EPA 906/9-75-002

PB 251 470

WATER QUALITY IMPACTS OF URANIUM MINING AND MILLING ACTIVITIES IN THE GRANTS MINERAL BELT, NEW MEXICO

011446

U. S. ENVIRONMENTAL PROTECTION AGENCY
REGION VI, DALLAS, TEXAS 75201

September 1975

928992

Sample No.	Station Description	Date	TDS	SO_4	Cl	NH_3	$NO_2 + NO_3$ as N
					mg/l		
9134	UN HP SUPPLY WELL 2	Mar. 3	1,600		0.2	0.03	0.42
9135	UN HP WELL 0	Mar. 3	4,500		340	1.0	2.6
9136	UN HP SUPPLY WELL 1	Mar. 3	2,000		<0.2	0.07	0.28
9137	[illegible] WELL - GALLUP	Mar. 5	730		14	0.03	0.07
9138	BOARDMAN TRAILER PARK - GALLUP	Mar. 5	930		<0.2	0.50	1.2
9139	G HASSLER - GALLUP	Mar. 5	[illegible]		98	0.02	27
9140	DIXIE WELL - GALLUP	Mar. 5	1,500		<0.2	0.30	0.16
9141	CHURCHROCK VILLAGE	Mar. 5	720		0.5	0.50	0.18
9142	WHITE WELL - GALLUP	Mar. 5	620		630	0.01	0.02
9143	TOGAY WELL - GALLUP	Mar. 5	340		14	0.02	8.0
9201	PHIL HARRIS (WILCOXSON) KM 46	Feb. 26	[illegible]		23	0.14	0.09
9202	COUNTY LINE STOCK TANK KM 52	Feb. 26	2,100		56	0.06	14
9203	NAVAJO WIND MILL KM 45	Feb. 26	400		6.8	0.02	4.0
9204	INGERSOLL RAND KM 49	Feb. 26	2,200		36	0.03	18
9205	BINGHAM (RAGLAND) KM 47	Feb. 26	2,000		40	0.04	4.7
9206	MARQUEZ (RAGLAND) KM 63	Feb. 26	1,900		34	0.05	44
9207	KM-S-12	Feb. 27	14,000		3,100	0.50	0.04
9208	KM-43	Feb. 27	7,900		38	NS	NS
9209	KM-44	Feb. 27	2,700		17	0.6	11
9210	KM-51	Feb. 27	6,300		44	0.30	79
9211	KM-48	Feb. 27	4,100		31	0.80	1.3
9212	KM SEEPAGE RETURN	Mar. 3	36,000		3,100	590	12
9213	KM 8-2	Mar. 3	8,900		3,400	0.12	0.25
9214	KM 36-2	Mar. 3	9,100		1,700	2.9	8.0
9215	KM 46	Mar. 3	3,700		130	10	2.0
9216	KM 47	Mar. 3	2,000		74	0.80	2.5
9217	KM 50	Mar. 3	4,700		470	9.1	16
9218	KM 51	Mar. 3	4,800		61	0.16	0.40
9219	KM 52	Mar. 3	6,700		1,300	0.08	1.3
9220	HARDGROUND FLATS WELL CRKM 2	Mar. 5	850		0.2	0.03	0.28
9221	E PUERCO R WELL CRKM 11	Mar. 5	340		14	0.04	14

C15

Pre-tailings Data, 2-3/75
Regional water Qual.
Radionuclides & nitrate

011448

Effects of Uranium Mining and Milling on Ground Water in the Grants Mineral Belt, New Mexico

by Robert F. Kaufmann, Gregory G. Eadie, and Charles R. Russell

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011449

ABSTRACT

Ground-water contamination from uranium mining and milling results from the infiltration of mine, mill, and ion-exchange plant effluents containing elevated concentrations of radium, selenium, and nitrate. Available data indicate that radium concentrations in the discharge waters of a producing mine tend to increase substantially as the ore body is developed. Whereas natural background radium concentrations are generally about several picocuries/liter (pCi/l), 100 to 150 pCi/l appear in the effluents of operating mines. The discharge of such highly contaminated mine effluents to streams and seepage from tailings ponds, creates a long-lived source of ground-water contamination. Seepage of mill tailings at two active mills ranges from 126,000 to 491,000 m^3/yr and, to date, has contributed an estimated 2400 Curies of uranium, radium, and thorium to the ground-water reservoir. The shallow aquifer in use and downgradient from another mill has been grossly contaminated with selenium, attributable to excessive seepage from a nearby tailings pond.

Radium, selenium, nitrate and, to a lesser extent, uranium, are of most value as indicators of ground-water contamination. Gross alpha results are not consistent indicators of radium or uranium in water, although uranium does appear to be the principal contributor of alpha activity. Accurate radium-226 analyses yield the most information for radiological evaluation of drinking water.

To date, no adverse impacts on municipal ground-water supplies have been observed. However, industry-sponsored environmental monitoring programs are inadequately designed and implemented, and may not define the full, long-term impact of mining and milling operations on the ground-water quality of the study area.

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Discussion open until February 1, 1977.

INTRODUCTION

At the request of the New Mexico Environmental Improvement Agency (NMEIA), Region VI of the U.S. Environmental Protection Agency (USEPA) arranged for a water quality survey in the Grants Mineral Belt in northwestern New Mexico. As of 1974, this area contained about 42 percent of the U.S. reserves, and in 1975 produced 5,500 tons of uranium concentrate, or approximately 45 percent of U.S. production. The following mining districts dominate the Grants Mineral Belt: Churchrock on the west, Grants-Ambrosia Lake in the center, and Paguate-Jackpile on the east (Figure 1).

Whereas the influence of uranium mining and milling on surface-water quality and stream biota has been documented (Anderson *et al.*, 1963; Sigler *et al.*, 1966; Tsivoglou *et al.*, 1956, 1959, 1960; and Wruble *et al.*, 1964), the effects on ground water are rather poorly understood. With the passage of the Safe Drinking Water Act and increased interest in the preservation of water quality, there is a continuing need for reassessment of mining and mineral-processing operations because of their intimate association with ground water. Mention of ground-water contamination in New Mexico from uranium milling is contained in studies by Tsivoglou and O'Connell (1962) and Clark (1974) and site specific, unpublished studies in the study area were conducted some years ago by the New Mexico Department of Public Health (1957) and by Chavez (1961).

Ground-water and surface-water data were collected in February-March, 1975 by the Office of Radiation Programs—Las Vegas Facility and the National Enforcement Investigations Center,

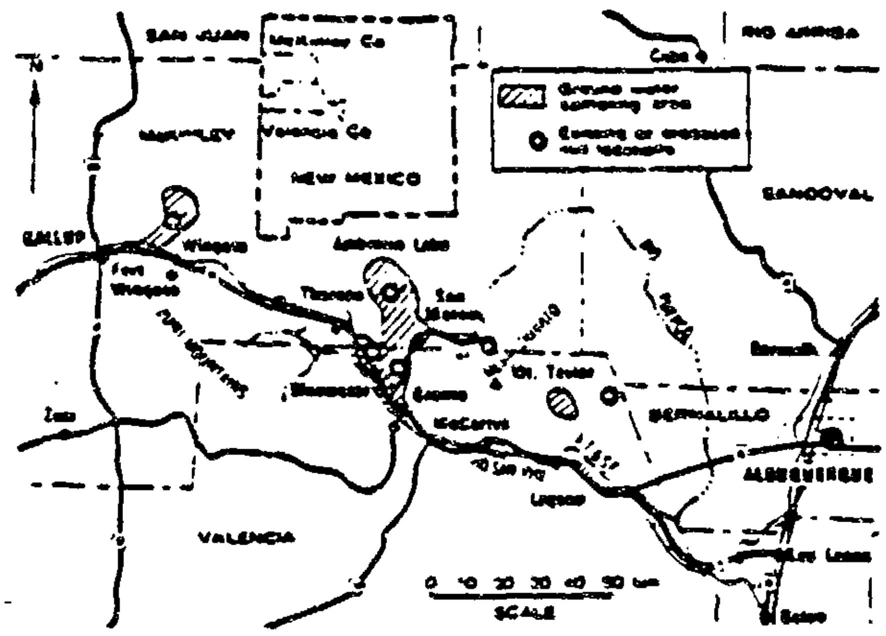

Fig. 1. Location of study areas in the Grants Mineral Belt.

respectively. This paper is a condensed version of an extensive report submitted to Region VI (Kaufmann *et al.*, 1975) which, in turn, reported the entire study results to the State (U.S. Environmental Protection Agency, 1975b).

GEOLOGY AND HYDROLOGY

The principal bedrock and alluvial stratigraphic units in the Grants Mineral Belt range in age from Pennsylvanian to Recent (Hilpert, 1963). Figure 2, which is a generalized geologic cross section through the Grants and Ambrosia Lake areas, portrays these units and the dominant structural feature which is the Chaco slope developed on the north flank of the Zuni uplift. Conditions in the Churchrock area are essentially the same.

Due to the scarcity of perennial surface-water bodies, ground water is the principal source of water in the study area. Industrial, municipal, stock, and private domestic wells tap both bedrock and alluvial aquifers. In general, wells of low to moderate productivity are possible in the unconsolidated valley fill which constitutes an aquifer, primarily along the broad valleys of the Rio San Jose and the Rio Puerco. Numerous shallow domestic wells south and southwest of the United Nuclear-Homestake Partners mill north of Milan also tap the shallow, unconfined aquifer. The principal bedrock aquifers are the San Andres Limestone and the Westwater Canyon Member of the Morrison Formation.

GROUND-WATER QUALITY

For about the last 20 years, uranium mining and milling activities in the Grants Mineral Belt consisted of underground and open-pit mining and alkaline or acid-leach milling. Active tailings piles are present in close association with three active mills run by the Kermac Nuclear Fuels Corporation (Kerr-McGee), the United Nuclear-Homestake Partners Corporation, and the Anaconda Company. Inactive tailings piles are related to the now inoperative United Nuclear-New Mexico Partners and Phillips mills located just north of Milan and in Ambrosia Lake, respectively. In recent years, increasing use has been made of ion exchange plants to recover uranium from mine drainage water and from injected fluids introduced for solution mining.

The variety of mining and milling operations in the study area and the paucity of hydrogeologic and water quality data necessitate that the following discussion be regarded as a preliminary assessment. For example, the hydraulic and water quality effects of solution mining and dewatering of ore bodies are scarcely known outside industry circles. Similarly unknown is the extent of dewatering of the ore-bearing formations, chief of which is the Westwater Canyon Member of the Morrision Formation. To a lesser extent, the overlying strata such as the Dakota Formation are also affected. In the Churchrock area, the static water level in an

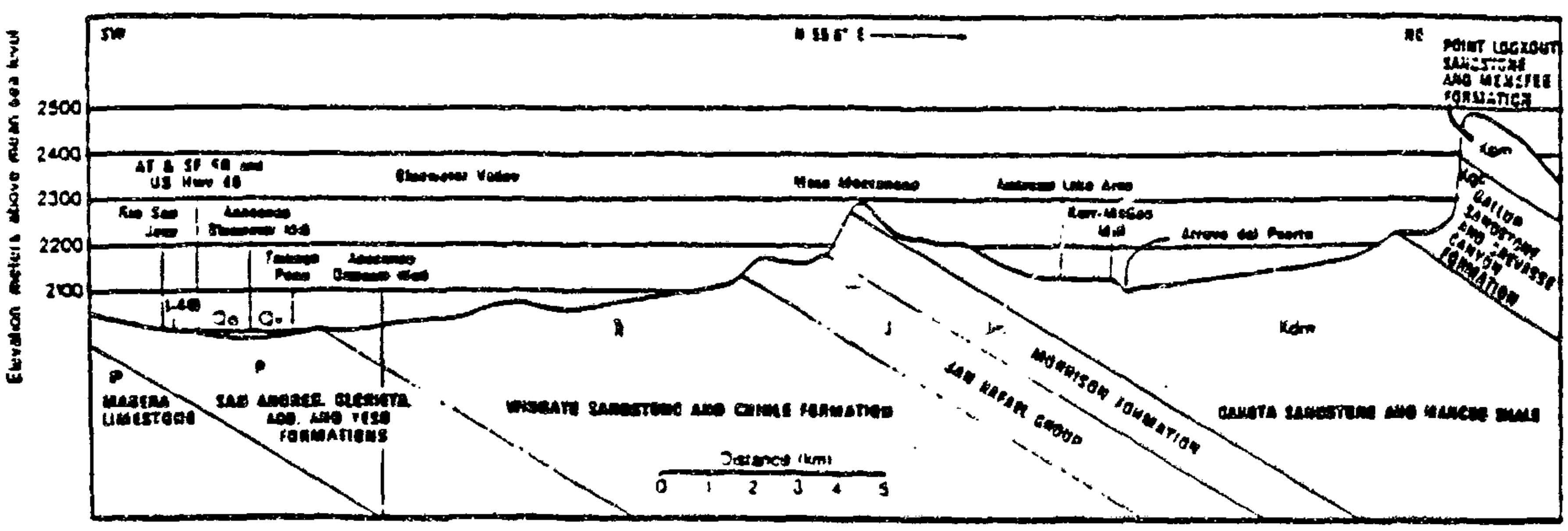

Fig. 2. Generalized geologic section from Bluewater to Ambrosia Lake.

inactive mine is declining about 0.3 meter per month due to dewatering at the nearby United Nuclear and Kerr-McGee mines.

Discharge of the mine water transforms nearby dry washes and ephemeral streams (Rio Puerco, Arroyo del Puerto, and San Mateo Creek) into perennial ones. Water introduced to these channels persists until the losses due to bed infiltration, evapotranspiration, and diversion equal inflow. Infiltration of such waters to shallow alluvial aquifers may be adverse, depending on the quality of infiltrating water relative to ambient water quality in the aquifer, and the use to which shallow ground water is or will be put.

