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Water Supply at Los Alamos During 1990

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Prepared by Belinda Harrigan, Group EM-8

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Cover photo: Cementing casing in new supply well, Otowi-1, in Pueblo Canyon

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WATER SUPPLY AT LOS ALAMOS DURING 1990

by

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ABSTRACT

Municipal potable water supply during 1990 was 1,642 $\times 10^6$ gallons from wells in three fields. The nonpotable water supply used exclusively for industry was about 9 $\times 10^6$ gallons from the spring gallery in Water Canyon. The nonpotable water used for irrigation was 2.2 $\times 10^6$ gallons from the Guaje Reservoir and 4.6 $\times 10^6$ gallons from the Los Alamos Reservoir. Thus, the total water usage in 1990 was about 1,658 $\times 10^6$ gallons. Water supply was satisfactory in that production met demand, and water quality in the distribution system was in compliance with State and Federal regulations. A new well, Otowi-1, was completed in August 1990 at a depth of 2,497 ft with a water level of 675 ft. Step and aquifer tests indicated that the well will have a yield of from 800 to 1,000 gallons per minute when construction is completed.

I. INTRODUCTION

This report summarizes production and aquifer conditions for water wells in the Los Alamos, Guaje, and Pajarito well fields (Fig. 1). The wells supply all of the potable water used for municipal and some industrial purposes in Los Alamos County and the Los Alamos National Laboratory. The spring gallery in Water Canyon supplies nonpotable water for industrial use while the rest of the nonpotable water supply used for irrigation is surface water from the Guaje and Los Alamos Reservoirs. Also discussed is the quality of water in the distribution system as compared with drinking water standards set by the U. S. Environmental Protection Agency (EPA).

This report is a joint effort between the Laboratory's Environmental Surveillance Group and the Utilities Department of Johnson Controls World Services Inc. (JCI). The purpose of this report is to ensure a continuing historical record and to provide guidance for management of water resources in long-range planning for the water supply system. We have issued one summary report for the period of 1947–1971 and 19 annual reports that contain the results of our studies of these water supplies.[1-20] An additional report summarized the hydrology of the main aquifer with reference to future development of groundwater supplies.[21] A report was prepared in 1987 to examine the current status of wells and future water supply.[22] On the basis of that report, two new supply wells were drilled in 1989 and 1990.

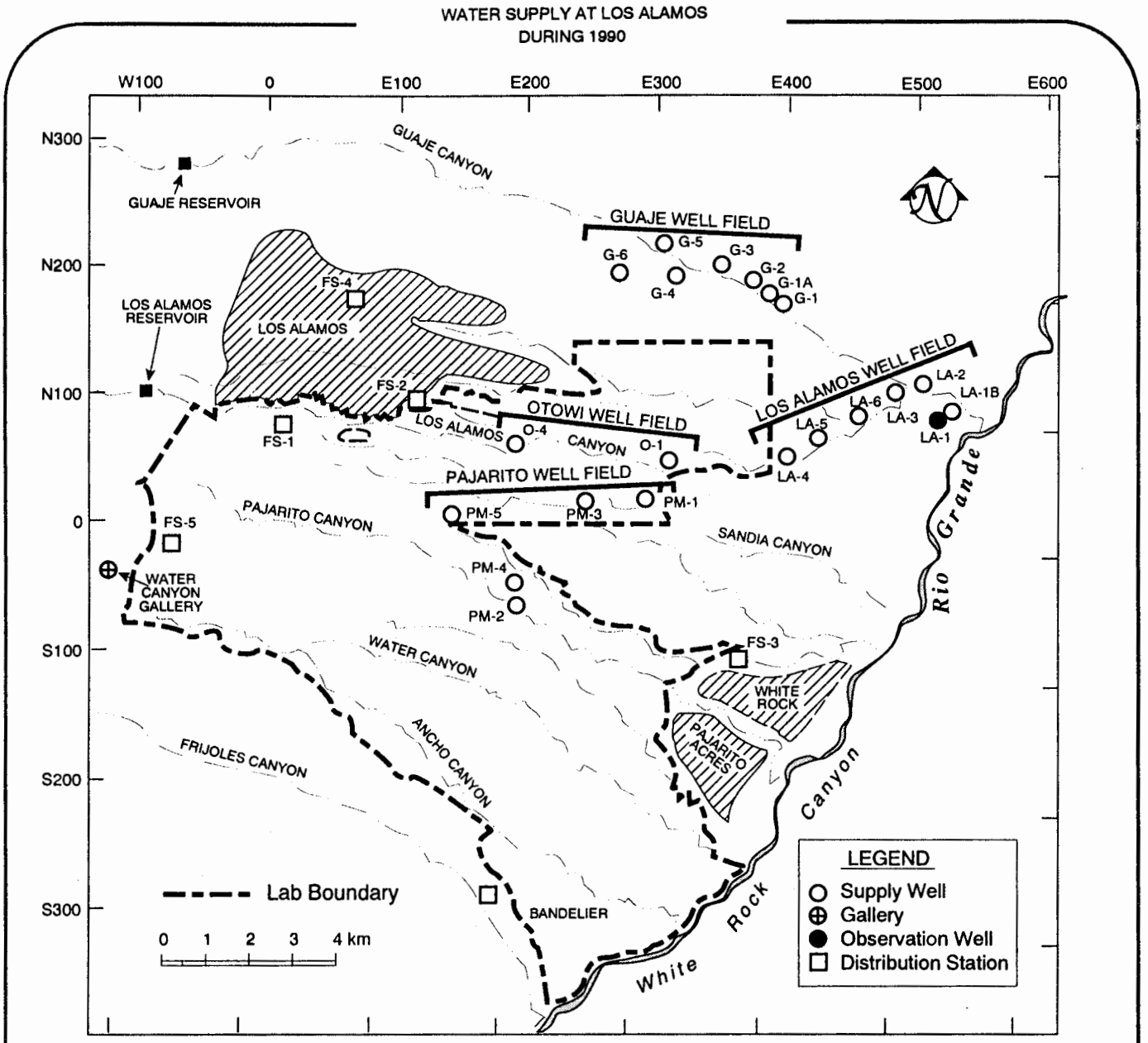

Fig. 1. Locations of reservoirs, well fields, water supply wells, and gallery water supply. Letter designations on the figure indicate wells in the Guaje (G), Pajarito (PM), Los Alamos (LA), and Otowi (O) well fields; some distribution stations are labeled (FS) to indicate fire station locations.

Construction of the first well, Otowi-4, began in September 1989; the well was completed and tested by March 1990. Construction of the second well, Otowi-1, began in March 1990. Construction and testing of the well was completed in August 1990. Construction data, and hydrologic data from Well Otowi-1 are included in this report.

JCI, the support contractor to the Laboratory and the Department of Energy (DOE) at Los Alamos, maintains and operates the water supply system. Water from the system is sold to the County for the communities of Los Alamos and White Rock and to the National Park Service for water supply at Bandelier National Monument.

After the potable water is pumped from the wells into the distribution lines, it is lifted by booster pumps into reservoirs for storage and distribution to the Laboratory and the community. The entire water supply is disinfected before distribution to Los Alamos, White Rock, Bandelier National Monument, and Laboratory areas (Fig. 1). The nonpotable water used for industrial use at TA-16 flows by gravity from the gallery in Water Canyon to the power plant. Other nonpotable water, used for irrigation, flows by gravity from the reservoirs in Guaje and Los Alamos Canyons. The transmission lines for the nonpotable water are a separate system from the potable transmission lines and storage system.

JCI maintains a record of the hours of operation for each well along with records of daily and monthly water production. The monthly average of nonpumping and pumping water levels are computed from air line pressure or transducer data recorded at each well.

These data are used in calculating the pumping rates, drawdown, and other well field statistics that are included in this report. The Appendix contains annual pumping and production information for each water supply well and the gallery for the period of record.

Water for the Laboratory, the communities of Los Alamos and White Rock, and Bandelier National Monument for 1990 was supplied from 16 deep wells in three well fields. The well fields are located on the Pajarito Plateau and in Los Alamos and Guaje Canyons east of the plateau (Fig. 1). The wells are completed in the main aquifer of the Los Alamos Area, the only aquifer capable of municipal and industrial water supply. Depth to water ranges from 25 to 30 ft (semi-artesian) in the well field in lower Los Alamos Canyon to about 760 ft along the eastern edge of the plateau to about 1,200 ft near the center of the plateau at Well PM-5. Water in the aquifer moves from the recharge area in the Caldera eastward beneath the plateau to the Rio Grande, where a part is discharged into the river through seeps and springs. [21]

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 aquifer perched in the volcanic rocks. Water from the two reservoirs is used for irrigation of lawns during the summer. The reservoirs are in canyons on the flanks of the mountains. Los Alamos Reservoir is located west, and the Guaje Reservoir, north west of Los Alamos. The source of water in the reservoirs is from springs, snowmelt, and summer run-off.

II. WELL FIELD CHARACTERISTICS

Production from the three well fields decreased 44 $\times 10^6$ gallons from 1,686 $\times 10^6$ gallons in 1989 to 1,642 $\times 10^6$ gallons in 1990 (Table I). The months of heaviest production in 1990 were May, June, and September. The production during these months was 612 $\times 10^6$ gallons, a decrease from 635 $\times 10^6$ gallons for a similar period of heavy production in 1989. The months of lightest production were February, November, and December with a production of 276 $\times 10^6$ gallons, an increase from 280 $\times 10^6$ gallons for a similar period in 1989.

The difference in demand between periods of heavy and light production (i.e., summer and winter demands) is mainly because of water usage for lawn irrigation. The 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.

Table I. Production from Wells and Gallery, 1947–1990 (in Millions of Gallons)

Year	Los Alamos Field	Guaje Field	Pajarito Field	Water Canyon Gallery	Production Total
1947	147	0	0	84	231
1948	264	0	0	97	361
1949	302	0	0	92	394
1950	547	3	0	54	604
1951	702	68	0	39	809
1952	448	350	0	48	846
1953	444	372	0	39	855
1954	380	374	0	40	794
1955	407	375	0	33	815
1956	437	506	0	23	966
1957	350	378	0	40	768
1958	372	395	0	60	827
1959	391	478	0	54	923
1960	530	533	0	48	1,111
1961	546	624	0	54	1,224
1962	577	597	0	67	1,241
1963	539	654	0	51	1,244
1964	627	665	0	45	1,337
1965	447	571	99	72	1,189
1966	450	613	127	82	1,272
1967	373	464	481	56	1,374
1968	345	474	584	65	1,468
1969	331	435	569	80	1,415
1970	360	423	595	65	1,443
1971	412	484	657	37	1,590
1972	380	467	662	40	1,549
1973	406	475	685	49	1,615
1974	369	453	802	35	1,659
1975	356	431	749	42	1,578
1976	343	531	817	41	1,732
1977	345	515	614	57	1,531
1978	302	444	690	45	1,481
1979	289	456	662	44	1,451
1980	339	485	743	32	1,599
1981	336	469	701	45	1,551
1982	317	422	773	46	1,558
1983	221	338	904	38	1,501
1984	326	460	780	34	1,600
1985	290	456	841	37	1,624
1986	179	460	858	28	1,525
1987	217	485	892	34	1,628
1988	158	477	824	—[a]	1,459
1989	219	506	961	—[a]	1,686
1990	187	532	923	—[a]	1,642
Total	16,307	18,698	17,993	2,129	55,127

[a]Water Canyon Gallery no longer a potable water supply (see nonpotable production, Table VI).

