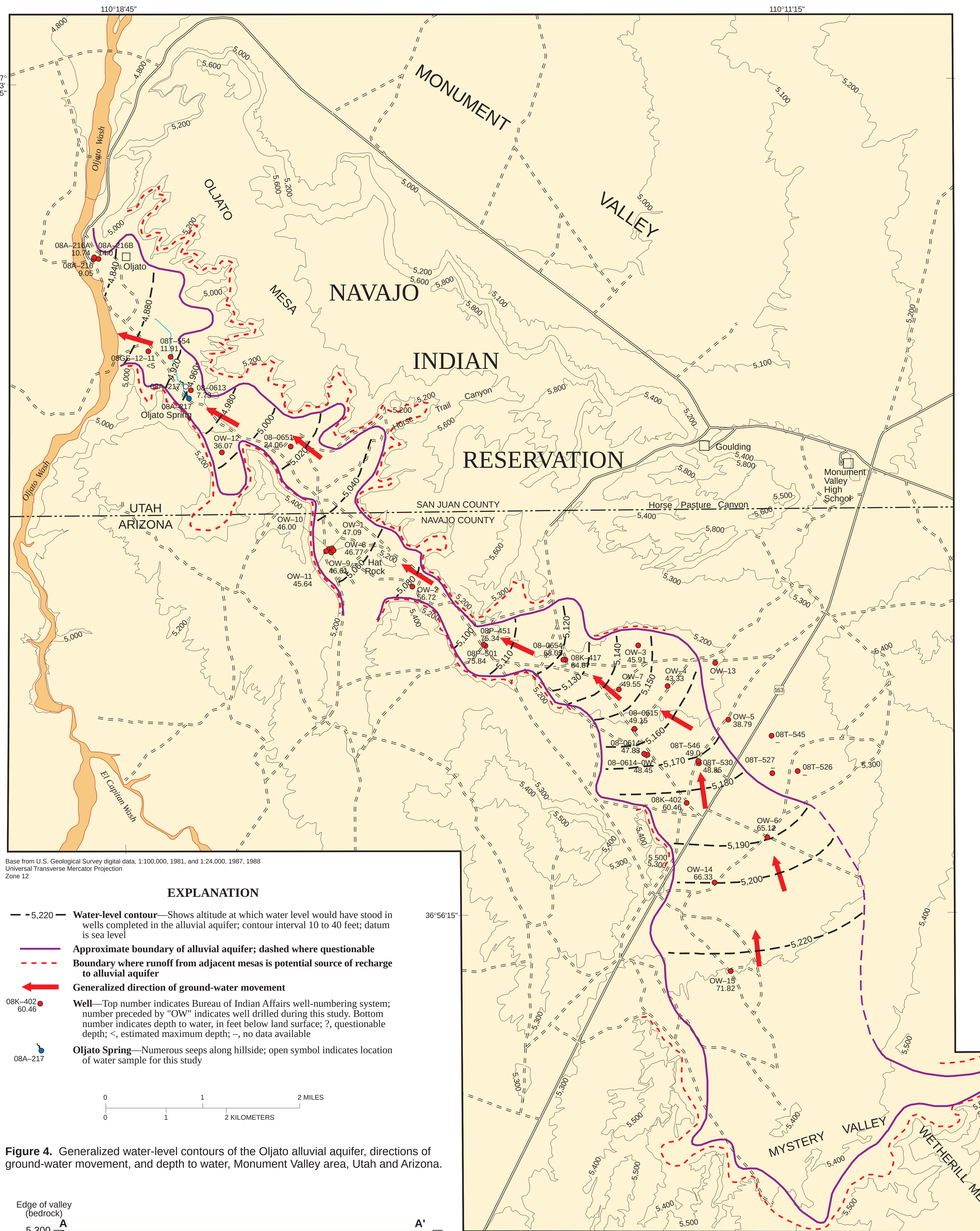

Figure 4. Generalized water-level contours of the Oljato alluvial aquifer, directions of ground-water movement, and depth to water, Monument Valley area, Utah and Arizona.