Concentrations of selected radionuclides, as well as gross and trace chemical constituents, were determined for 71 wells in the study area. The data plus inventory information concerning well locations, static water levels, well depths, and water use are contained in Kaufmann *et al.* (1975). Unequivocal bases for distinguishing truly background water quality conditions in an area of uranium mineralization do not exist. Variability in radionuclide concentrations is particularly pronounced in areas underlain by mid to late Mesozoic clastics. However, distinctions can be drawn between such units and Paleozoic or early Mesozoic strata. By comparing gross, trace, and radiochemical parameters in conjunction with hydrogeologic conditions and land/water use patterns, reasonable inferences can be made concerning natural and contaminated water quality. Selected radiochemical data, which were of chief concern in the ground-water portion of the study, are shown in Tables 1 and 2. The data are discussed by study area and by the principal uranium mining/milling activities therein. Concentrations are shown in picocuries (pCi) per liter, with a picocurie equal to 10^{-12} Curies. A Curie equals 3.7×10^{9} disintegrations per second or approximately the activity of one gram of radium.

Bluewater-Milan-Grants

Acidic uranium milling wastes from the Anaconda Company tailings ponds and injection well enter both shallow and deep ground-water bodies in the Bluewater-Milan-Grants area. The southeastward flow gradient in the unconfined aquifer (Figure 3) would cause contaminants to move toward points of withdrawal for irrigation, domestic, and municipal use. In the use of the injection well, there is concern whether contaminants continue to remain confined to the deep injection zone, as originally projected.

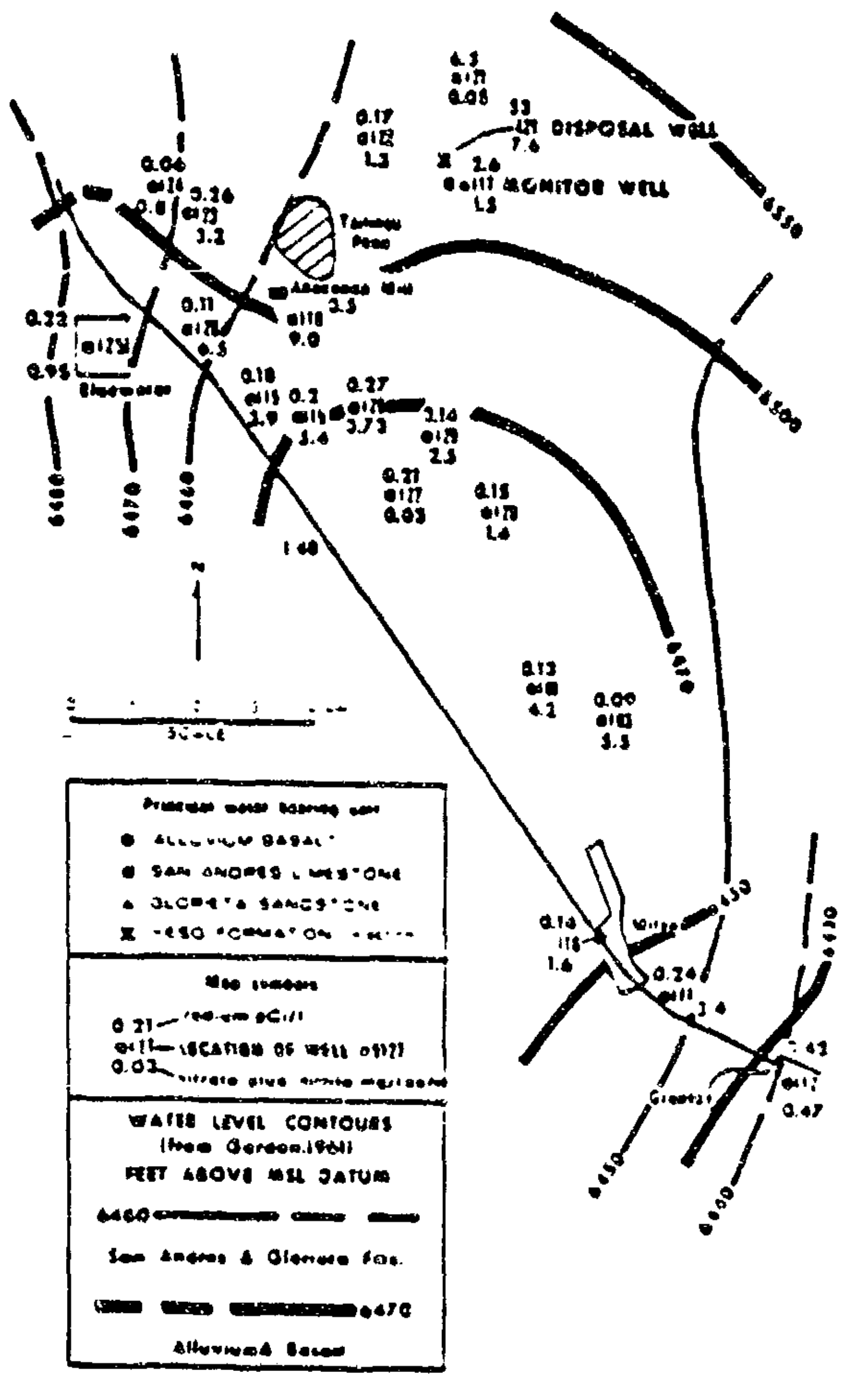

Fig. 3. Radium and nitrate concentrations in ground water—Bluewater-Grants area.

The New Mexico Department of Public Health (1957) noted that extensive migration of nitrate from the tailings ponds was contaminating the shallow aquifer. West (1972) stated that excessive leakage in the period 1953-1960 necessitated adoption of the injection well alternative for effluent disposal. The ponds are underlain by highly permeable basalt flows covered in places with a veneer of carbonate-rich silt and clay. Direct contact of the tailings with the basalt and dissolution of the silt and clay layer increase seepage.

In 1973 and 1974, the average seepage rate was 180,000 cubic meters per year (m^3/yr) compared to an average injection rate of 348,000 m^3/yr (Gray, 1975); thus, the ratio of seepage to injection is 0.52. Using this ratio and the injection volume (Gray, 1975; West, 1972) total seepage from 1960 through 1973 is estimated to have been 1.97 million m^3. Alternately, if seepage is calculated as a percentage of inflow to the ponds, approximately 8 percent (174,000 m^3) infiltrated

Table 1. Radiological Data for Selected Ground-Water Samples (Concentrations, pCi/l)[1] Grants Mineral Belt, New Mexico

Location Number	Location Description	Gross Alpha	Ra-226 NEIC	Ra-226 DTSL	Th-230	Th-232	Po-210
	Paguate-Jackpile						
9230	Well #4	<2 ± 6	0.31 ± .02	0.23 ± .095	<0.029	<0.012	0.31 ± .11
9231	Well P-10	10 ± 10	1.7 ± .05		<0.016	<0.016	0.29 ± .11
9232	New Shop Well	18 ± 13	3.7 ± .08		<0.016	<0.011	0.69 ± .20
9233	Paguate Municipal Well	2 ± 4	0.18 ± .02	0.10 ± .072	<0.018	<0.010	0.39 ± .18
	Grants--Bluewater Area						
9021	Injection well Anaconda Company	62,500 ± 1,300	53 ± 1	61 ± 1.4	82,000 ± 1,200	51 ± 30	3,100 ± 250
9101	Mt. Taylor Mill Works Old Rt. 56	9 ± 11	0.13 ± .01				
9103	Private well	7 ± 10	0.09 ± .01				
9111	C & E Concrete	7 ± 9	0.24 ± .01		<0.028	<0.012	0.35 ± .15
9112	Grants City Hall	19 ± 13	0.42 ± .02	0.13 ± .098	0.046 ± .038	0.0094 ± .021	0.26 ± .16
9115	Private well	7 ± 12	0.18 ± .01				
9116	Milan well No. 1	12 ± 10	0.14 ± .01	0.14 ± .081	<0.0072	<0.013	0.30 ± .12
9117	Monitor well Anaconda Company	180 ± 40	2.6 ± .1	2.6 ± .30	<0.016	<0.0097	2.3 ± .90
9118	Well No. 2 Anaconda Company	290 ± 50	0.50 ± .02	0.21 ± .09	0.52 ± .093	0.54 ± .094	1.1 ± .37
9119	Well No. 4 Anaconda Company	12 ± 11	0.20 ± .01	0.18 ± .089	<0.030	<0.019	0.26 ± .19
9120	Mexican Camp	21 ± 12	0.27 ± .02		<0.017	<0.0055	0.66 ± .25
9121	Private well	12 ± 14	6.3 ± .1		<0.008	<0.0081	0.28 ± .17
9122	North well	30 ± 17	0.17 ± .01	0.33 ± .12	0.034 ± .024	<0.0084	0.51 ± .17
9123	Engineer's Well	20 ± 13	0.25 ± .01	0.38 ± .11	0.033 ± .026	<0.016	0.48 ± .28
9124	Private well	16 ± 12	0.06 ± .01				
9125	LDS Church--Bluewater	8 ± 10	0.22 ± .01	0.91 ± .18	<0.034	<0.012	<0.070
9126	Private well	5 ± 9	0.11 ± .01	0.44 ± .13	0.049 ± .031	<0.015	<0.10
9127	Private well	10 ± 10	0.21 ± .01	0.28 ± .11	<0.034	<0.029	0.39 ± .14
9128	Private well	11 ± 11	0.15 ± .01				
9129	Private well	<1.6 ± 7	0.14 ± .01	0.87 ± .29	<0.018	<0.012	0.31 ± .16
	United Nuclear - Homestake Partners						
9102	Private well	<3 ± 13	0.19 ± .01	0.22 ± .091	<0.021	<0.012	1.0 ± .95
9104	Private well	13 ± 14	[illegible] ± .01		0.048 ± .029	<0.021	0.31 ± .14
9105	Private well	140 ± 30	0.25 ± .01				
9106	Private well	12 ± 11	0.75 ± .01	0.19 ± .087	<0.017	<0.010	0.40 ± .26
9107	Private well	2500 ± 200	0.72 ± .02	0.79 ± .27	0.99 ± .13	0.034 ± .031	1.2 ± .52
9108	Private well	47 ± 23	0.33 ± .02		0.025 ± .023	<0.013	0.31 ± .14
9109	Private well	39 ± 17	0.13 ± .01				
9113	Private well	31 ± 17	0.17 ± .02	[illegible]	<0.037	<0.042	2.3 ± .69
9114	Private well	42 ± 18	0.25 ± .01	0.26 ± .13			
9133	Private well	10 ± 12	0.61 ± .03	0.65 ± .15	0.35 ± .078	<0.016	0.35 ± .24
9134	Well #2 [illegible]	9 ± 11	0.25 ± .01		0.045 ± .039	<0.025	0.78 ± .41
9135	Well 3 [illegible]	400 ± 70	1.92 ± .04	2.3 ± .31	0.13	<0.13	2.2 ± 2.1
9136	Well #1 [illegible]	22 ± 16	0.27 ± .02				
	Ambrosia Lake						
9130	Private well	3 ± 9	0.17 ± .01				
9131	Private well	18 ± 11	0.05 ± .01	0.22 ± .10	0.036 ± .025	<0.021	<0.55
9132	Private well	<1.0 ± 7	0.31 ± .02	0.27 ± .14	0.018	<0.012	0.79 ± .43
9201	Private well	110 ± 30	1.4 ± .1	1.3 ± .24	0.03 ± .027	<0.014	0.52 ± .16
9202	County Line Stock Tank	86 ± 31	0.23 ± .02		<0.029	<0.011	0.22 ± .10
9203	Navajo Windmill	13 ± 15	0.07 ± .01				
9204	Ingersoll Rand	3 ± 13	0.14 ± .01	0.20 ± .11	<0.015	<0.012	0.61 ± .21
9205	Private well	170 ± 40	0.19 ± .01				
9206	Private well	56 ± 25	0.50 ± .02				
9207	KM-5-12	210 ± 120	1.15 ± .03		0.27 ± .066	0.23 ± .062	<0.13
9208	KM-43	49 ± 35	4.0 ± .1	4.7 ± .40	0.021 ± .019	<0.014	<2.9
9209	KM-44	<2.0 ± 10	1.35 ± .04		<0.025	<0.020	0.58 ± .53
9210	KM-51	45 ± 29	1.25 ± .02	0.28 ± .12	<0.023	<0.0068	0.24 ± .16
9211	KM-48	1.0 ± 15	0.27 ± .01	0.76 ± .17	<0.013	<0.0080	2.7 ± .83
9212	KM-Seepage Return	112,000 ± 1,000	4.9 ± .1	10.0 ± .55	180,000 ± 1,600	170 ± 53	160 ± 130
9213	KM-8-2	8 ± 32	4.6 ± .1	6.6 ± .47	<0.018	<0.011	<0.94
9214	KM-36-2	14 ± 34	1.18 ± .03	1.5 ± .23	0.015	<0.014	0.70 ± .26
9215	KM-46	104 ± 37	2.5 ± .2	2.[illegible] ± .30	0.17 ± .057	<0.016	<0.38
9216	KM-47	45 ± 25	0.64 ± .02	1.4 ± .22	0.079 ± .039	<0.013	0.29 ± .20
9217	KM-50	70 ± 38	0.94 ± .03	0.72 ± .16	0.055 ± .035	<0.018	1.2 ± .84
9218	KM-5-1	20 ± 24	0.34 ± .02	0.34 ± .11	<0.021	<0.016	3.8 ± 2.6
9219	KM-5-2	67 ± 42	0.59 ± .02	0.78 ± .17	0.039	<0.031	0.96 ± .64
	Gallup-Churchrock						
9137	Private well	10 ± 9	0.68 ± .03	1.4 ± .22			
9138	Private well	6 ± 8	0.64 ± .02		0.088 ± .038	0.019	0.27 ± .20
9139	Private well	14 ± 11	0.22 ± .01				
9140	Private well	6 ± 10	0.10 ± .01	0.15 ± .082	<0.030	<0.016	0.50 ± .20
9141	Churchrock Village	3 ± 7	0.12 ± .01	0.26 ± .10	<0.028	<0.015	0.23 ± .11
9142	Private well	9 ± 9	0.16 ± .01	0.42 ± .13	0.073 ± .035	<0.011	<0.083
9143	(same as 9221)	14 ± 9	0.83 ± .04	0.38 ± .12	<0.044	<0.034	0.42 ± .17
9220	Hardground Flats Well-CRKM-2	12 ± 10	0.12 ± .01				
9221	E. Puerco River Well-CRKM-11	17 ± 10	0.56 ± .02	0.21 ± .093	<0.029	<0.016	0.19 ± .16
9222	Puerco Well CRKM-16	4 ± 9	0.57 ± .02				
9223	Pipeline Road Well-CRKM-5	4 ± 9	0.37 ± .02		0.037 ± .029	<0.012	0.32 ± .15
9224	Nose Rock Well CRKM-3	24 ± 12	0.13 ± .01	0.34 ± .12	0.053 ± .049	<0.036	0.23 ± .10
9225	N. E. Pipeline well CRKM-10	12 ± 15	0.29 ± .01	0.50 ± .13	<0.015	<0.011	0.56 ± .33

