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Water Supply at Los Alamos during 1996

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WATER SUPPLY AT LOS ALAMOS DURING 1996

by

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ABSTRACT

Production of potable municipal water supplies during 1996 totaled about 1,368.1 million gallons from wells in the Guaje, Pajarito, and Otowi well fields. There was no water used from either the spring gallery in Water Canyon or from Guaje Reservoir during 1996. About 2.6 million gallons of water from Los Alamos Reservoir was used for lawn irrigation. The total water usage in 1996 was about 1,370.7 million gallons, or about 131 gallons per day per person living in Los Alamos County. Groundwater pumpage was up about 12.0 million gallons in 1996 compared with the pumpage in 1995.

I. INTRODUCTION

This report fulfills requirements specified in U.S. Department of Energy (DOE) Order 5400.1 (Groundwater Protection Management Program), which requires the Los Alamos National Laboratory (LANL) to monitor and document groundwater conditions below Pajarito Plateau and to protect the regional aquifer from contamination associated with Laboratory operations. Furthermore, this report also fulfills special conditions outlined in Module VIII of the Laboratory's Hazardous and Solid Waste Amendments (HSWA) portion of the Resource Conservation and Recovery Act (RCRA) operating permit (NM-0890010515), which was jointly issued by the U.S. Environmental Protection Agency (EPA) and the New Mexico Environment Department (NMED) to the Laboratory and DOE. This report satisfies portions of those requirements by providing information on hydrologic characteristics of the regional aquifer, including operating conditions of the municipal water supply system.

This report summarizes production statistics and aquifer conditions for water wells in the Guaje, Pajarito, and Otowi well fields (Fig. 1). During 1996 these wells supplied all of the potable water used for municipal and some industrial purposes in Los Alamos County, Los Alamos National Laboratory, and Bandelier National Monument. Only one of two wells in the Otowi well field was operational during 1996. In 1992 some of the wells in the Los Alamos well field were plugged and abandoned in accordance with New Mexico State Engineer Office requirements, and ownership of the remaining wells in the field was transferred from DOE to San Ildefonso Pueblo. Hence no hydrological data were available from the Los Alamos well field in 1996. The spring gallery in Water Canyon, which has supplied nonpotable water for industrial use in recent years, was not used in 1996, while Los Alamos Reservoir supplied some water for lawn irrigation. In 1996 no water was used from Guaje Reservoir. Due to high maintenance and operating costs associated with diverting surface water from these reservoirs, it was not economically feasible to continue their use for irrigation.

This report is a joint effort between the Laboratory's Water Quality and Hydrology Group (ESH-18) and the Utilities Department of Johnson Controls World Services, Inc. (JCI). The purpose of this report is twofold. First, it provides a continuing historical record of water usage. Second, it provides guidance to management for long-range water resources planning and operation of the water supply system. Furthermore, it also provides documentation of water level fluctuations in wells that penetrate into the regional

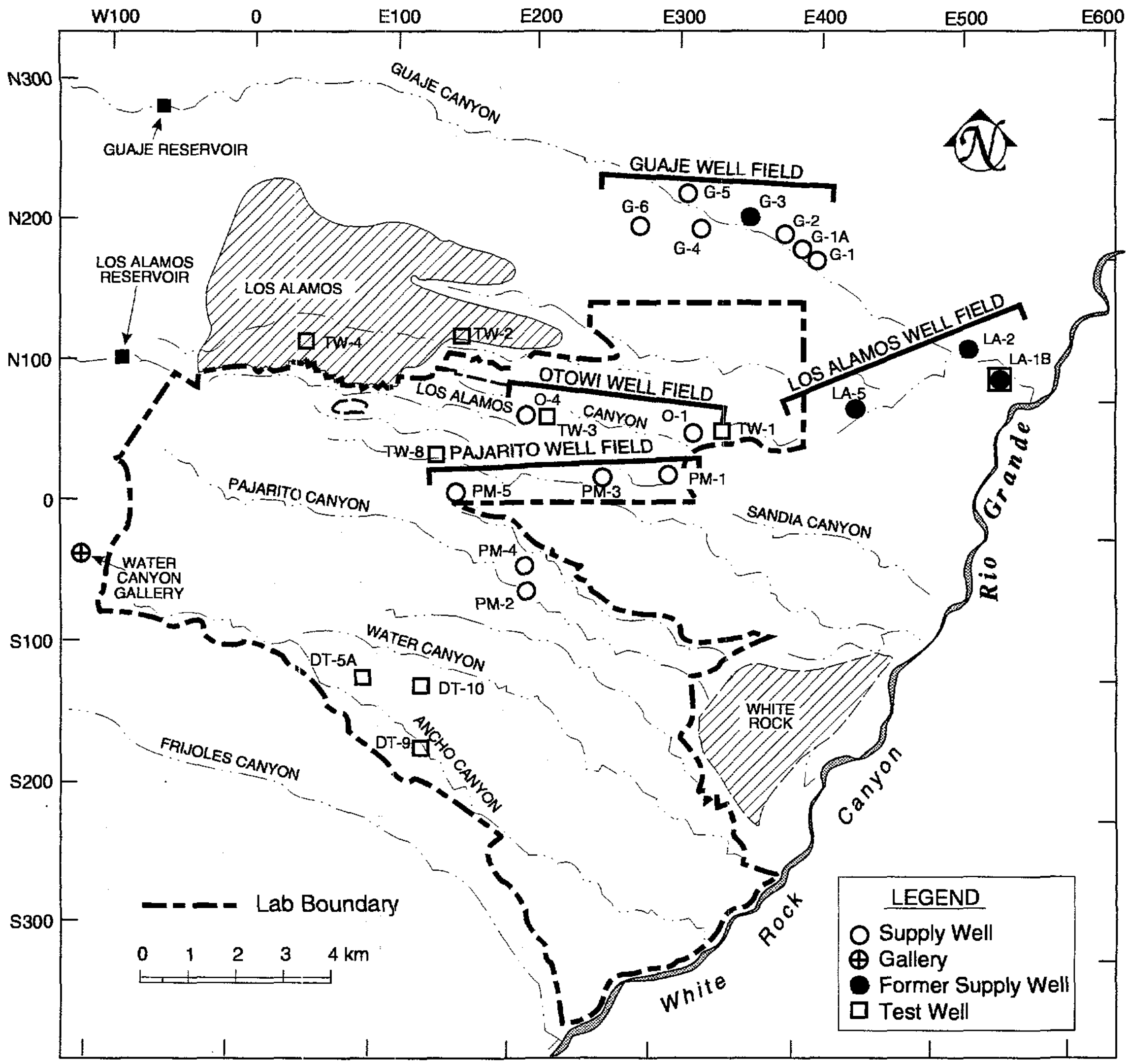

Fig. 1. Locations of reservoirs, well fields, water supply wells, test wells, and the water gallery supply. Letter designations indicate wells in the Guaje (G), Pajarito Mesa (PM), and Otowi (O) well fields. Ownership of the Los Alamos (LA) well field was transferred to San Ildefonso Pueblo in 1992.

aquifer, detailed results of pump test analyses, water quality data, and other important summaries of aquifer drilling and hydrological testing programs. One summary report [1] has been issued for the period of 1947 to 1971. Since then, 25 annual reports that contain the results of past water supply studies [2–26] have been published. An additional report summarized the hydrology of the regional aquifer and made recommendations for future development of groundwater supplies [27]. A 1988 report examined the status of wells and future water supply [28]. Finally, a 1995 report described individual drilling logs from water supply and test wells [29].

JCI, the support contractor to the Laboratory and DOE at Los Alamos, maintains and operates the water supply system. DOE sells water to Los Alamos County for the communities of Los Alamos and White Rock and to the National Park Service for water supply at Bandelier National Monument. Annual water production statistics and data representing aquifer characteristics for the Guaje, Pajarito, and Otowi wells are contained in Appendix A. Historical water level data from regional aquifer test wells (Fig. 1) are summarized in Appendix B. Historical water production and aquifer characteristics data for the Los Alamos well field were previously reported [26].

Potable water is pumped from the wells into the distribution lines. Booster pumps lift this water to reservoir storage tanks for distribution to the Laboratory and the community. The entire water supply is disinfected with chlorine before distribution to Los Alamos, White Rock, Bandelier National Monument, and Laboratory areas (Fig. 1). When needed, additional nonpotable water for industrial use at TA-16 flows by gravity from the gallery in Water Canyon to the steam plant. The transmission line from the gallery to the steam plant is separate from the potable supply.

JCI maintains a record of the hours of operation for each well, along with records of daily and monthly water production using in-line flow meters. Monthly averages of nonpumping and pumping water levels are computed from air-line bubble-pressure measurements or pressure transducer data recorded at each well. These data are used to determine individual well pumping rates, drawdown, and other important well field performance statistics. Appendix A contains 1996 annual pumping and production information for all active water supply wells.

Guaje, Pajarito, and Otowi well fields are located on Pajarito Plateau and in Guaje Canyon (Fig. 1). The supply wells are all completed into the regional aquifer located below the Los Alamos area. This is the only local aquifer capable of municipal and industrial water supply. The piezometric surface of the regional aquifer ranges from about 20 ft above ground level (artesian) in portions of the old well field in lower Los Alamos Canyon (i.e., near Los Alamos Well 1B [LA-1B]), to about 753 ft below ground surface along the eastern edge of the plateau near Pajarito Mesa Well 1 (PM-1), and to more than 1,230 ft below ground surface near the center of the plateau at PM-5. Water in the regional aquifer generally moves eastward to southeastward beneath the plateau toward the Rio Grande, where at least a portion is discharged into the river through seeps and springs [26–29]. Most of these seeps and springs are located adjacent to the western side of the Rio Grande between Otowi Bridge and Frijoles Canyon above Cochiti Reservoir.

The Water Canyon Gallery, which is located west of the Laboratory on the flanks of the Sierra de los Valles, discharges water from a small, shallow, perched aquifer located in the volcanic rocks (Fig. 1). The two man-made reservoirs, Guaje and Los Alamos, are located on the flanks of the Sierra de los Valles to the northwest and west of Los Alamos (Fig. 1) and are replenished by rainfall and snowmelt runoff and by shallow ephemeral spring flows.

II. WELL FIELD CHARACTERISTICS

Total water production from the three well fields increased about 12.0 million gallons from 1,356.1 million gallons in 1995 to about 1,368.1 million gallons in 1996 (Table 1). The months of heaviest production in 1996 were May, June, and August. The production during these months was 512.3 million gallons, an increase of 31.8 million gallons from a similar period of heavy production in 1995. The months of lightest production were January, February, and December with a production of 235.5 million gallons, an increase of 1.8 million gallons from a similar period in 1995.

The difference in demand between periods of heavy and light production (i.e., summer and winter demands) is mainly due to water usage for landscape irrigation. Nonpumping water levels in the wells respond accordingly, with the highest water levels observed during months of least production and the lowest water levels occurring during months of greatest production. The 1996 growing season, which required irrigation, occurred from May through October. About 62% (847.6 million gallons) of the total water (1,368.1 million gallons) used was during this time. The annual and monthly variation in water usage, however, could not be correlated with annual or monthly precipitation.

Peak-demand periods generally occur in the summer between late June and mid-July. For the past 10 years (1987–1996), these periods have ranged from 6 to 34 days in length (Table 2). The average daily production during these peak-demand periods has varied from 7.0 million gallons per day (mgpd) to 9.0 mgpd. In 1996, however, the peak-demand period occurred in May. This period encompassed a 13-day interval from May 11 through May 23 with a total production of 97.8 million gallons (Table 2). The average daily pumpage during this period was 7.5 mgpd as compared with 7.1 mgpd in 1995. This early peak-demand period resulted from an unusually dry spring and a large forest fire (the Dome fire) centered about 8 miles south of Los Alamos. This fire consumed vegetation on more than 17,000 acres of U.S. Forest Service and U.S. National Park lands. Municipal supply wells were heavily pumped during this period to keep storage tanks filled to capacity for local fire protection.

Table 1. Potable Water Production from Wells and Gallery: 1947–1996 (in millions of gallons)

Year	Los Alamos Field	Guaje Field	Pajarito Field	Otowi Field	Water Canyon Gallery[1]	Annual Total
1947	147	0	0	0	84	231
1948	264	0	0	0	97	361
1949	302	0	0	0	92	394
1950	547	3	0	0	54	604
1951	702	68	0	0	39	809
1952	448	350	0	0	48	846
1953	444	372	0	0	39	855
1954	380	374	0	0	40	794
1955	407	375	0	0	33	815
1956	437	506	0	0	23	966
1957	350	378	0	0	40	768
1958	372	395	0	0	60	827
1959	391	478	0	0	54	923
1960	530	533	0	0	48	1,111
1961	546	624	0	0	54	1,224
1962	577	597	0	0	67	1,241
1963	539	654	0	0	51	1,244
1964	627	665	0	0	45	1,337
1965	447	571	99	0	72	1,189
1966	450	613	127	0	82	1,272
1967	373	464	481	0	56	1,374
1968	345	474	584	0	65	1,468
1969	331	435	569	0	80	1,415
1970	360	423	595	0	65	1,443
1971	412	484	657	0	37	1,590
1972	380	467	662	0	40	1,549
1973	406	475	685	0	49	1,615
1974	369	453	802	0	35	1,659
1975	356	431	749	0	42	1,578
1976	343	531	817	0	41	1,732
1977	345	515	614	0	57	1,531
1978	302	444	690	0	45	1,481
1979	289	456	662	0	44	1,451
1980	339	485	743	0	32	1,599
1981	336	469	701	0	45	1,551
1982	317	422	773	0	46	1,558
1983	221	338	904	0	38	1,501
1984	326	460	780	0	34	1,600
1985	290	456	841	0	37	1,624
1986	179	460	858	0	28	1,525
1987	217	485	892	0	34	1,628
1988	158	477	824	0	0	1,459
1989	219	506	961	0	0	1,686
1990	187	532	923	0	0	1,642
1991	125	502	820	0	0	1,447
1992	13	472	1,044	0	0	1,529
1993	0	298	876	284	0	1,458
1994	0	179	1,042	206	0	1,427
1995	0	230	1,126	0	0	1,356
1996	0	269	889	210	0	1,368
Total	16,445	20,648	23,790	700	2,072	63,655

[1]Water Canyon Gallery not used as potable water supply after 1987; see nonpotable production, Table 7.