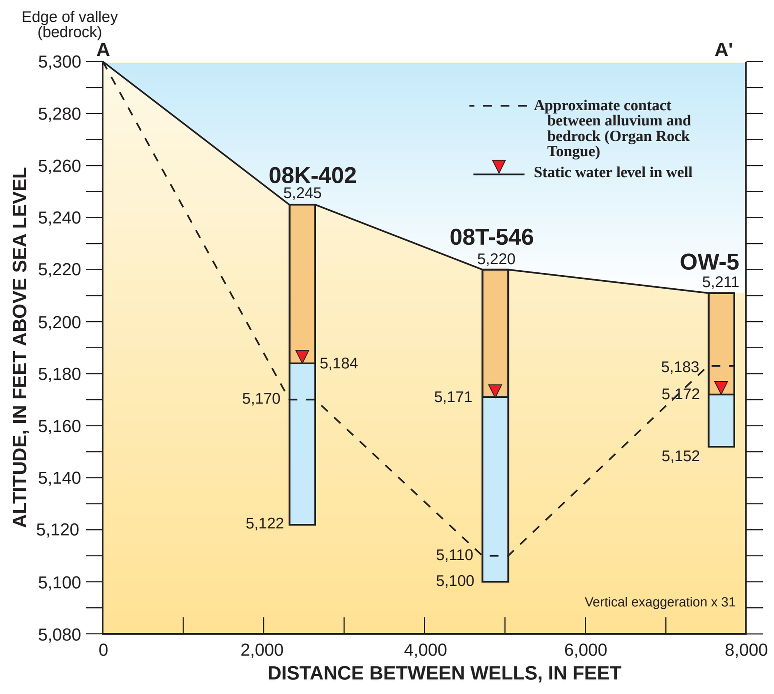

Figure 5. Hydrogeologic section from edge of valley to well OW-5, showing altitude of contact between alluvium and bedrock and thickness of the alluvial aquifer, Monument Valley area, Utah and Arizona. (Trace of section shown in figure 2.)

Water Levels and Ground-Water Movement

Ground-water availability and movement in the Oljato alluvial aquifer are influenced largely by the lithologic character and hydraulic properties of the alluvial deposits. Water levels measured in selected wells were used to determine directions of ground-water movement in the alluvial aquifer (fig. 4). Differences in water levels are attributed partially to differences in well depth and length of perforated or open interval in wells. Water levels in some wells can be influenced by vertical hydraulic gradients within the aquifer that result from semiconfining layers within the alluvium. In addition, water levels measured in some wells also can be influenced by inflow of water from underlying bedrock units where both the alluvium and bedrock are open to the well and head differences exist between the units.

Monthly measurements of water levels from August 1996 to September 1997 in five wells are shown in figure 6. Water levels in most wells varied only 0.2 ft or less during this period. Daily water-level measurements in well OW-2 for the month prior to an aquifer test in December 1996 also show variations of less than 0.04 ft, even during changes in barometric pressure (U.S. Geological Survey aquifer test, December 11-17, 1996). Water levels measured in some wells during this study were virtually the same as water levels measured when the wells were drilled (table 1). Long-term water-level data for the alluvial aquifer do not exist and would be necessary to document variability caused by seasonal effects and potential water-level declines from pumpage.

Depth to water in the study area generally decreases downgradient as land-surface altitude also decreases. Measured depth to water in some upgradient wells was more than 65 ft below land surface (fig. 4). Depth to water in the vicinity of Hat Rock was about 46 to 56 ft, and depth to water near Oljato Wash was only about 10 ft. The water table in the alluvial aquifer intersects land surface at Oljato Spring (fig. 4) and is shallow enough to be accessed by hand pumps (well 08GS-12-11) in this area.

Water-level contours indicate that ground-water movement in the alluvial aquifer is generally from southeast to northwest, from areas in Mystery Valley to Oljato Wash (fig. 4). The largest volume of ground water probably moves within paleochannel(s) that are present in at least parts of the study area (fig. 5). Discharge to Oljato Wash is mostly subsurface (underflow) because surface-water flow in the wash near Oljato is ephemeral. Altitude of the water table on September 23, 1997, in well OW-15 was about 82 ft higher than that in well OW-7, indicating a hydraulic gradient of about 26 ft/mi (0.005) between these wells (fig. 4). In downgradient areas near Oljato Wash, the gradient tends to be steeper because the canyon is substantially narrower than it is in upgradient areas and the aquifer is not as laterally extensive. Altitude of the water table in well 08T-554 was also about 82 ft higher than that in well 08A-216B; however, the hydraulic gradient between these wells is about 62 ft/mi (0.012) (fig. 4). Hydraulic gradients near water-supply wells also are steeper because of the cone of depression formed around pumping wells. Because well spacing in the study area is typically greater than 3,000 ft and public-supply wells are pumped intermittently at rates that are no greater than 85 gal/min, effects of pumpage on neighboring wells probably do not occur.

Recharge and Discharge

The Oljato alluvial aquifer appears to be largely contained within the tributary valley to Oljato Wash, although the boundaries of the valley, and hence, the aquifer, are less defined in the Mystery Valley area. Thus, recharge to the aquifer originates primarily from direct precipitation on the alluvial deposits in the valley and from infiltrating streamflow that originates as runoff from mesas immediately adjacent to the valley (fig. 4). Potential ground-water inflow from deeper consolidated-rock aquifers by upward or lateral movement also might take place in some areas.

