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UMTRA WATER SAMPLING AND ANALYSIS PLAN TUBA CITY, ARIZONA

Draft

September 1993

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**UMTRA WATER SAMPLING AND ANALYSIS PLAN
TUBA CITY, ARIZONA**

DRAFT

September 1993

**Prepared for
U.S. Department of Energy
UMTRA Project Office
Albuquerque, New Mexico**

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LIST OF ACRONYMS AND ABBREVIATIONS

<u>Acronym</u>	<u>Definition</u>
ac	acre
bls	below land surface
CLP SOW	Contract Laboratory Program Statement of Work
DOE	U.S. Department of Energy
DQO	Data Quality Objective
EPA	U.S. Environmental Protection Agency
ft	feet
ft/yr	feet per year
FY	fiscal year
GJPO	Grand Junction Projects Office
ha	hectare
HAZWREP	Hazardous Waste Remedial Action Program
km	kilometer
L/s	liters per second
LTSP	long-term surveillance plan
m	meter
m ³	cubic meter
m/yr	meters per year
MCL	maximum contaminant level
mg/L	milligrams per liter
mi	mile
NRC	U.S. Nuclear Regulatory Commission
pCi/L	picocuries per liter
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act
SOP	standard operating procedure
UMTRA	Uranium Mill Tailings Remedial Action

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this document is to provide background, guidance, and justification for fiscal year (FY) 1994 water sampling activities for the uranium mill tailings site at Tuba City, Arizona. This sampling and analysis plan will form the basis for groundwater sampling and analysis work orders to be implemented in FY94.

1.2 SITE LOCATION

The Tuba City site is on the Navajo Indian Reservation, 6 miles (mi) [10 kilometers (km)] east of Tuba City in Coconino County, Arizona, and 85 mi (140 km) northeast of Flagstaff, Arizona (Figures 1.1 and 1.2).

1.2.1 Surrounding land use

Land use in the immediate vicinity of the Tuba City disposal site is limited to grazing. Adjacent lands are used for dry land and irrigated farming, for home sites, and for gathering firewood, yucca, stone, and clay. Within 2 mi (3 km) of the site are five traditional Navajo hogans and several Navajo camps. Other farms and residences are scattered along both sides of U.S. Highway 160 between the tailings site and Tuba City.

Approximately 6 mi (10 km) west of the site are the Navajo community of Tuba City and the Hopi village of Moenkopi. Tuba City and Moenkopi Village have been expanding eastward toward the tailings site but are still several miles west. Moenkopi's population is approximately 1000, which represents nearly 10 percent of the Hopi tribe.

Although considerable open space is around the site, it is not available for new development because most of the land is subject to a village, clan, family, or other claim.

1.2.2 Surrounding water use

Stock watering and agricultural diversions are established water uses for the Hopi tribe and Navajo Nation at Moenkopi Wash in the former processing site vicinity. Irrigation from Moenkopi Wash is a vital water source for the Hopis.

The limited and highly variable supply of surface water makes groundwater an important resource. Currently, no withdrawals of groundwater are between the tailings pile and Moenkopi Wash. This includes the area currently contaminated and the area that may become contaminated as the contaminant plume moves toward the wash.

FIGURE 1.1
AREA MAP
TUBA CITY, ARIZONA, DISPOSAL SITE

FIGURE 1.2
DISPOSAL SITE LOCATION
TUBA CITY, ARIZONA

Two points of groundwater withdrawal exist within a 2-mi (3-km) radius of the site. A low-yield domestic well about 1.5 mi (2.4 km) east-northeast of the site is used by two or three families (see Figure 1.2). Jimmy's Spring, about 1.2 mi (1.9 km) east-southeast of the site near Moenkopi Wash, is used to water livestock. Because of their locations, these groundwater sources probably will not be affected by any contaminants emanating from the site.

The nearest residents to the site, less than a mile southeast, haul water from the Tuba City chapter house. This is a common practice on both reservations because more than half of the homes do not have plumbing or water supplies. The village of Lower Moenkopi does not have water or sewage systems, unlike Tuba City and parts of Upper Moenkopi.

1.3 SITE HISTORY

The Rare Metals Corporation of America operated the uranium mill at the Tuba City site from 1956 until 1962. In 1962, Rare Metals merged with the El Paso Natural Gas Company and ran the mill until 1966. During 10 years of milling, about 800,000 tons of ore were processed. The Tuba City mill was designed originally to process uranium ores using a sulfuric acid leaching, sand-slime separation, and resin-in-pulp ion exchange recovery system. However, in 1962, a high-lime content ore became the primary feed source, and the mill was modified to use a carbonate leach process. Chemicals used in processing included iron metal, lime, ammonia gas, magnesia, tertiary amine, kerosene, and sulfuric and nitric acid. The tailings were placed as slurry in three contiguous piles at the site (DOE, 1987).

In 1988, remedial action was initiated at the site to stabilize the tailings. Relocated tailings from the adjacent subpiles, windblown and waterborne deposits, and other contaminated materials, including demolished buildings, were placed into an engineered disposal cell. The remedial action was completed in April 1990. A total of 1,400,000 cubic yards [1,100,000 cubic meters (m³)] of contaminated materials was stabilized in a disposal cell covering 50 acres (ac) [20 hectares (ha)] within the 145-ac (59-ha) disposal site (Figure 1.2).

1.4 SITE STATUS

The Tuba City site will remain in poststabilization, prelicensing status until the U.S. Nuclear Regulatory Commission (NRC) licenses it for long-term surveillance and maintenance under the provisions of 10 CFR 40. When the general license becomes effective after NRC concurrence on the completion of the surface remedial action and approval of the long-term surveillance plan (LTSP), responsibility for conducting the long-term surveillance program for the disposal cell will transfer from the U.S. Department of Energy (DOE) Uranium Mill Tailings Remedial Action (UMTRA) Project Office to the DOE's long-term surveillance and maintenance program at the DOE Grand Junction Projects Office (GJPO).