Table 2. Peak-Demand Periods for the Years 1987–1996 (pumpage in millions of gallons)

Start Date	**7/2**	**6/18**	**6/18**	**5/31**	**6/24**	**7/1**	**6/25**	**7/1**	**7/8**	**5/11**
End Date	**7/17**	**6/26**	**7/11**	**7/3**	**6/29**	**7/9**	**7/12**	**7/18**	**7/14**	**5/23**
Year	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**
Total No. of Days	16	9	24	34	6	9	18	18	7	13
Total Pumpage	134.4	63.0	216.0	296.8	45.8	73.9	145.8	140.4	49.3	97.8
Average Daily Pumpage	8.4	7.0	9.0	8.7	7.6	8.2	8.1	7.8	7.1	7.5
No. of Days When Pumpage Was										
$>10 \times 10^6$ gal.	0	0	4	8	0	0	0	0	0	0
$>9 \times 10^6$ gal.	4	0	9	13	0	2	2	0	0	0
$>8 \times 10^6$ gal.	7	2	10	3	4	3	12	8	1	3
$>7 \times 10^6$ gal.	4	3	0	4	0	4	2	9	2	8
$<7 \times 10^6$ gal.	1	4	1	6	2	0	2	1	4	2

The annual production and use of water at the Laboratory and in the community increased from about 231 million gallons in 1947, to 1,732 million gallons in 1976. Water usage in 1977 declined to about 1,531 million gallons. Annual usage has ranged from about 1,451 million gallons in 1979, to about 1,686 million gallons in 1989 (Fig. 2). The 1976 maximum has not been approached in recent years.

The change that occurred in the long-term use pattern is partly attributable to a decline in per-capita water use by Los Alamos County. Per-capita use has declined to about 47,500 gallons per year (131 gpd/person) since 1980 after reaching a peak of about 74,100 gallons per year (203 gpd/person) in 1974. Some of this decline may be related to the cost of water, which has increased by a factor of about 10 in the last 20 years. Laboratory use has been nearly constant at about 500 million gallons per year (mgpy) (1.37 mgpd) since the late 1970s [26]. Annual residential water consumption from 1990 through 1996 in Los Alamos County is summarized in Table 3.

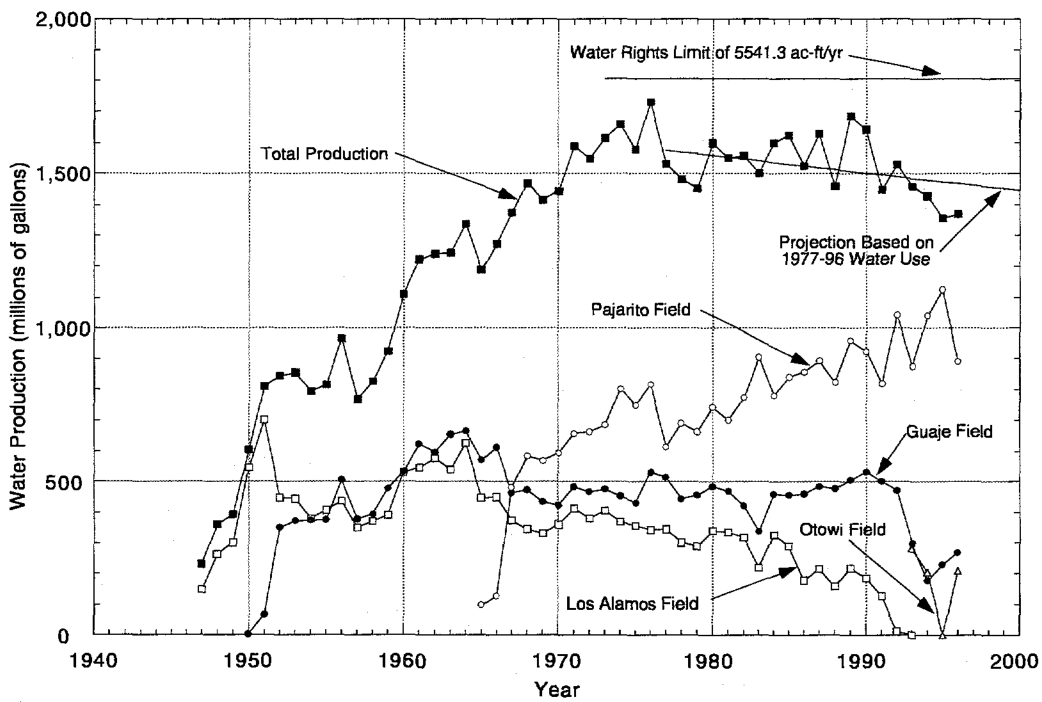

Fig. 2. Water production and usage from 1947 to 1996, as well as projected water demands.

Table 3. Residential Water Consumption in Los Alamos County

Year	Los Alamos County Population[1] (people)	Total Annual Water Use (mgpy)	LANL Water Use (estimated) (mgpy)	Residential Water Consumption (gpd/person)
1990	18,115	1,642	500	173
1991	18,029	1,447	500	144
1992	18,068	1,529	500	156
1993	18,352	1,458	500	143
1994	18,529	1,427	500	137
1995	18,635	1,356	500	126
1996	18,212	1,368	500	131

[1]Population Estimates Program, Population Division, U.S. Bureau of the Census, 1997.

A projection of future water use is plotted along with observed total water production in Fig. 2. This projection is an extrapolation of a least-squares linear regression curve fit of actual production versus time, using the 20-year interval from 1977 through 1996. This trend line shows a slight decline of about 5.72 mgpy (15,671 gpd). Annual production is plotted for the four well fields to show a comparison of the distribution of production (Fig. 2). The production from any individual well field peaks as another well field is brought on-line. For example, the production from the Los Alamos well field peaked in 1951 as the Guaje well field became operational. Similarly, the production from the Guaje well field peaked in 1964 as the Pajarito well field was phased into use. The last year of municipal supply from the Los Alamos well field occurred in 1991. As a result, the loss of production from the Los Alamos well field has been offset by an increase in production from the Pajarito well field. This expansion of well fields is necessary as older wells deteriorate with age and their production rates decrease. New wells must be added to the system to keep up with demand.

The present annual aquifer water yields reflect the distribution of production among the various well fields, routine cyclical pumping operations, and occasional shutdowns for pump maintenance. In addition, Guaje Well 3 (G-3) was nonoperational during all of 1996, while G-4 was on-line only during the summer peak demand. The pump in Otowi Well 4 (O-4) was repaired during 1996, and the well was returned to routine service. In addition, a new submersible pump was installed in O-1, and the well was test pumped in December 1996; however, O-1 did not enter routine service as a water supply well during 1996. During 1996, about 20% of total water production came from the Guaje well field, about 65% from the Pajarito well field, and 15% from the Otowi well field. In 1995 the percentages of production were about 16% from the Guaje well field, 84% from the Pajarito well field, and 0% from the Otowi well field (Table 4).

A. Guaje Well Field

The Guaje well field consists of seven wells ranging in depths from 1,500 to 2,000 ft. Wells G-1, G-2, G-3, G-4, and G-5 were completed in 1950. Well G-1A was completed in 1954, and G-6 was placed in service in 1964. Almost all of the 1996 Guaje well field production came from only four of these wells (G-1A, G-2, G-5, and G-6). Attempted rehabilitation of G-3 in 1986 damaged the casing beyond repair, and the well was permanently taken out of production. Hence no water levels have been collected from G-3 since 1986. Wells G-1 and G-4 were pumped sparingly during 1996, and nonpumping water levels were reported for only four months in these wells. Well G-5 was heavily pumped during 1996, but no water level records are available. Because of deteriorating well casings, screens, and gravel packs, most individual water yields in the Guaje well field have declined to the point where it is not economically feasible to routinely pump them. Except for G-1A and G-2, all wells in the Guaje well field are scheduled to be replaced with four new production wells by the end of 1998. Wells G-1A and G-2 will be retained as additional water production capacity for emergency fire protection. As these new wells are completed and enter routine water production, the older wells will be plugged and abandoned in accordance with New Mexico State Engineer Office regulations.

Table 4. Well Production Characteristics for 1995 and 1996

	Production					
	Amount (10^6 gal.)		Well Field (%)		Total Production (%)	
	1995	1996	1995	1996	1995	1996
Guaje Field						
Well G-1	28.5	12.9	12	5	2	1
Well G-1A	67.2	71.3	29	26	5	5
Well G-2	70.1	75.3	31	28	5	6
Well G-3	0.0	0.0	0	0	0	0
Well G-4	0.0	7.2	0	3	0	<1
Well G-5	17.6	66.9	8	25	1	5
Well G-6	46.4	36.0	20	13	3	3
Subtotal	229.8	269.6	100	100	16	20
Pajarito Field						
Well PM-1	29.7	36.3	3	4	2	3
Well PM-2	217.7	302.2	19	34	16	22
Well PM-3	159.7	118.5	14	13	12	9
Well PM-4	428.2	207.4	38	24	32	15
Well PM-5	291.0	224.6	26	25	21	16
Subtotal	1,126.3	889.0	100	100	84	65
Otowi Field						
Well O-4	0.0	209.6	0.0	100	0	15
Subtotal	0.0	209.6	0.0	100	0	15
Total Potable	1,356.1	1,368.1	—	—	100	100
Water C. Gallery	1.6	0.0	50	0	<1	0
Guaje Reservoir	0.0	0.0	0	0	0	0
Los Alamos Res.	1.6	2.6	50	100	<1	<1
Total Nonpotable	3.2	2.6	100	100	<1	<1
Total Production from Permitted Sources	1,359.3	1,370.7	—	—	100	100

The total production from the Guaje well field increased about 39.7 million gallons from 229.8 million gallons in 1995, to 269.6 million gallons in 1996. The well field contributed about 20% of the total production in 1996 (Table 4). The total well field pumping rate increased to 1,866 gallons per minute (gpm) in 1996 from 1,640 gpm in 1995 because G-4 was used for several months during the year (Table 5). However, a comparison of average annual pumping rates for individual wells in the Guaje field continues to reflect long-term declining yields of this aging well field. There were no significant changes in the specific capacities of individual pumped wells in 1996 compared with the previous year.

A comparison of the average nonpumping water levels in G-2, G-4, and G-6 indicates slightly lower levels in 1996 compared with 1995, while G-1 and G-1A showed slightly higher water levels (Table 6). These water level changes are due to changes in total pumped volume from individual wells in the field during 1996 compared with the previous year. Such changes are normal and indicate some decline in response to increases in pumped volumes (Fig. 3 and Table 6).

Table 5. Average Pumping Rate and Specific Capacity, 1995 and 1996

	Average Pumping Rate (gpm)		Average Specific Capacity (gpm/ft of drawdown)	
	1995	1996	1995	1996
Guaje Field				
Well G-1	187	191	1.1	1.1
Well G-1A	409	417	12.0	13.0
Well G-2	413	417	14.2	16.0
Well G-3[1]	0	0	0.0	0.0
Well G-4[1]	0	166	0.0	0.8
Well G-5[1]	364	415	—	—
Well G-6	267	260	3.2	3.2
Total for Field	1,640	1,866		
Pajarito Field				
Well PM-1	569	560	24.7	24.3
Well PM-2	1,306	1,252	20.4	—
Well PM-3	1,350	1,410	56.3	54.2
Well PM-4	1,244	1,270	—	26.5
Well PM-5	1,228	1,257	—	13.5
Total for Field	5,697	5,749		
Otowi Field				
Well O-4[1]	0	1,499	0.0	—
Total for Field	0	1,499		

[1]Well not in service during all or part of 1996.

B. Pajarito Well Field

The Pajarito well field consists of five wells. The wells were completed over an 18-year period, from 1965 through 1982, and range in depths from 2,300 to 3,100 ft. Because they are located on Pajarito Plateau, the depths to water range from about 753 ft at PM-1 to more than about 1,230 ft at PM-5. In late 1995 the pump assembly in PM-2 was reset approximately 60 ft lower, at a depth of 1,060 ft below the top of the surface casing. During this operation the water level measuring device was broken. Hence no water level records were collected during 1996.

The 1996 production from the Pajarito well field was about 889.0 million gallons, a decrease of 237.3 million gallons from the 1,126.3 million gallons produced in 1995 (Table 4). The field contributed about 65% of the total 1996 production. The production from PM-2, PM-4, and PM-5 represented about 53% of the total water produced at Los Alamos in 1996 (Table 4).

The average pumping rates of the Pajarito wells ranged from 560 to 1,410 gpm (Table 5). Four of the wells (PM-2, PM-3, PM-4, and PM-5) are high-yield wells with pumping rates over 1,000 gpm (Table 5). The pumping rates from the individual wells varied only slightly from 1995 to 1996. Furthermore, the entire well field showed an increase of about 52 gpm in total production rate from 5,697 gpm in 1995, to 5,749 gpm in 1996. There were no significant changes in the specific capacities of the wells from 1995 to 1996 in wells where data were available (Table 5).

The water levels in these wells fluctuated as would be expected from the amount of pumpage (Fig. 4). However where data are available, there were no significant changes in nonpumping and pumping water levels in 1996 compared with 1995.

Table 6. Average Depth to Water in Wells during Nonpumping and Pumping Periods and Average Drawdowns, 1995 and 1996

	Average Depth to Water					
	Nonpumping (ft)		Pumping (ft)		Drawdown (ft)	
	1995	1996	1995	1996	1995	1996
Guaje Field						
Well G-1	278	274	450	449	172	175
Well G-1A	312	310	346	342	34	32
Well G-2	361	364	390	390	29	26
Well G-3	—	—	—	—	—	—
Well G-4	368	374	—	570	—	196
Well G-5	—	—	—	—	—	—
Well G-6	577	581	660	661	83	80
Pajarito Field						
Well PM-1	753	755	776	778	23	23
Well PM-2	870	—	934	—	64	—
Well PM-3	772	776	796	802	24	26
Well PM-4	—	1,091	—	1,139	—	48
Well PM-5	—	1,258	—	1,351	—	93
Otowi Field						
Well O-4	—	—	—	—	—	—

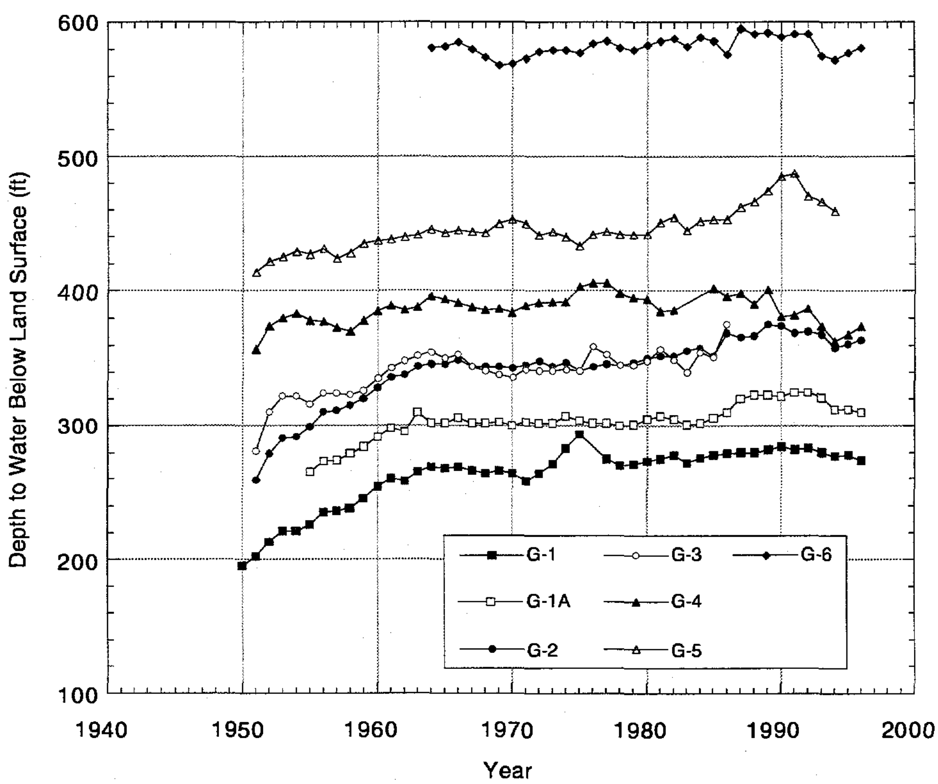

Fig. 3. Nonpumping water levels in wells from the Guaje well field.