Deposits of dune sand are widespread in the study area and precipitation tends to infiltrate rapidly with minimal runoff. Although recharge from precipitation occurs over an extensive area, the annual rate of recharge is probably low and evaporation rates can be high. During the summer, precipitation that infiltrates the surface deposits can evaporate directly through capillary motion or be absorbed by vegetation and subsequently transpired. During the winter, when temperatures and evaporation rates are substantially lower, infiltrating moisture can penetrate below the zone where evapotranspiration takes place. Thus, the greatest potential for areal recharge to the alluvial aquifer is during the winter (Cooley and others, 1969).

Runoff from precipitation on adjacent mesas also recharges the alluvial aquifer, particularly during and after summer thunderstorms. Runoff from mesas infiltrates the sandy alluvium along or within a short distance of cliff margins. In addition, runoff occurs in canyons that have developed by headward erosion into the cliff margins. Infiltration takes place where these ephemeral streams emerge from the canyons and flow into the valley. Areas of potential contribution to the alluvial aquifer from adjacent mesas and canyons are shown in figure 4.

Deeper regional aquifers underlie the study area and possibly could provide a source of recharge to the alluvial aquifer in some areas. Structural upwarping immediately west of Oljato has brought consolidated-rock formations to the surface, particularly the Permian-age Cedar Mesa Sandstone, where they can be recharged by infiltrating precipitation. Flowing wells in the El Capitan Wash area southwest of the study area (fig. 2) indicate that the DeChelly Sandstone is under artesian conditions and potentially could provide an upward source of water to alluvial aquifers along Oljato Wash. Head differences of less than 0.2 ft between wells OW-1 (completed in the alluvium and upper part of the DeChelly Sandstone), OW-8 (completed only in the alluvium), and OW-9 (completed only in the upper part of the DeChelly Sandstone) near Hat Rock, however, suggest that upward movement of water from the DeChelly Sandstone into the alluvial aquifer in this area is not likely.

Discharge from the Oljato alluvial aquifer is from ground-water pumpage, springs, and underflow to Oljato Wash. Eight wells in the study area withdraw water from the alluvial aquifer for public water supply (table 3). Average total discharge from public-supply wells is approximately 133 acre-ft/yr (table 3). Most springs in the study area are ephemeral. Oljato Spring is the largest perennial spring and discharges about 20 gal/min from the alluvial aquifer; however, water from the spring flows on the surface for only about 3,500 ft before infiltrating back into the alluvium (fig. 4).

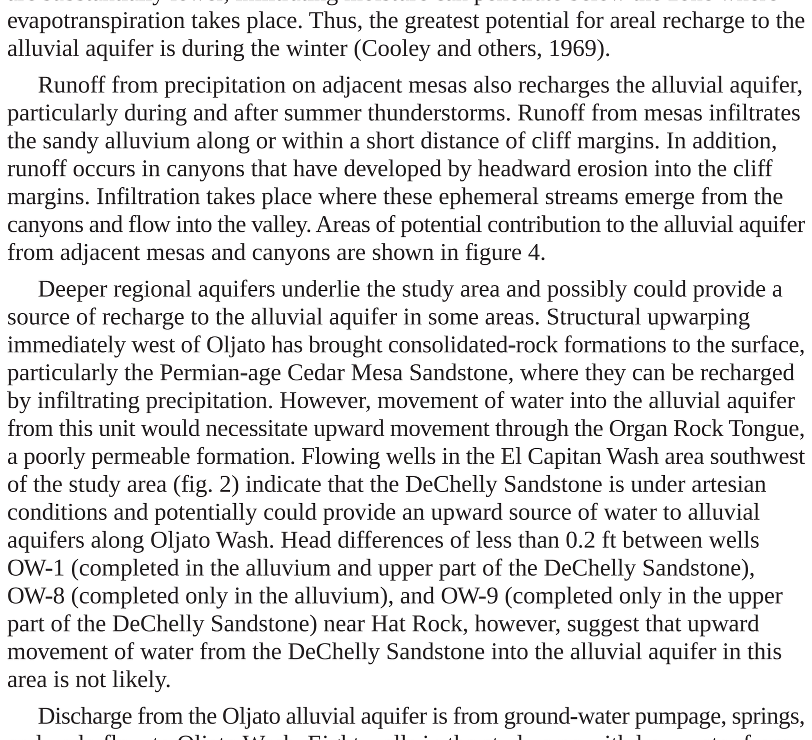

Figure 6. Monthly water-level measurements for selected wells in the Oljato alluvial aquifer, Monument Valley area, Utah and Arizona.

