthly river flows. Hsu and Hunter (1976) analyze annual series of air pollution SO_2 concentrations. McCollister and Wilson (1975) forecast daily maximum and hourly average total oxidant and carbon monoxide concentrations in the Los Angeles Basin. Hipel, McLeod, and Lennox (1977*a*, 1977*b*) illustrate improved Box-Jenkins techniques to simplify model construction. Reinsel et al. (1981*a*, 1981*b*) use Box-Jenkins models to detect trends in stratospheric ozone data. Two introductory textbooks are McCleary and Hay (1980) and Chatfield (1984). Box and Jenkins (1976) is recommended reading for all users of the method.

Disadvantages of Box-Jenkins methods are discussed by Montgomery and Johnson (1976). At least 50 and preferably 100 or more data collected at equal (or approximately equal) time intervals are needed. When the purpose is forecasting, we must assume the developed model applies to the future. Missing data or data reported as trace or less-than values can prevent the use of Box-Jenkins methods. Finally, the modeling process is often nontrivial, with a considerable investment in time and resources required to build a satisfactory model. Fortunately, there are several packages of statistical programs that contain codes for developing time series models, including Minitab (Ryan, Joiner, and Ryan 1982), SPSS (1985), BMDP (1983), and SAS (1985). Codes for personal computers are also becoming available.

16.4 MANN-KENDALL TEST

In this section we discuss the nonparametric Mann-Kendall test for trend (Mann, 1945; Kendall, 1975). This procedure is particularly useful since missing values are allowed and the data need not conform to any particular distribution. Also, data reported as trace or less than the detection limit can be used (if it is acceptable in the context of the population being sampled) by assigning them a common value that is smaller than the smallest measured value in the data set. This approach can be used because the Mann-Kendall test (and the seasonal Kendall test in Chapter 17) use only the relative magnitudes of the data rather

From Gilbert, Richard O., 1987. Statistical Methods for Environmental Pollution Monitoring, Van Nostrand Reinhold, NY, 320p.

than their measured values. We note that the Mann-Kendall test can be viewed as a nonparametric test for zero slope of the linear regression of time-ordered data versus time, as illustrated by Hollander and Wolfe (1973, p. 201).

16.4.1 Number of Data 40 or Less

If n is 40 or less, the procedure in this section may be used. When n exceeds 40, use the normal approximation test in Section 16.4.2. We begin by considering the case where only one datum per time period is taken, where a time period may be a day, week, month, and so on. The case of multiple data values per time period is discussed in Section 16.4.3.

The first step is to list the data in the order in which they were collected over time: $x_1, x_2, \ldots, x_n$, where x_i is the datum at time i. Then determine the sign of all $n(n-1)/2$ possible differences $x_j - x_k$, where $j > k$. These differences are $x_2 - x_1, x_3 - x_1, \ldots, x_n - x_1, x_3 - x_2, x_4 - x_2, \ldots, x_n - x_{n-2}, x_n - x_{n-1}$. A convenient way of arranging the calculations is shown in Table 16.1.

Let $\operatorname{sgn}(x_j - x_k)$ be an indicator function that takes on the values 1, 0, or -1 according to the sign of $x_j - x_k$:

$$\begin{aligned}\operatorname{sgn}(x_j - x_k) &= 1 \quad \text{if } x_j - x_k > 0\\ &= 0 \quad \text{if } x_j - x_k = 0\\ &= -1 \quad \text{if } x_j - x_k < 0\end{aligned} \qquad 16.1$$

Then compute the Mann-Kendall statistic

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \operatorname{sgn}(x_j - x_k) \qquad 16.2$$

which is the number of positive differences minus the number of negative differences. These differences are easily obtained from the last two columns of Table 16.1. If S is a large positive number, measurements taken later in time tend to be larger than those taken earlier. Similarly, if S is a large negative number, measurements taken later in time tend to be smaller. If n is large, the computer code in Appendix B may be used to compute S. This code also computes the tests for trend discussed in Chapter 17.

Suppose we want to test the null hypothesis, H_0, of no trend against the alternative hypothesis, H_A, of an upward trend. Then H_0 is rejected in favor of H_A if S is positive and if the probability value in Table A18 corresponding to the computed S is less than the a priori specified α significance level of the test. Similarly, to test H_0 against the alternative hypothesis H_A of a downward trend, reject H_0 and accept H_A if S is negative and if the probability value in the table corresponding to the absolute value of S is less than the a priori specified α value. If a two-tailed test is desired, that is, if we want to detect either an upward or downward trend, the tabled probability level corresponding to the absolute value of S is doubled and H_0 is rejected if that doubled value is less than the a priori α level.