1.5 SAMPLING PLAN SUMMARY

The groundwater monitoring network will consist of 14 existing monitor wells. Five of these wells (906, 908, 909, 912, and 913) will be plume monitor wells used to measure groundwater quality and static water levels. They will be located in the plume immediately downgradient from the site.

Background monitoring wells include two upgradient wells (monitor wells 901 and 910) screened at various depths (Table 1.1), one cross-gradient well (917), and six downgradient ("transition") wells. Three of the latter wells (monitor wells 903, 920, and 921) are in a cluster, are completed to various depths (Table 1.1), and are spatially near the leading edge of the nitrate plume. The other three wells (monitor wells 904, 914, and 915) are cross-gradient or further downgradient to detect contaminants if they move substantially further downgradient or further off the site. If the plume intersects these wells, they will become plume monitor wells.

The following constituents and/or parameters will be measured in all water samples collected annually at the site:

- Contaminants: cadmium, lead, molybdenum, nitrate, selenium, and uranium.
- Major cations: calcium, iron, potassium, magnesium, manganese, and sodium.
- Major anions: chloride, sulfate, and total dissolved solids.

Surface water locations will not be monitored for FY94 because no evidence exists after three rounds of sampling that the disposal cell impacts the water quality in Moenkopi Wash, the nearest downgradient surface water [approximately 1.1 mi (1.8 km) southeast of the site]. Nitrate is the major contaminant of concern at the site and is a conservative chemical species. Therefore, elevated nitrate concentrations in water sampled from Moenkopi Wash would be the strongest indication that water quality is being impacted by tailings seepage from the disposal cell. Nitrate levels are on the order of 1000 milligrams per liter (mg/L) in groundwater beneath the disposal cell, yet have been well within background groundwater concentrations (< 1.0 to 21 mg/L) in water sampled from Moenkopi Wash. The same general relationship between contaminated groundwater and water from Moenkopi Wash holds true for the other contaminants of cadmium, lead, molybdenum, selenium, and uranium.

Table 1.1 Existing groundwater monitoring well network, Tuba City, Arizona, disposal site

Well number	Screened interval (depth below surface)	
	ft	m
<u>Upgradient</u>		
901	58-78	18-24
910	95-195	30-60
<u>Downgradient</u>		
903	24-48	7-15
904	28-38	10-13
906	44-64	14-20
908	52-67	16-20
909	65-80	19-23
912	123-163	37-50
913	329-369	101-113
914	144-154	42-48
915	170-180	52-55
920	116-156	35-48
921	315-355	96-108
<u>Cross-gradient</u>		
917	128-148	40-46

ft - feet.
m - meter.

2.0 SITE CHARACTERISTICS

2.1 PHYSIOGRAPHIC SETTING

The Tuba City site lies approximately 5100 feet (ft) [1600 meters (m)] above sea level on alluvial and eolian deposits in the Southern Kaibito Plateau. The site is on a gently sloping terrace approximately 6000 ft (1800 m) northwest of Moenkopi Wash, an intermittent stream draining west-southwest into the Little Colorado River. Surface drainage is southeast toward Moenkopi Wash. North and west of the site is gently rolling terrain. Active and partially stabilized windblown sand deposits and occasional Navajo Sandstone outcrops control the topography. To the east and south, the terrain is more dissected because of erosion along the flank of Moenkopi Wash. South of the site, two broad terraces cut into the Navajo Sandstone. These terraces are modified by arroyos and capped by active and arrested windblown sand (dune) deposits. Although mostly covered by dune deposits, the Navajo Sandstone appears close to the surface throughout the area (DOE, 1987).

2.2 GEOLOGY

At the Tuba City site, near-surface geologic formations are part of the Glen Canyon group, which is composed of (in descending order from land surface) the Navajo Sandstone, the Kayenta Formation, and the Moenave Formation. The Navajo Sandstone is a fine- to medium-grained sandstone unit locally cemented with carbonate and displaying large-scale crossbeds. The Navajo Sandstone is approximately 430 ft (130 m) thick in the site vicinity. It intertongues with the underlying Kayenta Formation in a zone as much as 300 ft (90 m) thick. The Kayenta Formation consists of interbedded fine-grained sandstone and mudstone. The bedding is lenticular and cross-bedding is common in the sandy units. The Moenave Formation consists of very fine to fine-grained sandstone and thin siltstone strata (DOE, 1987).

Up to 20 ft (6 m) of dune sand, alluvium, and pediment gravels cover much of the Navajo Sandstone near the site. Figure 2.1 provides a generalized geologic cross section of the site stratigraphy. The bedrock dips northeast 1 to 2 degrees toward the Tuba City Syncline (DOE, 1987).

2.3 HYDROLOGY

2.3.1 Groundwater

The uppermost aquifer in the Tuba City site vicinity comprises the Navajo Sandstone and the Kayenta Formation. There is no continuous hydraulic barrier to groundwater flow between the Navajo Sandstone and Kayenta Formation. Together, they form the N-aquifer of the Navajo and Hopi reservations (DOE, 1987). The lower bound of the N-aquifer occurs at the contact between the Kayenta and Moenave formations. Although overlain by the Carmel

FIGURE 2.1
GENERALIZED GEOLOGIC CROSS SECTION OF TUBA CITY, ARIZONA, SITE

Formation and a silty member of the Entrada Sandstone, which creates confined aquifer conditions in many areas (Harshbarger et al., 1957), the N-aquifer is unconfined in the Tuba City area. The major recharge area for the N-aquifer is in the vicinity of Shonto, about 40 miles northwest of Tuba City (Eychaner, 1983). Groundwater flow diverges from the recharge area, flowing northeast toward Laguna Creek and south toward Tuba City and Moenkopi Wash. Local infiltration undoubtedly provides some recharge in the site area.