Total direct precipitation on the alluvium in the study area is approximately 6,300 acre-ft/yr, based on an average precipitation rate of 8 in/yr over an areal extent of about 9,500 acres. Given a conservative transmissivity value of about 300 ft^2/d, determined from pumping tests for water-supply wells 08-0613 and 08T-554 (table 2); a hydraulic gradient of about 0.025 ft/ft in the area of these wells; and an aquifer cross-sectional area of about 100,000 ft^2, based on an average aquifer thickness of 40 ft in the vicinity of these wells; then potential ground-water discharge from the alluvial aquifer to Oljato Wash (underflow) is estimated to be about 160 acre-ft/yr. On the basis of these assumptions and known withdrawals from the aquifer by pumpage, potential recharge to the alluvial aquifer is estimated to be about 5 percent (0.4 in.) of the precipitation that falls directly on this area, or about 300 acre-ft/yr. Because an additional unknown amount of recharge to the aquifer originates as runoff from adjacent mesas, recharge to the alluvial aquifer as a percentage of precipitation could be less.

Water Use

Water from the alluvial aquifer is used for municipal, domestic, commercial, irrigation, and stock purposes. Monument Valley Tribal Park, Gouldings Trading Post and Lodge, Monument Valley High School, Monument Valley Hospital/Mission, and the community of Oljato use this aquifer as their primary source of drinking water (table 3). On the basis of water-use records from January 1992 to June 1998, the average total amount of water withdrawn by these systems was about 3,600,000 gal/month (133 acre-ft/yr). Monument Valley High School and Gouldings Trading Post and Lodge are the principal users of water in the study area, averaging almost three-fourths of the total amount of water withdrawn from the aquifer during this period. Some ground water in the study area also is withdrawn by windmills (08K-402) and dug wells (08GS-12-11) or is supplied naturally by springs (08A-217) and used mostly for livestock watering. The amount of use from these sources is unknown and not monitored but is considered small in comparison with that utilized for public-water supply.

Table 3. Average water use from the Oljato alluvial aquifer by public-water systems, Monument Valley area, Utah and Arizona

System	Operator	Water-source wells	Average use (gallons per month)	Annual use (acre-feet per year)	Period of record
Monument Valley Tribal Park	Parks and Recreation Department	08T-546	31,376	1.2	01–92 to 01–96
Monument Valley High School	San Juan County School District	08-0614 08-0615	1,479,176	54.5	04–92 to 04-98
Monument Valley Hospital/Mission	Seventh Day Adventist Church	08P-451 08P-501	216,787	8.0	08–92 to 10–95
Oljato community	Navajo Tribal Utility Authority (NTUA)	08A-216B 08T-554	718,303	26.4	01–92 to 01–98
Goulding Trading Post and Lodge	RGJ, Incorporated	08K-417	1,166,477	43.0	07–93 to 06–98

Because water use for Monument Valley Tribal Park and Gouldings Trading Post and Lodge is mostly for tourism, water demand is seasonal. Greater amounts of water are used during the summer than are used during the winter. Monthly water use for the Tribal Park during March 1996 was about 3,000 gal and during August 1998, was 98,750 gal. Monthly water use for the Gouldings Trading Post and Lodge for August 1994 was about 2,180,000 gal and for February 1995, was about 580,000 gal. Water use for Monument Valley High School also varies seasonally. During the summer when school is not in session, less water is used for domestic purposes, but use for irrigation (lawn watering) is greater.

The total volume of water in storage in the alluvial aquifer and the volume of water potentially available for use cannot be determined accurately because of aquifer heterogeneity and large variations in thickness. If average saturated thickness is only 30 ft and specific yield (percentage of the aquifer that is potentially drainable) is about 20 percent for sand and gravel (Heath, 1989, p. 9), a volume of about 57,000 acre-ft potentially would be available for withdrawal from the aquifer. At an annual recharge rate of 300 acre-ft, as previously calculated, about 200 years would be required to replenish this loss from storage.

CHEMICAL QUALITY OF GROUND WATER

Water samples from 18 wells and 1 spring were collected during this study and analyzed for major ions, selected trace metals, alkalinity, and dissolved-solids concentration to assess variations in water quality in the Oljato alluvial aquifer (table 4). Water-quality data for three additional sites (wells 08A-216, 08A-216A, and 08-0613) are also reported. Temperature, pH, and specific conductance were measured in the field at most sites. Water-quality samples from public-supply wells were collected after wells had been pumping for at least 2 hours. Water-quality samples from monitoring wells drilled during the study were collected after wells had been developed for 1 to 2 hours. All water samples were analyzed by the U.S. Geological Survey National Water Quality Laboratory in Arvada, Colorado.