The production and use of water at the Laboratory and community increased from about 230×10^6 gallons in 1947 to $1,730 \times 10^6$ gallons in 1976. Water usage in 1977 declined to about $1,500 \times 10^6$ gallons and has varied from about $1,450 \times 10^6$ gallons in 1979 to about $1,628 \times 10^6$ gallons in 1987 (Fig. 2). The production in 1989 was $1,686 \times 10^6$ gallons. The water production declined to $1,642 \times 10^6$ gallons in 1990. The decline in 1977 and lower demand since then have been attributed largely to a rate increase for water used in the community and water-saving measures in the community and the Laboratory. Much of the landscaping in the community and Laboratory has been changed from lawns and shrubs, which require watering, to southwestern landscaping (native plants and gravels), which requires little if any water other than normal rainfall. However, regardless of the yearly variation in water demand for the past several years, in the long term there will be an increase in water usage.

A projection of future water demand is shown in Fig. 2. This line is an extrapolation of a least-squares line fitted to the actual data for 1977 through 1987 which had a rate of increase of about 10 million gallons a year or slightly more than one-half percent a year. Water usage in 1990 was only slightly greater than the ten-year trend. During the ten-year period analyzed for long range water supply planning, it was noted that Laboratory usage was almost constant at about 485 million gallons a year, with the least-squares trend declining by about 1.7 million gallons a year. The County usage showed a steady increase of about 13 million gallons a year or

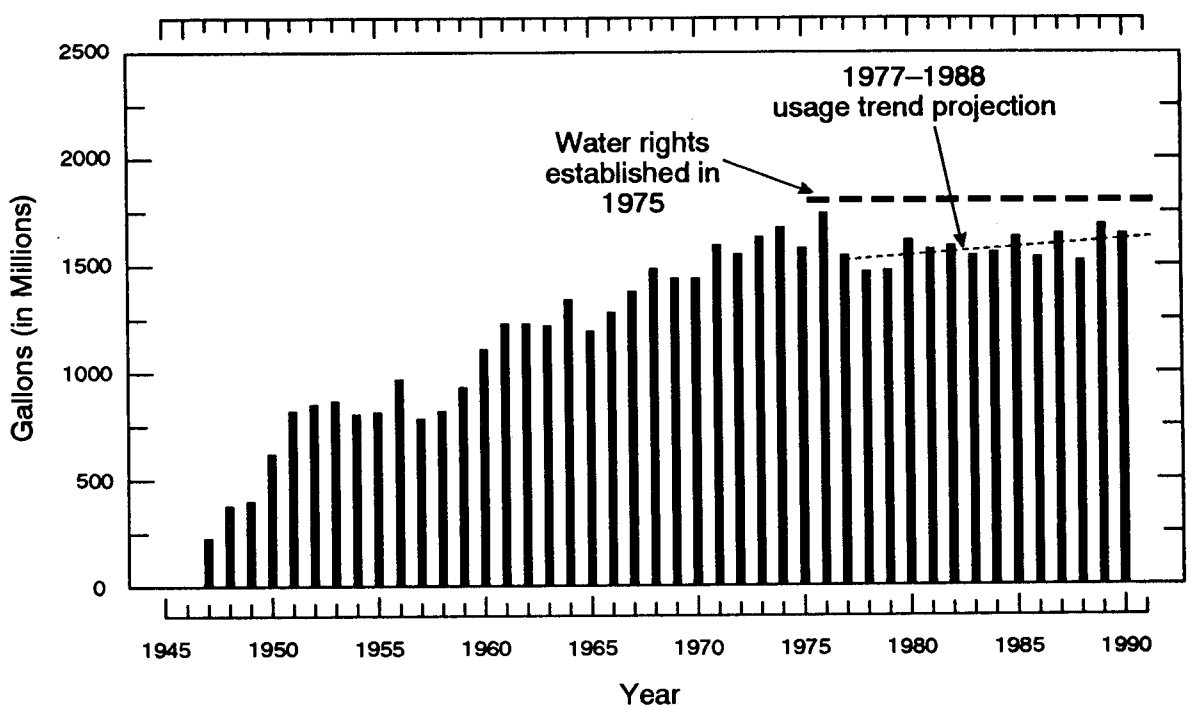

Fig. 2. Water production and usage from 1947 to 1990, and projected demand from 1985 to 1990.

about 0.8 percent a year increase. About 60 percent of total annual water use occurs during the spring and summer quarters. The annual variation in water usage, however, is not correlated in any statistically significant way with the amount of precipitation received during the year.

The peak demand period for 1990 was a 34 day period, May 31–July 3, when production was 297×10^6 gallons (Table II), or about 8.7×10^6 gallons per day (gpd). This was the longest peak demand period since 1982. It reflects below normal rainfall through the month of June.

Although cumulative well field productions are nearly equal (Table I), they do not reflect current proportionate contributions because production generally declines with the age of the well field. The wells in the Los Alamos field were constructed in the period 1947 through 1960, with production peaking in 1951 and generally declining since that time (Fig. 3); wells in Guaje field were constructed in the period 1950 through 1964, with production peaking in 1964 and declining since then. Wells in the Pajarito field were constructed in the period 1966 through 1982, with peak production occurring in 1983.

The present yield generally reflects the age of the wells in the three fields. In 1990 about 56% of the total production came from the Pajarito field, 32% from the Guaje field, and 11% from the Los Alamos field (Table III).

A. Los Alamos Well Field

The Los Alamos well field includes six supply wells and one observation well. Three wells (LA-1, -2, and -3) were completed in 1947 to depths of about 870 ft. Because Well LA-1 produced water containing excessive sand which rapidly wore out the pumps, it was replaced by Well LA-1B in 1960. Well LA-1B was completed to a depth of 1,750 ft. During the period 1948 through 1950, Wells LA-4, -5, and -6 were completed to depths of about 2,000 ft.

Rehabilitation of LA-4 in 1986 resulted in separation of the casing which permitted excessive sand to enter the well. Because the sand could not be controlled, and since the age of the well prevented repair of the casing, it was necessary to take the well out of production. Well LA-6 was placed on standby in 1976, as the water contained excessive amounts of natural arsenic.[23] The pumps, pump houses, and transmission were removed in 1990 from Wells LA-1, LA-4, and LA-6.

The production during 1990 was from Wells LA-1B, LA-2, LA-3, and LA-5. The production decreased about 32×10^6 gallons from 219×10^6 gallons in 1989 to 187×10^6 gallons in 1990 (Table III). The well field contributed about 11% of the total 1990 production.

The average pumping rates in 1990 ranged from 280 to 552 gallons per minute (gpm). The combine pumping rates of the field decreased from 1560 gpm in 1989 to 1534 gpm in 1990 (Table IV). There was a slight decrease in the specific capacities of the wells in use in 1990 when compared with the capacities of the same wells in 1989.

The water levels in the individual wells fluctuate with the amount of production (Fig. 4). The average water levels remained about the same in 1990 when compared to the 1989 water levels (Table V).

Table II. Peak Demand Periods 1982–1990

	Demand Period								
	June 23–July 11 1982	June 30–July 11 1983	June 8–June 18 1984	June 29–July 16 1985	July 28–August 10 1986	July 2–July 17 1987	June 18–June 26 1988	June 18–July 11 1989	May 31–July 3 1990
No. of days	19	12	11	18	14	16	9	24	34
Total production (gal.)	145×10^6	91×10^6	81×10^6	138×10^6	91×10^6	134×10^6	63×10^6	216×10^6	297×10^6
Average daily production (gal.)	8.1×10^6	7.6×10^6	7.4×10^6	7.7×10^6	6.5×10^6	8.4×10^6	7.0×10^6	9.0×10^6	8.7×10^6
No. of days exceeding									
10×10^6 gal.	—	—	—	—	—	—	—	4	8
9×10^6 gal.	1	—	—	3	—	4	—	9	13
8×10^6 gal.	9	6	2	4	2	7	2	10	3
7×10^6 gal.	9	2	6	9	2	4	3	0	4
$<7 \times 10^6$ gal.	0	4	3	2	10	1	4	1	6

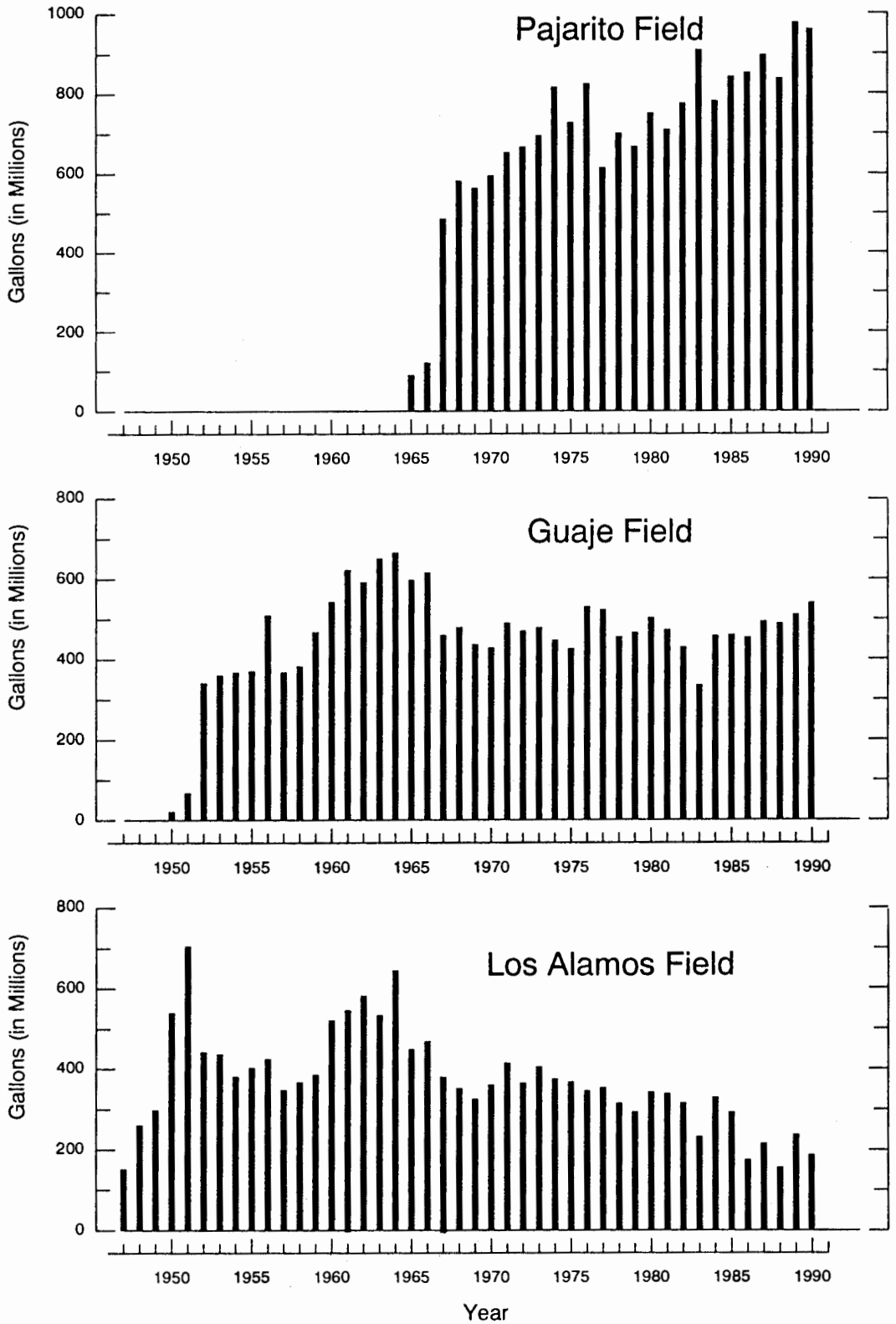

Fig. 3. Comparison of annual production from three well fields.