The water table in the Navajo Sandstone ranges from about 20 to 150 ft (6 to 45 m) below land surface (bls) in the site vicinity. The water table slopes toward Moenkopi Wash and groundwater flows southeast toward the wash (Figure 2.2). Springs occurring on both sides of Moenkopi Wash indicate that the N-aquifer discharges to the wash (USGS, 1969).

Slug tests have been performed on eight monitor wells. These data were analyzed using the Bouwer-Rice (Bouwer, 1989) and Hvorslev (Hvorslev, 1951) methods, yielding hydraulic conductivities ranging from 50 to 900 feet per year (ft/yr) [15 to 270 meters per year (m/yr)], with a geometric mean of 160 ft/yr (50 m/yr). Assuming a hydraulic gradient of 0.04 (based on the potentiometric surface contours) and an effective porosity of 0.2 [based on literature values (Freeze and Cherry, 1979)], the average linear groundwater velocity would range from 10 to 200 ft/yr (3 to 60 m/yr) with a geometric mean of 30 ft/yr (10 m/yr) (DOE, 1987).

2.3.2 Surface water

The Tuba City disposal site is approximately 10,000 ft (3000 m) northwest of Moenkopi Wash, an intermittent stream draining southwest into the Little Colorado River. No other watercourses, intermittent or ephemeral, exist in the tailings site vicinity. The disposal site is approximately 300 to 400 ft (90 to 120 m) in elevation above Moenkopi Wash.

Moenkopi Wash has a drainage area approximately 2500 square miles (6500 square kilometers) near the Tuba City disposal site. Surface drainage for the disposal site is southeast toward Moenkopi Wash. The drainage area above the disposal site is bounded by U.S. Highway 160, which runs along a low ridge. All drainage on the north side of the highway flows toward Greasewood Lake, a large depression centered approximately 1.5 mi (2.4 km) northeast of the disposal site.

A former stream gaging station at the bridge near U.S. Highway 89 [11 mi (18 km) southwest of Tuba City] recorded average annual flows in Moenkopi Wash of 10,650 acre-feet (13,000,000 m³) from 1926 to 1941. The magnitude of this flow varied substantially, ranging from several days of no flow to a measured peak flow of 14,500 cubic feet per second [410,000 liters per second (L/s)] (Beal, 1985).

2.4 WATER QUALITY

Figure 2.3 shows current monitor well locations. Table 1.1 lists the wells that form the monitor network and their completion information.

2.4.1 Background water quality data summary

Upgradient monitor wells 901 and 910 (Figure 2.3) establish background groundwater quality. Based on groundwater velocity calculations, well locations, and groundwater quality data, monitor wells 904 and 917 are sufficiently downgradient or cross-gradient from the disposal cell to be unaffected by the plume and are considered representative of background groundwater quality.

Background groundwater quality was characterized from groundwater samples collected between 1988 and 1992. Background groundwater quality in the N-aquifer is characterized as calcium carbonate or sodium carbonate water with low total dissolved solids (450 mg/L or less) and slightly basic pH. Graphs showing variations in conservative species (e.g., chloride and sulfate) can demonstrate the relationship between various groundwaters. These species do not react significantly with the aquifer matrix. However, their individual concentrations may vary depending on whether the groundwaters are subject to dilution or concentration (e.g., evaporation). In effect, the ratio of two conservative components is a fingerprint of the water origin. High sulfate concentrations can be controlled by gypsum precipitation in waters high in calcium.

Figure 2.4 shows a plot of chloride and sulfate concentrations in background waters. Waters from background wells have chloride to sulfate ratios mostly between 1:1 and 1:2. Generally, the chloride and sulfate concentrations decrease with increasing depth of sampling. Table 2.1 presents a statistical summary of background groundwater quality.

2.4.2 Baseline groundwater quality

Because tailings at the Tuba City site were stabilized in place, the groundwater quality under and downgradient of the disposal cell was degraded by contaminants leached from materials on the site prior to cell construction. To gauge the performance of the cell and evaluate the efficacy of any groundwater clean-up program initiated at the site, a baseline must be developed to reflect groundwater quality at the site prior to cell construction.

Wells in areas downgradient from the contaminant plume at the site are called "transition" wells in the LTSP. The present location of the contaminant plume beneath the site suggests that monitor wells 913, 914, 915, 920, and 921 (Figure 2.3) are not yet in the plume and should not exhibit contaminant concentrations above background. However, the plume is migrating in their direction and the contaminant concentrations in these wells could increase to

FIGURE 2.3
GROUNDWATER MONITOR WELL LOCATIONS
TUBA CITY, ARIZONA, DISPOSAL SITE

FIGURE 2.4
BIVARIATE PLOT OF CHLORIDE VERSUS SULFATE FOR BACKGROUND WELLS
TUBA CITY SITE

Table 2.1 Statistical summary of groundwater quality at Tuba City (1988 - 1992)