Specific conductance (field) of water from wells in the alluvial aquifer ranged from 330 to 1,290 µS/cm at 25°C; however, all but five wells and Oljato Spring contained water with a specific conductance less than 500 µS/cm (table 4). Concurrently, dissolved-solids (residue) concentration in water from the aquifer ranged from 179 to 789 mg/L, and water from most wells contained less than 300 mg/L (table 4). Water with dissolved-solids concentrations less than 1,000 mg/L is classified as "fresh" (Heath, 1989, table 2, p. 65). Water from wells 08A-216, 08A-216A, and 08A-216B in the community of Oljato contained the highest dissolved-solids concentrations in the study area (table 4). Temperature of water from most wells ranged from 14.0 to 17.0°C. The pH (field) of water from wells generally ranged from 7.8 to 8.2.

Hardness in water from wells ranged from 84 mg/L as $CaCO_3$ to as much as 452 mg/L; hardness in most water was between 120 and 180 mg/L (table 4). According to the classification of Durfor and Becker (1964, p. 27), most water from the alluvial aquifer would be considered "hard."

Results of chemical analyses indicate that water from most wells in the alluvial aquifer is a calcium-magnesium-bicarbonate type (fig. 7). Water from wells in the community of Oljato, well 08T-554, and from Oljato Spring, however, is a sodium-magnesium-bicarbonate-sulfate type. Higher dissolved-solids concentrations in water from the Oljato area are attributed to increased concentrations of sodium and sulfate (table 4).

Differences in water chemistry generally result from chemical interactions along ground-water flow paths and (or) mixing of waters with different chemical compositions. Some wells in the study area are open to both the alluvium and the underlying bedrock units, which allows water of potentially different chemical compositions to mix. Increased concentrations of sodium and sulfate in ground water in downgradient areas might have resulted from mixing with water from other areas or formations rather than from chemical interactions along the ground-water flow path. The driller's record for well 08A-216B indicates that specific conductance of water from the alluvium (land surface to 30 ft) was 1,230 µS/cm, and specific conductance of water from the underlying DeChelly Sandstone (30 to 50 ft) was 450 µS/cm. This implies that high sodium and sulfate concentrations in water from the alluvium do not result from mixing with water in the underlying bedrock in this area. Because water in the alluvium near Oljato Wash is within 15 ft of land surface, the aquifer is particularly susceptible to the effects of inflow from other bedrock units in the area that contain poorer quality water, particularly the Shinarump and Moenkopi Formations, and to potential effects of human activities. Thus, better quality water in downgradient areas possibly could be obtained by well completion in the underlying bedrock, although potential well yields generally are low.

SUMMARY

Water supply for residents of the Monument Valley area is limited. Because of this, the Navajo Nation Department of Water Resources, in cooperation with the U.S. Geological Survey, investigated the hydrology of, and quality of water in, an alluvial aquifer along a tributary of Oljato Wash, near Oljato, Utah. The Oljato alluvial aquifer is contained within unconsolidated deposits that overlie the DeChelly Sandstone Member and Organ Rock Tongue of the Permian-age Cutler Formation. Maximum thickness of the aquifer is 101 ft near Hat Rock and decreases both downgradient and upgradient from this area. Thickest alluvium probably is associated with paleochannel(s). Areal extent of the alluvial aquifer is about 9,500 acres.

Transmissivity values reported and determined for selected wells in the Oljato alluvial aquifer range from less than 100 to as much as 2,800 ft^2/d. On the basis of a U.S. Geological Survey aquifer test, potential well yield in some areas is at least 130 gal/min. Specific capacity ranges from 0.6 to 5.8 (gal/min)/ft of drawdown, and larger values generally correspond with areas of high transmissivity.

Water-level contours indicate that ground-water movement in the Oljato alluvial aquifer is generally from southeast to northwest, from areas in Mystery Valley to Oljato Wash. Monthly measurements of water levels from August 1996 to September 1997 varied only 0.2 ft or less. Depth to water in the study area generally decreases downgradient as land-surface altitude also decreases. Measured depth to water ranged from about 65 ft below land surface in upgradient areas to only about 10 ft near Oljato Wash. Because well spacing in the study area is typically greater than 3,000 ft and public-supply wells are pumped intermittently at low rates, effects of pumpage on neighboring wells probably do not occur.