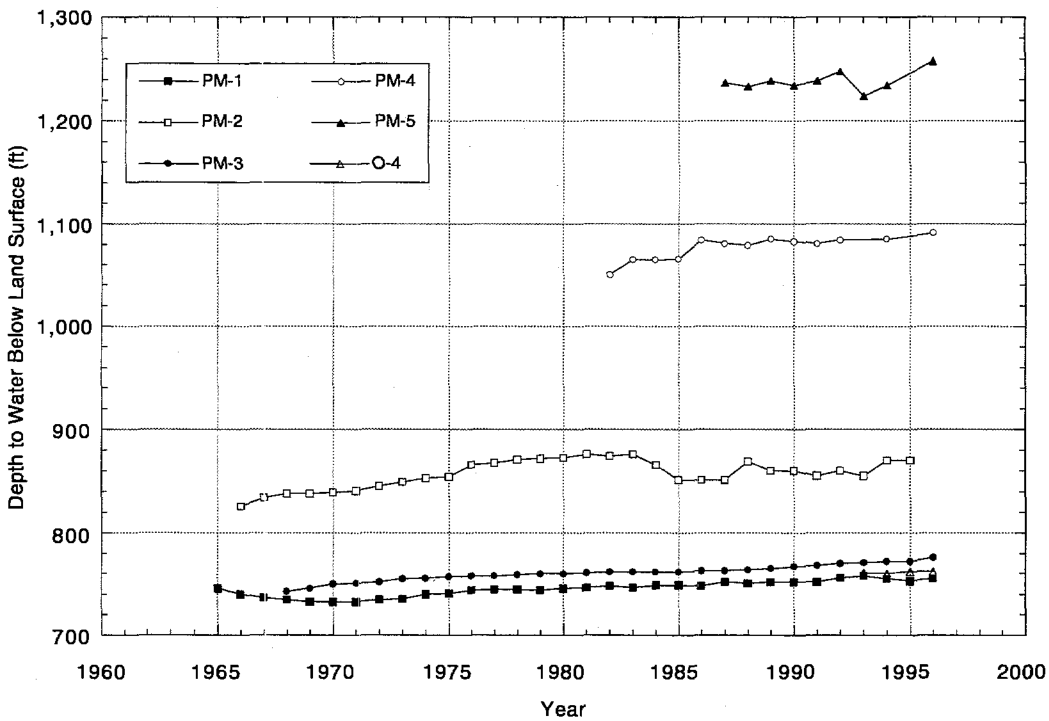

Fig. 4. Nonpumping water levels in wells from the Pajarito and Otowi well fields.

C. Otowi Well Field

The Otowi well field consists of two wells that were completed in 1990. Well O-1 was completed at a depth of 2,497 ft and showed a regional aquifer static depth-to-water reading at about 695 ft. Well O-4 was completed at a depth of 2,585 ft and showed a static depth-to-water level at 790 ft.

Well O-1 was not operational in 1996 and contributed no water production to the system. However, this well was zonally sampled at five separate intervals in December 1996 (actually Zone 5 was sampled in 1997 but is included in this report for completeness); results are reported in Sec. VI (Zonal Sampling in the O-1 Production Well). This well should enter routine service in 1997. Well O-4 resumed service in 1996 and pumped a total of 209.6 million gallons. This volume was about 15% of the combined water demand for the year. The average annual pumping rate in 1996 was 1,499 gpm. There is no functioning transducer line in O-4, so water level readings cannot be made.

III. WATER CANYON GALLERY AND GUAJE AND LOS ALAMOS RESERVOIRS

Water Canyon Gallery was a source of potable water from the early days of the Manhattan Project until 1988 (Table 1). Rapid recharge to the gallery caused heavy sediment loads to enter the potable system. In order to keep these sediments out of the distribution system, the use of the gallery as a potable supply was discontinued in 1988. Since then, water from the gallery has been occasionally used as a nonpotable supply for the steam plant at TA-16.

The spring gallery in Water Canyon is dug about 30 ft into the Bandelier Tuff. The gallery, or tunnel, is framed with timbers and sheet metal to keep the walls and overhead from collapsing. The floor of the gallery is constructed to form a basin to collect the spring flow. About one mile of water line connects the gallery to the power plant at TA-16 (S-Site). The water line is not part of the potable system.

The water occurs in the fractures of a welded tuff, which is underlain by a nonwelded tuff (the fractures in the welded tuff contain the water which is perched on the nonwelded tuff). The gallery furnished no water to the power plant during 1996. Instead, the entire discharge was released back into the environment. For the period from 1947–1996, the annual potable use is shown in Table 1, while the nonpotable use is shown in Table 7.

Table 7. Production from Water Canyon Gallery and Guaje and Los Alamos Reservoirs[1]

Year	Water Canyon Gallery[2] (10^6 gal.)	Guaje Reservoir[3] (10^6 gal.)	Los Alamos Reservoir (10^6 gal.)
Municipal Water-Supply Production			
1947		87.8	21.7
1948		119.8	21.9
1949		116.1	14.7
1950		79.9	20.6
1951		41.0	10.5
1952		131.0	33.6
1953		58.0	14.8
1954		66.0	16.9
1955		71.0	18.1
1956		24.0	4.8
1957		213.0	54.8
1958		193.0	49.4
Nonpotable Water Production			
1972		5.8	0.0
1973		9.7	0.0
1974		4.9	0.0
1975		5.3	0.0
1976		4.4	0.0
1977		4.1	0.0
1978		2.8	0.0
1979		3.7	1.3
1980		4.7	2.3
1981		2.7	2.1
1982		3.4	2.8
1983		3.4	1.4
1984		3.0	1.3
1985		2.8	0.9
1986		2.4	1.5
1987		2.8	3.2
1988	0.0	2.4	1.4
1989	0.0	4.6	3.3
1990	9.3	2.2	4.6
1991	12.0	1.5	2.4
1992	0.1	0.0	0.0
1993	6.4	0.0	0.5
1994	11.6	0.0	0.0
1995	1.6	0.0	1.6
1996	0.0	0.0	2.6

[1] Guaje and Los Alamos Reservoir municipal supply 1947–1958; irrigation 1972–1996.

[2] Water Canyon Gallery nonpotable industrial supply 1988–1996; see Table 1 and Appendix A for potable production for municipal supply from 1947–1987.

[3] Production from Guaje Reservoir for 1951–1958 is estimated.

Water from Guaje and Los Alamos Reservoirs was used for municipal and industrial water supply at Los Alamos during the early days of the Manhattan Project. Use of the reservoirs for potable water supply was discontinued in 1959 because of intermittent periods of turbidity caused by summer thunderstorm runoff. In addition, there were difficulties in maintaining bacteriological levels below allowable limits for a municipal water supply system.

Today the water from the reservoirs is available for irrigation of lawns and shrubs in the community and at the Laboratory. Parts of the water lines are above ground and are subject to freezing; thus, water use from the reservoirs is limited to the period from late spring to early fall. During 1996 about 2.6 million gallons of water was diverted from Los Alamos Reservoir for lawn irrigation; no water was diverted from Guaje Reservoir for any purpose. The age of the distribution system and need for rehabilitation, along with operation costs, may cause the Laboratory to eventually abandon the irrigation system since it is not economically feasible to operate. The total diverted production from the Guaje and Los Alamos Reservoirs for the period of record is shown in Table 7.

IV. LONG-TERM WATER LEVEL TRENDS

Water levels have been measured in wells tapping the regional aquifer since the late 1940s when the first exploratory wells were drilled by the U.S. Geological Survey (USGS). These data have been documented in various reports over the years. They are summarized here in Appendices A and B. Appendix A lists all historical water production and aquifer characteristics data for active wells. Appendix B summarizes all historical water level data collected from regional aquifer test (observation) wells. This portion of the water supply report compiles all available water level data for the regional aquifer and summarizes the changes in graphic form.

The annual summary data on each water supply well has been documented since 1971 in this series of water supply reports. There is one table in Appendix A for each of the wells used as an active water supply well at Los Alamos. Each table includes annual average information on the water levels obtained from both nonpumping and pumping conditions. Notes on each table provide information about the water level at the time of completion of the well. Data from the now-abandoned Los Alamos well field are reported elsewhere [26].

One additional table summarizes the data for the test wells reaching the regional aquifer (see Appendix B). This table includes completion information, initial static water levels, and annual average water levels in regional aquifer test wells. The test well water level data were compiled from the original records in the files of the Water Quality and Hydrology Group. Some of the data in the table represent averages when more than one measurement was made during a given year. In 1993, a program designed to equip each test well with a pressure transducer having an automatic data recording capability was started. The data in the table for years 1993–1996 represent the final reading of water levels recorded during each respective year.

A summary of the water level changes since the late 1940s is presented in several graphs (Figs. 5–8). For the most part, these figures are self-explanatory. Nonpumping water level data are presented for Los Alamos (Fig. 5), Guaje (Fig. 6), Pajarito (Fig. 7), and Otowi (Fig. 7) water supply well fields. Trends in the regional aquifer test wells are depicted in a separate graph (Fig. 8). Collectively, all of these individual trends reflect a plateau-wide decline in regional aquifer water levels in response to municipal water production.

The levels in the Los Alamos well field (Fig. 5) generally ranged from about 40 to 140 ft below initial levels until 1992 when the field was taken out of production. Since then levels have trended back toward initial conditions. The easternmost wells, which were artesian at completion, have regained much of their original water levels. Well LA-1B, with an installed mechanical packer and recording pressure transducer, has again become artesian. This well currently shows a packed-off water level that is about 21 ft above ground surface (i.e., above the overflow drain in the well casing, which is located about 6 ft below top-of-casing).

The levels in the Guaje field (Fig. 6) have ranged from almost no decline to about 120 ft of decline since 1950. In this field the westernmost wells show the least decline overall and have recovered significantly in recent years with somewhat lower production. Wells G-4 and G-6 recovered significantly in 1996 when they were not pumped.

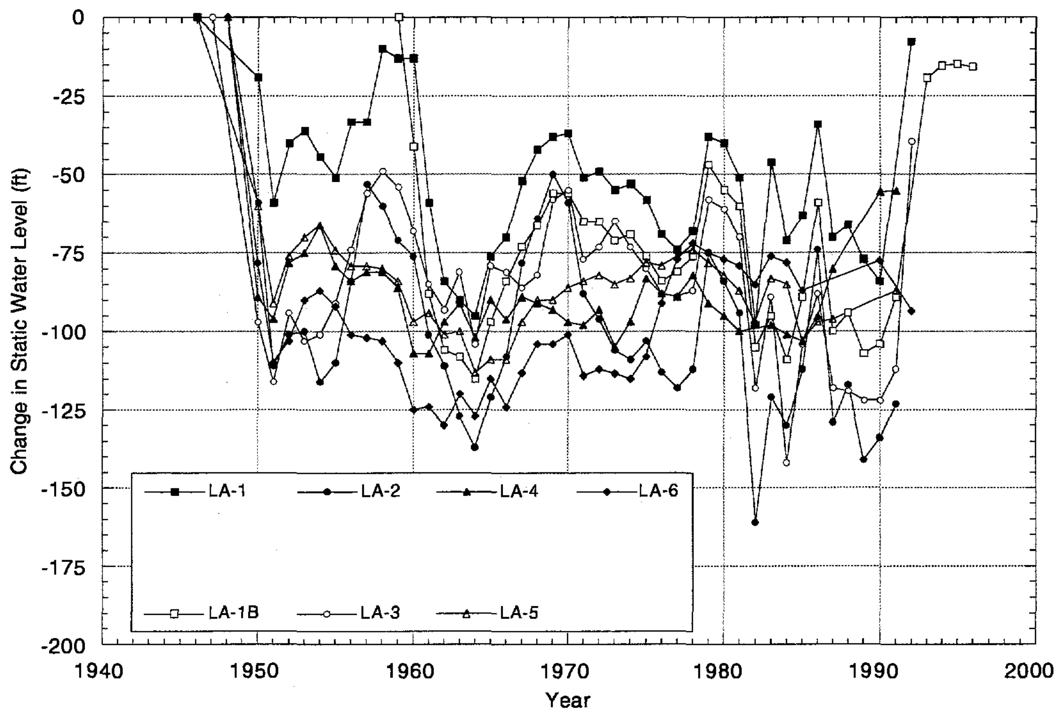

Fig. 5. Change from initial static water levels in wells from the Los Alamos well field.