Constituent	Number of samples	Detection limit(s) (mg/L)	Percent above detection	Observed ^a		
				Minimum	Median (mg/L)	Maximum
Aluminum						
Background	18	0.05-0.10	17	<0.01	<0.10	0.17
Plume	21	0.05-0.10	29	<0.05	<0.10	4.1
Ammonium						
Background	29	0.01-0.10	24	<0.01	<0.10	1.6
Plume	33	0.01-0.10	45	<0.01	<0.10	157
Antimony						
Background	12	0.003-0.006	8	<0.003	<0.003	0.007
Plume	12	0.003-0.006	0 ^b	-	-	-
Arsenic						
Background	22	0.01	0	-	-	-
Plume	28	0.01-0.05	11	<0.005	<0.01	0.017-0.05
Barium						
Background	28	0.0013-0.10	61	<0.63	0.07-0.10	0.11
Plume	31	0.0013-0.20	32	<0.01	0.08-0.92	0.14-0.20
Beryllium						
Background	16	0.005-0.010	0	-	-	-
Plume	19	0.005-0.010	0	-	-	-
Boron						
Background	15	0.01-0.20	33	<0.01	<0.05	0.067-0.20
Plume	15	0.01-0.20	67	<0.01	0.08-0.09	0.14-0.20
Bromide						
Background	21	0.1-1.0	43	<0.10	≤0.192	0.232-1.0
Plume	42	0.1-25	38	<0.10	≤1.34	6.2-25

Table 2.1 Statistical summary of groundwater quality at Tuba City (1988 - 1992) (Continued)

Constituent	Number of samples	Detection limit(s) (mg/L)	Percent above detection	Observed ^a		
				Minimum	Median (mg/L)	Maximum
Cadmium						
Background	22	0.001	0	-	-	-
Plume	28	0.001	21	<0.001	<0.001	0.004
Calcium						
Background	29	0.01-0.50	100	29	34	39.5
Plume	33	0.01-0.50	100	460	752	1070
Chloride						
Background	29	0.5-1.0	100	8	11	14
Plume	33	0.5-1.0	100	9	120	230
Chromium						
Background	34	0.003-0.010	3	<0.003	<0.01	<0.01
Plume	40	0.003-0.010	18	<0.003	<0.01	0.18
Cobalt						
Background	16	0.03-0.05	0	-	-	-
Plume	19	0.03-0.05	0	-	-	-
Copper						
Background	16	0.01-0.02	0	-	-	-
Plume	19	0.01-0.02	11	<0.01	<0.01	0.01-0.02
Cyanide						
Background	12	0.01	0	-	-	-
Plume	15	0.01	0	-	-	-
Fluoride						
Background	24	0.1	96	0.10	0.20	0.36
Plume	27	0.1	37	<0.10	<0.10	0.23

Table 2.1 Statistical summary of groundwater quality at Tuba City (1988 - 1992) (Continued)

Constituent	Number of samples	Detection limit(s) (mg/L)	Percent above detection	Observed ^a		
				Minimum	Median (mg/L)	Maximum
Iron						
Background	27	0.005-0.030	26	<0.005	<0.03	0.085
Plume	30	0.005-0.030	53	<0.005	0.03	0.21
Lead						
Background	34	0.001-0.010	9	<0.001	<0.008	0.003-0.010
Plume	40	0.001-0.011	23	<0.001	<0.010	0.02
Magnesium						
Background	29	0.001-0.1	100	5.2	6.1	7.6
Plume	33	0.001-0.5	100	120	242	753
Manganese						
Background	27	0.0008-0.01	0	-	-	-
Plume	30	0.0008-0.01	73	<0.0008	0.052	0.4
Mercury						
Background	13	0.0002	0	-	-	-
Plume	16	0.0002	0	-	-	-
Molybdenum						
Background	34	0.0048-0.01	3	<0.0048	<0.01	0.01
Plume	40	0.0048-0.01	38	<0.0048	<0.01	0.12
Nickel						
Background	28	0.0061-0.04	0	-	-	-
Plume	31	0.0061-0.04	23	<0.0061	<0.04	0.45
Nitrate						
Background	30	0.22-1.0	100	11	15	22
Plume	35	0.22-1.0	100	620	917	1200

Table 2.1 Statistical summary of groundwater quality at Tuba City (1988 - 1992) (Continued)

Constituent	Number of samples	Detection limit(s) (mg/L)	Percent above detection	Observed ^a		
				Minimum	Median (mg/L)	Maximum
Phosphate						
Background	18	0.04-0.10	28	<0.004	<0.10	0.40
Plume	18	0.04-10	28	<0.04	<0.10	0.42-10
Potassium						
Background	29	0.01-0.50	100	0.83	1.4	2.2
Plume	33	0.01-0.50	100	4.4	6.1	3.6
Selenium						
Background	34	0.0016-0.005	0	-	-	-
Plume	40	0.0016-0.05	65	<0.002	0.007-0.012	0.05
Silver						
Background	16	0.01	0	-	-	-
Plume	19	0.01	0	-	-	-
Sodium						
Background	29	0.002-5	100	6.9	14	20
Plume	33	0.002-5	100	133	215	606
Strontium						
Background	24	0.01-0.2	100	0.19	0.29	0.36
Plume	24	0.01-0.2	100	0.74	6.8	9.1
Sulfate						
Background	30	0.1-10	100	7.4	16	46
Plume	36	0.1-10	100	804	1720	3820
Sulfide						
Background	12	0.1	33	<0.1	<0.1	1.2
Plume	15	0.1	13	<0.1	<0.1	0.3

Table 2.1 Statistical summary of groundwater quality at Tuba City (1988 - 1992) (Continued)