Table III. Well Production Characteristics for 1989 and 1990

	Production					
	Amount (10^6 gal.)		Well Field (%)		Total Production (%)	
	1989	1990	1989	1990	1989	1990
Los Alamos Field						
Well LA-1	—	—	—	—	—	—
Well LA-1B	97.8	68.6	45	37	6	4
Well LA-2	43.2	40.3	19	21	2	2
Well LA-3	51.9	44.6	24	24	3	3
Well LA-4	—	—	—	—	—	—
Well LA-5	26.5	33.3	12	18	2	2
Well LA-6	<0.1	0.0	0	0	0	0
Subtotal	219.4	186.8	100	100	13	11
Guaje Field						
Well G-1	26.9	30.8	6	6	2	2
Well G-1A	131.2	145.5	26	28	8	9
Well G-2	133.9	134.5	26	25	8	8
Well G-3	—	—	—	—	—	—
Well G-4	21.6	16.8	4	3	1	1
Well G-5	110.9	119.2	22	22	6	7
Well G-6	81.6	84.9	16	16	5	5
Subtotal	506.1	531.7	100	100	29	32
Pajarito Field						
Well PM-1	104.9	88.2	11	10	6	6
Well PM-2	130.0	250.4	13	27	8	15
Well PM-3	221.0	244.6	23	26	13	15
Well PM-4	418.9	219.3	44	24	24	13
Well PM-5	86.2	121.0	9	13	5	7
Subtotal	961.0	923.5	100	100	56	56
Total Potable	1,686.5	1,642.0	—		—	
Total Nonpotable	30.9	16.1	—	—	2	1
Water Canyon (Gallery)	23.0	9.3	—	—	—	—
Guaje Reservoir	4.6	2.2	—	—	—	—
Los Alamos Reservoir	3.3	4.6	—	—	—	—
Total Production from Permitted Sources	1,717.4	1,658.1	—	—	—	100

B. Guaje Well Field

The Guaje well field includes seven wells ranging in depths from 1,500 to 2,000 ft. Wells G-1, -2, -3, -4, and -5 were completed in 1950. Well G-1A was completed in 1954, and Well G-6 was placed in service in 1964.

The 1990 production came from six of these wells. Rehabilitation of Well G-3 damaged the casing beyond repair and the well was taken out of production. The damage caused large amounts of sand to enter the well.

Table IV. Average Pumping Rate and Specific Capacity, 1989 and 1990

	Average Pumping Rate (gpm)		Average Specific Capacity (gpm/ft of drawdown)	
	1989	1990	1989	1990
Los Alamos Field				
Well LA-1	—	—	—	—
Well LA-1B	569	552	4.6	4.4
Well LA-2	272	280	1.4	1.4
Well LA-3	308	302	1.8	1.8
Well LA-4	—	—	—	—
Well LA-5	411	400	—	—
Well LA-6	—	—	—	—
Subtotal	1,560	1,534		
Guaje Field				
Well G-1	223	242	1.3	1.4
Well G-1A	470	499	13.1	12.5
Well G-2	463	443	14.0	13.4
Well G-3	—	—	—	—
Well G-4	207	182	1.3	1.0
Well G-5	392	390	9.8	9.5
Well G-6	272	272	3.5	3.4
Subtotal	2,027	2,028		
Pajarito Field				
Well PM-1	580	561	27.6	28.0
Well PM-2	1,322	1,319	22.0	19.4
Well PM-3	1,386	1,382	53.3	60.0
Well PM-4	1,296	1,293	35.0	32.3
Well PM-5	1,213	1,252	—	—
Subtotal	5,797	5,807		
Total	9,384	9,369		

The production from the Guaje field increased about 26 $\times 10^6$ gallons from 506 $\times 10^6$ gallons in 1989 to 533 $\times 10^6$ gallons in 1990. The well field contributed about 32% of the total production in 1990 (Table III).

The average pumping rate of the six wells ranged from 182 to 499 gpm (Table IV). The overall combined pumping rate remained about the same in 1990 when compared to that same rate in 1989. There was no significant change in the specific capacities of the individual wells from 1989 to 1990 (Table IV).

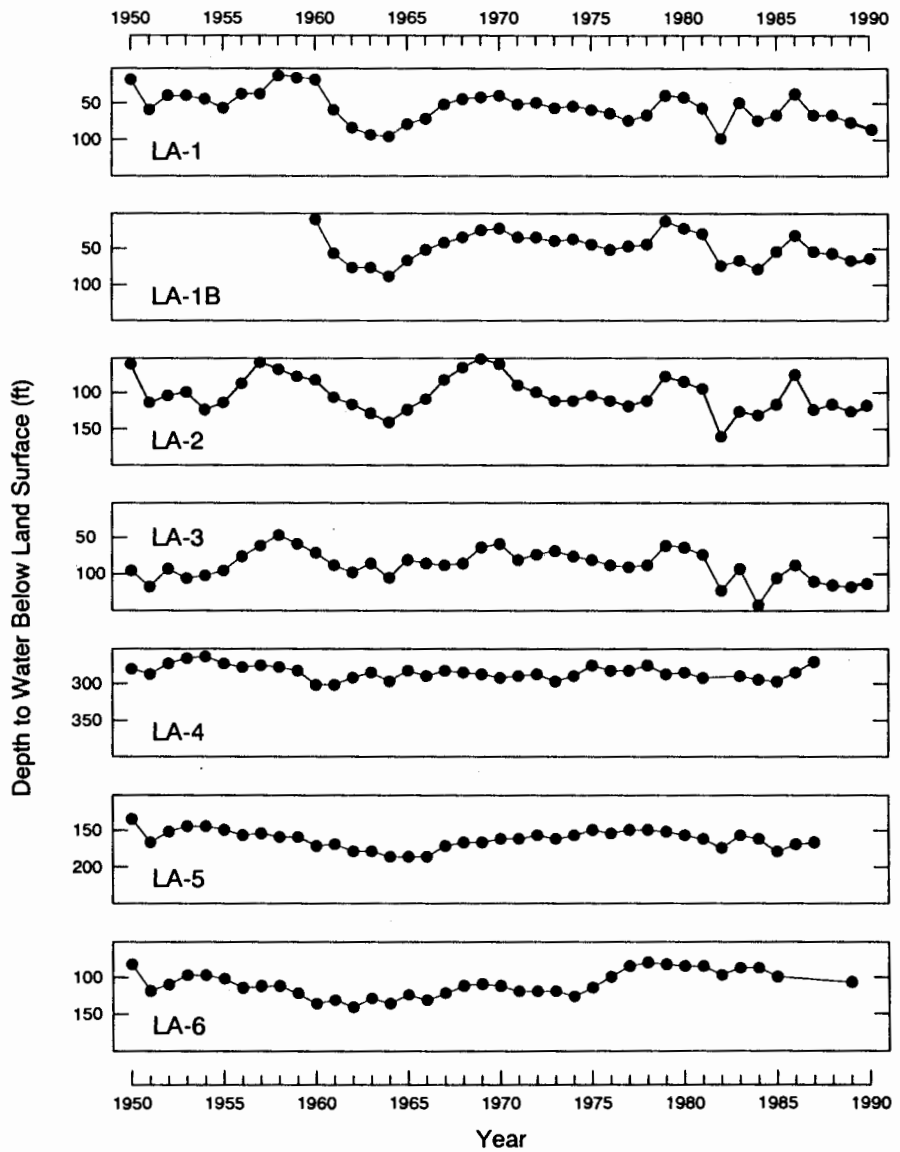

Fig. 4. Nonpumping water levels in wells in the Los Alamos well field.

The average nonpumping water levels 1990 in the well field remained about the same when compared to the 1989 water levels (Fig. 5). Increased or decreased pumpage in individual wells during the year resulted in slight declines or increases in water levels in that particular well. These water changes are normal and not considered significant (Table IV). Adjustments were made of water levels in Well G-2 for 1988 and 1989 due to an error in air line length used during that period.

Table V. Average Water Levels for Nonpumping and Pumping Wells and Average Drawdown, 1989 and 1990

	Average Water Levels				Average Drawdown (ft)	
	Nonpumping (ft)		Pumping (ft)			
	1989	1990	1989	1990	1989	1990
Los Alamos Field						
Well LA-1	77	84	—	—	—	—
Well LA-1B	73	70	197	196	124	126
Well LA-2	141	134	322	330	188	196
Well LA-3	122	122	298	295	176	173
Well LA-4	—	—	—	—	—	—
Well LA-5	—	—	—	—	—	—
Well LA-6	—	—	—	—	—	—
Average per field	103	102				
Guaje Field						
Well G-1	282	284	451	454	169	170
Well G-1A	323	322	359	362	36	40
Well G-2	375	374	408	407	33	33
Well G-3	—	—	—	—	—	—
Well G-4	401	381	562	564	161	183
Well G-5	474	485	514	526	40	41
Well G-6	592	589	669	670	77	81
Average per field	407	406				
Pajarito Field						
Well PM-1	752	752	774	772	21	20
Well PM-2	860	860	920	928	60	68
Well PM-3	765	767	791	790	26	23
Well PM-4	1,085	1,083	1,122	1,123	37	40
Well PM-5	—	—	—	—	—	—
Average per field	865	866				

C. Pajarito Well Field

The Pajarito well field includes five wells. The wells were completed over a 17-year period, from 1965 through 1982, and range in depths from 2,300 to 3,100 ft. Because they are located on the Pajarito Plateau, the depths to water range from about 750 ft at Well PM-1 to more than 1,200 ft at Well PM-5.

The production from the Pajarito well field in 1990 was about 923 $\times 10^6$ gallons, a decrease of 38 $\times 10^6$ gallons from the 961 $\times 10^6$ gallons produced in 1989 (Table III). The field contributed about 56% of the total 1990 production. The production from Wells PM-2, -3, and -4 represented about 43% total water produced at Los Alamos in 1990 (Table III).