EXAMPLE 16.1

We wish to test the null hypothesis H_0, of no trend versus the alternative hypothesis, H_A, of an upward trend at the $\alpha = 0.10$

Table 16.1 Differences in Data Values Needed for Computing the Mann-Kendall Statistic S to Test for Trend

Data Values Listed in the Order Collected Over Time							*No. of + Signs*	*No. of − Signs*
x_1	x_2	x_3	x_4	$\cdots$	x_{n-1}	x_n		
	$x_2 - x_1$	$x_3 - x_1$	$x_4 - x_1$	$\cdots$	$x_{n-1} - x_1$	$x_n - x_1$		
		$x_3 - x_2$	$x_4 - x_2$	$\cdots$	$x_{n-1} - x_2$	$x_n - x_2$		
			$x_4 - x_3$	$\cdots$	$x_{n-1} - x_3$	$x_n - x_3$		
				$\ddots$	$\vdots$	$\vdots$		
					$x_{n-1} - x_{n-2}$	$x_n - x_{n-2}$		
						$x_n - x_{n-1}$		
						$S =$	$\left(\text{sum of + signs}\right)$	$+ \left(\text{sum of − signs}\right)$

Table 16.2 Computation of the Mann-Kendall Trend Statistic S for the Time Ordered Data Sequence 10, 15, 14, 20

Time	*1*	*2*	*3*	*4*		*No. of + Signs*		*No. of − Signs*
Data	*10*	*15*	*14*	*20*				
		15 − 10	14 − 10	20 − 10		3		0
			14 − 15	20 − 15		1		1
				20 − 14		1		0
				S	=	5	−	1 = 4

significance level. For ease of illustration suppose only 4 measurements are collected in the following order over time or along a line in space: 10, 15, 14, and 20. There are 6 differences to consider: 15 − 10, 14 − 10, 20 − 10, 14 − 15, 20 − 15, and 20 − 14. Using Eqs. 16.1 and 16.2, we obtain $S = +1 + 1 + 1 - 1 + 1 + 1 = +4$, as illustrated in Table 16.2. (Note that the sign, not the magnitude of the difference is used.) From Table A18 we find for $n = 4$ that the tabled probability for $S = +4$ is 0.167. This number is the probability of obtaining a value of S equal to +4 or larger when $n = 4$ and when no upward trend is present. Since this value is greater than 0.10, we cannot reject H_0.

If the data sequence had been 18, 20, 23, 35, then $S = +6$, and the tabled probability is 0.042. Since this value is less than 0.10, we reject H_0 and accept the alternative hypothesis of an upward trend.

Table A18 gives probability values only for $n \le 10$. An extension of this table up to $n = 40$ is given in Table A.21 in Hollander and Wolfe (1973).

16.4.2 Number of Data Greater Than 40

When n is greater than 40, the normal approximation test described in this section is used. Actually, Kendall (1975, p. 55) indicates that this method may be used for n as small as 10 unless there are many tied data values. The test procedure is to first compute S using Eq. 16.2 as described before. Then compute the variance of S by the following equation, which takes into account that ties may be present:

$$\mathrm{VAR}(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p - 1)(2t_p + 5)\right] \qquad 16.3$$

where g is the number of tied groups and t_p is the number of data in the pth group. For example, in the sequence {23, 24, trace, 6, trace, 24, 24, trace, 23} we have $g = 3$, $t_1 = 2$ for the tied value 23, $t_2 = 3$ for the tied value 24, and $t_3 = 3$ for the three trace values (considered to be of equal but unknown value less than 6).

Then S and VAR(S) are used to compute the test statistic Z as follows:

$$Z = \frac{S-1}{[\mathrm{VAR}(S)]^{1/2}} \quad \text{if } S > 0$$

$$= 0 \quad \text{if } S = 0$$

$$= \frac{S+1}{[\mathrm{VAR}(S)]^{1/2}} \quad \text{if } S < 0 \qquad 16.4$$

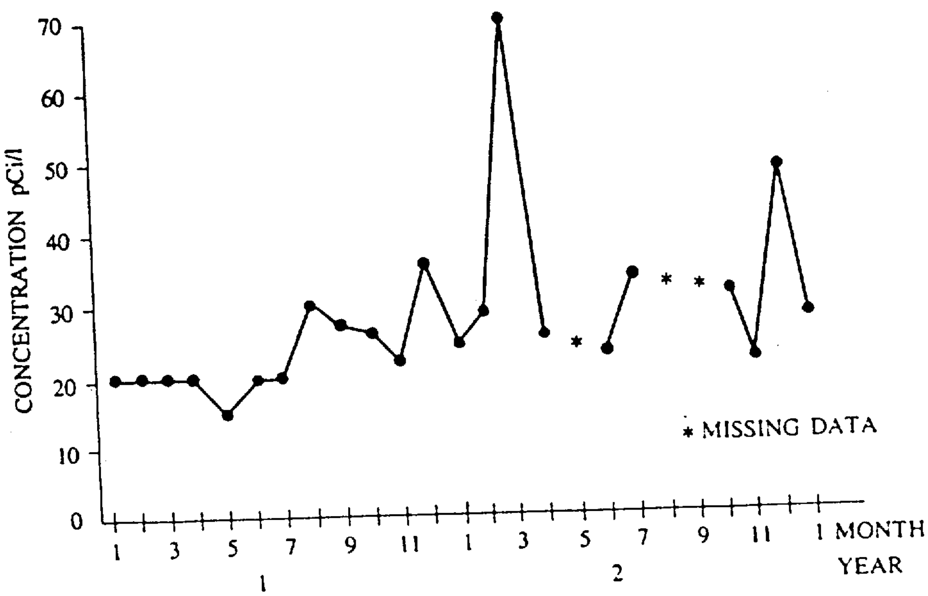

Figure 16.2 Concentrations of ^{238}U in ground water in well E at the former St. Louis Airport storage site for January 1981 through January 1983 (after Clark and Berven, 1984).

A positive (negative) value of Z indicates an upward (downward) trend. If the null hypothesis, H_0, of no trend is true, the statistic Z has a standard normal distribution, and hence we use Table A1 to decide whether to reject H_0. To test for either upward or downward trend (a two-tailed test) at the α level of significance, H_0 is rejected if the absolute value of Z is greater than $Z_{1-\alpha/2}$, where $Z_{1-\alpha/2}$ is obtained from Table A1. If the alternative hypothesis is for an upward trend (a one-tailed test), H_0 is rejected if Z (Eq. 16.4) is greater than $Z_{1-\alpha}$. We reject H_0 in favor of the alternative hypothesis of a downward trend if Z is negative and the absolute value of Z is greater than $Z_{1-\alpha/2}$. Kendall (1975) indicates that using the standard normal tables (Table A1) to judge the statistical significance of the Z test will probably introduce little error as long as $n \geq 10$ unless there are many groups of ties and many ties within groups.

EXAMPLE 16.2

Figure 16.2 is a plot of $n = 22$ monthly ^{238}U concentrations $x_1, x_2, x_3, \ldots, x_{22}$ obtained from a groundwater monitoring well from January 1981 through January 1983 (reported in Clark and Berven, 1984). We use the Mann-Kendall procedure to test the null hypothesis at the $\alpha = 0.05$ level that there is no trend in ^{238}U groundwater concentrations at this well over this 2-year period. The alternative hypothesis is that an upward trend is present.

There are $n(n-1)/2 = 22(21)/2 = 231$ differences to examine for their sign. The computer code in Appendix B was used to obtain S and Z (Eqs. 16.2 and 16.4). We find that $S = +108$. Since there are 6 occurrences of the value 20 and 2 occurrences of both 23 and 30, we have $g = 3$; $t_1 = 6$, and $t_2 = t_3 = 2$. Hence, Eq. 16.3 gives

$$\begin{aligned}\mathrm{VAR}(S) &= \tfrac{1}{18}[22(21)(44 + 5) \\ &\quad - 6(5)(12 + 5) - 2(1)(4 + 5) - 2(1)(4 + 5)] \\ &= 1227.33\end{aligned}$$

or $[\mathrm{VAR}(S)]^{1/2} = 35.0$. Therefore, since $S > 0$, Eq. 16.4 gives $Z = (108 - 1)/35.0 = 3.1$. From Table A1 we find $Z_{0.95} = 1.645$. Since Z exceeds 1.645, we reject H_0 and accept the alternative hypothesis of an upward trend. We note that the three missing values in Figure 16.2 do not enter into the calculations in any way. They are simply ignored and constitute a regrettable loss of information for evaluating the presence of trend.

16.4.3 Multiple Observations per Time Period

When there are multiple observations per time period, there are two ways to proceed. First, we could compute a summary statistic, such as the median, for each time period and apply the Mann-Kendall test to the medians. An alternative approach is to consider the $n_i \geq 1$ multiple observations at time i (or time period i) as ties in the time index. For this latter case the statistic S is still computed by Eq. 16.2, where n is now the sum of the n_i, that is, the total number of observations rather than the number of time periods. The differences between data obtained at the same time are given the score 0 no matter what the data values may be, since they are tied in the time index.