Constituent	Number of samples	Detection limit(s) (mg/L)	Percent above detection	Observed*		
				Minimum	Median (mg/L)	Maximum
Thallium						
Background	16	0.01-0.1	0	-	-	-
Plume	19	0.01-0.1	16	<0.005	<0.01	0.1
Tin						
Background	28	0.005	0	-	-	-
Plume	31	0.005-0.05	23	<0.005	≤0.013	0.057
Uranium						
Background	33	0.0001-0.001	76	<0.0003	0.001	0.012
Plume	40	0.0003-0.001	100	0.003	0.11	1.01
Vanadium						
Background	34	0.0051-0.01	88	<0.007	0.012	0.03
Plume	40	0.0051-0.01	63	<0.008	0.01	0.13
Zinc						
Background	34	0.0026-0.0064	65	<0.005	0.008	0.056
Plume	40	0.0026-0.0064	63	<0.0026	0.011	0.62

Table 2.1 Statistical summary of groundwater quality at Tuba City (1988 - 1992) (Concluded)

Radionuclides	Number of samples	Observed ^a		
		Minimum	Median	Maximum
		pCi/L		
Radium-226				
Background	34	0	0.1	0.4
Plume	40	0	0.1	0.6
Radium-228				
Background	34	0	0.45	3.6
Plume	40	0	0.70	11
Thorium-230				
Background	3	0.70	0.90	2.4
Plume	3	1.3	1.7	4.0
Polonium-210				
Background	3	0.3	1.2	1.6
Plume	3	0.2	0.3	2.2
Lead-210				
Background	3	0.0	0.0	0.2
Plume	3	0.2	0.7	2.5

^aDue to nondetectable measurements, these statistics may not be available. If a range is reported, the statistic is known to lie within that range.

^bFor analytes whose concentrations fall below the detection limit, the minimum, median, and maximum observed values were not reported.

pCi/L - picocuries per liter.

levels above background. Therefore, these wells were not included in the discussion of background. As with the background wells, data collected from 1988 to 1991 established a baseline for these wells. Fewer data points were available for wells 913 and 915 because they were not routinely sampled until 1990.

In terms of major ions, baseline groundwaters are similar to background waters. Total dissolved solids range from approximately 35 to 260 mg/L and pH ranges from 7.3 to 9.3. Sulfate concentrations are similar to those of background waters (excluding well 904); the range in chloride to sulfate proportions (1:1 to 1:2) is also similar. As in background water, many of the contaminant species concentrations in these "transition" wells were at or below detection. Barium, nitrate, uranium and combined Ra-226 + Ra-228 concentrations were above detection limits more than 50 percent of the time, but still below maximum contaminant levels (MCL).

The nitrate concentration in well 903 reveals one statistically significant difference between background and "transition" wells. Transition well 903, closest to the plume, had higher nitrate concentrations than other transition and background wells although the observed concentration is still below the MCL. The higher concentrations may indicate that the leading edge of the contaminant plume has reached monitor well 903. Sulfate appears to show similar behavior as discussed in Section 2.4.3 below.

2.4.3 Magnitude of site-related groundwater contamination

Monitor wells 906, 908, 909, and 912, which are within the plume area, have water quality data for 1988 to 1992. Waters from the wells have high total dissolved solids ranging from 750 to 7200 mg/L and a pH ranging from 6.0 to 7.0. Figure 2.5 is a plot of sulfate versus chloride concentrations. The plume waters are clearly enriched in both sulfate and chloride relative to background waters.

Concentrations of many inorganic constituents in the plume wells were found comparable to background (Table 2.1). However, 18 constituents were found in concentrations statistically higher in the plume wells than in the background wells: ammonia, cadmium, calcium, chloride, chromium, iron, lead, magnesium, molybdenum, nitrate, potassium, selenium, sodium, strontium, sulfate, tin, uranium, and zinc. Evidence for elevated concentrations of cadmium, chromium, lead, tin, and zinc is not conclusive because either the elevated values were obtained in a single sampling round or the detected values are at or near the detection limit. As such, these values could be an artifact of the sampling or analysis process.

In 1988, a screening for organic contaminants was conducted. Monitor wells 901, 906, and 908 were sampled and analyzed for all organic hazardous constituents listed in Appendix IX to 40 CFR Part 264 of the Resource Conservation and Recovery Act (RCRA). No hazardous organics were detected in this screening.

FIGURE 2.5

Figure 2.6 is a plot showing concentrations of uranium versus sulfate in plume waters. On the basis of this plot, there are at least two different source terms for uranium. One has a uranium:sulfate proportion of approximately 1:2500 (wells 908, 909, and 912), while the other (well 906) has a ratio closer to 1:30,000. Because wells 908, 909, and 912 are further from the tailings and have higher sulfate contents (i.e., sulfuric acid), they may reflect the early acid-leach operation at the site, while well 906 may reflect the later carbonate-leach/acid-leach operation.

Nitrate concentrations exceeded background in all plume monitor wells. Figure 2.7 is a map showing the schematic spatial distribution of "above background" nitrate levels. The contaminant plume is not migrating very fast, because the nitrate concentrations are relatively constant with time in a given well within the plume (Figures 2.8 and 2.9).

The sulfate contamination plume from the site shows similar behavior (Figure 2.10). However, in this case, well 908 displays a trend toward decreasing concentrations with time (Figure 2.11). In transition well 903, the time-series plot shows a clear increase in sulfate concentrations with time (Figure 2.10). If waters in well 903 originally had sulfate concentrations similar to those observed in background wells 901 and 914, the trend line for well 903 suggests that part of the plume might have reached this well prior to 1988. The trend for well 903 likely reflects a rather irregularly shaped leading edge of the plume resulting from longitudinal dispersion (Freeze and Cherry, 1979). The trend in nitrate data for well 903 may reflect the same phenomenon.

2.4.4 Surface water monitoring

Flow rate calculations using mean groundwater velocities [30 ft/yr (10 m/yr)] show that groundwater from underneath the disposal cell requires more than 200 years to reach Moenkopi Wash. Since the mill did not begin operating until 1956, it is highly unlikely that the water in Moenkopi Wash originated as groundwater from under the disposal cell.