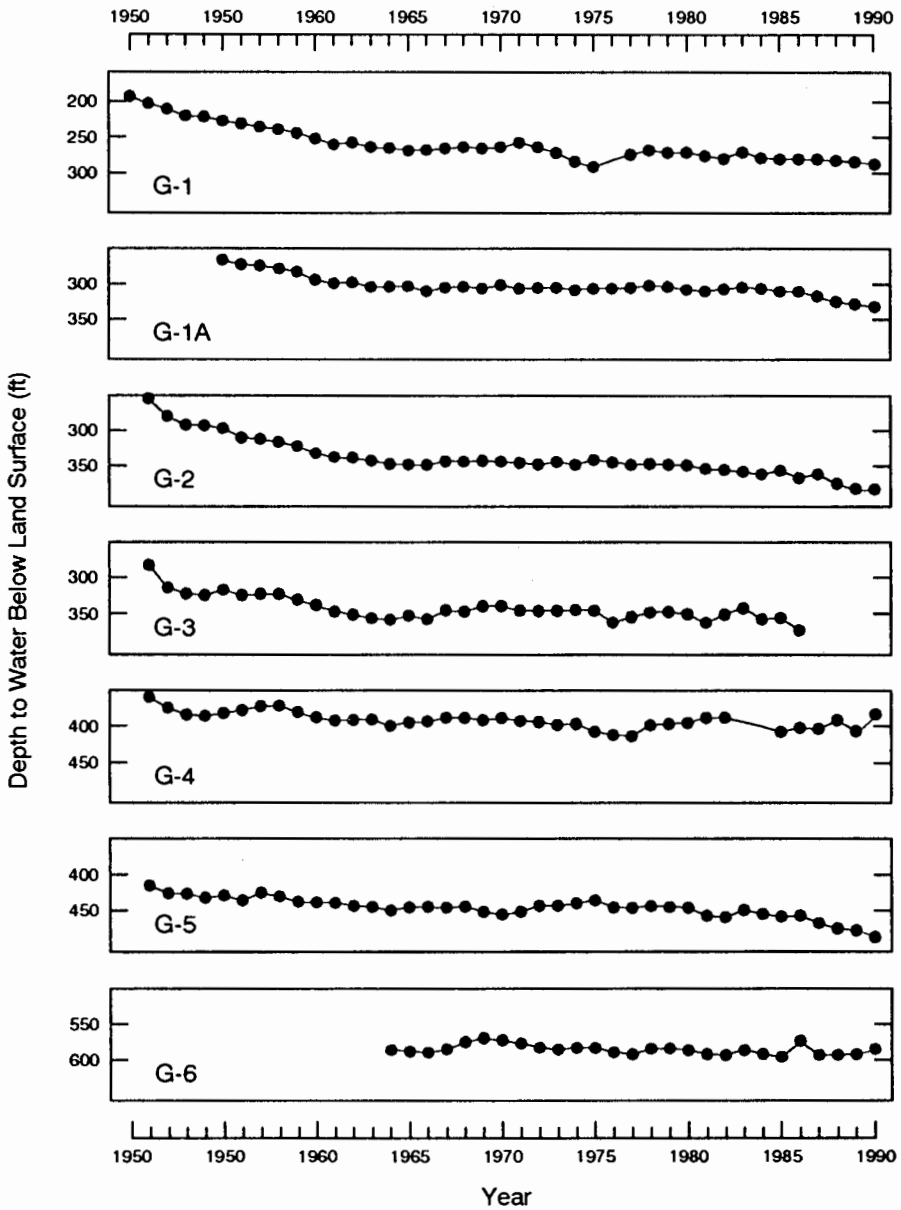

Fig. 5. Nonpumping water levels in wells in the Guaje well field.

The average pumping rates of the Pajarito wells ranged from 561 to 1,382 gpm (Table IV). Four of the wells (PM-2, -3, -4, and -5) are high-yield wells with pumping rates over 1,000 gpm (Table IV). The pumping rates from the individual wells varied slightly from 1989 to 1990 with a slight increase of the combined rate of about 10 gpm from 5,797 gpm in 1989 to 5,807 gpm in 1990.

The specific capacities of the wells in 1990 ranged from 19.4 to 60 gpm/ft of drawdown. There was no significant change in the specific capacities from 1989 to 1990 though there was some variation in the specific capacities of individual wells (Table IV).

The water levels in these wells fluctuated as would be expected from the amount of pumpage (Fig. 6). The average water levels in the field remained about the same in 1990 compared to the 1989 average water levels (Table V).

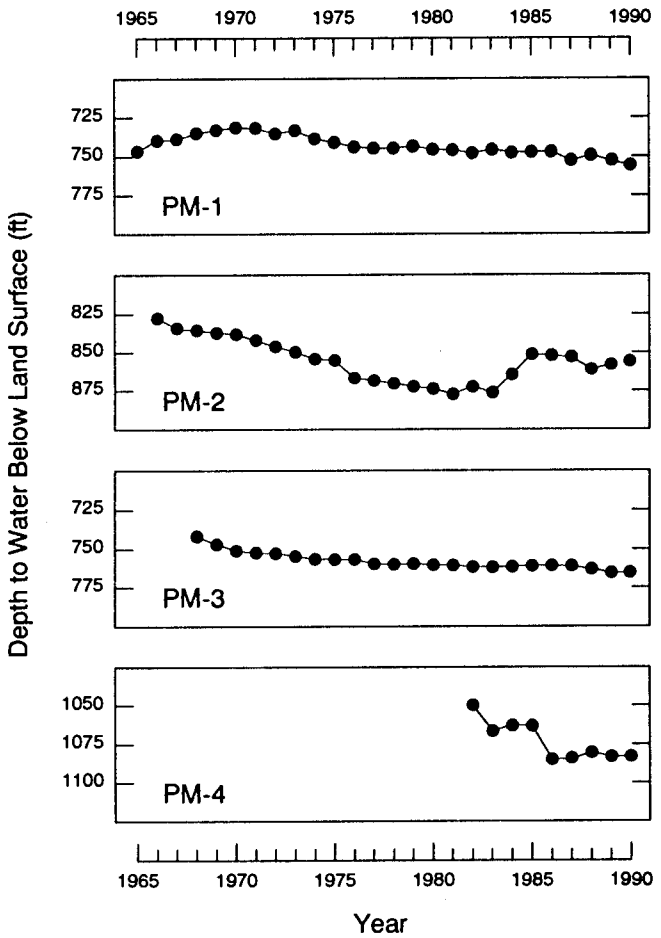

Fig. 6 Nonpumping water levels in wells in the Pajarito well field (no water level data are available for well PM-5.)

D. Well and Well Field Conditions

The gear drive of the natural gas engine on Well PM-4 failed in December 1989. The well was returned to service in April 1990.

The continuous water level recorders or transducers on Wells LA-5 and PM-5 were not working, or calibrations were in error; hence, no water levels were obtained for 1989. There were no operating airlines or transducers in Wells LA-4 and G-3 as these wells were not used due to screen and casing damage. No water level data was collected in 1990.

III. WATER CANYON GALLERY, GUAJE, AND LOS ALAMOS RESERVOIRS

The nonpotable water from the gallery in Water Canyon, Guaje Reservoir, and Los Alamos Reservoir is used for industrial water supply (boiler makeup) or irrigation. Water Canyon Gallery was a source of potable water from the early days of the Manhattan Project until 1989 (Table I). Rapid recharge to the gallery causes heavy sediment loads to enter the potable system. In 1989, to keep the sediments out of the potable system, the use of the of the gallery was ended.

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 causing storm run-off and because of difficulties in maintaining bacteriological levels below limits allowed for a municipal supply.

Both of the reservoirs and adjacent areas are now open for recreational use. The water from the reservoirs is available for irrigation of lawns and shrubs in the community and 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.

A. Water Canyon Gallery

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 occurs in the fractures of a welded tuff, which is underlain by a non-welded tuff (the fractures in the welded tuff perch the water). The recharge to the perched aquifer is rapid. In the spring when snowmelt occurs, the discharge from the gallery increases and causes increased suspended sediment in the water. The water is used for industrial purposes only, make up water to the power plant at TA-16.

The gallery furnished about 9.3×10^6 gallons of water to the power plant during 1990 (Table VI). The total discharge from the gallery was not utilized at the power plant. The excess discharge was released to waste. The annual use during the period 1947–1988 has ranged from 23×10^6 to 97×10^6 gallons (Appendix).

Table VI. Production from Water Canyon (Gallery), Guaje, and Los Alamos Reservoirs.[a]

Year	Water Canyon Gallery (10^6 gal.)	Guaje Reservoir[b] (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	10.5
1952		131	33.6
1953		58	14.8
1954		66	16.9
1955		71	18.1
1956		24	4.8
1957		213	54.8
1958		193	49.4
Irrigation Production			
1972		5.8	—
1973		9.7	—
1974		4.9	—
1975		5.3	—
1976		4.4	—
1977		4.1	—
1978		2.8	—
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		2.4	1.4
1989		4.6	3.3
1990	9.3	2.2	4.6

[a]Nonpotable Water, Guaje, and Los Alamos Reservoir municipal supply 1947–1959; irrigation 1972–1990: Water Canyon (Gallery) municipal supply 1947–1989; industrial supply 1990 (see Table 1 and Appendix).

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

B. Guaje Reservoir

Guaje Reservoir in upper Guaje Canyon has a capacity of 0.25 $\times 10^6$ gallons and has a drainage area of 5.6 sq miles. The reservoir is for diversion rather than storage as perennial flow is maintained by springs in the canyon above the reservoir. Water flows by gravity through 6.8 miles of water line for irrigation of lawns and shrubs at Los Alamos Middle School and Guaje Pines Cemetery. The line from the reservoir is not a part of, nor is it connected to, the distribution system for municipal supply.

The annual production from Guaje Reservoir, when it was used for municipal water supply from 1947 through 1958, ranged from an estimated 24 $\times 10^6$ gallons to 213 $\times 10^6$ gallons (Table VI). There is no record of the amounts of water used for irrigation from 1959 through 1971. Since 1972 the amount of water used for irrigation has ranged from 2.2 $\times 10^6$ gallons to 9.7 $\times 10^6$ gallons. The amount used in 1990 was 2.2 $\times 10^6$ gallons, down from 4.6 $\times 10^6$ gallons used in 1989.

C. Los Alamos Reservoir

Los Alamos Reservoir in upper Los Alamos Canyon has a capacity of 13.4 $\times 10^6$ gallons and has a drainage area of 6.4 sq miles. The water flows by gravity through about 2.6 miles of distribution lines for irrigation of lawns and shrubs at the Laboratory's Health Research Building, the Los Alamos High School, and Mesa School. The line from the reservoir is not a part of, nor is it connected to, the distribution system for the municipal water supply.

The annual production from the Los Alamos Reservoir, when it was used for the municipal water supply from 1947 through 1958, ranged from 4.8 $\times 10^6$ gallons to 54.8 $\times 10^6$ gallons (Table VI). There is no record of water usage from the reservoir from 1959 through 1978, but since 1978 the amount of water used for irrigation has ranged from 0.9 $\times 10^6$ gallons to 4.6 $\times 10^6$ gallons. The amount of water from the reservoir used for irrigation in 1990 was 4.6 $\times 10^6$ gallons, up from the 3.3 $\times 10^6$ gallons used in 1989.