Recharge to the Oljato alluvial aquifer originates primarily from direct precipitation in the valley and from infiltrating streamflow that originates as runoff from mesas immediately adjacent to the valley. The greatest potential for areal recharge to the alluvial aquifer is during the winter. Discharge from the alluvial aquifer is from ground-water pumpage, springs, and underflow to Oljato Wash. Total direct precipitation on the alluvium in the study area is approximately 6,300 acre-ft/yr. Given an average precipitation rate of 8 in/yr, potential recharge to the alluvial aquifer is estimated to be about 300 acre-ft/yr. Potential ground-water discharge from the alluvial aquifer to Oljato Wash is estimated to be about 160 acre-ft/yr.

Water from the alluvial aquifer is used for municipal, domestic, commercial, irrigation, and stock purposes. The average total amount of water withdrawn by eight public supply wells is about 133 acre-ft/yr. If the average saturated thickness is 30 ft and specific yield is about 20 percent, about 57,000 acre-ft potentially would be available for withdrawal from the aquifer.

Dissolved-solids concentration in water from the Oljato alluvial aquifer ranged from 179 to 789 mg/L, and water from most wells contained less than 300 mg/L. Water from most wells is a calcium-magnesium-bicarbonate type and would be considered "hard." Water from wells in the community of Oljato contains the highest dissolved-solids concentrations in the study area that result from increased concentrations of sodium and sulfate. Better quality water in downgradient areas possibly could be obtained by well completion in the underlying bedrock.

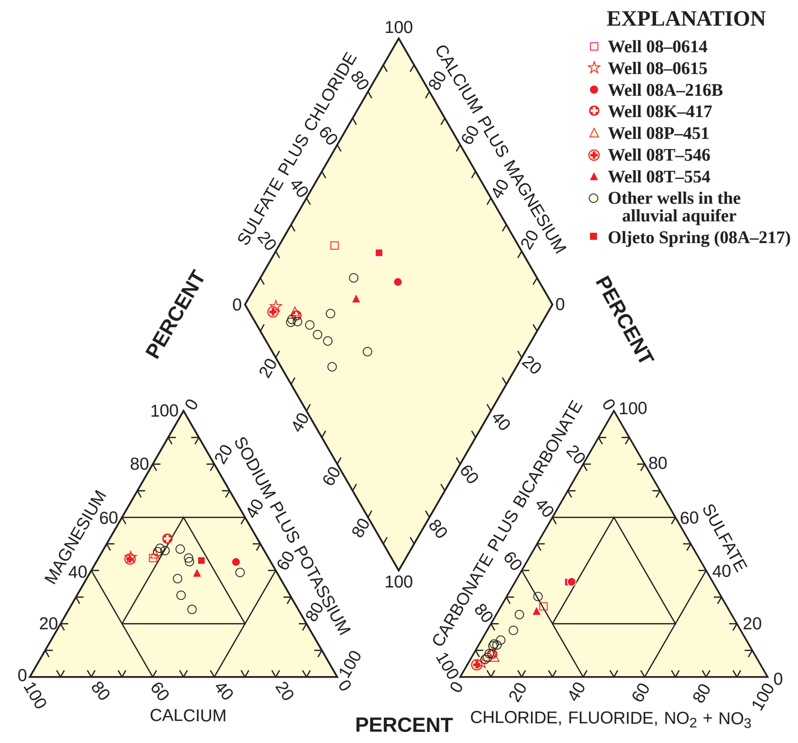

Figure 7. Quality of water in the Oljato alluvial aquifer, Monument Valley area, Utah and Arizona.

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
inch (in.)	0.0254	meter
inch per year (in/yr)	0.0254	meter per year
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
foot (ft)	0.3048	meter
square foot (ft^2)	0.0929	square meter
foot per day (ft/d)	0.3048	meter per day
foot squared per day (ft^2/d)[1]	0.0929	square meter per day
foot per mile (ft/mi)	0.1894	meter per kilometer
gallon (gal)	3.785	liter
gallon per minute (gal/min)	0.0631	liter per second
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter
gallon per month (gal/month)	3.785	liter per month
acre	0.4047	square hectometer
acre-foot (acre-ft)	0.001233	cubic hectometer
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year

[1]The standard unit for transmissivity is cubic foot per day per square foot of aquifer thickness $[(ft^3/d)/ft^2]ft$. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

In this report, degrees are reported in Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$°F = 9/5(°C)+32.$$

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Chemical concentration and water temperature are given only in metric units. Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to 1 milligram per liter. For concentrations less than 7,000 milligrams per liter, the numerical value is about the same as for concentrations in parts per million. Specific conductance is given in microsiemens per centimeter (µS/cm) at 25 degrees Celsius.