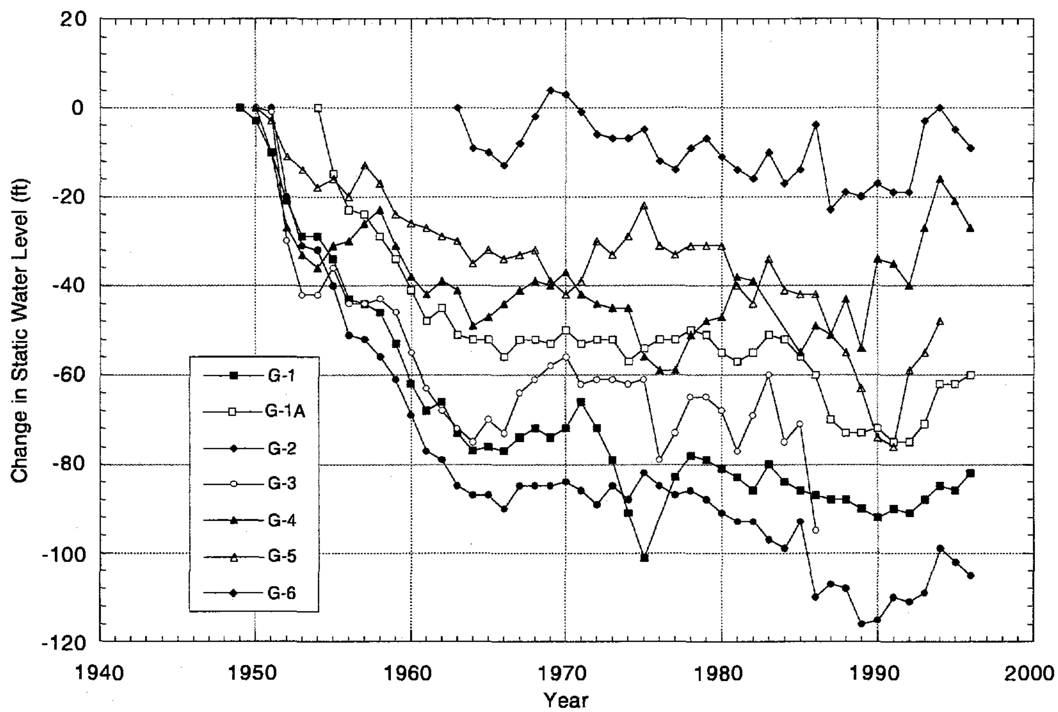

Fig. 6. Change from initial static water levels in wells from the Guaje well field.

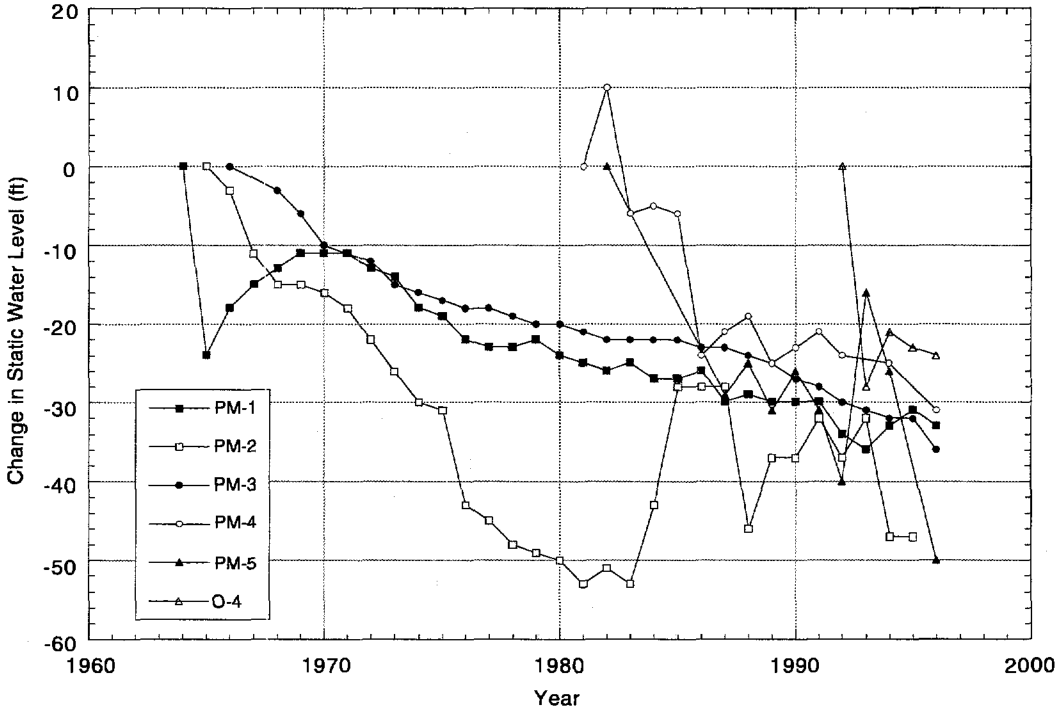

Fig. 7. Change from initial static water levels in wells from the Pajarito and Otowi well fields.

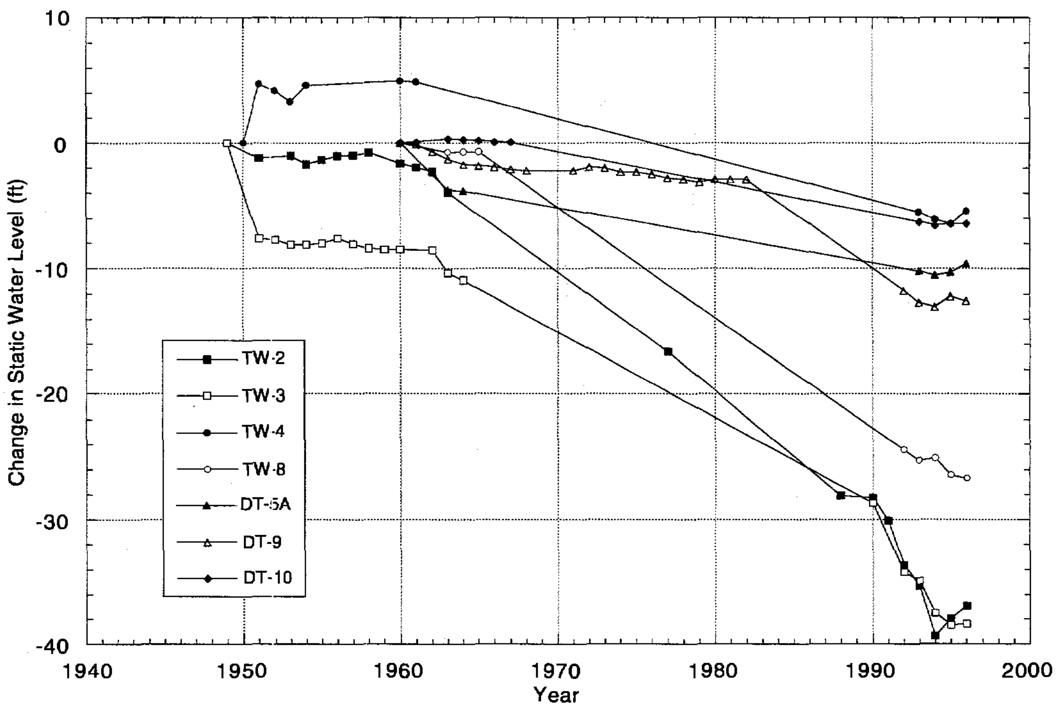

Fig. 8. Change from initial static water levels in regional aquifer test wells.

Wells in the Pajarito and Otowi well fields (Fig. 7) have always been the best producers, with generally much higher specific capacities. As expected, they show the least declines in water levels. Since 1990 these declines have varied between about 20 and 40 ft.

The test wells penetrating to the regional aquifer show declines ranging from less than 10 to about 35 ft over the 48-year period of record (Fig. 8). They fall into geographic groups. The westernmost well, TW-4, shows less that 10 ft of change. The southernmost group of wells, DT-5A, DT-9, and DT-10, all located within TA-49, show a decline of about 10 to 15 ft since 1960. The one well in the central part of the plateau, TW-8, shows a decline of about 25 ft and is within the range of declines shown by the Pajarito supply wells. The north-central wells, TW-2 and TW-3, both show about 35 ft of decline over the 48-year period of record. It is important to note that these declines in test well water levels are gradual and have not been observed during recent intensive short-term pump testing of production wells [20–23].

Only one test well (TW-1) has shown an apparent increase in recent water levels after many years of no measurements (see Appendix B) and was not depicted in Fig. 8. The anomalous behavior of this well is not fully understood and is currently under investigation. Some preliminary tests to determine possible reasons for this behavior are discussed in two recently published environmental surveillance reports for Los Alamos [30, 31]. There is apparently some indication of communication with the surface as reflected by water level fluctuations and low-level tritium measurements [32, 33]; however, major ion water quality and recent water level data suggest that TW-1 is hydraulically isolated from a nearby shallow test well (TW-1A) and adjacent surface waters within Pueblo Canyon. Hence the apparent communication of TW-1 with the atmosphere may actually be through the formation and not through a leaky wellbore as previously thought. An alternative possibility is that these observed water level increases in TW-1 may be in response to lost fluid circulation during the 1990 drilling of the O-1 water supply well, located approximately 1,000 ft to the west. If this is the case, then these water level increases should begin to decline, as recent measurements (i.e., 1995 and 1996) indicate. This interpretation suggests the unlikely possibility that elevated tritium levels must have originated either in O-4 water supplies used for the original drilling fluids or from atmospheric deposition in the open mud pit over the three-month drilling interval. Low-level tritium measurements have failed to detect any tritium in O-4 well waters. The investigation is continuing, and additional progress will be documented in future water supply reports.

V. QUALITY OF WATER

The Laboratory conducts two separate programs to monitor the quality of both surface water and groundwater in the area and to meet multiple federal and state regulatory requirements. The first program, under the Laboratory's long-term environmental surveillance program, includes monitoring the quality of water from the supply wells, the test wells, the gallery in Water Canyon, surface waters, and the reservoirs in Guaje and Los Alamos Canyons. Analytical results for this program are reported in a series of annual environmental surveillance reports. The most recent reports [30, 31] contain data from 1995 and 1996, respectively.

The second program monitors the quality of water in the Laboratory and county distribution systems to ensure compliance with the Safe Drinking Water Act (SDWA). Water samples are collected from the water distribution systems located at the Laboratory, Los Alamos County, and Bandelier National Monument on a routine basis. Furthermore, water samples are also routinely collected at individual wells before the water is chlorinated and pumped into the distribution system. This sampling methodology is designed to monitor the water both at the source and within the distribution system. These samples are analyzed for microbiological organisms, organic and inorganic chemical constituents, and radioactivity in the drinking water. During 1996, more than 500 samples were analyzed for microbiological organisms. All parameters regulated under the SDWA were in compliance with maximum contamination levels (MCLs) established by regulation in 1996. Historically, the Los Alamos water system has never incurred a violation for a SDWA-regulated chemical or radiological contaminant. On occasion, however, the water distribution system has yielded samples that have shown the presence of total coliforms or other noncoliform bacteria. On rare occasions, fecal coliforms have been historically detected. Furthermore, the water supply wells have, on occasion, exceeded the proposed SDWA MCLs for arsenic (1996 MCL of 50 ppb; proposed MCL of 5 ppb) and radon (1996 MCL of 1,000 pCi/l; proposed MCL of 300 pCi/l). Both of these constituents are naturally occurring in regional aquifer waters below Pajarito Plateau. Detailed results of this program are documented in the report, "Environmental Surveillance and Compliance at Los Alamos during 1996" [31].

Complete chemical and radiochemical analyses, along with an interpretation of data related to the chemical quality in individual wells in the Los Alamos, Guaje, Pajarito, and Otowi well fields and in Water Canyon Gallery and Guaje and Los Alamos Reservoirs were presented in the report "Water Supply at Los Alamos during 1991" [22].

VI. ZONAL SAMPLING IN THE O-1 PRODUCTION WELL

In December 1996 O-1 was zonally sampled prior to its scheduled entry into routine service as a municipal water supply well. The sampling device was constructed at the Laboratory from 4-in.-diameter steel pipe approximately 46.4 ft long. A 16-in.-diameter, threaded K-packer was attached to each end of the 4-in.-diameter pipe, and the pipe was torch-perforated to resemble a well screen. A 5-horsepower (hp) submersible pump was put inside the pipe about midway between the K-packers. The entire sampling apparatus was then attached to 2.625-in. drill pipe and lowered to the desired sampling depth. The drill pipe served as the production casing for the 5-hp pump, which was capable of producing approximately 18 gpm during sample collection operations. The outside circumference of the K-packers has several rubber rings that resemble the rubber portion of automobile windshield wiper blades. These rubber rings match the inside diameter of the production well casing and screen in O-1. Hence the sampling apparatus snugly fits inside the permanent well casing and provides a water-tight seal over the 46.4-ft-long zonal sampling interval. The 5-hp pump slowly draws water from the sampling interval at about 18 gpm. Pumped water flows from the geological interval located immediately outside the well screen and between the K-packer levels into the sampling device. This sampling methodology was designed to pull formation water from a target interval while minimizing vertical mixing inside the wellbore. Results of the chemical and radiological analyses are discussed below.

Water samples were collected from five different zones. Table 8 summarizes the depth of each sampling interval, and the total amount of water pumped from each zone prior to sample collection. In addition, this table also lists the volume of pumped water in terms of packer volumes. A packer volume is defined as the volume of water inside the 16-in.-diameter wellbore and between the two K-packer seals. The geological log and the well completion diagram for O-1 were previously reported [21]. This log and diagram indicate that the top of the screened interval in O-1 is located approximately 268 ft below the Puye Conglomerate–Tesuque Formation contact and approximately 339 ft below the top of the regional aquifer water table. During the zonal sampling at O-1, the depth to static water was approximately 678 ft below top-of-casing. This water level did not appreciably change during sample collection operations.

Results from the general inorganic chemical analyses of water samples from each sampled zone are summarized in Table 9. Note that both unfiltered and filtered sample splits were collected and analyzed. All of the unfiltered samples were analyzed by the Laboratory's Chemical Science and Technology (CST) analytical laboratory, while all of the filtered samples were analyzed by the Environmental Restoration Program's contract laboratory. For comparison, water quality standards issued by the EPA and the New Mexico Water Quality Control Commission (NMWQCC) are given. The results in Table 9 indicate that there are only minor differences between filtered and unfiltered samples for these general inorganic analytes.