[1] Concentrations ± two sigma counting error, in pCi/L. Sources of analyses: Environmental Monitoring and Support Laboratory, USEPA: Ra-226, Th-230, Th-232, Po-210. National Enforcement Investigations Center, USEPA: Gross alpha, Ra-226. All analyses are on the filtered sample and therefore represent the concentrations actually in solution.

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Table 2. Uranium Concentration in Selected Ground-Water Samples[1] (Concentrations, pCi/l)[2]

LOCATION NUMBER	DESCRIPTION	U-234	U-235	U-238	U-NAT.
9021	Injection Well Anaconda Company	10,000 ± 750	420 ± 67	11,000 ± 770	88,000
9117	Monitor Well Anaconda Company	100 ± 7.7	3.3 ± .58	74 ± 5.7	379
9102	Private Well	10 ± .73	0.22 ± .048	7.7 ± .57	47
9133	Private Well	5.1 ± .44	[illegible] ± .06	[illegible] ± .31	-
9135	Well O-UNHP	240 ± 16	9.8 ± 1.1	240 ± 16	1,760
9132	Private Well Windmill	81 ± 5.1	2.8 ± .23	74 ± 4.7	68
9212	KM-Seepage Return	3100 ± 230	110 ± 35	3100 ± 280	-
9214	KM-36-2	11 ± .78	0.31 ± .058	6.8 ± .52	-
9219	KM-5-2	12 ± .83	0.27 ± .039	4.7 ± .37	-
9140	Private Well	1.8 ± .16	0.053 ± .022	1.4 ± .14	-
9232	New Shop Well-Jackpile	-	-	-	14
9233	Paguate Municipal Supply	-	-	-	27
9118	Well #2-Anaconda Company	-	-	-	880
9107	Private Well	-	-	-	9,478
9113	Private Well	-	-	-	54
9134	Well #2-UNHP	-	-	-	27
9201	Private Well	-	-	-	677
9141	Churchrock Village	-	-	-	14

1. Concentrations ± two sigma counting error, in pCi/l.
2. Sources of analyses: Isotopic uranium-Environmental Monitoring Support Laboratory (USEPA)
Uranium-natural by National Enforcement Investigations Center (USEPA), Denver, Colorado.

in 1973 and 1974 (from data supplied by Gray, 1975). Assuming 8 percent infiltration, and using inflow data from Beck (1975), seepage from 1960-1973 is estimated to have been 1.59 million m^3. Averaging both estimates, seepage from 1960-1973 is estimated to have been 127,000 m^3/yr. From mill startup in 1953 through 1959, pond inflow equaled 13.01 million m^3. Assuming 8 percent seepage loss, 1.04 million m^3 entered the shallow potable aquifer in Bluewater Valley. In summary, total seepage for the period 1953-1973 is estimated at 2.82 million m^3. Considering that from 1960 through 1973 the volume injected was 3.7 million m^3, the seepage to injection ratio was 0.76. In effect, there is almost as much water seeping into the shallow potable aquifer as there is being injected, thereby casting doubt on the efficiency of the tailings ponds for waste retention.

Because of excessive seepage from the tailings ponds in the period 1953-1960, the Anaconda Company developed an injection well for effluent disposal. Anaconda and U.S. Geological Survey reports (Fitch, 1959; West, 1972) showed that geologic, hydraulic, and water quality conditions justified this disposal method. However, subsequent evaluation of the monitoring data and inadequacies in the number and location of monitoring wells necessitate that this conclusion be reconsidered.

The disposal well was drilled in the period January-May 1959. Continuous core samples from 136 meters to total depth (765 meters) were tested for porosity, permeability, and ion exchange characteristics. Geophysical logs were taken for comparison with other lithologic and reservoir data. The thickness and character of the geologic units penetrated, as well as the construction features of the well, are summarized in Kaufmann *et al.* (1975). Detailed descriptions of the geologic formations and their transmissive properties are available (West, 1972).

From 1960 to date, injection has been into the Yeso and Abo formations at depths of 289 to 433 meters. Injection pressures of about 9 kg/cm^2 are developed from gravity head alone. The average injection rate from 1960 through 1973 was 504 l/min (0.5 m^3/min). Pretreatment of the injected waste consists of settling, filtration, and addition of chemicals to retard precipitation and plugging with organics (Clark, 1974).

From January 1960 through December 1965, 1.9 million m^3 of wastes with the following characteristics were injected (West, 1972):

	mg/l	*other*	*pCi/l*	*total Curies*
chloride	2,010			
nitrate	105			
sodium	1,390			
TDS	13,200			
pH		2.5		
uranium (natural)			7,340	13.89
Th-230			166,000	312.6
Ra-226			292	0.062

Although only intermittent data were available for the period from 1966 through 1973, they provide some indication of variations in the quality of water injected and (or) seeping from the tailings ponds. Clark (1974) reported that the mean radium content from 1960-1969 was 221 pCi/l. In 1972 and in the first half of 1974, respective concentrations of 41.1 and 156 pCi/l were observed. At the time of the field survey in February 1975, the average for two samples was 40 pCi/l. Thorium-230 is less variable. West (1972) reported 166,000 pCi/l of Th-230 for 1960-1965 versus 294,000 pCi/l in 1972 and 192,000 pCi/l in 1974.

Reported uranium values vary from 7,340 pCi/l for 1960-1965 (West, 1972) to 21,400 pCi/l in February 1975 (Table 2). Company data for 1972 and 1974 average 13,450 pCi/l.

Despite the volume of seepage from the ponds, contamination is not evident and the conclusion reached by the New Mexico Department of Public Health (1957) concerning the spread of a nitrate front is not borne out. Radium and nitrate concentrations in potable ground water that could be affected by seepage from the tailings are depicted in Figure 3. With the exception of the Berryhill Section 5 well (station no. 9121) and the Anaconda injection well (no. 9021), radium-226 in both the alluvial/basalt aquifer and in the underlying San Andres Limestone ranges from 0.06 to 0.42 pCi/l, and is well below the proposed drinking water standard of 5 pCi/l (U.S. Environmental Protection Agency, 1975a). If well no. 9124 is considered as a background, radium in the alluvial aquifer decreases as a function of distance from the tailings ponds. The elevated radium level in well no. 9123 is possible if there is a local radial flow pattern centered on the tailings ponds and superimposed on the natural, southeastward flow gradient. Trends for nitrate, TDS, chloride, sulfate, and gross alpha data from the foregoing study, from the Anaconda Company (Gray, 1975), and from the present investigation, were plotted to determine changes in ground-water quality with respect to distance from the tailings ponds and with time. Well no. 9127, completed in alluvium, and the Mexican Camp well (no. 9120), which taps the San Andres Limestone, show essentially no change in TDS, sulfate, chloride, or nitrate for the period 1956 to 1975. The slight decline in TDS in well no. 9127 is contrary to what would be expected if gross contamination was present. However, the similarity between gross alpha and sulfate fluctuations for the Mexican Camp well suggests that wastes may be within the area of influence of the well.

With respect to upward leakage associated with the injection well, concentrations of chloride and uranium through time are shown in Figure 4 for two observation wells. The Monitor well, located 91 meters northeast of the disposal well, is 191 meters deep. It fully penetrates and is open to the San Andres Limestone-Glorieta Sandstone fresh-water aquifer. North well, 1.5 kilometers northwest from the disposal well, is 76 meters deep and completed in the San Andres Limestone. The increasing concentrations of uranium and chloride in the Monitor well may indicate leakage out of the injection zone. Uranium serves as a tracer because it is not precipitated like thorium and radium when the carbonate reservoir strata neutralize the acidic waste. The concentration of polonium-210 exceeds that in all other wells in the Bluewater-Grants area and is well above the average of 0.33 pCi/l for six wells tapping bedrock.

North well is fairly stable, which may reflect the shallower completion depth and an upgradient location. Another well (no. 9121), located one kilometer to the north and completed in the Chinle Formation-San Andres Limestone sequence, also shows essentially stable TDS and sulfate from 1969 on and stable gross alpha from 1962 to present.

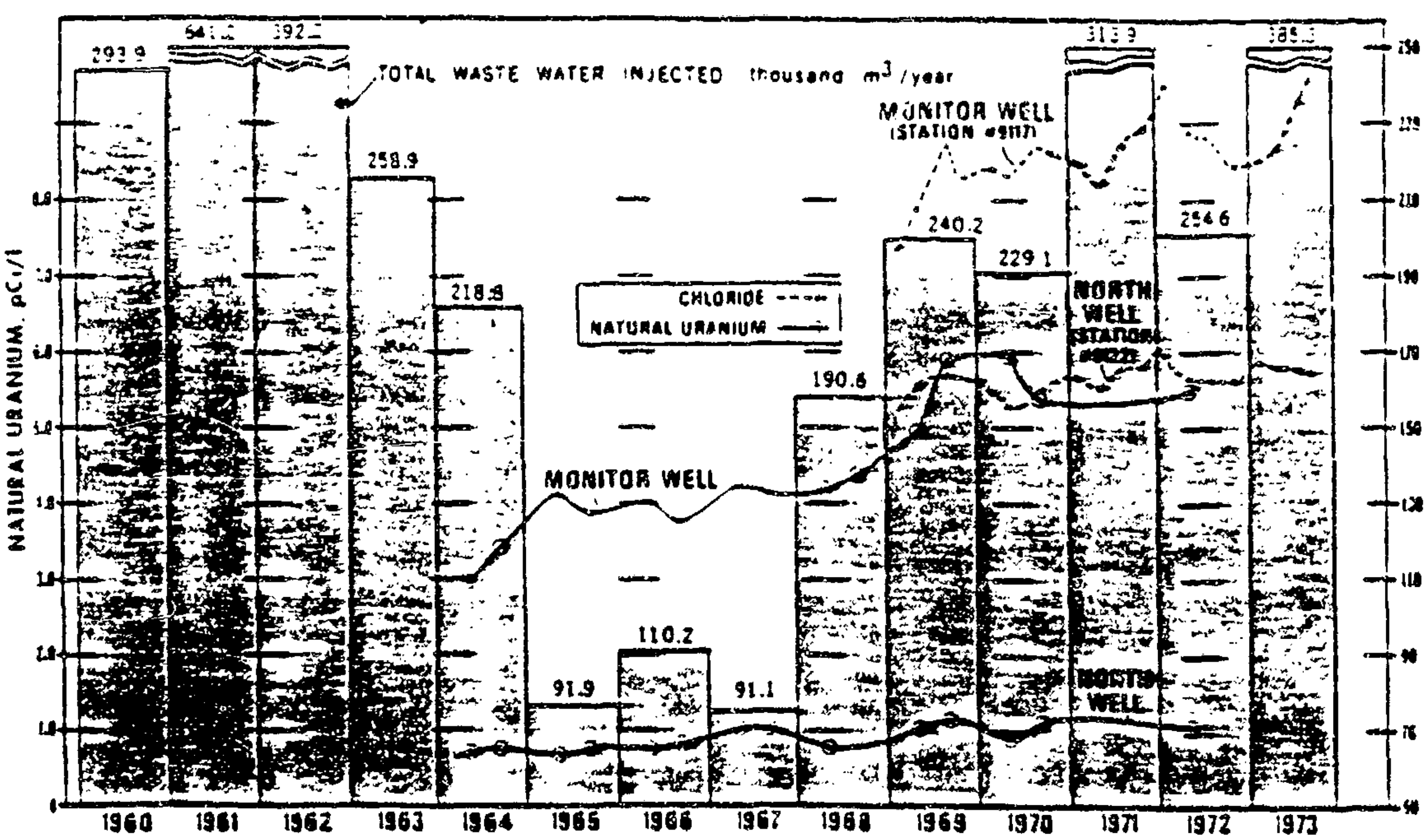

Fig. 4. Anaconda Company injection volumes and monitoring well water quality.

There are major deficiencies in the monitoring programs associated with the Anaconda Company waste disposal operations. These include the lack of water quality data from the top of the zone of saturation in close proximity to the tailings ponds and the lack of monitoring wells completed in the injection zone. In effect, reliance is placed on detecting contaminants after they have escaped from a restricted area/zone.