IV. QUALITY OF WATER

The Laboratory conducts two separate programs to monitor the quality of groundwater in the area and to meet regulatory requirements. The first program, under the Laboratory's long-term environmental surveillance program includes sampling of each water supply well and test wells completed into the main aquifer. The results of this program are documented in detail in the annual surveillance report for 1990, Section VI.A.5.[24]

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). During 1990, all water samples collected under the SDWA program at Los Alamos were in compliance with the regulations. The following paragraphs summarize the results of this compliance program while detail of the program and data collected are documented in the annual surveillance report for 1990 in Section VII.E.[24]

Water samples were collected from three locations in the distribution system (Los Alamos Airport, White Rock Fire Station, and Barranca Mesa School). These samples were analyzed by

the State Scientific Laboratory Division (SLD). At the three distribution system locations, the water supply system was in compliance with all Federal and State regulations pertaining to water quality, as determined by the EPA's primary, secondary, and radiochemical standards.[24]

Each month during 1990 approximately 45 samples were collected throughout the Laboratory and County distribution system to determine the free chlorine and residual available for disinfection and the microbiological quality of the distribution system. These samples were collected and analyzed by JCI (certified EPA Laboratory) for the presence of coliform bacteria, which is an indicator bacteria used to determine if harmful bacteria could be present. During 1990, no coliform bacteria were found. Thirty-nine of the microbiological samples (about 7%) were found to have some noncoliform bacteria present. Although the presence of noncoliform bacteria is not a violation of SDWA, it does indicate stagnate water in the distribution lines. A summary of these results can be found in the annual surveillance report for 1990.[24]

V. CONSTRUCTION AND DEVELOPMENT OF SUPPLY WELL OTOWI-1

The construction of the wells in the new Otowi well field is part of the "Restoration Water Well Replacement Program" that is a long-range plan to replace the Los Alamos well field and boost declining production of the Guaje well field. The capacity of wells in both fields has deteriorated significantly with time.[22] The age of the wells to be replaced range from 29 to 43 years. The new Otowi well field, which will replace the Los Alamos field, is located west of the Los Alamos field and north of the Pajarito well field. The Otowi field, when complete, will be composed of four wells (Fig. 1).[21]

Two wells were scheduled for drilling and construction in 1989 and 1990. The drilling and construction of Otowi-4, the first well, began in September 1989 and was completed in March 1990. The well was completed at a depth of 2,585 ft with the top of the main aquifer at 790 ft. Step and aquifer tests indicate that the well will have a high yield of about 1,500 gpm when construction is complete. Construction and hydrologic data for the well are presented in the "Water Supply at Los Alamos during 1989."[20]

Drilling and construction of Otowi-1 began in March 1990; construction and testing were completed by August 1990. Otowi-1 was drilled to a depth of 2,609 ft and was completed at a depth of 2,497 ft (Fig. 7 and Table VII). The surface and near-surface groundwater were cased out of the well with a surface conductor pipe set and cemented in to a depth of about 55 ft. A second conductor pipe was set and cemented in to a depth of 664 ft. A perched water was encountered in the fanglomerate member of the Puye Conglomerate at a depth of about 183 ft. The same perched zone occurs in Test Well TW-1A about 400 ft to the east. The casing cemented in to a depth of 664 ft sealed the perched water from the well. The final casing string is blank to a depth of 1,017 ft, screened from 1,017 ft to 2,477 ft, and blank casing with a plate on the end from 2,477 ft to 2,497 ft.

Otowi-1 was completed into the main aquifer as are all supply wells in the area. The top of the main aquifer occurred at a depth of about 675 ft below land surface. The geologic log of the well indicated that the bore hole penetrated a weathered section of the Bandelier Tuff, Basalt Rocks of Chino Mesa, Puye Conglomerate with some interbedded Basalt Rocks of Chino Mesa,

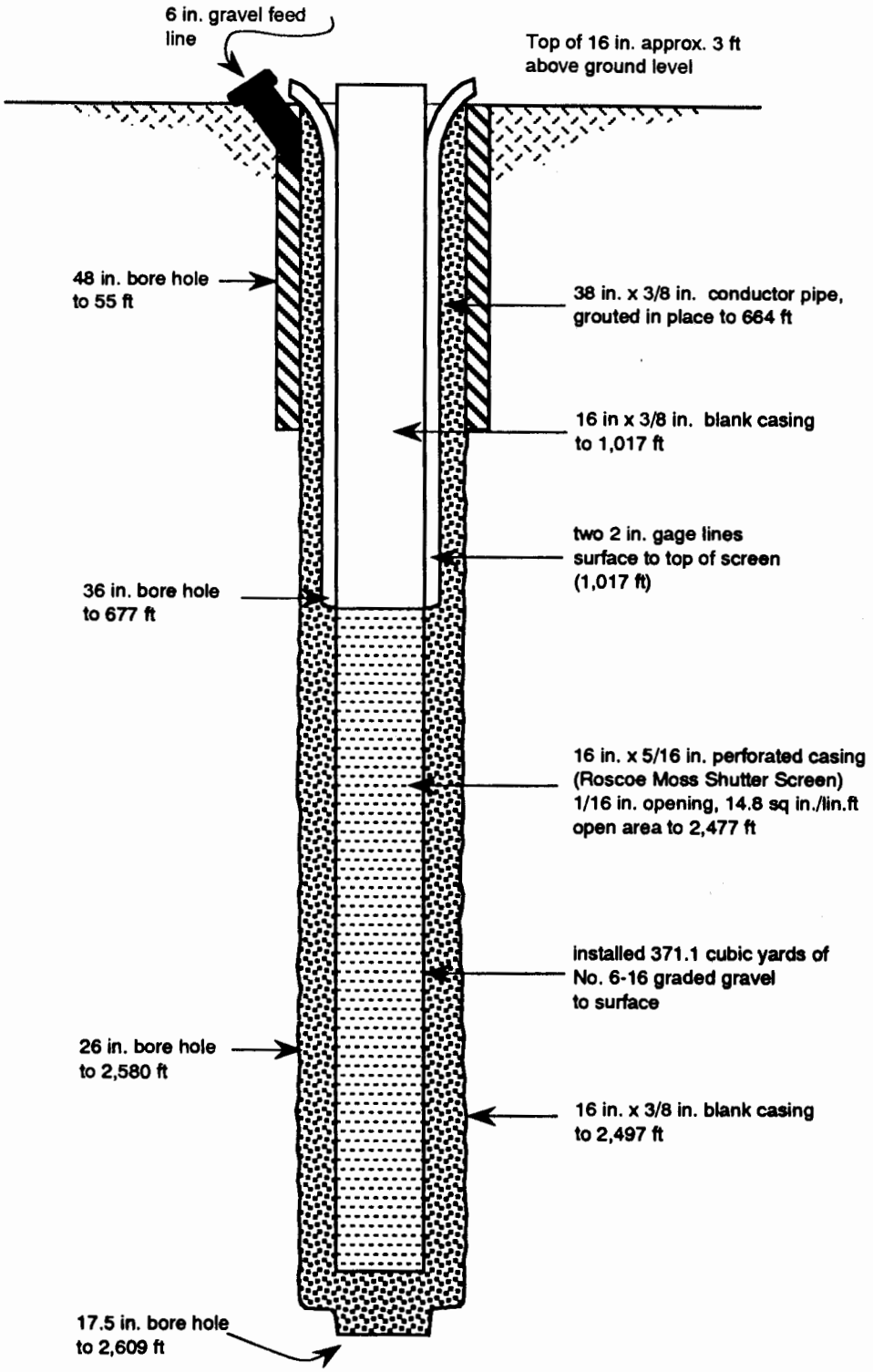

Fig. 7. Construction details of Well Otowi-1.

Table VII. Construction Data for Well Otowi-1

Hole Log

Depth (ft) From	Depth (ft) To	Hole Diameter (in.)
0	55	48
55	677	36
677	2,580	26
2,580	2,609	17.5

Casing Log

Depth (ft) From	Depth (ft) To	Casing Dimension	Material
0	55	38 in. I.D.	Surface conductor pipe, 3/8 in. wall thickness cemented in from 0 to 55 ft
0	664	28 in. 0.D.	Conductor pipe, cemented in 0 to 664 ft
0	2,497	16 in. I.D.	Production string: 0 to 1,017 ft blank pipe; 1,017 to 2,477 ft Roscoe Moss shutter screen, 1,017 to 2,157 ft (1,140 ft) 16 in. diameter (5/16 in. wall thickness) with screen openings of 0.050-in.; 2,157 to 2,477 ft (320 ft) of 16 in. I.D. (5/16 in. wall thickness) with screen openings of 0.060 in.; blank pipe 2,477 to 2,497 ft with a bull nose plug on end.

Construction Log

- Cement or gravel fills the space between the borehole or production string and the conductor pipe (see Fig. 7):
  1. Cement 0 to 55 ft between the 38 in. diameter surface conductor pipe and the 48 in. diameter hole wall.
  2. Cement pumped from the bottom of the 28 in. diameter conductor pipe from 664 ft to land surface (between the 28 in. diameter conductor pipe and the surface conductor pipe 36 in. diameter from 0 to 55 ft); between the 28 in. diameter conductor pipe and 36 in. diameter hole wall from 55 to 664 ft.
  3. Gravel placed 371 cubic yards of No. 6-16 graded gravel from 2,497 ft to the land surface between the production string and the conductor pipe to 664 ft and between the production string and hole wall from 664 to 2,497 ft.
- A gravel steel pipe (feed line) 6 in. O.D. diameter extends from the well head into the gravel pack between the 28 in. diameter conductor pipe and the 16 in. diameter production string.
- Two gage lines, 2 in. diameter I.D., are welded to the outside of the production string from the well head to 1,017 ft where they enter the production string.
- A gyroscopic multishot (straight hole survey) was run of the cased well on October 10, 1990 by Eastman-Christensen of Midland, Texas. The survey indicated that the closure from the well head to a depth of 1,000 ft was 16.67 ft, north 9 degrees 46 minutes east.

and into the Tesuque Formation. The Tesuque in this well is composed mostly of silt and clay with only minor amounts of sand and gravel. The lithology of the Tesuque at Otowi-1 was completely different than found at Otowi-4 or other wells located on the Pajarito Plateau. The Tesuque at Otowi-1 penetrated no basalts in the upper section of the hole as at Otowi-4 and encountered only one thin flow, probably a sill, at a depth of 2,219 to 2,231 ft. The geologic log of the well was prepared from inspection of the cuttings and geophysical logs of the hole (Table VIII). Geophysical logs of the well include temperature, microlog, dual induction, and compensated neutron-formation density.