Table 8. Summary of Pumped Water Volumes from Zonal Sampling in O-1

Zone Number	Depth Interval (feet)	Geological Formation	Volume Pumped (gallons)	Packer Volumes (dimensionless)
1	1,012.3–1,058.7	Tesuque	7,750	16.0
2	1,290.5–1,336.9	Tesuque	21,270	43.9
3	1,721.6–1,768.0	Tesuque	24,110	49.8
4	2,152.1–2,198.5	Tesuque	23,540	48.6
5	2,308.7–2,355.1	Tesuque	19,540	40.3

Table 9. Chemical Quality of Water Samples from O-1 (µg/l)

Sample Depth[1]	Date Sampled	Code[2]	SiO_2	Ca	Mg	K	Na	Cl	SO_4	CO_3 Alkalinity	Total Alkalinity	F	PO_4-P	NO_3-N	CN	TDS[3]	TSS[4]	Hardness as $CaCO_3$	pH[5]	EC[6] (µS/cm)
Unfiltered Samples (standard sample preservation[7]):																				
TOW	06/24/96	1		2.30	<0.04	0.46	62.00						0.02	<0.04				5.9		
TOW	06/24/96	R											<0.02							
Zone 1	12/17/96	1	32.0	2.32	0.04	<1.00	62.48	5.70	5.70	18.0	140.0	0.30	<0.02	0.35	<0.01	160	<1.0	5.7	9.25	273
	12/17/96	R										0.29								
Zone 2	12/18/96	1	32.0	2.51	0.20	<1.00	60.28	5.80	5.80	8.0	150.0	0.31	<0.02	0.27	<0.01	170	13.0	7.1	8.98	271
	12/18/96	R											<0.02		<0.01	170	12.0			
Zone 3	12/19/96	1	32.0	2.42	0.07	<1.00	60.98	5.80	5.90	17.0	150.0	0.31	0.08	0.28	<0.01	160	6.0	6.3	9.09	275
Zone 4	12/20/96	1	33.0	2.10	0.11	<1.00	61.19	5.90	6.10	15.0	150.0	0.32	<0.02	0.34	<0.01	160	2.0	5.7	9.10	270
Zone 5	01/08/97	1	38.0	3.50	0.77	<1.00	63.80	6.00	6.00	5.0	144.0	0.35			<0.01	224	17.0	12.0	8.68	285
	01/08/97	R	39.0	2.99	0.32	<1.00	63.94					0.37			<0.01	218	19.0	8.7		
Filtered Samples (0.45-µm filter followed by standard sample preservation[7]):																				
Zone 1	12/17/96	1	30.8	2.47	<0.02	0.42	66.00	4.94	4.89	12.0	141.0	0.29	<0.05	1.61					8.83	287
Zone 2	12/18/96	1	31.2	2.48	0.03	1.12	67.40	6.27	4.91	8.4	150.0	0.29	<0.05	1.62					8.44	294
Zone 3	12/19/96	1	30.6	2.46	<0.02	0.42	65.70	5.12	5.03	11.8	140.0	0.30	<0.05	0.97					8.80	293
Zone 4	12/20/96	1	30.8	2.43	<0.02	0.65	64.20	5.56	5.28	11.7	141.0	0.29	<0.05	1.42					8.78	287
Zone 5	01/08/97	1	36.2	2.87	<0.02	0.65	65.30	5.86	5.38	14.8	137.0	0.26	<0.05	1.46					9.01	291
Water Quality Standards:																				
EPA Primary Drinking Water Standard									500			4.00		10	0.20					
EPA Secondary Drinking Water Standard								250	250							500			6.8–8.5	
EPA Health Advisory							20													
NMWQCC Groundwater Limit								250	600			1.60		10	0.20	1,000			6.0–9.0	

[1] See Table 8 for individual zone sample depth intervals; TOW—top of water.
[2] Codes: 1—primary analysis; R—lab replicate.
[3] Total dissolved solids.
[4] Total suspended solids.
[5] Standard pH units.
[6] Electrical conductance.
[7] EPA, SW-846 (1987) (Ref. 34); and Williams (1990) (Ref. 35).

Several analytes show some apparent differences between unfiltered and filtered samples; however, these differences are the result of different laboratory detection limits. Finally, even though some of the pH values are slightly elevated above the standard maximum of 9, these general inorganic chemical analyses still reflect the excellent water quality that typifies the regional aquifer below Pajarito Plateau.

Results from the total recoverable trace metal analyses for water samples from each sampled zone are summarized in Table 10. Again, both unfiltered and filtered sample splits were collected and analyzed. Except for iron and manganese in unfiltered samples, these results indicate that no drinking water standards were exceeded by any of the analytes. Furthermore, the unfiltered samples contained higher levels of aluminum, barium, copper, iron, and manganese than the filtered samples. These differences are undoubtedly the result of different amounts of suspended material in the unfiltered and filtered samples. These differences are caused by two primary factors: (1) corrosion of the mild steel casing and louvered screen (recall that O-1 was completed in early 1990 and had remained capped until December 1996), and (2) fine suspended formation material passing through the filter pack and well screen before entering the well during sample pumping at about 18 gpm. Several other analytes also show apparent differences between unfiltered and filtered samples; however, these differences are the result of different laboratory detection limits. Again, the overall conclusion is that these total recoverable trace metal analyses tend to reflect the excellent water quality that typifies the regional acquifer below Pajarito Plateau.

Results of the radionuclide analyses for unfiltered samples from each sampled zone are summarized in Table 11. Except for total uranium, most of the radionuclide results are very near or below their respective detection limits of the analytical methods used. Furthermore, all of the radionuclide results except uranium have large uncertainties associated with them. Hence, results should be viewed with caution since only total uranium values were detected above the uranium detection limit with statistical certainty. Total uranium is naturally occurring in northern New Mexico and is commonly observed in groundwater samples at comparable levels [30, 31]. In other words, while we cannot conclusively state that all radionuclides (other than total uranium) were absent in these zonal samples, we can conclude that respective values were at or below their respective detection limits. Finally, it should be noted that none of the radionuclide results exceeded established federal or state drinking water limits.

Overall, the analytical results reported in Tables 9–11 confirm the generally excellent water quality that characterizes the regional aquifer below Pajarito Plateau. Figure 9 depicts a Piper plot of major ion water quality from each zone in O-1. These Piper plots reveal that O-1 waters are predominately a sodium bicarbonate type, whereas other production wells in the Guaje, Pajarito, and Otowi well fields produce a calcium bicarbonate type water [22]. This difference may account for the small, but significant, difference in average pH values between O-1 and other municipal well waters. In addition, one also concludes that there is little difference between zones within O-1. However, this well has been capped since its completion in 1990. Hence these analytical results may simply reflect long-term (i.e., from 1990 through 1996) borehole mixing resulting from vertical hydraulic gradients within the long well column and filter pack.

After all zonal samples were collected, the O-1 wellbore was disinfected with 165 gallons of liquid sodium hypochlorite (10% solution). The disinfection procedure used a large 16,400-gallon holding tank and the zonal sampling device so that the sodium hypochlorite concentrations could be accurately controlled. After zonal sampling was completed, approximately 3,000 gallons of water from Zone 5 was pumped into the holding tank where the liquid sodium hypochlorite had been placed. This pumping operation diluted the sodium hypochlorite from approximately 100,000 mg/l to approximately 5,500 mg/l of free chlorine. Then this mixed solution was pumped into the sampling device and allowed to flow into the well at controlled depths. The sampling device was moved up and down to agitate the mixture and swab it into the filter pack opposite the sampling device. This procedure was systematically repeated until the entire well screen and filter pack were disinfected. The volumetric dilution of sodium hypochlorite in the filter pack was carefully controlled so that it was approximately 500 mg/l at the point of delivery (i.e., in the filter pack). This procedure was selected for several reasons, including (1) to control the release depth of the solution, (2) to control the concentration of the solution, and (3) to minimize safety risks associated with the state (liquid, powder, gas) of the disinfectant.

Table 10. Total Recoverable Trace Metals in Water Samples from O-1 (μg/l)

Sample Depth[1]	Date Sampled	Code[2]	Ag	Al	As	B	Ba	Be	Cd	Co	Cr	Cu	Fe	Hg
Unfiltered Samples (standard sample preservation[3]):														
TOW	06/24/96	1	<3	<90	4.3	70.0	3.0	<1	<2	<3	<10.0	70.0	24,000	<0.2
	06/24/96	R												<0.2
Zone 1	12/17/96	1	<10	<500	<4.0	63.6	32.6	<2	<7	<8	12.8	<10.0	514	<0.5
	12/17/96	R												<0.5
Zone 2	12/18/96	1	<10	543	4.0	73.0	17.6	<2	<7	<18	14.4	<10.0	3,145	<0.3
	12/18/96	R												<0.3
Zone 3	12/19/96	1	<10	<500	<4.0	99.8	21.9	<2	<7	<8	15.3	13.5	3,124	<0.2
	12/19/96	R												<0.2
Zone 4	12/20/96	1	<10	<500	<4.0	71.2	7.1	<2	<7	<8	<17.0	<10.0	586	<0.4
	12/20/96	R												<0.4
Zone 5	01/08/97	1	<10	1,000	6.0	71.2	33.5	<2	<7	<8	16.3	<10.0	4,483	<0.3
	01/08/97	R	<10	<500	6.0	71.1	30.2	<2	<7	<8	15.3	<10.0	4,104	<0.3
Filtered Samples (0.45-μm filter followed by standard sample preservation[3]):														
Zone 1	12/17/96	1	<0.2	40	4.3	70.0	3.0	<2	<2	<2	14.0	<2.0	20	<0.2
Zone 2	12/18/96	1	<0.2	30	4.2	70.0	2.0	<2	<2	<2	12.0	6.0	50	<0.2
Zone 3	12/19/96	1	<0.2	30	4.0	70.0	3.0	<2	<2	<2	14.0	<2.0	60	<0.2
Zone 4	12/20/96	1	<0.2	30	4.4	70.0	5.0	<2	<2	<2	11.0	<2.0	90	<0.2
Zone 5	01/08/97	1	<0.2	30	5.5	70.0	5.0	<2	<2	<2	11.0	<2.0	90	<0.2
Water Quality Standards:														
EPA Primary Drinking Water Standard					50.0		2k	4	5		100.0			2.0
EPA Secondary Drinking Water Standard				50–200									300	
EPA Action Level														
EPA Health Advisory												1.3k		
NMWQCC Livestock Watering Standard				5k[4]	200.0	5k			50	1k	1k	500.0		10.0
NMWQCC Groundwater Limit			50	5k	100.0	750.0	1k		10	50	50.0	1k	1k	2.0

[1]See Table 8 for individual zone sample depth intervals; TOW—top of water.
[2]Codes: 1—primary analysis; R—lab replicate.
[3]EPA, SW-846 (1987) (Ref. 34); and Williams (1990) (Ref. 35).
[4]k—values are 1,000 times value shown.

Table 10. Total Recoverable Trace Metals in Water Samples from O-1 (µg/l) (Cont.)

Sample Depth[1]	Date Sampled	Code[2]	Mn	Mo	Ni	Pb	Sb	Se	Sn	Sr	Tl	V	Zn
Unfiltered Samples (standard sample preservation[3]):													
TOW	06/24/96	1	230.0	<14	<27	<50	<10	3	<100	10.0		11.0	100.0
	06/24/96	R											
Zone 1	12/17/96	1	35.1	<30	<20	3	<3	6	<30	12.3	<3	19.4	73.8
	12/17/96	R											
Zone 2	12/18/96	1	105.0	<28	<20	3	<3	12	<30	15.8	<3	26.7	68.2
	12/18/96	R											
Zone 3	12/19/96	1	185.8	<30	<20	<3	<3	<10	<100	14.9	<3	18.7	271.4
	12/19/96	R											
Zone 4	12/20/96	1	20.5	<30	<20	<3	<3	9	<30	10.1	<3	18.7	<50.0
	12/20/96	R											
Zone 5	01/08/97	1	300.0	<30	<20	3	<3	14	<30	26.0	<3	36.6	172.0
	01/08/97	R	277.0	<30	<20	<3	<3	5	<30	23.9	<3	43.3	135.0
Filtered Samples (0.45-µm filter followed by standard sample preservation[3]):													
Zone 1	12/17/96	1	5.0	<10	<2	<4	<0.2	<0.2					
Zone 2	12/18/96	1	5.0	30	<2	<4	0.8	<0.2					
Zone 3	12/19/96	1	6.0	<10	<2	<4	0.3	<0.2					
Zone 4	12/20/96	1	10.0	<10	<2	<4	0.5	<0.2					
Zone 5	01/08/97	1	16.0	<10	<2	<4	0.3	<0.2					
Water Quality Standards:													
EPA Primary Drinking Water Standard					100		6	50			2		
EPA Secondary Drinking Water Standard			50.0										5k
EPA Action Level						15							
EPA Health Advisory												80–110	
NMWQCC Livestock Watering Standard							100	50		25k–90k		100.0	25k
NMWQCC Groundwater Limit			200.0	1k[4]	200	50		50					10k

[1]See Table 8 for individual zone sample depth intervals; TOW—top of water.
[2]Codes: 1—primary analysis; R—lab replicate.
[3]EPA, SW-846 (1987) (Ref. 34); and Williams (1990) (Ref. 35).
[4]k—values are 1,000 times value shown.

Table 11. Radiochemical Analysis[1] of Unfiltered Water Samples from O-1

Sample Depth[2]	Date Sampled	Code[3]	^{3}H (pCi/l)	^{90}Sr (pCi/l)	^{137}Cs (pCi/l)	Total U (μg/l)	^{238}Pu (pCi/l)	^{239,240}Pu (pCi/l)	^{241}Am (pCi/l)	Total Alpha (pCi/l)	Total Beta (pCi/l)	Total Gamma (pCi/l)
Unfiltered Samples (standard sample preservation[4]):												
Zone 1	12/17/96	1	–1 (140)[5]	0.4 (0.4)	0.40 (0.60)	3.17 (0.32)	0.0093 (0.0086)	0.0101 (0.0087)	0.0619 (0.0194)	5.9 (3.2)	3.0 (0.5)	70.0 (50.0)
Zone 2	12/18/96	1	–162 (139)	0.4 (0.4)	1.22 (1.83)	3.11 (0.31)	–0.0041 (0.0019)	0.0103 (0.0073)	0.0224 (0.0116)	3.9 (2.2)	2.6 (0.5)	40.0 (50.0)
	12/18/96	R	–417 (137)									
Zone 3	12/19/96	1	–112 (140)	0.6 (1.0)	0.68 (1.01)	3.06 (0.31)	–0.0078 (0.0033)	0.0176 (0.0099)	0.0362 (0.0165)	3.9 (2.2)	3.0 (0.5)	20.0 (50.0)
	12/19/96	R							0.0460 (0.0160)			
Zone 4	12/20/96	1	–489 (137)	0.0 (0.4)	0.74 (1.12)	2.82 (0.28)	0.0053 (0.0077)	0.0191 (0.0103)	0.0372 (0.0145)	7.7 (4.1)	3.1 (0.5)	40.0 (50.0)
Zone 5	01/08/97	1	169 (136)	0.1 (0.4)		1.72 (0.17)	0.0242 (0.0182)	0.0085 (0.0113)	0.0177 (0.0136)			110.0 (50.0)
	01/08/97	R	–144 (133)				0.0010 (0.0100)	0.0050 (0.0090)	0.0760 (0.0270)			
Detection Limit:			2,000	3.0	4.00	0.10	0.0400	0.0400	0.0400	3.0	3.0	
Water Quality Standards:												
DOE DCG[6] for Public Safety			2,000k[7]	1,000	1,000	800	40.0	30.0	30.0	30.0	1,000	
DOE Drinking Water System DCG			80k	40	120	30	1.6	1.2	1.2	1.2	40	
EPA Primary Drinking Water Standard			20k	8		20			15.0			
EPA Screening Level											50	
NMWQCC Groundwater Limit						5,000						

[1] Environmental Surveillance Program Radionuclide Detection Criteria (see Ref. 31):
(a) reported radionuclide value exceeds its detection limit (DL); and
(b) reported radionuclide value >4.66σ, where σ = counting uncertainty (one standard deviation).
Conclusion: only Total U was detected at values >DL with statistical certainty.