In summary, widespread adverse water quality effects are not apparent as a result of the Anaconda Company disposal practices. This conclusion is based on analyses for seven offsite wells (nos. 9118, 9119, 9124, 9125, 9126, 9127, 9129) completed in alluvium and in bedrock and generally located peripheral to and within 4 kilometers of the tailings ponds. However, onsite Anaconda water-supply wells no. 2 and no. 4, located closer to the waste ponds, are 69-118 meters deep and are completed in the San Andres Limestone and possibly in the alluvium. Both wells show slightly increasing trends for TDS, chloride, or sulfate. Monitoring of the waste front in the injection zone is not under-way, yet there is evidence of leakage into overlying, potable aquifers. Positive steps to define contaminant fronts associated with both the seepage and the injection operation are recommended.

United Nuclear-Homestake Partners (UNHP) Mill and Surrounding Area

The UNHP mill is flanked on the southwest or downgradient side by housing developments and irrigated farm lands, both of which depend on local ground-water supplies. Seepage from the pile proper and from the encircling moat enters the ground-water reservoir. Adjacent to the mill buildings is an inactive tailings pile that was formerly part of the Homestake-New Mexico Partners mill (Figure 5). In all likelihood, seepage from this pile also resulted in contamination.

Three distinct aquifers are present in the area of the mill and surrounding developments. In ascending order, these include the San Andres Limestone, the Chinle Formation, and the alluvium. Water-table conditions and a southwestward flow gradient prevail in the latter, with static water levels about 15 meters below land surface. The San Andres Limestone originally was under artesian head, but heavy pumping for irrigation and for industry has removed much of the head once present. Data presented by Gordon (1961) indicate a downward flow gradient, but the permeability of the Chinle

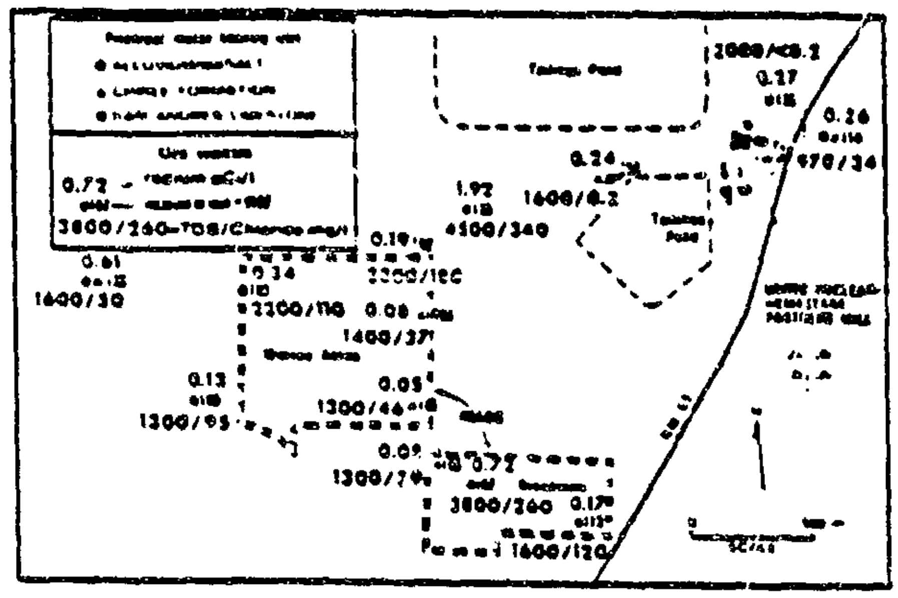

Fig. 5. Radium, TDS, and chloride in ground water—United Nuclear-Homestake Partners mill area.

Formation is low, and actual vertical water transfer is probably minimal.

Geologic and hydrologic conditions are not suitable for land disposal of milling wastes in that sandy soils and a relatively shallow water table are present. Contamination of the shallow aquifer is indicated by several chemical and radiochemical parameters.

The possibility of ground-water contamination due to the United Nuclear-Homestake Partners tailings pond was noted in the early 1960's by Chavez (1961). Samples from on-site monitoring wells completed in the alluvium contained from 0.8 to 9.5 pCi/l radium less than two years after the start of milling. The normal range was 0.1 to 0.4 pCi/l in wells several miles west of the mill and from wells in the alluvium between San Rafael and Grants.

Radium concentrations in ground water (Figure 5) from the San Andres and Chinle range from 0.05 to 0.27 pCi/l, with a mean of 0.16 pCi/l for six determinations. The peak value from shallow wells tapping the water-table aquifer in the alluvium is 1.92 pCi/l in well D, the single active monitoring well (no. 9135). Although below the EPA drinking water standard of 5 pCi/l, this value does indicate movement of contaminants away from the tailings pond. Attenuation due to sorption may mask a very sharp concentration gradient between this well and the pond. At a distance of approximately 0.6 kilometers from the ponds, radium in the shallow aquifer reverts to levels of 0.13 to 0.72 pCi/l and averages 0.36 pCi/l, or about twice that present in the bedrock reservoirs at depth. Relatively high concentrations (0.72, 0.61 pCi/l) in nearby wells (nos. 9107, 9133) may reflect plumes or fronts of contaminants that have advanced ahead of the main body through highly permeable zones in the alluvium.

Total uranium in well D is about 500 pCi/l, compared to 10-20 pCi/l in wells of comparable depth but located about twice the distance downgradient from the mill. For comparison, seepage from the mill tailings pile contains 52 pCi/l radium-226 and 101,000 pCi/l (150 mg/l) U-natural.

Elevated levels of polonium-210 are also present in well D (no. 9135) and in other wells (nos. 9102, 9106, 9107, and 9113) downgradient from the mill tailings ponds. Background for polonium-210 is approximately 0.34 pCi/l (Table 1) in wells tapping either the Chinle Formation or the alluvium, whereas concentrations range from 1.0 to 2.3 pCi/l in wells suspected to be contaminated. The highest value (2.3 ± 2.1 pCi/l) for polonium-210 was from well D.

The most significant contaminant is selenium. As shown in Figure 6, downgradient domestic wells contain up to 3.4 mg/l selenium or 340 times the recommended maximum for drinking water (National Academy of Sciences-Engineering, 1972). Concentrations are greatest in shallow wells and in wells closer to the mill. Although the background level for selenium is not fully defined, the deeper aquifers (Chinle, San Andres) contain < 0.01 mg/l, whereas the seepage collection ditches and the monitor well contain 0.92 and 3.5 mg/l, respectively. Data collected in the course of the study showed that selenium concentrations in ground water throughout the Grants Mineral Belt were generally 0.01 mg/l or less. Prominent exceptions include the foregoing wells and seepage adjacent to the United Nuclear-Homestake Partners mill. Elsewhere, mine and ion exchange plant effluents averaged 0.027 and 0.15 mg/l, respectively at the time of sampling. As a result of widespread selenium contamination, a cooperative State-industry program is underway to provide alternate potable water supplies for the local populace.

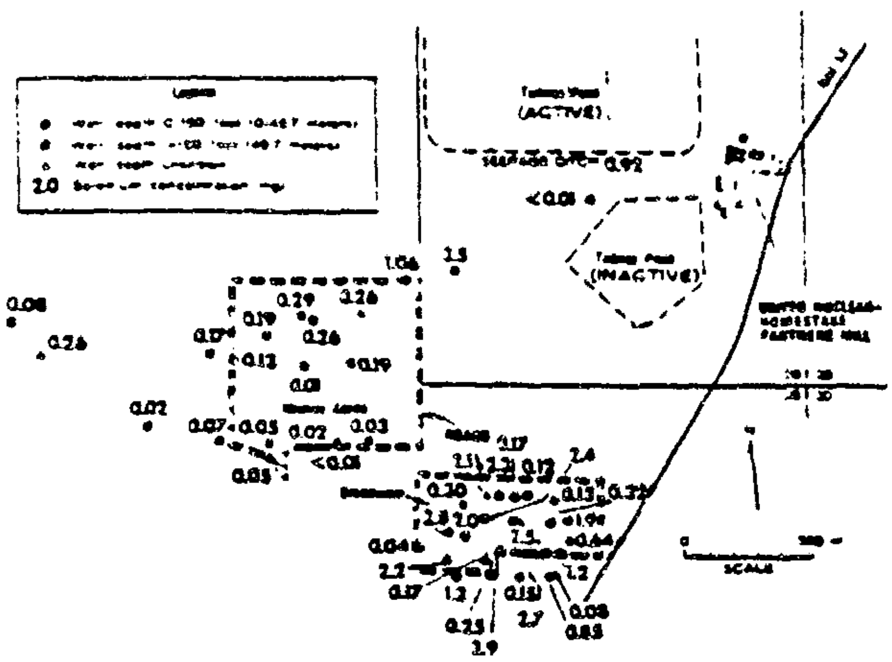

Fig. 6. Selenium in ground water—United Nuclear-Homestake Partners mill area.

Ambrosia Lake Area

In the Ambrosia Lake area, contamination of shallow ground water results from infiltration of (1) effluents from the tailings ponds at the Kerr-McGee mill, (2) mine drainage water that is introduced to settling lagoons and natural water courses, and (3) discharges from ion exchange plants. Seepage from the now inactive United Nuclear, Inc. (formerly Phillips) mill tailings pile is also undoubtedly present in the shallow subsurface. The ultimate effect of these waste waters on ground-water quality is unknown, but probably of consequence only to the shallow, alluvial aquifer. It is unlikely that seepage will reach the bedrock aquifer (Westwater Canyon Member) because of depth and due to intervening thick clay shales between the alluvium and the aquifer.

The Kerr-McGee mill is located on the dip slope of a southeast-facing cuesta in an area underlain by a veneer of silt and clay alluvium over Mancos Shale. A large network of tailings ponds and water storage reservoirs was built by excavation and by selectively sorting the coarse tailings for retention dams. Seepage from the ponds plus discharge from mines and ion exchange plants now causes perennial flow in the southward flowing Arroyo del Puerto.

Ground-water sampling in the Ambrosia Lake area focused on the Kerr-McGee tailings disposal operation and on the effects of various ion exchange plant and mine water discharges on ground water beneath San Mateo Creek and Arroyo del Puerto. The streams represent line sources of recharge to the shallow ground-water reservoir. Of the 22 wells sampled in the area (see Figure 7), all but 3 were part of the Kerr-McGee environmental monitoring network. The results of other ground-water monitoring programs, if any, associated with mining in the area are not reported to regulatory agencies.

Several parameters clearly indicate the infiltration of wastewater. Whereas shallow ground water beneath San Mateo Creek contains about 700 mg/l TDS in the reach above Arroyo del Puerto, the reach below has about 2000 mg/l. Ammonia increases four-fold from 0.05 to 0.22 mg/l, and nitrate plus nitrite (as N) increases from less than 1 mg/l to 24 mg/l. Nitrate, derived from very high concentrations of ammonia in the mill

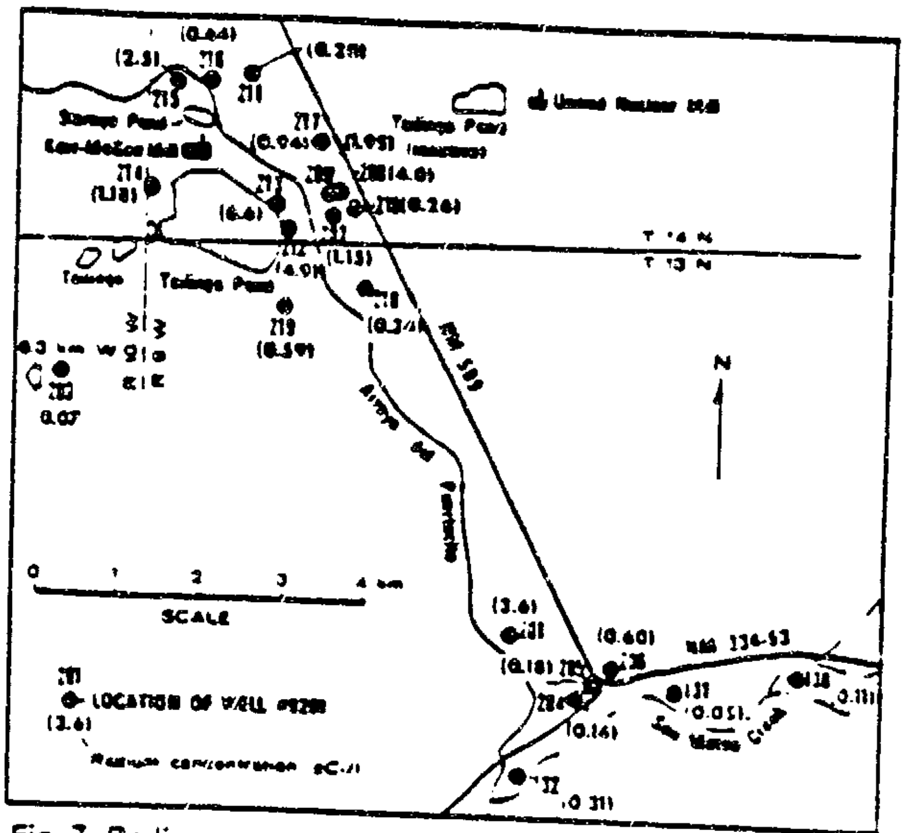

Fig. 7. Radium concentrations in ground water—southern part of the Ambrosia Lake area.

effluents, persists in shallow ground water. This is particularly true for shallow wells located east of the ponds and along San Mateo Creek, both above and below the county line. Selenium and vanadium concentrations in ground water do not markedly increase near the tailings ponds. One exception is well KM-43 (no. 9208) which contains 0.29 mg/l selenium as well as high radium and TDS. A nearby well (no. 9132) is also enriched in selenium which further substantiates the TDS, chloride, ammonia, and nitrate data results indicating contamination of the shallow aquifer.