VI. ANALYSIS OF THE OTOWI-1 STEP-DRAWDOWN PUMP TEST

A 14-hour step-drawdown pump test was conducted on July 19, 1990, in Otowi-1 immediately after the completion of well development procedures and recovery of the static water level. Water levels were recorded over time in the pumping well using an electrical pore pressure transducer with digital readout. This diaphragm-type transducer was factory calibrated approximately one week prior to its use; it has an accuracy and resolution of approximately 1.15 and 0.02 feet of water, respectively. Four different pumping rates were used during this test, with each step lasting between 100 and 340 minutes. Observed drawdowns from the test versus time in Otowi-1 are plotted in Fig. 8, while the recorded pumping rates versus time are shown in Fig. 9.

Table VIII. Geologic Log of Otowi-1 (elevation 6,396 ft)

	Thickness (ft)	Depth from Surface (ft)
Coalluvium		
Silty, clayey sand, tan, with a few cobbles and boulders; rock fragments of weathered tuff 50 to silty sand, few small rock fragments of tuff and pumice; appears to be section of Bandelier Tuff weathered in place.	80	80
Basaltic Rocks of Chino Mesa		
Basalt, dark gray, dense, some vesicules, some tan clay and occasional sand with quartz which probably represents occasional interflow breccia of gravels and clay.	200	280
Puye Conglomerate		
Fanglomerate Member		
Fanglomerate, dark gray, composed of latites, rhyolites, some quartz latite, dark gray basalt in a matrix of silt, sand, and gravels; some thin lenses of clay, siltstone, and pumice.	160	440
Basaltic Rocks of Chino Mesa		
Basalt, dark gray to black, contains vesicales; some clays and gravels as probable thin interflow breccias of gravels, sands, and clays.	30	470

Table VIII. (Cont.)

	Thickness (ft)	Depth from Surface (ft)
Puye Conglomerate		
Fanglomerate Member		
Fanglomerate, gray to dark gray, composed of rock fragments of latite, rhyolite, quartz latite, dark gray to black fragments of basalts, some milky quartz, brown-pink-gray quartzite; rock fragments angular to semi-round.	220	690
Puye Conglomerate		
Totavi Lentil		
Conglomerate, loosely consolidated, composted mostly of quartzite, in a variety of colors, clear-pink-orange-milky-yellow-gray-brown; pebbles, cobbles, and boulders subrounded to well rounded in a matrix of sand and gravels.	60	750
Tesuque Formation		
Siltstone with some sand and clay, minor amounts of gravel, tan.	20	770
Silty sandstone, some thin lenses of sandstone and pebbly conglomerate, mainly of quartz, quartzite, and feldspar, fine matrix of tan silt and clay; claystone and siltstone from 830 to 835 ft; 874 to 778 ft; 904 to 911 ft; 974 to 981 ft.	225	997
Claystone and siltstone, minor amounts of sand, tan.	21	1,018
Silty sandstone and sandstone with some clay, tan to brown, consisting of fine to medium sand-size grains of quartz and fragments of quartzite, some orthoclase feldspar; sand grains subrounded to rounded; claystone and siltstone, tan, from 1,014 to 1,021 ft; 1,030 to 1,039 ft; 1,132 to 1,136 ft.	214	1,232
Claystone and siltstone, tan to brown, minor amounts of sand size quartz.	47	1,279
Silty sandstone and sandstone with some clay, tan to brown, fine-to medium-size sand, quartz and feldspar, colors milky, orange, gray to black, subangular to subrounded; claystone from 1,310 to 1,314 ft.	66	1,345
Claystone and siltstone with an occasional thin lense of fine to medium grain-size sand, tan to brown, some white clay probably ash; silty sandstone, tan to gray, fine grained, quartz and quartzite, few small gray to dark gray rock fragments from 1,402 to 1,411 ft; 1,722 to 1,728 ft; 1,794 to 1,798 ft; 1,815 to 1,822 ft; 1,882 to 1,890 ft; 1,995 to 1,998 ft; and 2,143 to 2,155 ft.	874	2,219
Basalt, black, fine grained, crystalline, probably a thin sill.	12	2,231
Claystone and siltstone, tan to light brown, some thin lenses of white ash; silty sandstone, tan to light brown, 2,310 to 2,318 ft; 2,391 to 2,398 ft; 2,449 to 2,458 ft; 2,469 to 2,474 ft; and 2,505 to 2,518 ft.	378	2,609

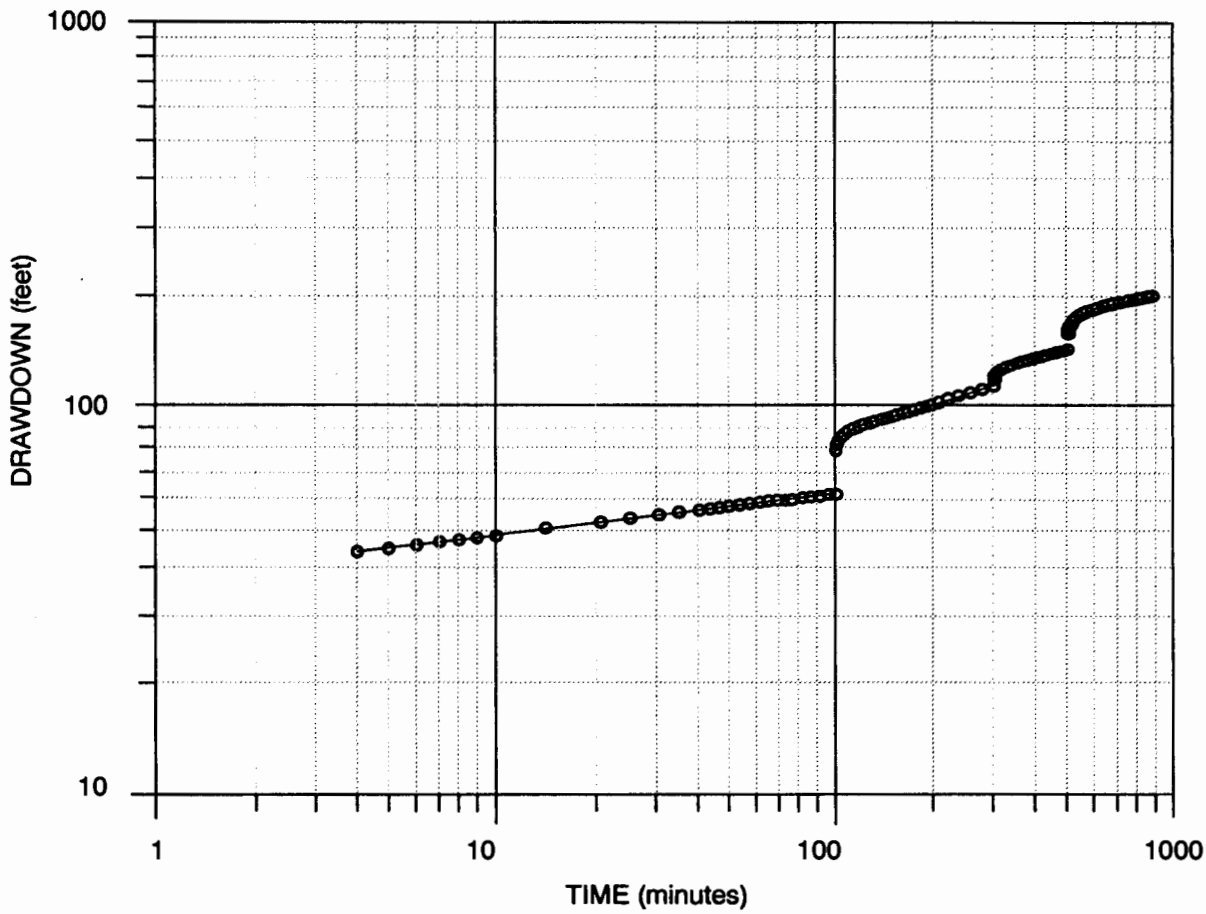

Fig. 8. Observed drawdown over time in Otowi-1 on July 19, 1990.

The step-drawdown test procedure described in Bear was used in this test.[25] Data analysis procedures are described in Bouwer.[26] Basically the step-drawdown test procedure is utilized to characterize well losses, and establish the success of well development activities. Future step-drawdown tests in Otowi-1 can be directly compared to those reported here (Table IX). Temporal changes in the well-loss coefficient, C, as defined below, would be an indication of changes in the well's gravel-pack over time. A large increase in the value of this coefficient over time is an indication of wellbore clogging in the production screen or gravel pack.[27] Hence, the current step-drawdown test may prove helpful in future Otowi-1 performance evaluations, in addition to evaluating the present condition of the gravel pack.

Pumping-induced drawdown inside a water well (s_{iw}) is the vertical distance between the static piezometric surface in the formation and the water level inside the well during production. This distance is effectively the sum of drawdown in the aquifer (s_a) and drawdown caused by friction losses in the gravel pack (s_{wl}). Water flow in the aquifer varies linearly with discharge (Q), and is described by various well flow equations (for example, the Theis equation for confined aquifers). Hence, when s_a varies linearly with Q, flow will be laminar. However, flow

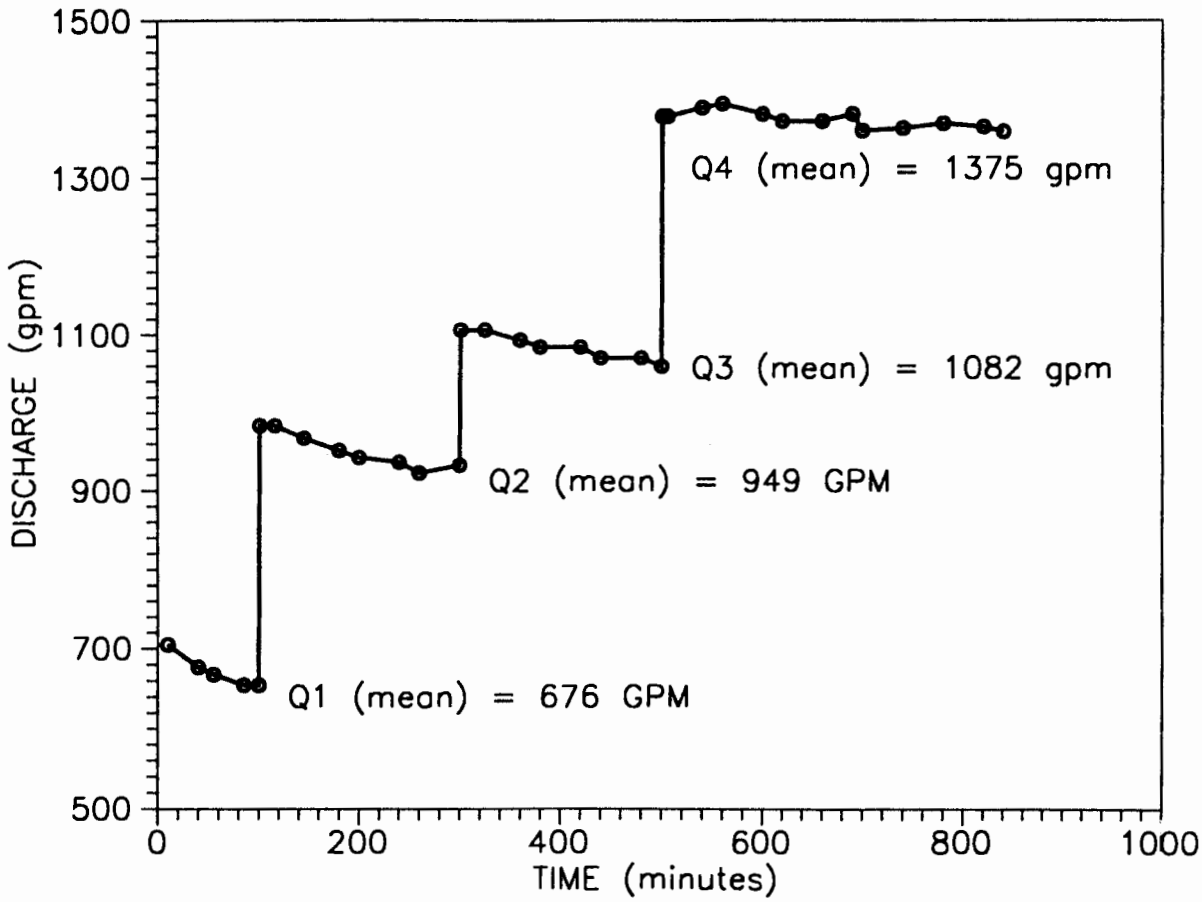

Fig. 9. Observed discharge over time in Otowi-1 on July 19, 1990.