Table 2. Hydraulic properties reported and determined from aquifer testing and specific capacity for selected wells in the Oljato alluvial aquifer, Monument Valley area, Utah and Arizona
[gal/min, gallons per minute; min, minutes; ft^2/d, feet squared per day; ft/d, feet per day; NA, data not available or not applicable]

Pumping and observation wells: Refer to numbering system for hydrologic-data sites; locations shown in figure 2.
Duration: PUM, pumping time; REC, recovery time.
Drawdown: PW, pumping well; OW, observation well.
Specific capacity: (gal/min)/ft, gallons per minute per foot of drawdown.
Transmissivity (reported): values of transmissivity reported by Navajo Nation Department of Water Resources; D, determined from drawdown data; R, determined from recovery data.
Transmissivity (estimated from specific capacity): range in values based on storage coefficients of 0.0004 and 0.0047 determined by Neuman (1974) and Jacob (1963) methods, respectively; calculated values generally overestimate transmissivity where delayed yield effects (gravity drainage) occur.
Transmissivity (calculated): values determined by U.S. Geological Survey.
Remarks: T, transmissivity.

Pumping well	Observation well (distance from pumping well, in feet)	Test date	Pumping rate (gal/min)	Duration (PUM) (min)	Duration (REC) (min)	Drawdown (PW) (feet)	Drawdown (OW) (feet)	Specific capacity [(gal/min)/ft]	Transmissivity (reported) (ft^2/d)	Transmissivity (estimated from specific capacity)(ft^2/d)	Transmissivity (calculated) (ft^2/d)	Hydraulic conductivity (ft/d)	Storage coefficient (dimensionless)	Remarks
08A-216B	NA	10-15-81	23	1,440	60	4.0	NA	5.8	NA	1,300-1,500	NA	NA	NA	Single-well test
08T-546	08T-530 (50)	03-01-78	10-43	1,440	30	6.0	0.5	4.5	NA	960-1,100	NA	NA	NA	Step-drawdown test
08T-554	NA (25)	09-01-83	40	1,440	60	28.3	5.3	1.4	290D 310R	260-320	NA	7.3	NA	T determined by Neuman method
08-0613	NA	08-16-92	31	1,350	NA	17.6	NA	1.8	NA	340-410	NA	NA	NA	Single-well test
08-0614	08-0614-OW (200)	03-02-78	15	4,000	400	25.5	2.32	.6	190	120	NA	3.2	$4.7x10^{-3}$	T determined by Jacob method
08-0615	NA	05-12-78	40	1,350	100	9.0	NA	4.4	2,100D 2,800R	940-1,100	NA	40	NA	T determined by Jacob method
OW-4	NA	12-12-96	10.9	48	55	4.57	NA	2.4	NA	370-470	NA	NA	NA	Single-well test
OW-7	NA	12-11-96	10.9	60	60	5.13	NA	2.1	NA	330-420	NA	NA	NA	Single-well test
OW-8	OW-1 (50) OW-9 (50) OW-10 (100) OW-11 (300)	12-11-96	130	4,320	4,320	23	11.47 7.19 7.87 3.47	5.6	NA	1,600	1,300D 1,200R	13.4	$4.0x10^{-4}$	T determined by Neuman method
OW-14	NA	09-24-97	10.3	25	25	18.8	NA	.6	NA	70-100	NA	NA	NA	Single-well test

Table 4. Physical properties and major chemical constituents in ground-water samples collected from selected wells and a spring in the Oljato alluvial aquifer, Monument Valley area, Utah and Arizona
[°C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; —, no data; <, less than stated value]
Map number: Refer to numbering system for hydrologic-data sites; locations shown in figure 2.