[2] See Table 8 for individual zone sample depth intervals.

[3] Codes: 1—primary analysis; R—lab replicate.

[4] EPA, SW-846 (1987) (Ref. 34); and Williams (1990) (Ref. 35).

[5] Radioactivity counting uncertainties are shown in parentheses (1 standard deviation); values are less than analytical uncertainties. Values less than 2 standard deviations are considered nondetections.

[6] Derived Concentration Guide.

[7] k—values are 1,000 times value shown.

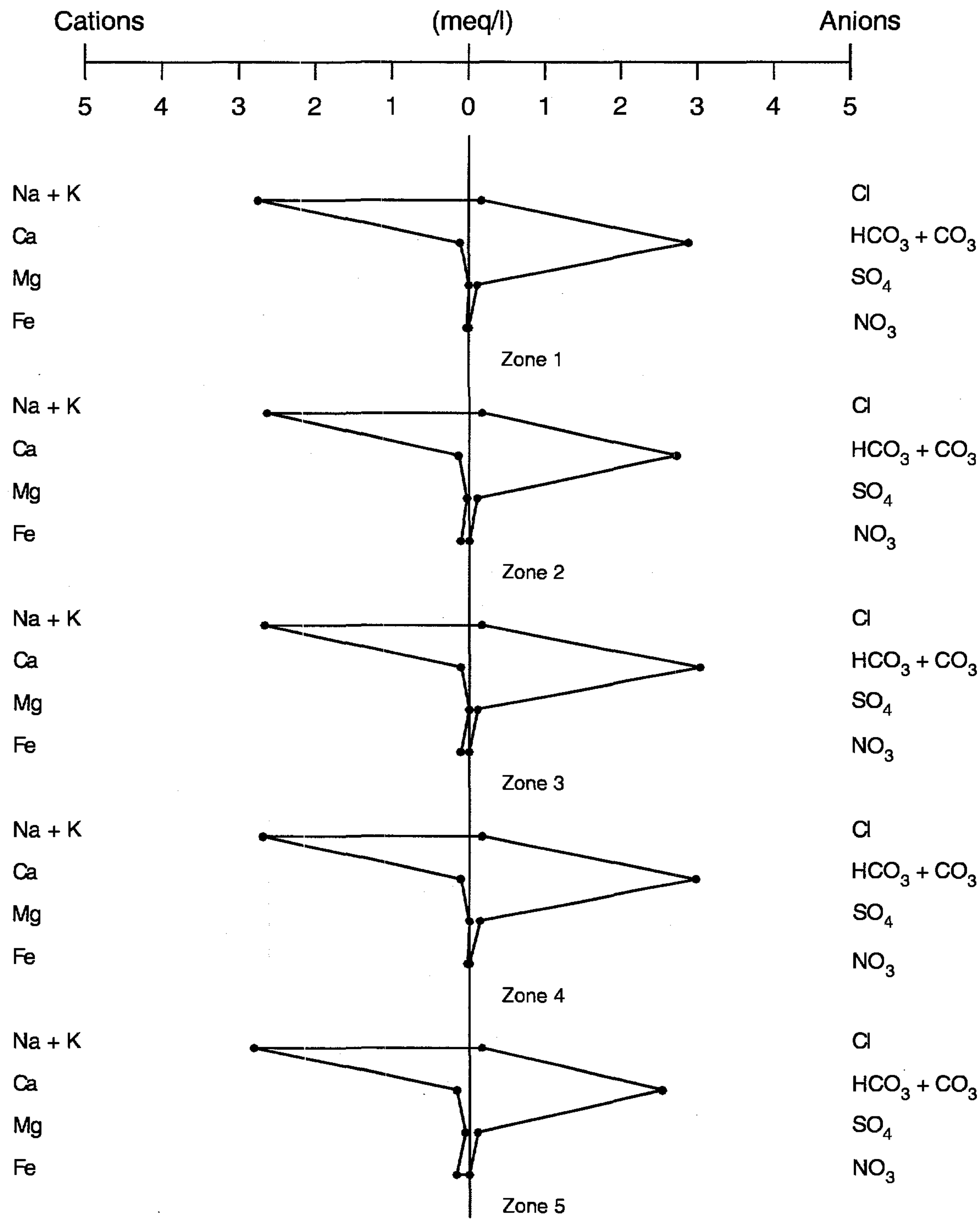

Fig. 9. Piper plots showing variations in major ion water quality from different zones within O-1.

VII. SUMMARY

Operations of wells and well fields in 1996 were satisfactory. Water level trends in the wells were as expected under the current amount of annual pumpage. Since the Los Alamos well field was abandoned in 1992, however, there are fewer wells that supply a larger percentage of the total water production for the system. Hence, efforts must be made to keep each of these high-yield wells on-line. Furthermore, the Guaje replacement well project for four new production wells is on schedule. During 1996, O-1 was equipped with a permanent production pump and should enter routine production during 1997. However, a dry year, coupled with numerous equipment failures, could still cause summer demand to exceed production capability.

Some effort should be made to ensure that all water level recorders and wellhead flow meters are operational. The data from this equipment are essential in documenting the operation of individual wells and summarizing well field performance characteristics. Furthermore, these data are vital in planning well field operations and expansions.

The zonal sampling of O-1 in late December 1996 proved successful. Water samples were collected from five different zones representing significant portions of the entire production well screen length. Laboratory analyses included general inorganic water quality, total recoverable trace metals, and radionuclides. Results from these analyses are summarized in Tables 9–11. These and other [30, 31] analyses confirm that all regulated constitutents under the Safe Drinking Water Act meet or exceed all regulatory compliance standards. Well O-1 had remained capped from its completion in 1990 until a new pump was installed in late 1996. During this period, the well screen and casing experienced some natural metal (i.e., the casing and screen) corrosion as reflected in differences in total recoverable trace metals between unfiltered and filtered water samples. The unfiltered samples contained somewhat higher levels of aluminum, barium, copper, iron, and manganese than the filtered samples.

Finally, any newly constructed municipal supply wells should utilize well casings and louvered or wire-wrapped screens that are constructed from stainless steel of a type that is at least as corrosion-resistant as type 304 (preferability type 316). Louvered screens are generally less expensive, whereas wire-wrapped screens allow for lower entrance velocities and less corrosion (especially as the well ages). Both screen designs have similar strength characteristics at depth settings typical of Pajarito Plateau municipal supply wells. Gravel filter pack material should contain a high percentage (i.e., more than 98%) of near-spherical quartz or quartzite grains that are resistant to potential chemical treatment techniques for future well rehabilitation efforts. Furthermore, a high-quality gravel filter pack that is 4–6 in. thick should be employed during well construction. Finally, serious consideration should be given to larger-diameter well screens that are between 18–24 in. in diameter. Larger-diameter well screens yield more water with less corresponding drawdown than smaller-diameter well screens. In addition, all of these combined design features tend to reduce wellbore entrance velocities and thereby minimize well screen corrosion. If implemented, these construction practices would potentially increase well service life beyond 50 years on Pajarito Plateau.

ACKNOWLEDGMENTS

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APPENDIX A

ANNUAL STATISTICS ON AQUIFER CHARACTERISTICS

Well G-1

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1950	0	2.8	0.0	195.0	—	—	—
1951	1,168	37.7	538.0	202.0	309.0	107.0	5.0
1952	2,476	75.5	508.2	213.0	295.0	82.0	6.2
1953	3,275	97.3	495.2	221.0	292.0	71.0	7.0
1954	2,616	77.8	495.7	221.0	290.0	69.0	7.2
1955	2,406	70.5	448.4	226.0	295.0	69.0	7.1
1956	2,958	83.2	468.8	235.0	303.0	68.0	6.9
1957	2,098	55.9	444.1	236.0	307.0	71.0	6.3
1958	2,460	68.1	461.4	238.0	308.0	70.0	6.6
1959	2,952	82.4	465.2	245.0	314.0	69.0	6.7
1960	3,564	96.0	448.9	254.0	325.0	71.0	6.3
1961	4,236	112.4	442.2	260.0	333.0	73.0	6.1
1962	3,431	93.6	454.7	258.0	342.0	84.0	5.4
1963	4,519	114.9	423.8	265.0	348.0	83.0	5.1
1964	4,374	113.8	433.6	269.0	352.0	83.0	5.2
1965	3,530	90.7	428.2	268.0	352.0	84.0	5.1
1966	4,074	102.6	419.7	269.0	363.0	94.0	4.5
1967	2,615	69.9	445.5	266.0	362.0	96.0	4.6
1968	2,996	78.9	438.9	264.0	366.0	102.0	4.3
1969	2,657	68.3	428.4	266.0	376.0	110.0	3.9
1970	2,712	64.7	397.6	264.0	377.0	113.0	3.5
1971	2,908	67.9	389.2	258.0	378.0	120.0	3.2
1972	2,865	66.1	384.5	264.0	389.0	125.0	3.1
1973	2,997	67.5	375.4	271.0	403.0	132.0	2.8
1974	2,767	62.3	375.3	283.0	412.0	129.0	2.9
1975	2,467	55.7	376.3	293.0	411.0	118.0	3.2
1976	2,962	65.1	366.3	—	—	—	—
1977	2,734	57.9	353.0	275.0	426.0	151.0	2.3
1978	2,656	56.0	351.4	270.0	419.0	149.0	2.4
1979	2,998	61.7	342.9	271.0	422.0	151.0	2.3
1980	3,459	68.3	329.0	273.0	428.0	155.0	2.1
1981	4,427	81.6	307.2	275.0	444.0	169.0	1.8
1982	3,678	69.0	313.0	278.0	443.0	165.0	1.9
1983	2,871	52.2	303.0	272.0	443.0	171.0	1.8
1984	3,804	62.8	275.0	276.0	448.0	172.0	1.5
1985	3,004	48.3	268.0	278.0	450.0	172.0	1.6
1986	2,027	30.3	249.0	279.0	450.0	171.0	1.5
1987	2,070	29.2	235.0	280.0	451.0	171.0	1.4
1988	395	5.4	227.0	280.0	445.0	165.0	1.4
1989	2,010	26.9	223.0	282.0	451.0	169.0	1.3
1990	2,121	30.8	242.0	284.0	454.0	170.0	1.4
1991	1,730	20.9	201.0	282.0	451.0	169.0	1.2
1992	1,077	12.0	186.0	283.0	439.0	156.0	1.2
1993	2.5	0.03	200.0	280.0	—	—	—
1994	1,585	18.5	194.5	277.0	451.0	174.0	1.1
1995	2,542	28.5	186.9	278.0	450.0	172.0	1.1
1996	1,128	12.9	190.6	244.0	449.0	175.0	1.1

NOTE: Well completed July 1950; initial depth to water: 192 ft; surface elev. 5,973 ft.

Well G-1A

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1954	108	4.6	709.0	—	—	—	—
1955	1,531	53.0	577.0	265.0	316.0	51.0	11.3
1956	3,130	107.7	573.5	273.0	323.0	50.0	11.5
1957	2,470	87.0	587.0	274.0	327.0	53.0	11.1
1958	2,670	92.5	577.4	279.0	331.0	52.0	11.1
1959	2,965	102.7	577.3	284.0	333.0	49.0	11.8
1960	3,641	122.8	562.1	291.0	342.0	51.0	11.0
1961	4,297	147.3	571.3	298.0	350.0	52.0	11.0
1962	3,972	136.1	571.1	295.0	344.0	49.0	11.7
1963	4,525	149.7	551.4	301.0	350.0	49.0	11.3
1964	3,852	129.3	559.4	302.0	353.0	51.0	11.0
1965	3,505	116.5	554.0	302.0	353.0	51.0	10.9
1966	3,964	133.4	560.9	306.0	355.0	49.0	11.4
1967	2,720	91.3	559.4	302.0	351.0	49.0	11.4
1968	3,089	103.2	556.8	302.0	352.0	50.0	11.1
1969	2,695	90.7	560.9	303.0	356.0	53.0	10.6
1970	2,772	92.5	556.2	300.0	357.0	57.0	9.8
1971	3,313	111.8	562.4	303.0	361.0	58.0	9.7
1972	2,879	94.0	544.2	302.0	361.0	59.0	9.2
1973	2,760	87.9	530.8	302.0	362.0	60.0	8.8
1974	2,974	92.7	519.5	307.0	355.0	48.0	10.8
1975	2,740	85.3	518.9	304.0	351.0	47.0	11.0
1976	2,983	91.6	511.8	302.0	350.0	48.0	10.7
1977	2,942	88.7	502.5	302.0	350.0	48.0	10.5
1978	2,631	77.9	493.5	300.0	345.0	45.0	11.0
1979	2,974	88.0	493.9	301.0	345.0	44.0	11.0
1980	3,480	103.2	494.4	305.0	345.0	40.0	12.4
1981	4,212	131.2	519.1	307.0	347.0	40.0	13.0
1982	3,618	109.7	505.0	305.0	347.0	42.0	12.0
1983	2,901	86.7	498.0	301.0	336.0	35.0	14.2
1984	3,789	113.9	501.0	302.0	345.0	43.0	11.7
1985	4,430	128.4	483.0	306.0	348.0	42.0	11.5
1986	4,644	130.4	468.0	310.0	351.0	41.0	11.4
1987	4,468	122.5	457.0	320.0	362.0	42.0	10.9
1988	5,016	133.5	443.0	323.0	364.0	41.0	10.8
1989	4,663	131.5	470.0	323.0	359.0	36.0	13.1
1990	4,860	145.5	499.0	322.0	362.0	40.0	12.5
1991	5,120	150.2	489.0	325.0	361.0	36.0	13.6
1992	4,676	134.1	478.0	325.0	361.0	36.0	13.3
1993	3,862	108.2	467.0	321.0	355.0	34.0	13.7
1994	2,629	68.2	432.3	312.0	347.0	35.0	12.3
1995	2,736	67.2	409.4	312.0	346.0	34.0	12.0
1996	2,853	71.3	416.5	310.0	342.0	32.0	13.0

NOTE: Well completed Dec. 1954; initial depth to water: 250 ft; surface elev. 6,014 ft.