through the gravel pack and well screen will usually be turbulent. In equation form these losses are expressed as

$$s_{iw} = BQ + CQ^n \tag{1}$$

where BQ represents drawdown in the well caused by the aquifer loss, while CQ^n represents drawdown in the well due to wellbore entrance losses. The parameters B, C, and n can be uniquely determined from a step-drawdown pump test for a particular well at a given time. [26] During the Otowi-1 test, the well was pumped at a nearly constant Q (i.e., between a 2.5% and a 7.1% variation in Q for any given step, as seen in Fig. 9) until s_{iw} changed relatively little. Then Q was increased to a higher value, and s_{iw} was again measured after the same time interval (in this test, $t^* = 100$ minutes). This procedure was repeated until incremental s_{iw} values resulting from the new Q at t^* were known for four different values of Q. These incremental s_{iw} values were then summed for use in the final analysis. These data are summarized in Table VII.

Table IX. Otowi-1 Step-Drawdown Pump Test Data

Pumping Step	Q (gpm)	Total s_{iw} at t^* (ft)	Specific Capacity (gpm/ft)	Summed s_{iw} at t^* (ft)
1.	676	63.34	10.7	63.34
2.	949	102.32	9.3	96.73
3.	1,082	134.10	8.1	113.29
4.	1,357	178.67	7.6	145.64

Since the pumping rate during the first two steps varied by more than 5%, the procedure of Hantush was utilized to analyze the step-drawdown test data.[28] Here n is 2.0 in Eq. (1), and we obtain

$$s_{iw}/Q = B + CQ \qquad (2)$$

Values of Q and summed s_{iw} from Table VII were then used in Eq. (2) in order to find B and C for $n = 2$, using a least squares linear regression technique. This analysis yields $B = 8.1564 \times 10^{-2}$ and $C = 2.0030 \times 10^{-5}$. Computed drawdowns at varying Q values are shown in Fig. 10, using these values for B, C, and n in Eq. (1). These parameters can also be used to determine well efficiency. Here well efficiency is defined by the expression

$$\text{Eff}\,(\%) = 100\, BQ/(BQ + CQ^{n}) \qquad (3)$$

where all terms have been previously defined. Equation (3) is a measure of the effectiveness of the well screen and gravel pack to transmit water from the aquifer to the well. Using the step-drawdown test values for B, C, and n, we see that at $Q \leq 1{,}000$ gpm, the Otowi-1 Well efficiency will exceed 80%.

An assumed value of $n = 2$ is more conservative than that obtained from the Bouwer procedure, and indicates that full wellbore turbulence will not completely develop over the entire well screen length during production.[26] These results also indicate that a good gravel pack condition exists in the Otowi-1 well. However at well discharges above about 1,500 gpm, excessive wellbore drawdown effects may potentially exceed 250 ft after extended pumping. A water production rate of 800 to 1,000 gpm is recommended for Otowi-1 because drawdown should remain below 150 ft. Furthermore, gravel pack losses are much less than formation losses at these lower production rates, and wellbore entrance velocities over the entire well screen length are laminar.

Figure 11 shows the observed values of specific capacity versus discharge. Specific capacity is defined as discharge divided by drawdown, and is an indication of well yield per foot of drawdown. At production rates above 1,000 gpm, specific capacity is projected to drop to relatively low values.

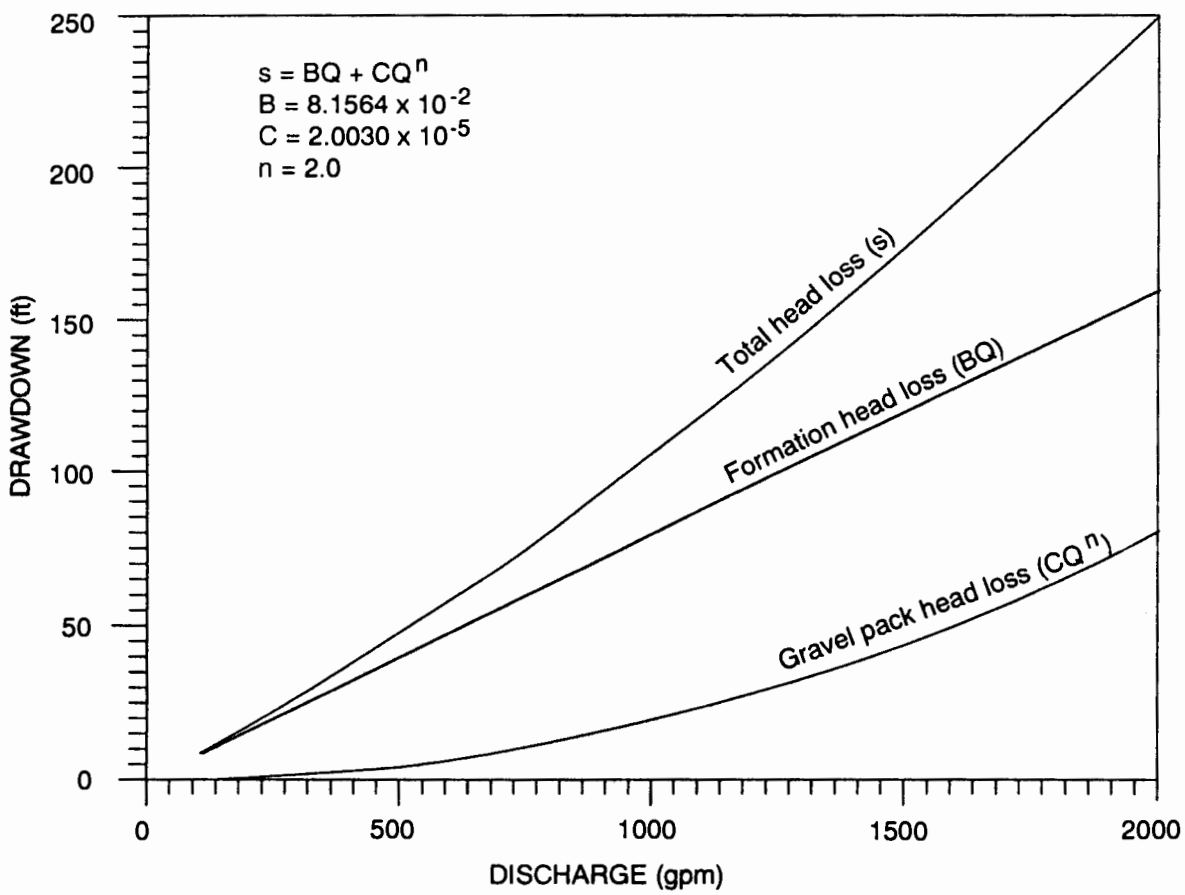

Fig. 10. Step-drawdown test results in Otowi-1 on July 19, 1990.

Using the step-drawdown test data, it was also possible to compute preliminary values for formation transmissivity (T) and storage coefficient (S) from the first pumping cycle. The time-drawdown data from this first pump cycle are shown in Fig. 12, along with a trace of the corresponding Boulton phreatic aquifer type curves.[29] Using the type curve matching procedure, a match point corresponding to the $r/D = 0.1$ curve is obtained; hence at $s = 8.8$ ft and $t = 0.27$ minutes (see Fig. 12), $W(u_y,r/D) = 1.0$ and $1/u_y = 10$. Thus at $Q = 676$ gpm and $r = 1$ ft, values for T and S are computed from

$$s = QW(u_y,r/D)/(4piT); \quad u_y = r^2S/4Tt. \tag{4}$$

Equation (4) yields $T = 8{,}803$ gpd/ft and $S = 0.088$. The type-curve matching procedure used here implies that the main aquifer is presumably phreatic, and the value for S represents a storage coefficient characteristic of specific yield. This perception is consistent with other

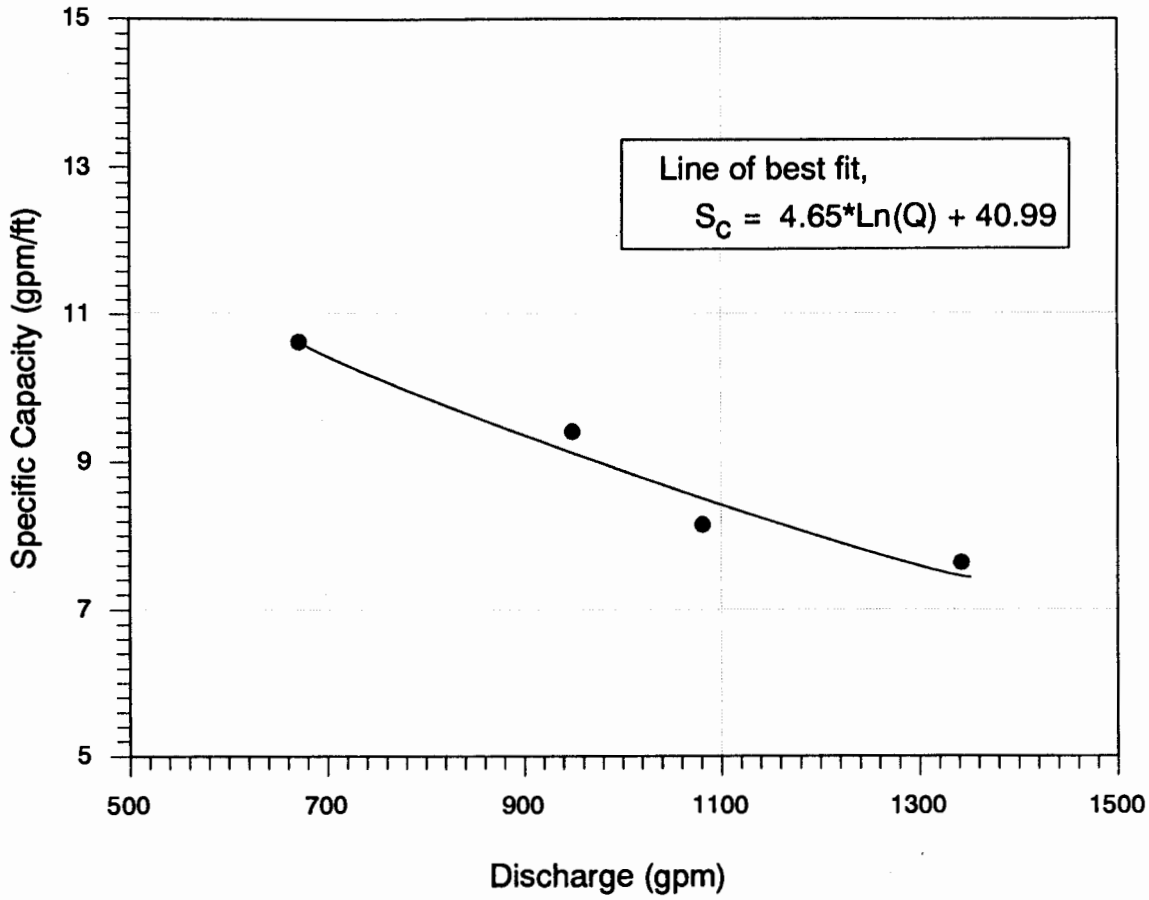

Fig 11. Discharge versus specific capacity (S_C) as recorded for Well Otowi-1 on July 19, 1990.