The concentration of radium in ground water in the vicinity of the tailings piles at the Kerr-McGee mill averages 1.7 pCi/l for the 12 wells sampled. The highest concentration, 6.6 pCi/l, occurs at station no. 9213 near the base of the seepage catchment basin. Although contamination is relatively local, water in the basin, per se, contains 65 pCi/l radium.

As in the case of the Anaconda Company tailings ponds, there is question whether the Kerr-McGee tailings ponds are an adequate means of waste disposal. Company data for 1973 and 1974 reveal that seepage from the ponds averaged 491,400 m^3/yr. Influent averaged 1.67 million m^3/yr. Therefore, 29 percent of the wastes entered the ground water and the balance evaporated. The company data indicate that the seepage rate was fairly constant and averaged 1,348 m^3/day for 1973 and 1974.

Churchrock Area

Hydrogeologic conditions in the vicinity of the Churchrock mines basically resemble those in Ambrosia Lake with respect to potential impacts of mining and milling on ground water. The potential for contamination of shallow ground-water resources is greatest along the channel of the Rio Puerco. Unfortunately, wells specifically located for monitoring are nonexistent and full reliance is placed on existing stock and water-supply wells. Although monitoring data can detect whether contaminated water is being put to beneficial use, the program is markedly deficient in delineating the extent of contamination in aquifers not in use but likely to be receiving wastewater.

The Puerco River at Gallup was ephemeral until mining reached a scale such that wastewater discharge was sufficient to cause perennial flow. At present the combined discharge from the United Nuclear and Kerr-McGee mines, located as shown in Figure 8, is about 16,000 m^3/day and characterized by 8 to 23 pCi/l radium, 700 to 4900 pCi/l uranium, 0.01 to 0.04 mg/l selenium, and 0.4 to 0.8 mg/l vanadium. In terms of radium, selenium, and vanadium, the drainage water is unfit for stock or potable uses and not recommended for irrigation. Infiltration of the mine wastewater represents a threat to potable ground water in the vicinity of the Puerco River and possibly part of the Gallup municipal supply. At the present time, approximately 0.046 to 0.13 Curies per year of radium are discharged to the river. The radium is sorbed onto stream bed sediments and (or) infiltrates to the shallow water table. Because shallow ground water most commonly occurs in valley fill deposits recharged by ephemeral streams,

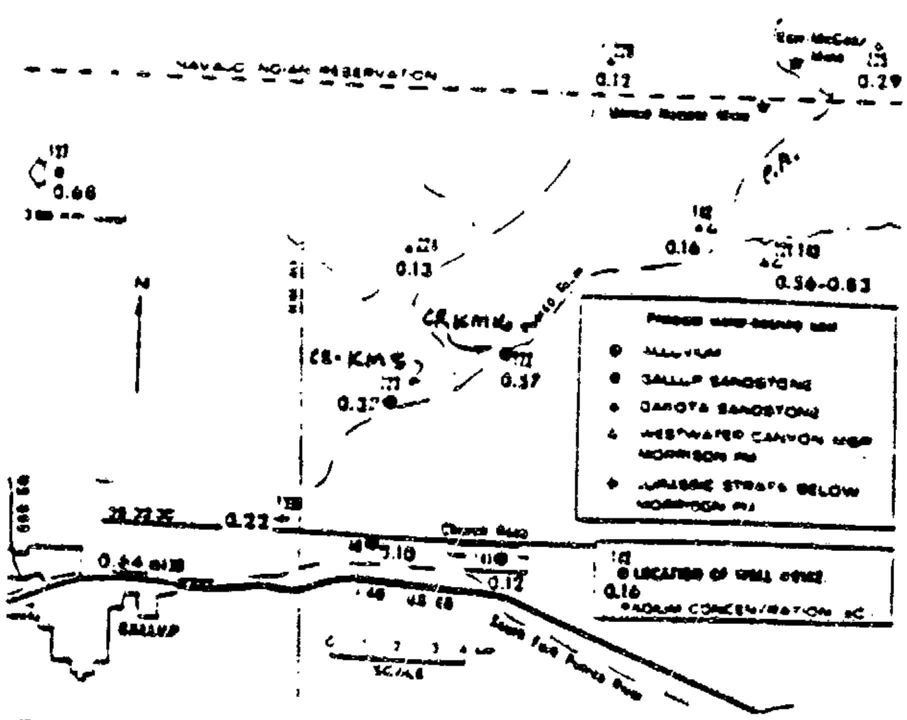

Fig. 8. Radium concentrations in ground water—Churchrock area.

there is a potential conflict between mine water discharge and development of shallow supplies for stock and domestic use. Declining water levels in some of the deeper wells completed in the Dakota and Morrison Formations also result from dewatering of the ore bodies.

To ascertain whether noticeable ground-water quality deterioration has occurred to date, sampling in the Churchrock area involved 13 wells located along the Puerco River and South Fork Puerco River. Essentially all of the known available wells were sampled in the upper reach of the Rio Puerco. For control purposes, ground water in an adjacent watershed tributary to the Rio Puerco was also sampled as was a new high-capacity well completely removed from the mining influences and serving the Gallup area. The sampling points included water used for stock, domestic use, and for public drinking water supplies. Alluvial and bedrock aquifers were sampled in an area of 200 km^2 located generally east and northeast of Gallup.

At present, none of the ground-water samples contain sufficient radionuclides to constitute a health problem. The radiochemical, trace element, and gross chemical data do not indicate that contamination of ground water is occurring as a result of the mining operations underway. Two of the wells (nos. 9139 and 9221) contain 119.6 and 62 mg/l nitrate, respectively. However, mine drainage contains less than 4 mg/l and is not believed to be the source.

By comparison, the effects of mining on the concentration of radium in ground water removed from the mines is marked. Discharge from the Kerr-McGee mine averages 7.9 pCi/l as compared to 23.3 pCi/l for the United Nuclear mine. The latter is producing ore, whereas the former is still in the development stage and the ore bodies are not yet well exposed. In both cases, elevated radium concentrations are present. In large part, these are attributable to mining operations and practices and do not represent natural water quality, evident from samples of ground water collected from 4 wells and 3 long holes, all in the Westwater Canyon Member (Hiss and Kelley, 1975). Radium varied from 0.05 to 0.62 pCi/l compared to 0.28 to 184.8 pCi/l uranium. An additional sample collected in November 1973 from the settling pond discharge at the United Nuclear mine contained 8.1 pCi/l radium and 847 pCi/l natural uranium. Thus, initial penetration and dewatering of the ore body increased radium at least 13-fold (8 ÷ 0.62) and subsequent mine development work over a two-year period resulted in another three-fold

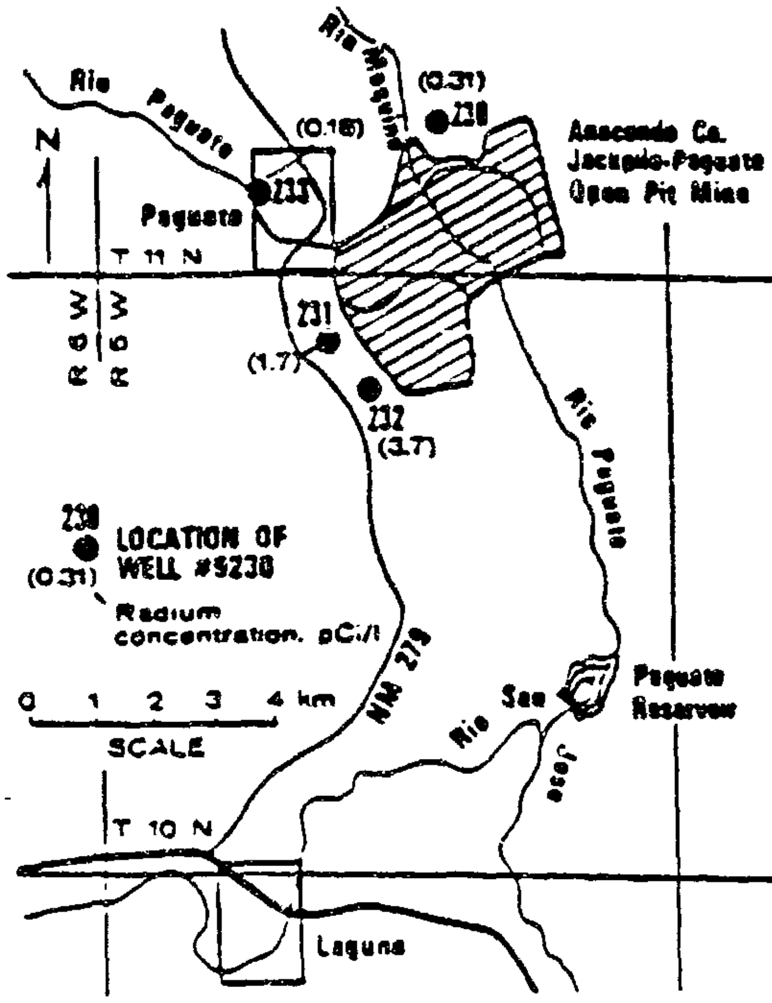

Fig. 9. Radium concentrations in ground water—Jackpile-Paguate area.

(23.3 ÷ 8.1) increase. Compared to natural concentrations, radium increased some 38 times. If a trend similar to that seen in the Ambrosia Lake area prevails, the ultimate radium concentrations should approach 50 to 150 pCi/l. Initial stages of the trend are tentatively confirmed by company, self-monitoring data.

Jackpile-Paguate Area

Sampling in the vicinity of the Jackpile-Paguate open pit uranium mine included four wells located as shown in Figure 9. One of these (no. 9233) is the Paguate municipal supply which is a flowing well located upgradient from the mine and completed in alluvium at a depth of 22.9 meters. The remaining three were former exploration holes that were developed into supply wells. Water quality for the latter three wells is probably representative of the Jackpile Sandstone Member of the Morrison Formation, the principal ore body in the Laguna mining district. With the exception of another nearby municipal well for Paguate, there were no other wells available for sampling in the area.

Dissolved radium in water from the Jackpile Sandstone aquifer ranges from 0.31 to 3.7 pCi/l. The latter value is from the new shop well which is a source of potable and nonpotable water for the facility.

Slightly elevated levels of radium in the P-10 well (no. 9231) and the new shop well (no. 9232) are possibly related to mining operations which tend to increase levels of uranium and radium in ground water. Widespread disruption of the Jackpile Sandstone and overburden, combined with leaching by ground water, undoubtedly increase radium and uranium concentrations. Influent ground-water conditions characterize the area insofar as the water-table gradient slopes southward and the water-level contour pattern indicates recharge by the Rio Paguate and Rio Moquino.

Although the mine floor is generally above the water table, there are local areas where water is encountered. In the South Paguate pit, ponded water derived from dewatering of the pit faces and drainage from the angled drift mines now in development contained 190 pCi/l radium and 170 pCi/l uranium in August of 1970. At that time, water from the pond was being pumped into the Rio Paguate which flows southward into Paguate Reservoir and the Rio San Jose. The absence of downstream wells precluded assessment of the effects of mine drainage on ground-water quality. It is recommended that additional shallow well points be installed and that sediment cores from Paguate Reservoir be taken for analysis of radionuclide content. These data may provide a record of the long-term effects of mining on sediment yield and water quality.

SIGNIFICANCE OF RADIONUCLIDES IN GROUND WATER

Of the 71 ground-water samples collected, only one showed radium-226 in excess of the 5 pCi/l drinking water standard (U.S. Environmental Protection Agency, 1975a). This location is in a restricted area downgradient from the Kerr-McGee tailings ponds at Ambrosia Lake. At five other locations, the former U.S. Public Health Service guide of 3 pCi/l radium is exceeded but quality is within the present EPA standard of 5 pCi/l. Furthermore, the locations are monitor wells in restricted areas or are irrigation or stock watering wells. Radium concentrations in municipal supplies in the study area ranged from 0.12 to 0.68 pCi/l and are well below the drinking water standard.

With respect to the use of 15 pCi/l gross alpha as an indication of radium in excess of 5 pCi/l (U.S. Environmental Protection Agency, 1975a), only one location would meet this criterion. Location no. 9021 had a gross alpha activity (including uranium isotopes) of 62,500 pCi/l and a radium-226 content of 53 pCi/l. At 33 locations (excluding no. 9021) where gross alpha activity exceeded 15 pCi/l, radium-226 contents ranged from 0.05 to 4.9 pCi/l. The two highest radium-226 results (locations no. 9213 and 9121) of 6.6 and 6.3 pCi/l have corresponding gross alpha determinations of 8 and 12 pCi/l. Furthermore, gross alpha activity determinations have large error terms which make data interpretation rather difficult. For this study, the gross alpha determination does not appear to have any correlation to radium-226 content. The reason for the poor correlation between the sum of isotopic uranium concentration and total uranium (natural uranium) is unknown. For ground-water samples, suspended solids are absent or very low, thereby eliminating the importance of sample filtration.

Since uranium, thorium and polonium-210 contents fluctuate about background levels, routine radiological monitoring of potable water supplies might best be limited to analysis for radium-226. The use of gross alpha determinations for routine surveillance of a water supply may not necessarily provide reliable data on which to base accurate radiological assessments of the supply.