Well G-2

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1951	123	3.9	528.5	259.0	—	—	—
1952	2,372	78.3	550.2	279.0	327.0	48.0	11.5
1953	3,254	105.6	540.9	290.0	334.0	44.0	12.3
1954	2,682	86.3	536.3	291.0	335.0	44.0	12.2
1955	2,487	78.8	528.1	299.0	345.0	46.0	11.5
1956	3,109	95.8	513.6	310.0	357.0	47.0	10.9
1957	2,458	76.1	516.0	311.0	360.0	49.0	10.5
1958	2,707	80.1	493.2	315.0	361.0	46.0	10.7
1959	2,938	84.6	479.9	320.0	363.0	43.0	11.2
1960	3,535	96.6	455.4	328.0	370.0	42.0	10.8
1961	3,982	105.3	440.7	336.0	375.0	39.0	11.3
1962	4,076	99.8	408.1	338.0	374.0	36.0	11.3
1963	4,563	105.7	386.1	344.0	379.0	35.0	11.0
1964	4,541	105.3	386.5	346.0	380.0	34.0	11.4
1965	3,535	82.6	389.4	346.0	381.0	35.0	11.1
1966	3,994	94.7	395.2	349.0	383.0	34.0	11.6
1967	2,743	67.6	410.7	344.0	379.0	35.0	11.7
1968	2,732	66.5	405.7	344.0	379.0	35.0	11.6
1969	2,679	68.6	426.8	344.0	381.0	37.0	11.5
1970	2,431	62.8	430.5	343.0	381.0	38.0	11.3
1971	3,420	87.4	425.9	345.0	384.0	39.0	10.9
1972	2,887	73.4	423.7	348.0	388.0	40.0	10.6
1973	2,816	72.4	428.5	344.0	385.0	41.0	10.5
1974	3,056	82.0	447.2	347.0	390.0	43.0	10.4
1975	2,724	74.5	455.8	341.0	384.0	43.0	10.6
1976	2,990	81.1	452.1	344.0	388.0	44.0	10.3
1977	2,981	80.4	449.5	346.0	388.0	42.0	10.7
1978	2,562	71.6	451.9	345.0	386.0	41.0	11.0
1979	2,975	80.0	448.0	347.0	388.0	41.0	11.0
1980	3,478	92.4	443.0	350.0	389.0	39.0	11.4
1981	1,432	38.3	445.8	352.0	390.0	38.0	11.7
1982	2,833	25.7	476.0	352.0	399.0	47.0	10.1
1983	624	16.5	441.0	356.0	399.0	43.0	10.3
1984	2,018	43.7	361.0	358.0	385.0	27.0	13.4
1985	4,339	96.6	371.0	352.0	381.0	29.0	12.8
1986	4,769	109.3	382.0	369.0	395.0	26.0	14.7
1987	4,526	109.7	404.0	366.0	399.0	33.0	12.2
1988	4,836	132.8	457.0	367.0	400.0	33.0	13.9
1989	4,820	133.9	463.0	375.0	408.0	33.0	14.0
1990	5,060	134.5	443.0	374.0	407.0	33.0	13.4
1991	4,792	123.3	428.0	369.0	401.0	32.0	13.4
1992	5,075	129.0	424.0	370.0	401.0	31.0	13.7
1993	3,871	97.1	418.0	368.0	399.0	31.0	13.5
1994	2,450	62.7	426.4	358.0	389.0	31.0	13.7
1995	2,829	70.1	413.0	361.0	390.0	29.0	14.2
1996	3,007	75.3	417.3	364.0	390.0	26.0	16.0

NOTE: Well completed Aug. 1951; initial depth to water: 259 ft; surface elev. 6,056 ft.

Well G-3

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1951	192	7.3	633.7	281.0	—	—	—
1952	2,379	65.4	458.2	310.0	358.0	48.0	9.5
1953	3,192	76.4	398.9	322.0	360.0	38.0	10.5
1954	2,675	66.1	411.8	322.0	370.0	48.0	8.6
1955	2,369	69.4	488.3	316.0	368.0	52.0	9.4
1956	3,149	87.9	465.2	324.0	380.0	56.0	8.3
1957	2,517	70.2	464.8	324.0	385.0	61.0	7.6
1958	2,562	69.5	452.1	323.0	386.0	63.0	7.2
1959	2,931	74.6	424.2	326.0	395.0	69.0	6.1
1960	3,591	82.5	382.9	335.0	407.0	72.0	5.3
1961	3,612	79.9	368.7	343.0	414.0	71.0	5.2
1962	4,057	83.7	343.9	348.0	418.0	70.0	4.9
1963	4,555	86.7	317.2	352.0	422.0	70.0	4.5
1964	4,487	78.6	292.0	355.0	424.0	69.0	4.2
1965	3,498	65.6	312.6	350.0	419.0	69.0	4.5
1966	3,991	73.7	307.8	353.0	420.0	67.0	4.6
1967	2,752	52.9	320.4	344.0	418.0	74.0	4.3
1968	3,086	56.5	305.1	341.0	418.0	77.0	4.0
1969	2,672	50.8	316.9	338.0	417.0	79.0	4.0
1970	2,736	55.4	337.5	336.0	419.0	83.0	4.1
1971	3,337	64.2	320.6	342.0	423.0	81.0	4.0
1972	2,838	50.9	298.9	341.0	421.0	80.0	3.7
1973	2,843	47.3	277.3	341.0	418.0	77.0	3.6
1974	3,006	49.3	273.3	342.0	424.0	82.0	3.3
1975	2,632	43.1	272.9	341.0	428.0	87.0	3.1
1976	2,971	82.6	463.4	359.0	447.0	88.0	5.3
1977	2,961	78.9	444.1	353.0	448.0	95.0	4.7
1978	2,590	66.4	427.5	345.0	443.0	98.0	4.4
1979	3,014	69.0	381.0	345.0	450.0	105.0	3.6
1980	3,448	61.8	298.6	348.0	453.0	105.0	2.8
1981	4,315	66.6	257.2	357.0	467.0	110.0	2.3
1982	3,550	51.0	239.0	349.0	459.0	110.0	2.2
1983	2,183	31.3	239.0	340.0	463.0	123.0	1.9
1984	1,211	19.0	267.0	355.0	475.0	120.0	2.2
1985	1,587	22.1	232.0	351.0	470.0	119.0	2.0
1986	2,266	26.7	196.0	375.0	492.0	117.0	1.7
1987	—	<0.1	—	—	—	—	—
1988	—	3.4	—	—	—	—	—
1989	—	<0.1	—	—	—	—	—
1990	—	—	—	—	—	—	—
1991	—	—	—	—	—	—	—

NOTE: Well completed July 1951; initial depth to water: 280 ft; surface elev. 6,139 ft.
Well out of service in 1989 due to pumpage of excessive sand.

Well G-4

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1951	—	12.5	—	357.0	477.0	120.0	—
1952	2,401	56.9	395.0	374.0	474.0	100.0	3.9
1953	2,677	55.2	343.7	380.0	472.0	92.0	3.7
1954	2,256	58.8	434.4	383.0	526.0	143.0	3.0
1955	1,172	22.7	322.8	378.0	481.0	103.0	3.1
1956	1,800	33.9	313.9	377.0	491.0	114.0	2.8
1957	1,324	24.2	304.6	373.0	498.0	125.0	2.4
1958	1,970	35.9	303.7	370.0	490.0	120.0	2.5
1959	1,819	31.6	289.5	378.0	494.0	116.0	2.5
1960	2,457	37.0	251.0	385.0	509.0	124.0	2.0
1961	2,787	45.0	269.1	389.0	512.0	123.0	2.2
1962	2,738	41.7	253.8	386.0	505.0	119.0	2.1
1963	3,519	46.4	219.8	388.0	504.0	116.0	1.9
1964	3,561	42.9	200.8	396.0	499.0	103.0	1.9
1965	2,100	23.8	188.9	394.0	492.0	98.0	1.9
1966	2,219	33.6	252.4	391.0	498.0	107.0	2.4
1967	2,690	44.8	277.6	388.0	509.0	121.0	2.3
1968	2,083	31.4	251.2	386.0	509.0	123.0	2.0
1969	1,309	17.4	221.5	387.0	505.0	118.0	1.9
1970	606	7.7	211.8	384.0	504.0	120.0	1.8
1971	1,640	21.0	213.4	389.0	503.0	114.0	1.9
1972	2,840	33.3	195.4	391.0	507.0	116.0	1.7
1973	3,006	37.2	206.3	392.0	521.0	129.0	1.6
1974	2,672	34.3	213.9	392.0	519.0	127.0	1.7
1975	1,977	41.0	345.6	403.0	559.0	156.0	2.2
1976	2,859	57.8	336.9	406.0	571.0	165.0	2.0
1977	2,954	62.4	352.1	406.0	589.0	183.0	1.9
1978	2,607	49.5	316.5	398.0	589.0	191.0	1.7
1979	2,974	52.9	296.4	395.0	586.0	191.0	1.6
1980	2,235	35.6	265.7	394.0	580.0	186.0	1.4
1981	432	8.2	316.4	385.0	573.0	188.0	1.7
1982	3,657	65.2	297.0	386.0	578.0	192.0	1.5
1983	2,604	42.2	270.0	—	—	—	—
1984	3,766	49.7	220.0	—	—	—	—
1985	1,747	21.7	207.0	402.0	572.0	170.0	1.2
1986	2,678	33.9	211.0	396.0	574.0	178.0	1.2
1987	2,011	25.1	208.0	398.0	573.0	175.0	1.2
1988	301	4.1	227.0	390.0	545.0	155.0	1.4
1989	1,739	21.6	207.0	401.0	562.0	161.0	1.3
1990	1,539	16.8	182.0	381.0	564.0	183.0	1.0
1991	1,254	13.7	181.0	382.0	559.0	177.0	1.0
1992	1,116	12.0	179.0	387.0	544.0	157.0	1.1
1993	0	0.0	0.0	374.0	—	—	—
1994	8	<0.1	162.5	363.0	525.0	162.0	1.0
1995	0	0.0	0.0	368.0	—	—	0.0
1996	721	7.2	166.4	374.0	570.0	196.0	0.8

NOTE: Well completed May 1951; initial depth to water: 347 ft; surface elev. 6,229 ft.

Well G-5

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1951	—	6.7	—	414.0	—	—	—
1952	2,579	73.8	476.9	422.0	480.0	58.0	8.2
1953	1,433	37.8	439.6	425.0	467.0	42.0	10.5
1954	2,617	80.9	515.2	429.0	473.0	44.0	11.7
1955	2,529	80.4	529.9	427.0	472.0	45.0	11.8
1956	3,052	97.0	529.7	431.0	478.0	47.0	11.3
1957	2,385	64.1	447.9	424.0	466.0	42.0	10.7
1958	1,523	49.1	537.3	428.0	477.0	49.0	11.0
1959	2,917	101.7	581.1	435.0	495.0	60.0	9.7
1960	2,828	98.0	577.6	437.0	501.0	64.0	9.0
1961	3,908	134.0	571.5	438.0	507.0	69.0	8.3
1962	4,186	142.0	565.4	440.0	511.0	71.0	8.0
1963	4,528	151.0	555.8	441.0	513.0	72.0	7.7
1964	4,532	150.4	553.1	446.0	516.0	70.0	7.9
1965	3,520	117.1	554.5	443.0	516.0	73.0	7.6
1966	2,555	83.2	542.7	445.0	520.0	75.0	7.2
1967	2,405	80.0	554.4	444.0	519.0	75.0	7.4
1968	2,513	81.2	538.5	443.0	517.0	74.0	7.3
1969	2,649	83.3	524.1	450.0	520.0	70.0	7.5
1970	2,771	88.9	534.7	453.0	521.0	68.0	7.9
1971	2,657	88.3	553.9	450.0	521.0	71.0	7.8
1972	2,902	92.4	530.7	441.0	514.0	73.0	7.3
1973	3,003	97.5	541.1	444.0	515.0	71.0	7.6
1974	2,054	69.0	559.9	440.0	513.0	73.0	7.7
1975	2,266	74.7	549.4	433.0	500.0	67.0	8.2
1976	2,955	95.0	535.8	442.0	504.0	62.0	8.6
1977	2,836	92.1	541.3	444.0	504.0	60.0	9.0
1978	2,608	84.2	538.4	442.0	502.0	60.0	9.0
1979	2,766	86.5	521.5	442.0	502.0	60.0	8.7
1980	2,896	89.0	512.4	442.0	502.0	60.0	8.5
1981	2,124	66.7	523.4	451.0	528.0	77.0	6.8
1982	1,219	38.2	522.0	455.0	510.0	55.0	9.5
1983	2,904	73.2	420.0	445.0	492.0	47.0	8.9
1984	3,838	115.4	501.0	452.0	507.0	55.0	9.4
1985	2,193	67.9	516.0	453.0	509.0	56.0	9.2
1986	2,219	52.5	394.0	453.0	494.0	41.0	9.6
1987	5,732	116.7	379.0	462.0	504.0	42.0	9.0
1988	4,841	115.3	396.0	466.0	507.0	41.0	9.7
1989	4,715	110.9	392.0	474.0	514.0	40.0	9.8
1990	5,094	119.2	390.0	485.0	526.0	41.0	9.5
1991	4,981	113.0	378.0	487.0	534.0	47.0	8.0
1992	5,006	114.4	376.0	470.0	508.0	38.0	9.9
1993	3,859	92.2	398.0	466.0	503.0	37.0	10.8
1994	109	2.5	388.0	459.0	494.0	35.0	11.1
1995	807	17.6	363.5	—	—	—	—
1996	2,686	66.9	415.1	—	—	—	—

NOTE: Well completed May 1951; initial depth to water: 411 ft; surface elev. 6,306 ft.

Well G-6

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1964	1,912	45.0	392.3	581.0	659.0	78.0	5.0
1965	3,200	74.9	390.1	582.0	660.0	78.0	5.0
1966	3,931	92.2	390.9	585.0	658.0	73.0	5.4
1967	2,454	57.8	392.6	580.0	653.0	73.0	5.4
1968	2,597	56.2	360.7	574.0	647.0	73.0	4.9
1969	2,698	55.6	343.5	568.0	636.0	68.0	5.1
1970	2,765	51.0	307.4	569.0	634.0	65.0	4.7
1971	2,932	42.8	243.3	573.0	629.0	56.0	4.3
1972	2,516	57.0	377.6	578.0	670.0	92.0	4.1
1973	2,991	65.3	363.9	579.0	667.0	88.0	4.1
1974	2,950	63.8	360.5	579.0	665.0	86.0	4.2
1975	2,717	56.7	347.8	577.0	659.0	82.0	4.2
1976	2,966	57.8	324.8	584.0	662.0	78.0	4.2
1977	2,954	54.4	306.9	586.0	659.0	73.0	4.2
1978	2,218	38.4	288.9	581.0	645.0	64.0	4.5
1979	1,030	18.2	295.1	579.0	645.0	66.0	4.8
1980	1,789	34.5	321.5	583.0	670.0	87.0	3.7
1981	4,302	76.5	296.4	586.0	673.0	87.0	3.4
1982	3,763	63.6	281.0	588.0	669.0	81.0	3.5
1983	1,960	35.4	301.0	582.0	668.0	86.0	3.5
1984	3,010	55.3	306.0	589.0	666.0	77.0	3.9
1985	3,980	71.4	299.0	586.0	664.0	78.0	3.8
1986	4,420	76.7	293.0	576.0	654.0	78.0	3.8
1987	5,100	81.4	266.0	595.0	671.0	76.0	3.5
1988	5,121	82.1	267.0	591.0	669.0	78.0	3.4
1989	5,000	81.6	272.0	592.0	669.0	77.0	3.5
1990	5,202	84.9	272.0	589.0	670.0	81.0	3.4
1991	5,063	81.2	267.0	591.0	674.0	83.0	3.2
1992	4,382	70.2	268.0	591.0	673.0	82.0	3.3
1993	—	—	—	575.0	—	—	—
1994	1,660	27.5	276.0	572.0	652.0	80.0	3.5
1995	2,892	46.4	267.4	577.0	660.0	83.0	3.2
1996	2,311	36.0	259.6	581.0	661.0	80.0	3.2

NOTE: Well completed Mar. 1964; initial depth to water: 572 ft; surface elev. 6,422 ft.