Figure 2.12 shows surface water sampling points in Moenkopi Wash. No evidence exists that the disposal cell has impacted the water quality of Moenkopi Wash. Nitrate is the major contaminant of concern at the site and is a conservative chemical species. Therefore, elevated nitrate concentrations in water sampled from Moenkopi Wash would be the strongest indication that water quality is being impacted by tailings seepage from the disposal cell. Nitrate levels are on the order of 1000 mg/L in groundwater beneath the disposal cell, yet have been found to be well within background groundwater concentrations (<1.0 to 21 mg/L) in water sampled from Moenkopi Wash. The same general relationship between contaminated groundwater and water from Moenkopi Wash holds true for the other contaminants of cadmium, lead, molybdenum, selenium, and uranium.

GROUNDWATER QUALITY DATA SITE: TUB01
 LOCATION: 0903, 0906, 0908, 0909, 0912, 0917

FIGURE 2.6
 BIVARIATE PLOT OF URANIUM VERSUS SULFATE
 TUBA CITY SITE

FIGURE 2.7
EXTENT OF NITRATE-CONTAMINATED GROUNDWATER
TUBA CITY, ARIZONA, DISPOSAL SITE

FIGURE 2.8
NITRATE CONCENTRATIONS IN PLUME WELLS, 1988 - 1992
TUBA CITY SITE

FIGURE 2.9
NITRATE CONCENTRATIONS IN BACKGROUND WELLS AND WELL 903, 1988 - 1992
TUBA CITY SITE

FIGURE 2.10
SULFATE CONCENTRATIONS IN BACKGROUND WELLS AND WELL 903, 1988 - 1992
TUBA CITY SITE

FIGURE 2.11
SULFATE CONCENTRATIONS IN PLUME WELLS, 1988 - 1992
TUBA CITY SITE

FIGURE 2.12
SURFACE WATER MONITORING LOCATIONS

2.5 SITE CONCEPTUAL MODEL

Figure 2.13 shows a conceptual hydrogeologic model of the processing site. This model forms the basis for the site hydrogeochemical model.

The background groundwaters are relatively dilute sodium and calcium bicarbonate waters with a pH somewhat above 7 and generally oxidizing redox potentials. Because these waters occur in essentially the same unit (N-aquifer), they do not show much chemistry variation.

The plume waters contain chemicals (e.g., sulfuric acid) used in uranium processing operations and have lower pH and lower redox potentials.

Hazardous constituents in the plume waters will be subject to dilution and various chemical reactions including redox reactions, precipitation and coprecipitation reactions, adsorption onto aquifer mineral surfaces, and reactions with biologic organisms. Of the main contaminants of concern, uranium, molybdenum, and possibly selenium concentrations will decrease mainly by dilution and adsorption. Selenium concentrations also might decrease as a result of elemental selenium precipitation. Ammonium concentrations will decrease as a result of oxidation to nitrate. Nitrate concentrations will decrease as a result of natural denitrification reactions involving indigenous organisms. These reactions produce nitrogen gas, which will be released to the atmosphere.

REF: FBDU, 1977

FIGURE 2.13
SIMPLIFIED STRATIGRAPHIC CROSS SECTION OF THE TUBA CITY
URANIUM MILL TAILINGS PILE AND SUBSURFACE GEOLOGY

3.0 DATA COLLECTION OBJECTIVES

Water quality and hydrologic data obtained by implementing this sampling plan will address data collection objectives relating to 1) regulatory requirements compliance, 2) initial performance demonstration of the disposal cell, 3) site characterization, 4) risk assessment considerations, and 5) other site-specific considerations.

3.1 REGULATORY REQUIREMENTS

To obtain conditional concurrence for the proposed remedial action, the DOE will monitor and characterize the existing plume until the U.S. Environmental Protection Agency (EPA) promulgates the final groundwater standards. The DOE then will determine what actions are needed to bring groundwater into compliance and submit its strategy to the NRC for concurrence.

3.2 LONG-TERM PERFORMANCE MONITORING

The data collection objectives for cell performance assessment at the Tuba City site are discussed in the LTSP for Tuba City, Arizona (DOE, 1992). The data collection objectives focus on early detection of contaminant leakage from the disposal cell through a screening monitoring program. This program consists of regular sampling of background wells and wells downgradient of the disposal cell for contaminants of concern. The data collection objectives may also involve evaluative monitoring and/or indirect monitoring if cell performance is in question. Section 5.0 discusses selecting monitor well locations, analytes, and monitoring frequency for cell performance assessment.

3.3 SITE CHARACTERIZATION MONITORING

Characterization of contaminant migration will be an ongoing site characterization activity. Because nitrate is a major contaminant of concern and is not retarded by precipitation or adsorption reactions, its concentration guides the plume distribution and migration rate. Although the nitrate concentration may decrease due to denitrification reactions, the natural rate of these reactions is slow enough to be a secondary effect. Additionally, sulfate concentrations provide a backup to nitrate concentrations in terms of plume distribution and migration rate. Sampling well 903 is particularly important in defining the plume migration rate because it is on the plume's outermost edge. Additional wells would be required to sufficiently characterize the lateral and vertical extent of groundwater contamination at the site.

No evidence exists that the Tuba City disposal cell contributes to water quality in Moenkopi Wash. Those contaminants found in the plume are at or near background groundwater concentrations for water sampled from Moenkopi Wash. To the extent practicable, surface stabilization of the tailings has eliminated the source of any surface water contamination from the site.