When there are multiple observations per time period, the variance of S is computed by the following equation, which accounts for ties in the time index:

$$\begin{aligned}\mathrm{VAR}(S) &= \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{g} t_p(t_p-1)(2t_p+5) \right. \\ &\quad \left. - \sum_{q=1}^{h} u_q(u_q-1)(2u_q+5)\right] \\ &\quad + \frac{\sum_{p=1}^{g} t_p(t_p-1)(t_p-2) \sum_{q=1}^{h} u_q(u_q-1)(u_q-2)}{9n(n-1)(n-2)} \\ &\quad + \frac{\sum_{p=1}^{g} t_p(t_p-1) \sum_{q=1}^{h} u_q(u_q-1)}{2n(n-1)} \qquad 16.5\end{aligned}$$

where g and t_p are as defined following Eq. 16.3, h is the number of time periods that contain multiple data, and u_q is the number of multiple data in the qth time period. Equation 16.5 reduces to Eq. 16.3 when there is one observation per time period.

Equations 16.3 and 16.5 assume all data are independent and, hence, uncorrelated. If observations taken during the same time period are highly correlated, it may be preferable to apply the Mann-Kendall test to the medians of the data in each time period rather than use Eq. 16.5 in Eq. 16.4.

Table A18 Probabilities for the Mann-Kendall Nonparametric Test for Trend

S	Values of n: 4	5	8	9	S	Values of n: 6	7	10
0	0.625	0.592	0.548	0.540	1	0.500	0.500	0.500
2	0.375	0.408	0.452	0.460	3	0.360	0.386	0.431
4	0.167	0.242	0.360	0.381	5	0.235	0.281	0.364
6	0.042	0.117	0.274	0.306	7	0.136	0.191	0.300
8		0.042	0.199	0.238	9	0.068	0.119	0.242
10		$0.0^{2}83$	0.138	0.179	11	0.028	0.068	0.190
12			0.089	0.130	13	$0.0^{2}83$	0.035	0.146
14			0.054	0.090	15	$0.0^{2}14$	0.015	0.108
16			0.031	0.060	17		$0.0^{2}54$	0.078
18			0.016	0.038	19		$0.0^{2}14$	0.054
20			$0.0^{2}71$	0.022	21		$0.0^{3}20$	0.036
22			$0.0^{2}28$	0.012	23			0.023
24			$0.0^{3}87$	$0.0^{2}63$	25			0.014
26			$0.0^{3}19$	$0.0^{2}29$	27			$0.0^{2}83$
28			$0.0^{4}25$	$0.0^{2}12$	29			$0.0^{2}46$
30				$0.0^{3}43$	31			$0.0^{2}23$
32				$0.0^{3}12$	33			$0.0^{2}11$
34				$0.0^{4}25$	35			$0.0^{3}47$
36				$0.0^{5}28$	37			$0.0^{3}18$
					39			$0.0^{4}58$
					41			$0.0^{4}15$
					43			$0.0^{5}28$
					45			$0.0^{6}28$

Source: From Kendall, 1975. Used by permission.
Repeated zeros are indicated by powers; for example, $0.0^{3}47$ stands for 0.00047.
Each table entry is the probability that the Mann-Kendall statistic *S* equals or exceeds the specified value of S when no trend is present.
This table is used in Section 16.4.1.

Appendix B

Comprehensive List of EA Commitments

Commitment	Primary Agency(ies)
ICs	Navajo UMTRA
Range Management – Grazing Permits	Shiprock Chapter
Well Permits	Navajo Water Code
Right-Of-Way Application	Bureau of Indian Affairs
Mesa Verde Cactus Mitigation	Navajo Fish and Wildlife Service
Ground Water and Surface Water Monitoring	Navajo UMTRA/Navajo EPA
Cultural Resources Mitigation	Navajo Natural Heritage Program
Endangered Species Consultation	U.S. Fish and Wildlife Service
Secure Water Rights	N.M. State Engineer's Office/Navajo EPA
Wildlife Management Plan/Biological Assessment	U.S. Fish and Wildlife Service/Navajo Fish and Wildlife Service
404 Permits (if needed)	U.S. Corps of Engineers
Air Monitoring	Navajo EPA
Waste Management	Navajo EPA
ACLs (if required)	Navajo UMTRA/EPA/NRC

End of current text