Analysis of the flow and water quality data to ascertain radionuclide release to ground water is shown in Table 3. Approximately 2,000 to 3,000 Curies of radioactivity have been introduced to the subsurface by waste disposal operations at two of the three mills now operating in the Grants Mineral Belt. Not included in the data is the much greater activity in the solids fraction. Estimation of this is a separate problem which is currently being addressed in another study by the Office of Radiation Programs. Although essentially all of the activity released to the subsurface to date appears to be confined to presently restricted areas, there is an implicit and grave assumption that the same will be

Table 3. Dissolved Radioactivity in Effluents from the Kerr McGee and Anaconda Company Uranium Mills

Mill	Radionuclide	Source	Total Flow(1)	Concentration pCi/l	Radioactivity Curies
Anaconda	Radium-226	seepage	2.817	125	0.352
Company	(1622)[3]	injection	3.712	125	0.464
	Thorium-230	seepage	2.817	150,000	423
	(80,000)	injection	3.712	150,000	557
	Uranium (nat.)[4]	seepage	2.817	15,000	42.2
		injection	3.712	15,000 (88,019)[2]	55.7 (327)
Kerr-McGee	Radium-226	seepage	7.863	10 (65)[2]	0.079 (0.514)
	Thorium-230	seepage	7.863	160,000	1,258
	Uranium	seepage	7.863	6,319 (120,299)[2]	49.4 (951)
					Total 2,386 (3,559)[5]

(1). Million cubic meters, from start of operation through 1973

(2). Values reported by National Enforcement Investigations Center (USEPA), for seepage below the tailings ponds; analysis was for natural uranium on an unfiltered sample.

(3). Half life, years

(4). Half lives range from 2.48×10^5 for U-234 to 4.51×10^9 years for U-238

(5). Alternate estimate based on uranium and radium data from National Enforcement Investigations Center.

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true for many hundreds of years to come.

Estimation of the seepage rates in Table 3 involves several basic assumptions. For the Anaconda mill, it was assumed that seepage has the same quality as the injected waste. The average concentration data shown are simply reasonable estimates based on the 1975 measurements and various company dating from 1960. In the case of Kerr-McGee, seepage for 1973 and 1974 is assumed to be representative of past conditions as are the 1975 water quality data. Obviously seepage rates have not been constant and seepage quality at the toe of the main retention dam may not be typical of area-wide conditions. Nevertheless, the calculations are believed to provide at least an approximation of the magnitude of radionuclide release. Because of sorption, not all of the activity is necessarily dispersed in the ground-water reservoir.

It is apparent that the largest amount of activity consists of thorium-230. The half-lives for the three elements shown provide some idea of the temporal significance of the hazard presented by uranium mining and milling wastes. As for waste toxicity, a recent report (Midwest Research Institute, 1975) of waste generation, treatment, and disposal in the metals mining industry stated that "wastes produced and land-disposal by the uranium mining industry . . . have the highest toxic hazardous rating of the . . . industries studied."

Because of the extremely long period over which such wastes are toxic, it is fundamental that detailed ground-water monitoring data be able to determine and predict the extent of contamination. The stark contrast between a typical 20-year mill life and an 80,000-year half life for the dominant radionuclide (thorium-230) necessitates a much greater forward look than is now evident in waste disposal practices and preservation of ground-water quality. As of 1972, some 99 × 10^6 metric tons of tailings containing 60,000 Curies of radium-226 were stockpiled in the western States from Texas to Washington.

For the period 1960-1973, waste disposal practices of the Kerr-McGee and Anaconda Company mills introduced an estimated 200,000 kilograms of dissolved uranium to the subsurface via seepage and direct injection. Although it may be uneconomical to effect recovery at the historic prices of $10 to $20/kg of yellowcake ($U_3O_8$), recent contracts for delivery over the next 5 years involve prices of $88/kg (Anonymous, 1976). For reasons of mineral conservation, if not economic advantage, recovery of uranium from wastes associated with present and future milling operations should perhaps be more closely examined.

RECOMMENDATIONS

Several areas necessitating additional research are apparent from this study. These include: (a) delineating the effects on water resources of solution, shaft and open pit mining practices and dewatering of ore bodies, (b) thorough reevaluation of the injection method of waste disposal, (c) determining the adequacy of tailings ponds as a means of waste disposal, (d) assessment of the validity of gross alpha as an indication of the presence of other alpha emitters, (e) further research on the adequacy of geologic media for the sorption and retention of radionuclides, and (f) recovery of uranium from mill effluents.

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PROCESSING SITE CHARACTERIZATION REPORT

FOR THE

URANIUM MILL TAILINGS SITE

AT

SHIPROCK, NEW MEXICO

011462

APRIL, 1984

Uranium Mill Tailings Remedial Action Project Office
Albuquerque Operations Office
Department of Energy
Albuquerque, New Mexico 87108