3.4 RISK ASSESSMENT CONSIDERATIONS

The baseline risk assessment determined that the contaminants of concern are cadmium, lead, molybdenum, nitrate, selenium, sulfate, and uranium. Molybdenum exceeded its MCL only once in two separate wells. Data are inconclusive whether lead is present above background levels. Additional sampling for lead is needed to evaluate its presence because even low levels can be significant. Selenium was detected above its MCL in background and in on-site wells close to the former tailings pile or the evaporation ponds. Uranium and nitrate exceeded their respective MCLs in on-site wells and, therefore, are the main contaminants of concern.

3.5 OTHER CONSIDERATIONS

Currently, no other water sampling concerns are at the site that have not already been addressed in Sections 3.1 through 3.4.

4.0 DATA QUALITY OBJECTIVES

For most purposes of the UMTRA Project, the data quality objectives (DQO) will be defined by the analytical support levels required to meet DQOs. Four analytical support levels are defined (DOE, 1990) as follows:

- Levels A and B for field analyses.
- Levels C and D for laboratory analyses.

Data meeting Level A criteria are nonquantitative or semiquantitative and are used as indicator parameters. Level B analyses are quantitative analyses conducted in the field. Level C analyses are analyses conducted in a qualified laboratory.

The UMTRA Project has established standard operating procedures (SOP) for water sampling, preservation, and transport (SOP 16.2.1) and various field procedures [SOP 16.1.3 through 16.3.1 (titles available in Permanent Site File)] (TAC, 1985). Subcontract laboratory work is performed according to specifications provided in the project statement of work (TAC, 1993).

Quality assurance (QA) activities, including analytical data management (SOP 16.3.3) and data validation (SOP 16.3.2), will be performed in accordance with standard industry practice and DOE Order 5700.6C, *Quality Assurance*.

The UMTRA Project Office will be responsible for groundwater monitoring compliance at the Tuba City disposal site until the Tuba City UMTRA site is licensed. During this time, all groundwater monitoring aspects will be conducted in accordance with these SOPs and will be updated regularly to reflect changes in industry standards, best management practices, or EPA guidance. The QA procedures described in this section are consistent with the *RCRA Ground Water Monitoring Technical Enforcement Guidance Document* (EPA, 1986).

Upon licensing, responsibility for groundwater monitoring will transfer to the GJPO. The GJPO will establish procedures and develop a quality assurance/quality control program consistent with EPA guidance.

The following sections summarize standard procedures to be followed by both the UMTRA Project Office and GJPO.

4.1 WATER SAMPLING PROCEDURES

Qualified personnel trained in field data collection, sample preservation and shipping, and chain-of-custody documentation will perform all sampling. The permanent site file will include all field forms, records, and chain-of-custody forms.

During sampling, temperature, pH, specific conductance, dissolved oxygen, and oxidation/reduction potential will be monitored during the purging process.

These parameters will be measured to ensure stabilization prior to sample collection and to provide data for geochemical evaluation. A carbonate alkalinity test will be performed on each sample. Appropriate preservatives will be added to the sample bottles and the samples will be refrigerated, if required, and shipped to the laboratory no later than 72 hours after sampling.

4.2 ANALYTICAL QUALITY CONTROL

Analyses performed at the subcontract laboratories generally consist of concentration or activity determination for analytes of interest in water samples. EPA's Contract Laboratory Statement of Work (CLP SOW) (TAC, 1993) specifies the type and frequency of quality control (QC) analyses. While the CLP SOW does not address all analytes of interest for the UMTRA Project, CLP QC practices extend to UMTRA Project analytes where possible.

The UMTRA Technical Assistance Contractor statement of work (TAC, 1993) identifies specifications for QC samples (type and number).

4.3 ANALYTICAL QUALITY ASSURANCE

The UMTRA Project implemented a formal analytical subcontract laboratory selection process that includes prequalification, annual systems audits, and quarterly performance evaluations. Subcontract laboratories performing radiochemical analyses are required to participate in the DOE Environmental Measurement Laboratory interlaboratory comparison program, in conformance with DOE Order 5400.1, *General Environmental Protection Program*, as well as the EPA Environmental Monitoring Systems Laboratory intercomparison program.

4.4 ANALYTICAL DATA VALIDATION

UMTRA Project Office guidelines for subcontract laboratory data validation conform to or exceed the level C DQOs set forth in the DOE's Hazardous Waste Remedial Actions Program (HAZWRAP) *Requirements for Quality Control of Analytical Data* (DOE, 1990). Precision and accuracy criteria specified for level C data validation in HAZWRAP are employed in the validation process for most general inorganic analyses; however, these QC practices are not applicable to all analytes of interest on the UMTRA Project. SOP 16.3.2 provides specific data validation procedures covering all UMTRA analytes.

In addition to the HAZWRAP QC requirements, verification of unbroken chain of custody and conformance with UMTRA Project sampling procedures and EPA-specified holding times will be monitored. Analytical results are archived in the permanent site file.

Furthermore, a statistical program associated with the project data base compares new and existing data to check for anomalies.

5.0 SAMPLING PLAN

5.1 SAMPLING LOCATIONS

5.1.1 Monitor wells

The groundwater monitoring network will consist of 14 existing monitor wells. Five of these wells (906, 908, 909, 912, and 913) will be plume monitor wells used to measure groundwater quality and static water levels. They will be located in the plume immediately downgradient from the site (Figure 2.1). The wells have been placed to provide early detection of baseline water quality changes. As shown in Table 1.1, six wells are screened approximately 60 ft bls, six are screened approximately 150 ft bls, and two are screened approximately 350 ft bls.