Map number	Date sampled	Water temperature (°C)	Specific conductance, field (µS/cm)	Specific conductance, lab (µS/cm)	pH, field (standard units)	pH, lab (standard units)	Hardness, total (mg/L as $CaCO_3$)	Alkalinity, lab (mg/L as $CaCO_3$)	Solids, sum of constituents, dissolved (mg/L)	Solids, residue at 180°C, dissolved (mg/L)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Bromide, dissolved (mg/L as Br)	Silica, dissolved (mg/L as SiO_2)	Iron, dissolved (mg/L as Fe)	Manganese, dissolved (mg/L as Mn)	Nitrate, total (mg/L as NO_3)
OW-1	07-18-96	20	345	354	8.7	8.1	140	153	191	194	20	21	24	2.6	22	6.8	0.3	0.06	2.4	4	30	—
OW-2	12-14-96	14	330	328	8.0	8.3	84	117	178	—	7.7	16	34	2.4	39	7.7	.3	—	.3	3	1	—
	07-18-96	20	445	423	8.7	8.0	96	149	254	253	17	13	59	2.7	62	9.3	.4	.08	1.3	21	46	—
OW-3	07-19-96	—	—	826	—	8.1	120	215	495	501	16	20	130	5.3	150	33	.6	.27	11	3	1	—
OW-4	07-20-96	17	420	408	8.3	7.9	170	180	235	263	25	27	25	2.4	26	6.8	.3	.08	14	4	52	—
OW-6	07-22-96	19	475	484	—	7.9	190	147	282	287	28	28	35	3.1	72	17	.4	.2	10	27	80	—
OW-7	07-25-96	17	420	385	8.2	8.0	180	179	223	229	29	26	19	2.5	18	6.4	.3	.08	14	7	29	—
OW-8	12-14-96	14.5	350	361	8.0	8.0	150	168	196	196	26	21	14	2.0	13	6.3	.3	—	13	3	1	—
	07-24-96	16	375	359	8.2	8.0	150	161	197	190	25	22	16	2.4	15	6.7	.3	.08	13	6	2	—
OW-14	08-27-97	17.5	410	401	8.2	8.1	140	161	223	240	30	16	31	1.7	27	7.8	.3	—	12	69	20	—
OW-15	08-28-97	17	385	373	8.2	8.2	120	158	210	224	27	12	35	1.8	22	5.9	.2	—	12	71	44	—
08A-216	10-01-48	—	1,230	—	—	—	452	[1]394	778	—	46	82	[6]124	—	226	61	1.9	—	—	—	—	.9
08A-216A	09-30-54	15	989	—	—	—	304	[1]294	629	—	28	57	[6]116	—	180	50	1.0	—	18	—	—	2.9
08A-216B	01-27-97	15	1,290	1,270	7.8	8.0	370	320	783	789	31	72	140	2.1	240	86	.9	—	19	3	1	—
	09-30-54	20	986	—	—	—	316	[1]307	—	—	31	58	—	—	—	46	1.0	—	—	—	—	—
[7]08A-217	01-28-97	8.0	860	846	8.2	8.1	300	[2]217	521	525	41	49	70	1.1	160	56	.6	—	13	3	1	—
	06-08-48	—	997	—	—	—	450	[1]230	659	—	50	79	[6]56	—	299	20	.7	—	16	—	—	.3
08K-402	01-25-97	13	480	481	8.1	8.1	180	173	263	282	34	23	33	1.9	40	13	.3	—	14	26	1	—
	08-11-49	15.5	913	—	—	—	300	[3]174	598	—	59	37	[6]88	—	230	42	.3	—	16	—	—	2.2
08K-417	01-28-97	15	400	386	8.0	8.0	170	179	216	207	24	26	16	2.4	18	7.9	.3	—	14	4	1	—
	11-10-48	—	392	—	—	—	168	[4]190	213	—	23	27	[6]23	—	19	6.0	.4	—	—	—	—	2.2
08P-451	01-23-97	15	365	368	8.0	8.0	160	168	204	198	28	22	14	2.2	15	9.2	.3	—	13	3	1	—
08T-546	12-18-96	15	335	328	8.0	7.8	150	159	175	179	30	18	6.6	2.0	8.2	3.0	.2	—	12	3	1	—
08T-554	01-27-97	16	710	701	7.8	7.9	250	244	423	417	40	36	59	2.9	92	33	.4	—	13	4	3	—
08-0613	[5]06-12-96	—	—	407	—	7.4	190	285	—	230	31	28	20	2.7	32	6.5	.3	—	—	110	<10	.71
08-0614	12-16-96	14	530	525	8.0	8.0	220	158	293	312	40	29	20	2.3	68	25	.2	—	14	3	1	—
08-0615	12-16-96	14	330	338	8.0	8.0	160	158	180	184	31	19	6.8	2.0	9.5	4.5	.2	—	12	3	1	—
08-0651	12-15-96	16	365	362	8.0	8.1	150	173	198	197	25	22	14	2.2	13	5.6	.3	—	12	3	1	—

[1] Alkalinity determined from bicarbonate concentration.
[2] Alkalinity (field), 210 mg/L as $CaCO_3$; bicarbonate, 256 mg/L as HCO_3.
[3] Alkalinity reported as field value; bicarbonate, 212 mg/L as HCO_3.
[4] Alkalinity reported as field value; bicarbonate, 216 mg/L as HCO_3; carbonate, 6 mg/L as CO_3.
[5] Analysis by Inter-Mountain Laboratories, Farmington, New Mexico; barium, 0.12 mg/L; selenium, 0.005 mg/L; zinc, 0.12 mg/L.
[6] Sodium plus potassium.
[7] 08A-217, Spring discharges from numerous seeps along hillside; source of sample collected in 1948 unknown.

Hydrology and water quality of the Oljato alluvial aquifer, Monument Valley area, Utah and Arizona

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1999

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