Approved

J.A. Morley, Manager
UMTRA Project
Department of Energy

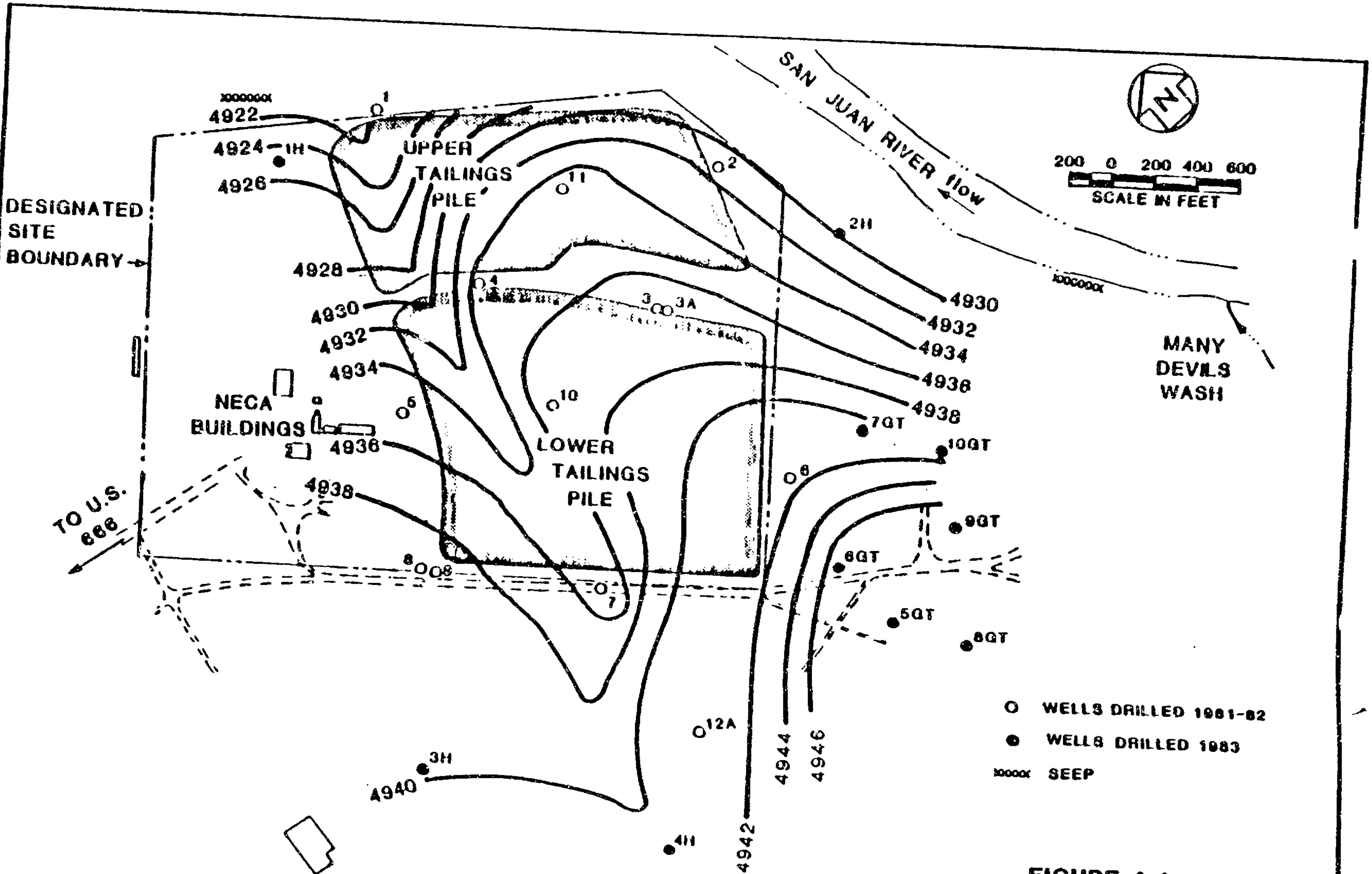

FIGURE 4.1
POTENTIOMETRIC SURFACE AND WELL LOCATIONS
SHIPROCK SITE

011463

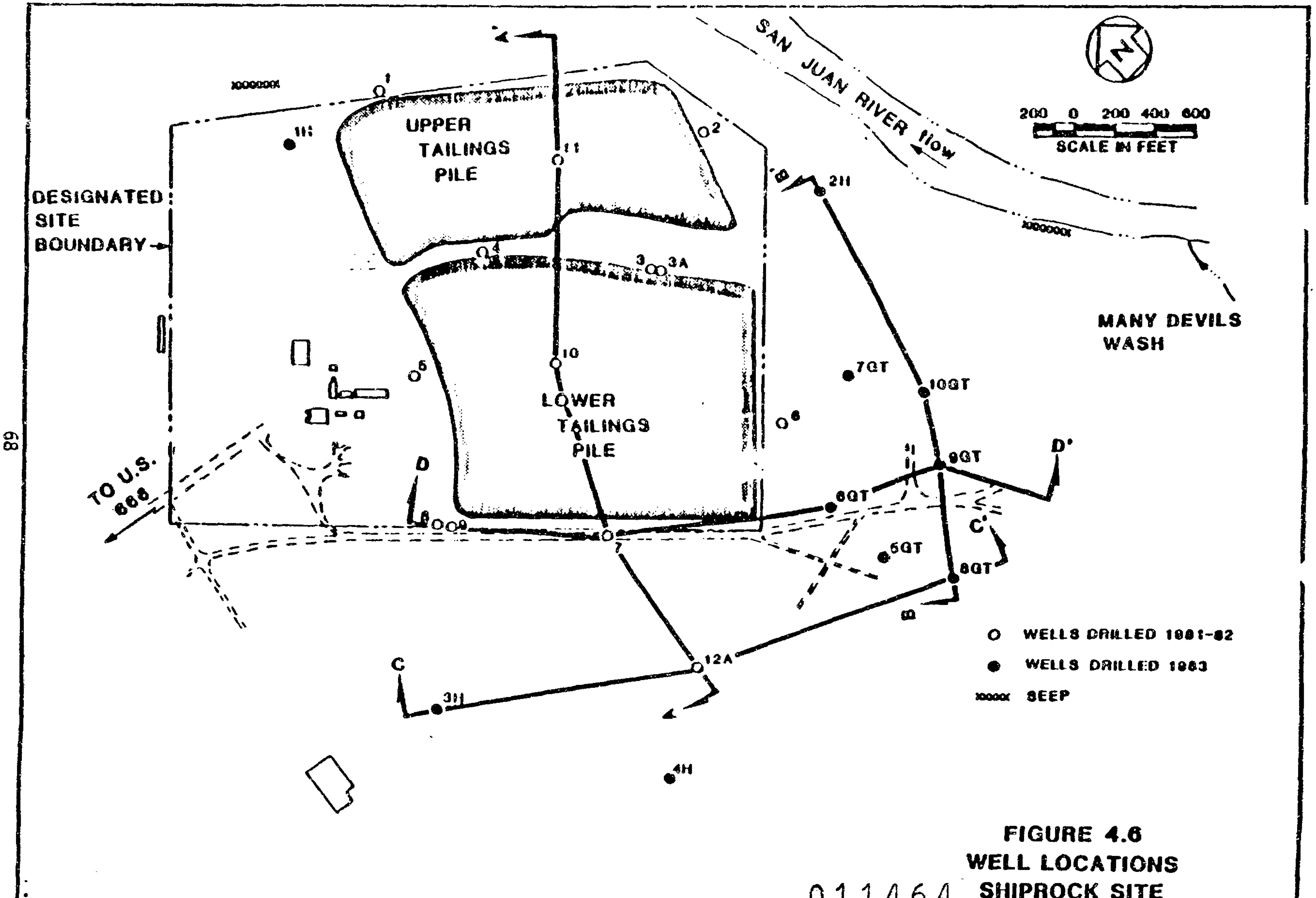

FIGURE 4.6
WELL LOCATIONS
SHIPROCK SITE

0 1 1 4 6 4

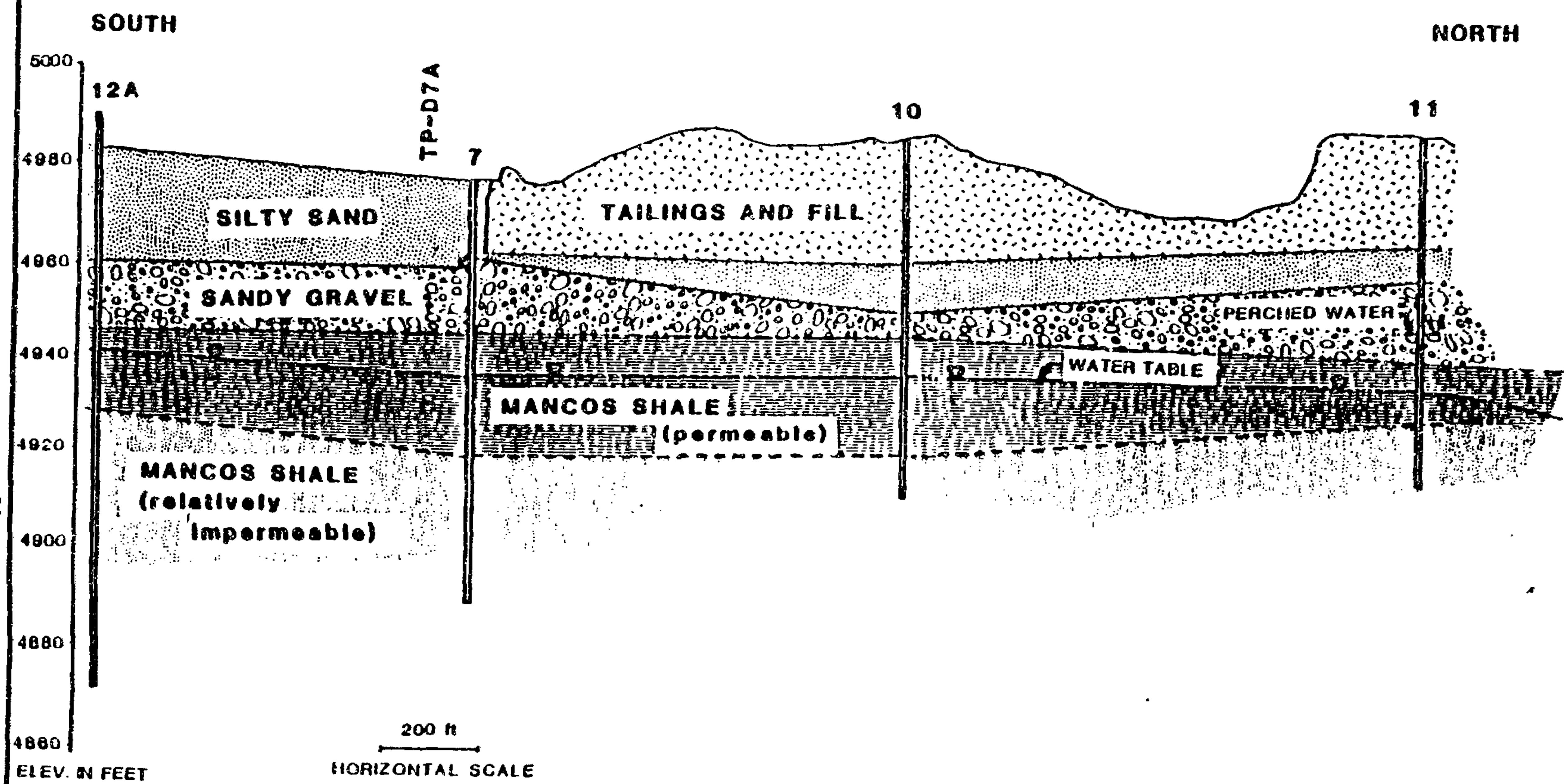

FIGURE 4.2
PROFILE A – A'
EXISTING STRATIGRAPHY

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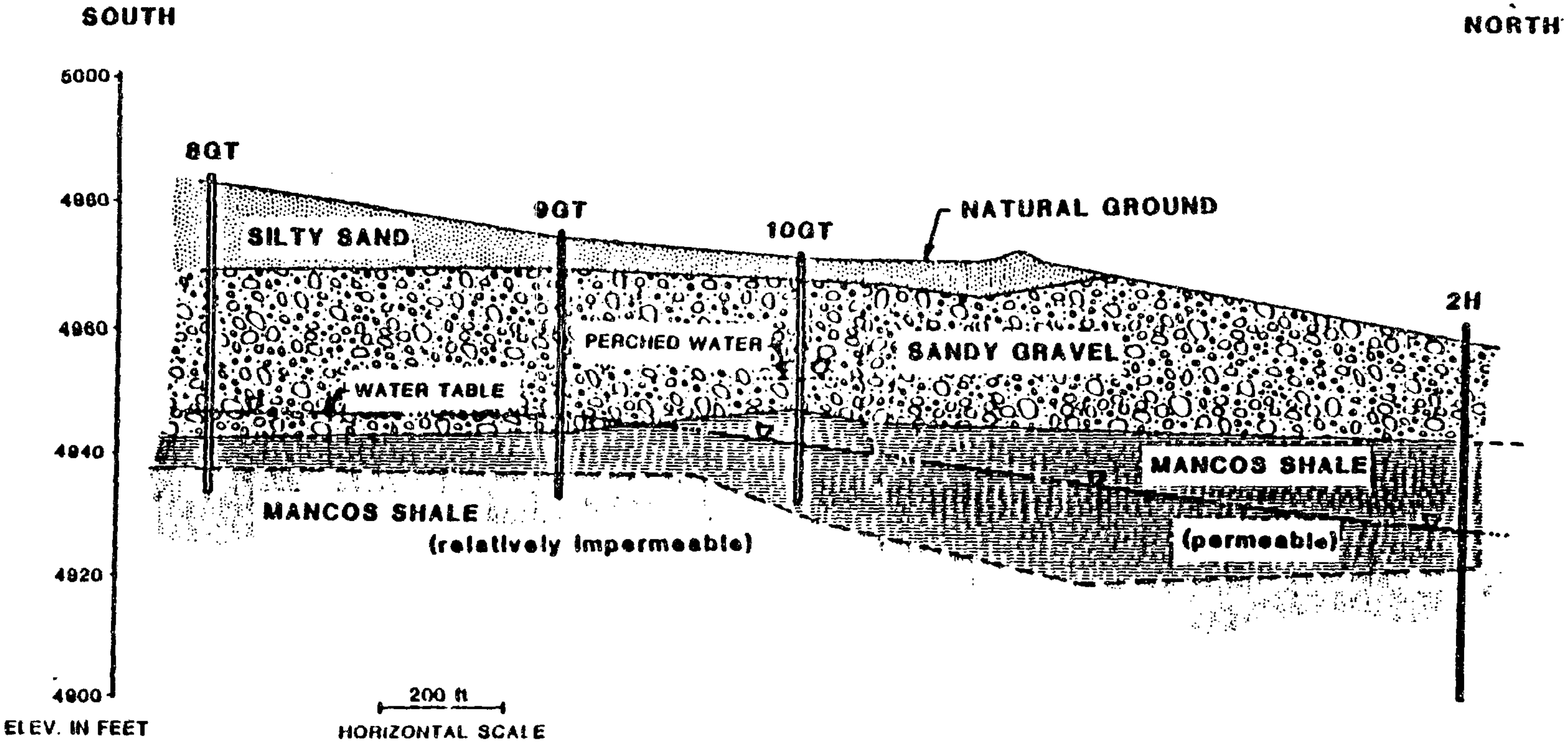

FIGURE 4.3
PROFILE B - B'
EXISTING STRATIGRAPHY

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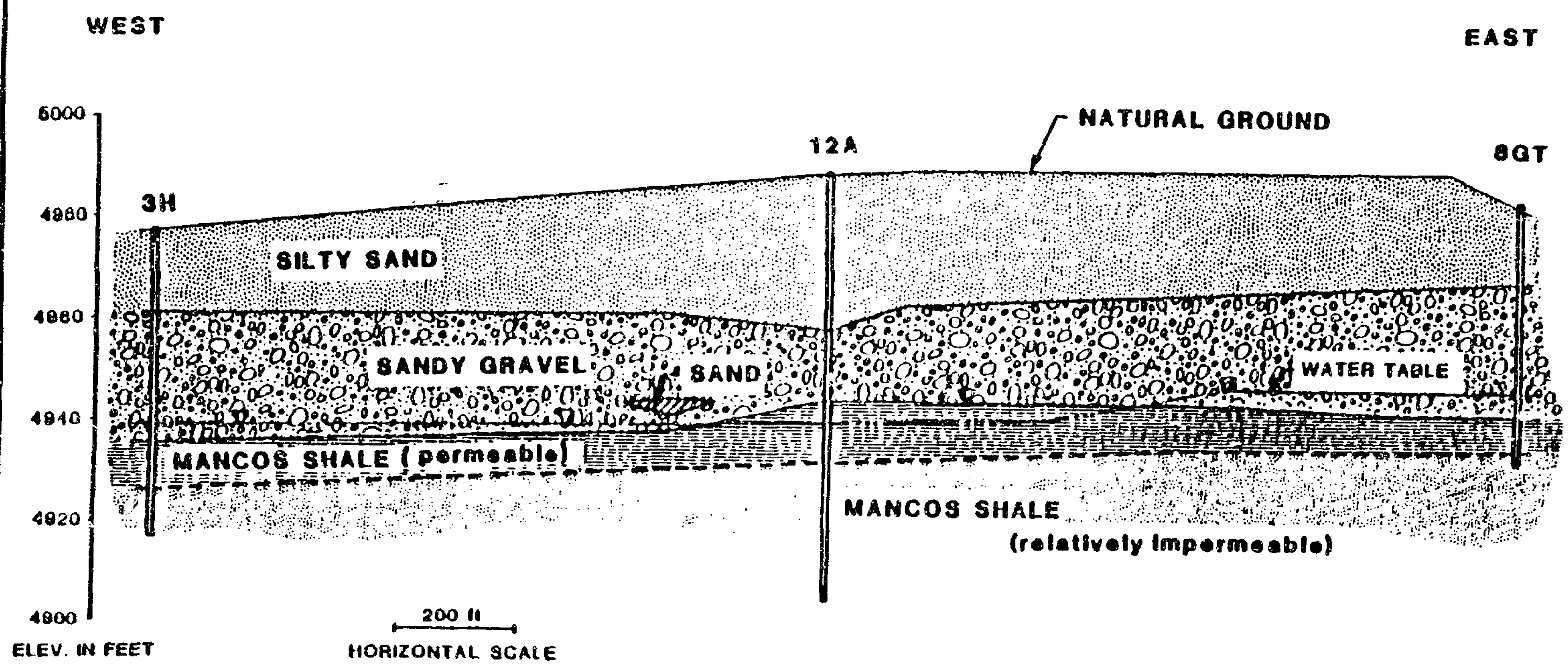

FIGURE 4.4
PROFILE C - C'
EXISTING STRATIGRAPHY

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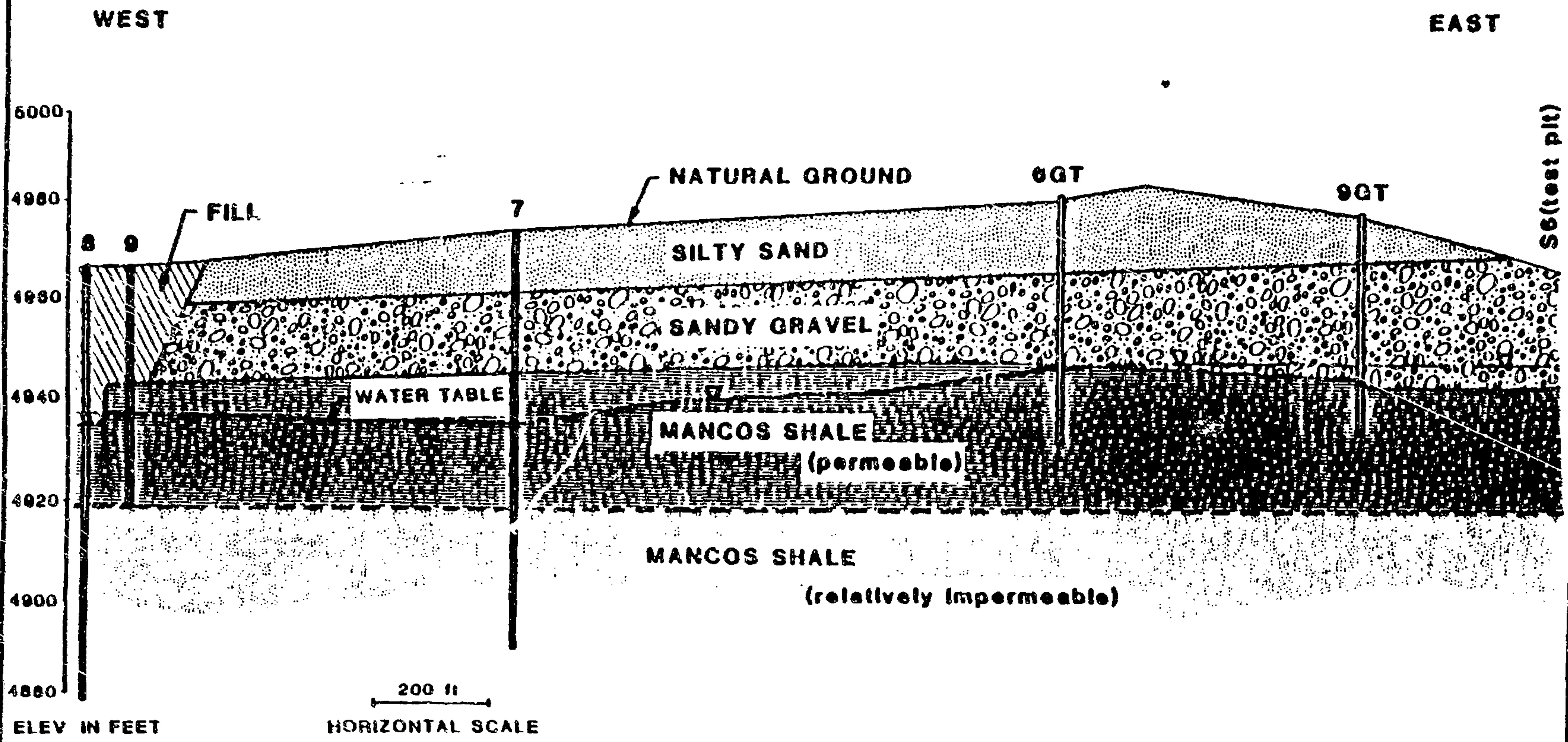