Background monitoring wells include two upgradient wells (monitor wells 901 and 910) screened at various depths (Table 2.1), one cross-gradient well (917), and six downgradient ("transition") wells. Three of the latter wells (monitor wells 901, 920, and 921) are in a cluster, are completed to various depths (Table 2.1), and are spatially near the leading edge of the nitrate plume. The other three wells are further downgradient to detect contaminants if they move substantially further downgradient or further off the site. If the plume intersects these wells, they will become plume monitor wells.

Surface sampling sites along Moenkopi Wash (shown in Figure 2.12) will not be sampled in FY93 for reasons discussed in Section 2.4.4.

5.2 CONSTITUENT SELECTION

5.2.1 Field parameters

Alkalinity, pH, specific conductance, temperature, dissolved oxygen, oxidation/reduction potential, and selected redox couples are constituents and/or parameters measured in the field. Alkalinity, pH, specific conductance, and temperature are easily measured and provide early indications of changes in groundwater quality. Redox couple measurements are the only accurate method to obtain Eh data for the different wells. The Eh data will be used to predict transport behavior of redox-sensitive contaminants of concern (e.g., uranium and selenium).

5.2.2 Laboratory analysis

Based on the discussion in Section 3.0, the following constituents and/or parameters will be measured in all water samples collected at the site:

- Contaminants: cadmium, lead, molybdenum, nitrate, selenium, and uranium.

- Major cations: calcium, iron, potassium, magnesium, manganese, and sodium.
- Major anions: chloride, sulfate, and total dissolved solids.

Contaminant species are sampled and analyzed when they exceed their MCLs in one or more monitoring wells at the site. If future sampling and analysis show one or more of these constituents consistently below its MCL, that constituent can be removed from this list.

There are two reasons for sampling and analysis of the major ions: 1) these constituents provide an early indication of plume behavior, and 2) the waters should be sufficiently well-characterized to calculate saturation indices of the major mineral phases likely to occur in the system. The precipitation or dissolution of these phases could significantly affect the migration rate of the contaminants.

5.3 SAMPLING FREQUENCY

The schedule for water sampling is designed to provide a reasonably complete characterization of the contaminant plume at the Tuba City, to allow adequate performance monitoring of the disposal cell, and to monitor any variations in background water quality. The schedule accounts for background water quality, the geochemistry of the tailings pore solution, groundwater flow rate, possible seasonal variations in groundwater quality, and risk to human health and the environment.

For the evaluation of contaminant concentration trends, monitor wells (background, plume, and downgradient) will be sampled annually. For consistency, sampling will be conducted at approximately the same time each year. Data will be evaluated with respect to the statistical data presented in Table 2.1 and the trends and associations shown in Figures 2.4 through 2.11.

5.4 RESPONSE TO ANOMALOUS DATA

With regard to cell performance monitoring, if a concentration or activity is above or below a range of expected values established for the site, the following steps will be taken:

- The result will be examined to determine if a procedural error has occurred in the field, in the laboratory, or during data management. This examination may include, but not be limited to the following:
 - Review of field notes to ascertain potential error in sampling location or procedure.
 - Verification that the laboratory work has met QA requirements.

- Review of data management work to determine if a transcription or other data-handling error has occurred.
- If a procedural error is uncovered and can be corrected (e.g., a mistake in transcription), no further verification action will be taken and routine monitoring will resume.
- If a lapse in laboratory QA is discovered, which can be corrected by reanalysis within required holding times of the portion of the sample that remains in the laboratory, reanalysis will be performed.
- Resampling may be necessary if an insufficient sample remains in the laboratory for reanalysis, if holding-time requirements cannot be met, if a lapse in field sampling procedure is determined to have occurred, or, more generally, if confirmation of the result is desired. The decision to resample immediately or wait until the next regularly scheduled sampling depends on the nature and level of the contaminant species exceeding its MCL, hydrogeologic conditions (e.g., location of the sampling point and groundwater velocity), water quality at other locations, and potential risk due to the MCL exceeded. The NRC and other interested parties will consult to determine when to resample.
- After completing the aforementioned steps, the data that still exceed the limits will be reviewed to determine a cause other than a shortfall in cell performance. This review may include any of the following means of assessment:
 - Review of background water quality for potential trends.
 - Comparison of upgradient and downgradient water quality.
 - Investigation of changes in the major-ion concentrations or field parameters.
 - Review of the statistical distributions of other monitored contaminant concentrations and determination of whether the sample is a statistical outlier.
 - Review of variations in the hydrologic regime (e.g., water levels, recharge, and climate).

Data will be evaluated, including determinations of trends or MCLs exceeded, using statistical methods that are in accord with standard industry practice. Specifically, EPA's *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities - Interim Final Guidance* (EPA, 1989) will be used as the basis for statistical methodologies.

6.0 LIST OF CONTRIBUTORS

The following individuals contributed to the preparation of this report.

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R. Bennett, J. Gibb, M. Minter, R. Saar	Technical review
L. Keith	Text processing
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K. Walston	Technical editing

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CODE OF FEDERAL REGULATIONS

- 10 CFR 40, "Domestic Licensing of Source Material," *Code of Federal Regulations*, Title 10, Part 40, U.S. Nuclear Regulatory Commission, Office of the Federal Register National Archives and Records Administration, Washington, D.C.
- 40 CFR 264, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," *Code of Federal Regulations*, Title 40, Part 264, U.S. Environmental Protection Agency, Office of the Federal Register National Archives and Records Administration, Washington, D.C.

DOE ORDERS

- Order 5400.1, *General Environmental Protection Program*, June 29, 1990, U.S. Department of Energy, Environmental Protection Division, Office of Environment, Safety and Health, Washington, D.C.
- Order 5700.6C, *Quality Assurance*, August 21, 1991, Office of Nuclear Energy and Office of Environment, Safety, and Health, U.S. Department of Energy, Washington, D.C.

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