Well PM-1

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1965	2,754	99.2	600.3	746.0	786.0	40.0	15.0
1966	3,086	108.0	583.3	740.0	779.0	39.0	15.0
1967	2,870	111.0	644.6	737.0	781.0	44.0	14.6
1968	1,846	68.1	614.8	735.0	769.0	34.0	18.1
1969	951	34.4	602.9	733.0	766.0	33.0	18.3
1970	1,781	66.2	619.5	733.0	769.0	36.0	17.2
1971	2,728	101.0	617.1	733.0	766.0	33.0	18.7
1972	2,415	84.9	585.9	735.0	762.0	27.0	21.7
1973	1,688	46.5	459.1	736.0	755.0	19.0	24.2
1974	2,649	96.3	605.9	740.0	768.0	28.0	21.6
1975	2,567	94.8	615.5	741.0	766.0	25.0	24.6
1976	2,933	106.8	606.9	744.0	767.0	23.0	26.4
1977	2,969	105.4	591.7	745.0	767.0	22.0	26.9
1978	2,544	90.6	593.3	745.0	767.0	22.0	27.0
1979	2,350	83.4	591.5	744.0	766.0	22.0	26.9
1980	2,786	98.5	588.6	746.0	769.0	23.0	25.7
1981	2,789	98.5	588.6	747.0	769.0	22.0	26.8
1982	2,820	99.6	589.0	748.0	770.0	22.0	26.8
1983	2,464	86.5	585.0	747.0	769.0	22.0	26.6
1984	2,667	92.8	580.0	749.0	772.0	23.0	25.6
1985	2,760	95.4	576.0	749.0	770.0	21.0	27.4
1986	2,130	73.9	578.0	748.0	770.0	22.0	26.3
1987	2,912	102.4	586.0	752.0	773.0	21.0	27.9
1988	2,758	98.0	592.0	751.0	775.0	24.0	24.7
1989	3,014	104.9	580.0	752.0	774.0	22.0	26.4
1990	2,620	88.2	561.0	752.0	772.0	20.0	28.0
1991	2,600	88.6	568.0	752.0	774.0	22.0	25.8
1992	2,503	92.7	617.0	756.0	780.0	24.0	25.7
1993	1,802	63.9	591.0	758.0	779.0	21.0	28.1
1994	1,254	43.4	576.9	755.0	778.0	23.0	25.1
1995	870	29.7	569.0	753.0	776.0	23.0	24.7
1996	1,084	36.3	559.6	755.0	778.0	23.0	24.3

NOTE: Well completed Mar. 1965; initial depth to water: 722.1 ft; surface elev. 6,520 ft.

Well PM-2

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1966	221	18.9	1,425.3	826.0	889.0	63.0	22.6
1967	4,336	370.0	1,422.2	834.0	888.0	54.0	26.3
1968	3,865	328.2	1,415.3	838.0	889.0	51.0	27.8
1969	3,304	279.9	1,411.9	838.0	890.0	52.0	27.2
1970	3,529	300.6	1,419.7	839.0	893.0	54.0	26.3
1971	4,035	339.5	1,402.3	841.0	898.0	57.0	24.6
1972	4,611	385.3	1,392.7	845.0	902.0	57.0	24.4
1973	4,571	380.6	1,387.7	849.0	907.0	58.0	23.9
1974	5,443	450.9	1,380.7	853.0	912.0	59.0	23.4
1975	4,644	385.3	1,382.8	854.0	913.0	59.0	23.4
1976	5,382	442.0	1,368.8	866.0	924.0	58.0	23.6
1977	3,306	272.8	1,375.3	868.0	924.0	56.0	24.6
1978	4,743	388.4	1,364.9	871.0	928.0	57.0	23.9
1979	4,671	381.8	1,262.2	872.0	924.0	52.0	26.2
1980	5,023	409.6	1,359.2	873.0	931.0	58.0	23.4
1981	4,551	370.1	1,355.4	876.0	934.0	58.0	23.4
1982	4,319	359.3	1,386.0	874.0	934.0	60.0	23.1
1983	1,922	157.9	1,369.0	876.0	935.0	59.0	23.2
1984	996	81.6	1,365.0	866.0	930.0	64.0	21.7
1985	1,749	143.3	1,365.0	851.0	916.0	65.0	21.0
1986	1,036	84.4	1,359.0	851.0	915.0	64.0	21.2
1987	351	28.3	1,340.0	851.0	907.0	56.0	23.9
1988	1,843	146.8	1,328.0	869.0	931.0	62.0	21.4
1989	1,639	130.0	1,322.0	860.0	920.0	60.0	22.0
1990	3,164	250.4	1,319.0	860.0	928.0	68.0	19.4
1991	2,141	170.7	1,329.0	855.0	918.0	63.0	21.1
1992	3,486	277.7	1,328.0	860.0	929.0	69.0	19.2
1993	3,420	267.8	1,305.0	855.0	924.0	69.0	18.9
1994	3,922	298.9	1,270.3	870.0	934.0	64.0	19.8
1995	2,778	217.7	1,306.1	870.0	934.0	64.0	20.4
1996	4,023	302.2	1,250.0	—	—	—	—

NOTE: Well completed July 1965; initial depth to water: 823 ft; surface elev. 6,715 ft.

Well PM-3

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1968	2,327	187.4	1,342.2	743.0	771.0	28.0	47.9
1969	3,241	254.7	1,309.8	746.0	772.0	26.0	50.4
1970	2,905	227.8	1,306.9	750.0	774.0	24.0	54.5
1971	2,774	216.3	1,299.6	751.0	774.0	23.0	56.5
1972	2,445	192.1	1,309.5	752.0	775.0	23.0	56.9
1973	3,256	257.8	1,319.6	755.0	778.0	23.0	57.4
1974	3,241	255.3	1,312.9	756.0	779.0	23.0	57.1
1975	3,421	269.3	1,312.0	757.0	780.0	23.0	57.0
1976	3,171	268.3	1,410.2	758.0	784.0	26.0	54.2
1977	2,792	235.5	1,405.8	758.0	784.0	26.0	54.1
1978	2,516	211.0	1,397.6	759.0	784.0	25.0	55.9
1979	2,359	197.2	1,393.0	760.0	784.0	24.0	58.0
1980	2,796	234.4	1,397.2	760.0	785.0	25.0	55.9
1981	2,784	232.4	1,391.3	761.0	786.0	25.0	55.6
1982	2,831	238.1	1,402.0	762.0	785.0	23.0	60.9
1983	2,496	207.6	1,386.0	762.0	785.0	23.0	60.3
1984	3,317	275.6	1,385.0	762.0	787.0	25.0	55.4
1985	2,643	221.2	1,395.0	762.0	784.0	22.0	63.4
1986	2,920	244.8	1,397.0	763.0	787.0	24.0	58.2
1987	2,984	250.2	1,397.0	763.0	788.0	25.0	55.9
1988	2,766	232.0	1,397.0	764.0	788.0	24.0	58.2
1989	2,656	221.0	1,386.0	765.0	791.0	26.0	53.3
1990	2,949	244.6	1,382.0	767.0	790.0	23.0	60.0
1991	2,752	229.5	1,385.0	768.0	791.0	23.0	60.2
1992	3,610	307.4	1,419.0	770.0	794.0	24.0	59.1
1993	2,018	168.5	1,391.0	771.0	797.0	26.0	53.5
1994	966	78.8	1,358.9	772.0	796.0	24.0	56.6
1995	1,971	159.7	1,350.4	772.0	796.0	24.0	56.3
1996	1,401	118.5	1,409.7	776.0	802.0	26.0	54.2

NOTE: Well completed Nov. 1966; initial depth to water: 740 ft; surface elev. 6,640 ft.

Well PM-4

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1982	869	76.2	1,460	1,050	1,091	41	35.6
1983	5,267	452.5	1,432	1,066	1,101	35	40.9
1984	4,059	325.8	1,338	1,065	1,104	39	34.3
1985	4,759	379.2	1,328	1,066	1,101	35	37.9
1986	3,925	307.4	1,305	1,084	1,119	35	37.3
1987	5,071	392.2	1,289	1,081	1,117	36	35.8
1988	2,435	218.7	1,313	1,079	1,117	38	34.6
1989	5,387	418.9	1,296	1,085	1,122	37	35.0
1990	2,827	219.3	1,293	1,083	1,123	40	32.3
1991	2,832	219.5	1,292	1,081	1,123	42	30.8
1992	2,064	158.3	1,278	1,084	1,125	41	31.2
1993	3,901	249.7	1,295	—	—	—	—
1994	6,178	463.5	1,250	1,085	1,128	43	29.1
1995	5,736	428.2	1,244	—	—	—	—
1996	2,721	207.4	1,270	1,091	1,139	48	26.5

NOTE: Well completed Aug. 1981; initial depth to water: 1,060 ft; surface elev. 6,920 ft.

Well PM-5

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1985	—	2.0	—	—	—	—	—
1986	2,047	147.3	1,199	—	—	—	—
1987	1,620	118.6	1,220	1,237	1,345	108	11.3
1988	1,754	128.6	1,221	1,233	1,345	112	10.9
1989	1,184	86.2	1,213	1,239	1,352	113	10.7
1990	1,611	121.0	1,252	1,234	1,347	113	11.1
1991	1,497	112.1	1,248	1,239	1,346	107	11.7
1992	2,823	208.4	1,233	1,248	1,345	97	12.7
1993	1,709	126.0	1,229	1,224	1,321	97	12.6
1994	2,131	156.9	1,227	1,234	1,314	80	15.3
1995	3,948	291.0	1,228	—	—	—	—
1996	2,978	224.6	1,257	1,258	1,351	93	13.5

NOTE: Well completed Sept. 1982; initial depth to water: 1,208 ft; surface elev. 7,095 ft.

Well O-4

Year	Pump Time (h)	Production (10^6 gal.)	Pump Rate (gpm)	Water Level Nonpumping (ft)	Water Level Pumping (ft)	Drawdown (ft)	Specific Capacity (gpm/ft)
1993	2,942	283.8	1,603	761	789	28	57.3
1994	2,456	205.7	1,396	760	781	21	66.5
1995	0	0.0	0	762	—	—	0.0
1996	2,330	209.6	1,499	—	—	—	—

NOTE: Well completed Mar. 1990; initial depth to water: 780 ft; surface elev. 6,627 ft.

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APPENDIX B

STATIC WATER LEVELS IN REGIONAL AQUIFER TEST WELLS

Depth-to-Water Measurements from Regional Aquifer Test Wells (feet below surface elevation datum)

Year	TW-1	TW-2	TW-3	TW-4	TW-8	DT-5A	DT-9	DT-10	LA-1B
Drilled:	**1950**	**1949**	**1949**	**1950**	**1960**	**1959**	**1960**	**1960**	**1960**
Datum:	**6,369.19**	**6,647.63**	**6,595.31**	**7,244.56**	**6,877.62**	**7,143.86**	**6,936.71**	**7,019.92**	**5,622.00**
Init WL	**584.9**	**758.9**	**743.3**	**1,170.8**	**968.0**	**1,173.2**	**1,003.3**	**1,090.6**	**–34.0[1]**
1949		758.9	743.3						
1950	584.9			1,170.8					
1951	592.3	760.1	750.9	1,166.1					
1952	591.4		751.0	1,166.6					
1953	591.2	759.9	751.4	1,167.5					
1954	591.8	760.6	751.4	1,166.2					
1955		760.2	751.3						
1956	592.0	759.9	750.9						
1957	593.1	759.9	751.3						
1958	593.8	759.7	751.7						
1959	593.9		751.8						
1960	593.4	760.5	751.8	1,165.9	968.0	1173.2	1,003.3	1,090.6	–34.0[1]
1961	591.8	760.8		1,165.9			1,003.4	1,090.6	54.0
1962	590.0	761.2	751.8				1,004.0		72.0
1963	588.3	762.8	753.6		968.7	1176.9	1,004.6	1,090.3	74.0
1964	587.8		754.2		968.7	1177.0	1,005.0	1,090.4	81.0
1965	588.4				968.7		1,005.1	1,090.5	63.0
1966							1,005.2	1,090.6	50.0
1967							1,005.4	1,090.6	39.0
1968							1,005.5		32.0
1969									22.0
1970									22.0
1971							1,005.5		31.0
1972							1,005.2		31.0
1973							1,005.3		37.0
1974							1,005.6		35.0
1975							1,005.6		42.0
1976							1,005.8		50.0
1977		775.5					1,006.1		47.0
1978							1,006.2		42.0
1979							1,006.4		13.0
1980							1,006.2		21.0
1981							1,006.2		26.0
1982							1,006.2		71.0
1983									61.0
1984									75.0
1985									55.0
1986									25.0
1987									66.0
1988		787.0							60.0
1989									73.0
1990	508.4	787.2	772.0						70.0
1991	507.0	789.0							55.0
1992	536.5	792.5	777.5						
1993[2]	545.76	794.17	778.22	1,176.29	993.31	1,183.35	1,015.96	1,096.92	–14.83[1,3]
1994[2]	548.70	798.25	780.80	1,176.89	993.11	1,183.65	1,016.31	1,097.21	–18.72[1,3]
1995[2]	550.15	796.84	781.78	1,177.23	994.43	1,183.47	1,015.50	1,097.03	–19.29[1,3]
1996[2]	550.91	796.75	783.97	1,176.44	995.12	1,183.58	1,015.84	1,097.04	–18.43[1,3]

[1]Negative values indicate feet above surface elevation datum.
[2]Continuous hourly water level measurements begin on June 19, 1993, using pressure transducers; table values represent end-of-year measurement.
[3]Mechanical packer and hourly pressure transducer measurements begin on July 27, 1993.