FIGURE 4.5
PROFILE D - D'
EXISTING STRATIGRAPHY

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Table 4.4 Water quality analyses, Shiprock site (Concluded)

Parameter	Well Identification 11	12A	1H[f]	3H	4H	5CI[f]	6GT	9GT	10GT[a]	Seep
Al	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
As	< .01	< .01	< .01	< .01	< .01	< .01	< .01	< .01	< .01	< .010
Cd	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.35	0.13	0.14	<0.01
Ba	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cr	<0.01	<0.01	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cu	0.02	0.04	0.13	0.02	<0.01	0.04	1.3	0.02	0.02	<0.01
Fe	<0.02	<0.01	<0.01	0.09	0.01	0.07	16	5.0	0.02	<0.01
Pb	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Hg	< .002	< .002	< .002	< .002	< .002	< .002	< .002	< .002	< .002	< .002
Mo	0.02	<0.01	0.06	<0.01	0.04	0.03	<0.01	<0.01	<0.01	<0.01
Ni	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	4.5	<0.5	<0.5	<0.5
Se	<0.01	<0.01	0.08	0.04	0.32	0.11	0.36	0.27	0.27	0.62
Ag	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zn	<0.5	<0.5	<0.5	<0.5	<0.5	0.6	3.8	<0.5	0.9	<0.5
V	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	0.01
B	0.9	0.9	<0.1	0.6	1.0	0.1	0.2	0.3	0.2	0.8
Cl	250	880	660	740	2800	1200	650	550	695	650
NO_3	100	890	4800	3100	5800	<10	180	1600	4300	3800
NH_4	370	12	42	130	10	2300	1650	3660	2865	140
Na	2100	5000	3500	2600	5300	1500	1800	1900	1850	4100
Ca	450	680	480	580	480	500	500	515	420	
Mg	710	1700	190	2600	1400	1500	2400	2300	2000	2200
K	100	49	73	120	50	250	300	500	380	160
PO_4	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Mn	1.9	0.4	0.03	1.0	0.8	36	100	170	89	0.4
SO_4	6700	14000	4700	12000	7600	14000	29000	25000	17500	14000
ALK	1420	1560	235	1340	775	785	450	505	420	---
TDS	12500	25900	15000	25100	27400	21800	34600	34600	28150	26100
pH	6.8	6.9	10.2	6.6	7.2	8.7	6.3	6.7	6.9	---
umhos/cm COT[b]	12400	18900	13700	18600	26400	18800	29100	29100	30900	---
°C Temp[c]	16	16	18	22	18	17	16	19	17	
Th-230[d]	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	---
Pb-210[d]	<1.5	<1.5	---	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	---
Po-210[d]	<1	<1	---	<1	<1	2	<1	<1	<1	---
U-238[d]	599	45	1.0	71	22	15	75	9.1	9.5	47.6[e]
U-234[d]	635	131	1.0	154	85	17	77	12	10	---
Ra-226[d]	1.5	1.0	<1.0	1.9	<1.0	<1.0	1.2	1.6	1.9	---

[a]Average of two samples.
[b]Corrected to 25°C.
[c]Measured at hose outlet.
[d]In pCi/l.
[e]Total of U-234 and U-238.
[f]Samples taken October, 1983.

Water Resources of the Zuni Tribal Lands, McKinley and Cibola Counties, New Mexico

By BRENNON R. ORR

Prepared in cooperation with
the Pueblo of Zuni

U.S. GEOLOGICAL SURVEY WATER-SUPPLY PAPER 2227

Development of the upper spring has included the construction of a rectangular stone-masonry reservoir, headgates, and a ditch-distribution system. The lower spring has been developed by the construction of an earthen dike, rock retaining wall, and headgate. Recently, both springs have been made part of a pipeline-distribution system that ultimately discharges to the Rio Pescado upstream from a concrete irrigation-diversion structure.

A series of periodic discharge measurements have been made at the Pescado Springs since 1978 in order to determine the volume and the variability of flow (fig. 20). Measurements shown in figure 20 represent the flow from both springs. Measured discharges ranged from 0.87 cubic foot per second on December 4, 1979, to 1.60 cubic feet per second on February 25, 1980. The average discharge for this period was approximately 1.1 cubic feet per second, or 500 gallons per minute, for a total annual flow of approximately 800 acre-feet. Irrigation return flow and overflow from the diversion on the Rio Pescado infiltrate to the channel alluvium or are lost to evaporation. Some variability in discharge throughout the year is due to changes in water levels within the spring reservoirs. Fluctuations may be attributed, in part, to runoff across the recharge areas. Changes in storage in nearby Pescado Reservoir also may have some effect on spring discharge.

Alluvial seepage of perhaps 200 to 300 gallons per minute has been partly developed for community use at Black Rock. This seepage emerges from buried channel deposits exposed where an arroyo has been incised around the north side of the Pescado basalt flow. A collection gallery known locally as the "spring house" (10.19.13.224) has been constructed in the arroyo channel. Water from the spring house is pumped to Black Rock, where it is mixed with more mineralized water from the two wells completed in the Glorieta-San Andres aquifer (PHS well and Black Rock well 3).

The concentrations of dissolved solids in water from alluvial aquifers ranged from 207 to 2,940 milligrams per liter (table 3). Major cations were calcium, ranging in concentration from 34 to 500 milligrams per liter; magnesium, from 2.4 to 560 milligrams per liter; and sodium, from 22 to 1,000 milligrams per liter. Major anions were bicarbonate, ranging in concentration from 79 to 540 milligrams per liter; chloride, from 18 to 1,100 milligrams per liter; and sulfate, from 3.4 to 2,200 milligrams per liter. Nitrate concentrations ranged from 0.31 to 86 milligrams per liter.

No distinctive chemical composition of water is indicated by water-quality analyses from wells completed in alluvium within the study area; however, local water-quality similarities exist as a result of geohydrologic conditions. The similarities are shown on trilinear plots of chemical analyses (fig. 21). Alluvial wells in upland tributary canyons produce water with large concentrations of calcium, sodium, and sulfate. In the buried channel deposits of the Rio Pescado, water has a small dissolved-solids concentration. Major ions are calcium and bicarbonate. In alluvial wells near Zuni Village, water has large concentrations of sodium and chloride. The predominant ions in the water along the downstream reaches of the Zuni River typically are calcium, sodium, and sulfate.

Water-quality variations in different alluvial wells and springs are the result of several factors, including the lithology of alluvium, the source of recharge to the alluvium, and the potential for surface contamination. Clay minerals within the alluvium enhance the ion-exchange process, increasing dissolved sodium in the water and decreasing some of the divalent cations (calcium, magnesium, and iron). Salts that accumulate in the soil from evaporation and transpiration are flushed into the alluvial aquifer by periodic flooding, increasing the dissolved-chloride and dissolved-solids concentrations. Inflow to the alluvium from adjacent aquifers locally increases the dissolved constituents found in those waters. Finally, the quality of water in shallow alluvial wells in the Zuni River valley is more easily affected by surface processes such as flooding, waste-disposal contamination, and seasonal fluctuations in precipitation.

The susceptibility of alluvial water to surface contamination and the limited extent of alluvial aquifers in the Zuni study area preclude extensive use of this water resource. If it becomes necessary to further evaluate the availability and quality of water in the alluvium, test wells could be drilled in the Zuni River valley southwest of Zuni Village and in the buried channel deposits along the Rio Pescado.

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Table 3. Water-quality analyses from wells and springs on and adjacent to Zuni tribal lands (including trace-element and radiochemical analyses from selected wells and springs) – Continued

Name of well or spring	Location	Date	Temperature (°C)	Major cations: Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Major anions: Bicarbonate (mg/L)	Carbonate (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Nitrate (mg/L)
Nastacio	10.19.30.232	08-02-72	—	34	7.3	189	T	542	25	44	3.4	.62
Zuni F-2	10.19.33.121	08-03-72	20.0	8.0	1.2	356	T	561	19	66	251	.62
RWP-27	10.20.8.243	07-25-72	14.0	64	6.1	17	1.17	143	14	20	21	33
Irrigation 1	10.20.18.314	07-26-72	—	62	4.9	22	2.0	117	11	43	27	34
Do.	do.	09-05-79	17.5	53	4.9	25	2.6	134	—	34	23	7.3
Bosson Ranch	10.20.22.211	07-25-72	16.0	62	7.3	108	T	306	25	53	61	1.6
ECW-9	10.20.32.421	09-04-79	28.5	6.1	.50	350	2.2	451	0	51	320	.11
RWP-28	11.16.8.131	08-16-72	—	140	34	160	5.5	315	12	21	471	.62
Nutria Campground	11.17.5.322	07-31-72	22.0	14	2.4	145	2.0	267	24	5.3	105	.62
ECW-14	11.17.24.432	11-06-79	14.0	140	50	15	5.2	390	—	15	530	.09
ECW-10	11.17.28.143	07-31-72	13.5	34	12	367	6.3	387	21	12	547	.62
ECW-1	11.18.21.132	10-23-63	13.0	—	—	—	—	—	—	8.9	434	—
RWP-34	11.18.27.411	07-31-72	—	42	13	172	4.7	228	15	1.8	327	.62
Do.	do.	08-10-72	14.5	42	12	167	T	214	20	5.3	320	.62
RWP-38	11.20.22.211	09-05-79	19.5	32	8.2	24	1.2	159	0	7.2	11	1.4
Spring	11.20.34.244	03-26-80	8.0	8.8	2.1	78	.70	207	—	5.6	10	.69
RWP-32	12.16.7.331	08-01-72	16.0	74	27	158	8.2	402	19	60	196	0.62
Nutria Spring	12.16.8.314	12-14-50	11.0	78	26	8.5	—	283	—	8.0	72	0.50
Spring near Nutria	12.16.17.214	03-26-80	4.0	100	8.3	8.5	1.70	317	—	10	35	0.08
RWP-29	12.16.30.242	11-06-79	14.5	41	9.8	170	3.8	402	—	20	120	0.13
ECW-16	12.17.15.213	11-13-79	—	56	21	69	4.2	329	0	20	90	0.14
Hand pump	12.17.23.244	08-01-72	12.0	126	51	171	2.0	349	13	122	337	86
Z-7R	12.17.32.323	04-01-76	—	60	22	55	2.7	367	T	11	53	T
16T-567	12.18.28.434	06-20-73	—	34	8.5	49	2.4	218	16	3.6	6.2	0.25
Jones Ranch PM-3	12.20.17.133	09-24-73	—	38	8.5	39	2.0	146	14	28	37	11
Cheechilgeetiio School	12.20.25.122	06-13-52	—	—	—	586	—	249	7	340	656	—
16T-545	12.21.24.423	10-11-72	—	4.0	T	124	T	194	51	13	4.8	0.62

Silica (mg/L)	Iron (mg/L)	Fluoride (mg/L)	Phosphate as ortho-phosphate (mg/L)	Boron (mg/L)	Total alkalinity CaCO₃ (mg/L)	Hardness		Specific conductance	Dissolved solids (mg/L)	pH (units)	Sodium adsorption ratio	Lab	Geologic unit
						Non-carbonate (mg/L)	Ca/Mg (mg/L)						
—	.03	1.0	.02	.58	444	—	115	990	541	8.3	7.67	BIA	Qal
—	T	.54	.02	.34	460	—	25	1,620	1,003	8.3	31.00	BIA	TRc
—	T	.21	T	.12	118	67	185	450	256	7.7	.54	BIA	Tb
—	T	.20	T	1.9	96	79	175	470	269	8.0	.72	BIA	Tb
22	.02	.40	—	—	110	43	150	360	263	8.4	.90	USGS	Tb
—	T	.33	T	.50	251	—	185	800	458	7.8	3.46	BIA	TRc
10	.40	6.2	—	—	370	0	17	1,300	969	8.3	37	USGS	TRc
—	T	.35	T	T	—	231	490	1,360	971	8.6	3.14	BIA	Kc
—	T	1.5	T	.20	219	—	45	700	428	8.8	9.38	BIA	Kg
15	—	.40	—	—	320	240	560	1,300	1,100	7.6	2.80	USGS	Kg
—	.02	.39	T	T	318	—	135	1,810	1,199	8.1	13.75	BIA	Kd
—	—	—	—	—	—	—	—	1,020	—	—	—	USGS	Jz
—	T	.29	.02	.12	187	—	160	1,030	685	8.4	5.93	BIA	Kd
—	T	.25	T	T	176	—	155	970	668	8.9	5.85	BIA	Kd
21	.06	.30	—	—	130	0	110	240	189	8.1	1.00	USGS	Jz
17	.73	.30	—	—	170	0	31	325	229	8.1	6.10	USGS	TRc
—	0.01	0.56	T	0.20	330	—	295	1,190	632	8.2	3.99	BIA	Kg
8.4	—	.30	—	—	—	—	341	573	341	—	—	USGS	Pgs
11	.03	.20	—	—	260	24	280	500	331	8.2	0.20	USGS	Pgs
10	—	1.9	—	—	330	0	140	900	575	7.8	6.20	USGS	Kc
22	.01	.40	—	—	270	0	230	811	446	8.0	2.00	USGS	Kc
—	T	.52	.03	.28	286	239	525	1,660	1,098	8.2	33.32	BIA	Qal
—	T	.98	.02	.19	301	—	240	660	342	7.9	1.6	BIA	Kc
—	T	.26	T	.11	179	—	120	420	254	8.5	1.95	BIA	Kg
—	T	.30	.03	T	120	10	130	410	246	8.0	1.49	BIA	Jz
—	—	.80	—	—	—	0	107	2,760	—	—	—	USGS	Pgs
—	.18	—	T	.32	—	—	10	530	339	9.2	17.11	BIA	TRc

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