hydrogeological observations from adjacent production wells. However, the aquifer production zone is highly stratified; hence, it may only appear to be phreatic. This apparent phreatic aquifer behavior may have also resulted from wellbore storage effects that did not completely dissipate in 100 minutes, or from slightly variable discharge. It should be emphasized that these values for T and S represent preliminary estimates made from a very short pump test cycle. Furthermore, water level observations were recorded in the production well, and these are not as desirable as those from a separate fully penetrating observation well. More precise values for these parameters should be available when a longer term constant Q pump test is performed later.

Observation well TW-1, located approximately 500 ft east of Otowi-1, is completed to a depth of about 642 ft. Well TW-1 did not show any pumping induced drawdown effects during the Otowi-1 test. Furthermore, recovery data in the Otowi-1 well was not collected because the test pump did not have a nonreturn check valve. Hence, once the pump was turned off, a column of water approximately 700 ft long immediately flowed back into the well.

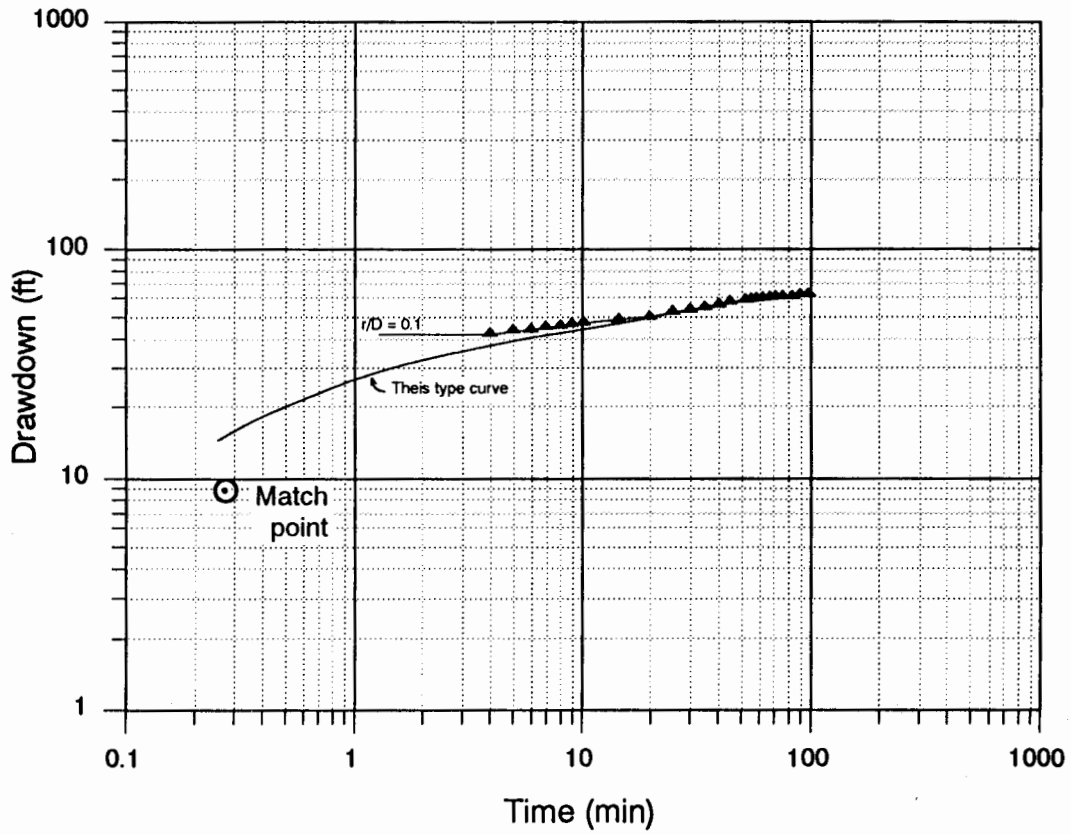

Fig. 12. Curve showing field drawdown versus time as recorded for Well Otowi-1 on July 19, 1990. Note that the indicated field curve match point at s = 8.8 ft and t = 0.27 min. corresponds with the type curve match point at W(u_y, r/D) = 1.0 and 1/u_y = 10, with r/D = 0.1.

VII. SUMMARY

Operations of wells and well fields in 1990 were satisfactory. Water level trends in the wells were as expected under the current amount of annual pumpage. Future operations of the wells and water supply system should be continued as in the past. Continued collection of data from wells and well fields is necessary to evaluate present and future wells and well field operations.

ACKNOWLEDGEMENTS

Statistics on well production were collected by personnel from Johnson Control World Services Inc. and were compiled for this report by the Laboratory's Environmental Protection Group.

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Appendix

Annual Statistics on Aquifer Characteristics

Well LA-1

Year	Pumping Time (h)	Production (10^6 gal.)	Pumping Rate (gpm)	Water Level (Nonpumping) (ft)
1947	3,468	54.0	259.5	—
1948	2,988	34.7	193.6	—
1949	1,361	26.7	327.0	—
1950	563	10.5	310.8	19.0
1951	1,215	14.6	200.3	59.0
1952	286	3.4	198.1	40.0
1953	0	0.0	0.0	36.0
1954	0	0.0	0.0	44.0
1955	690	9.7	234.3	51.0
1956	39	0.0	0.0	33.0
1957	0	0.0	0.0	33.0
1958	0	0.0	0.0	10.0
1959	0	0.0	0.0	13.0
1960	0	0.0	0.0	13.0
1961	0	0.0	0.0	59.0
1962	0	0.0	0.0	84.0
1963	0	0.0	0.0	90.0
1964	0	0.0	0.0	95.0
1965	0	0.0	0.0	76.0
1966	0	0.0	0.0	70.0
1967	0	0.0	0.0	52.0
1968	0	0.0	0.0	42.0
1969	0	0.0	0.0	38.0
1970	0	0.0	0.0	37.0
1971	0	0.0	0.0	51.0
1972	0	0.0	0.0	49.0
1973	0	0.0	0.0	55.0
1974	0	0.0	0.0	53.0
1975	0	0.0	0.0	58.0
1976	0	0.0	0.0	69.0
1977	0	0.0	0.0	74.0
1978	0	0.0	0.0	68.0
1979	0	0.0	0.0	38.0
1980	0	0.0	0.0	40.0
1981	0	0.0	0.0	51.0
1982	0	0.0	0.0	98.0
1983	0	0.0	0.0	46.0
1984	0	0.0	0.0	71.0
1985	0	0.0	0.0	63.0
1986	0	0.0	0.0	34.0
1987	0	0.0	0.0	70.0
1988	0	0.0	0.0	66.0
1989	0	0.0	0.0	77.0
1990	0	0.0	0.0	84.0

Appendix (Cont)

Well LA-1B

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)
1960	415	36.3	1,457.8	7.0	111.0	104.0	14.0
1961	3,727	124.7	557.6	54.0	154.0	100.0	5.6
1962	3,936	129.1	546.7	72.0	169.0	97.0	5.6
1963	3,649	117.4	536.2	74.0	170.0	96.0	5.6
1964	4,174	130.3	520.3	81.0	183.0	102.0	5.1
1965	3,007	97.9	542.6	63.0	170.0	107.0	5.1
1966	2,589	83.9	540.1	50.0	169.0	119.0	4.5
1967	2,519	84.9	561.7	39.0	153.0	114.0	4.9
1968	2,183	74.0	565.0	32.0	147.0	115.0	4.9
1969	2,244	75.7	562.2	22.0	142.0	120.0	4.7
1970	2,369	79.7	560.7	22.0	143.0	121.0	4.6
1971	2,633	89.1	564.0	31.0	162.0	131.0	4.3
1972	2,215	75.3	566.6	31.0	163.0	132.0	4.3
1973	2,628	87.2	553.0	37.0	170.0	133.0	4.2
1974	2,282	73.9	539.7	35.0	161.0	126.0	4.3
1975	2,308	74.4	537.3	42.0	168.0	126.0	4.3
1976	2,521	79.6	526.2	50.0	176.0	126.0	4.2
1977	2,782	84.2	504.4	47.0	167.0	120.0	4.2
1978	2,306	75.6	546.3	42.0	162.0	120.0	4.6
1979	1,354	45.9	564.6	13.0	134.0	121.0	4.7
1980	1,955	62.9	536.3	21.0	146.0	125.0	4.3
1981	2,299	73.9	537.7	26.0	144.0	118.0	4.5
1982	3,707	108.1	486.0	71.0	180.0	109.0	4.5
1983	407	12.1	495.0	61.0	160.0	99.0	5.0
1984	2,673	96.9	604.0	75.0	201.0	126.0	4.8
1985	1,919	68.5	595.0	55.0	179.0	124.0	4.8
1986	1,598	54.9	573.0	25.0	144.0	119.0	4.8
1987	2,753	97.3	589.0	66.0	187.0	121.0	4.9
1988	2,187	75.4	574.0	60.0	192.0	132.0	4.4
1989	2,864	97.8	569.0	73.0	197.0	124.0	4.6
1990	2,072	68.6	552.0	70.0	196.0	126.0	4.4

Appendix (Cont)

Well LA-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)
1947	963	27.6	477.7	—	—	—	—
1948	3,659	59.3	270.1	—	—	—	—
1949	1,654	41.8	421.2	—	—	—	—
1950	614	15.6	423.5	59.0	285.0	226.0	1.9
1951	2,415	57.7	398.2	111.0	305.0	194.0	2.1
1952	1,980	46.3	389.7	101.0	300.0	199.0	2.0
1953	2,201	47.2	357.4	100.0	301.0	201.0	1.8
1954	2,601	56.8	364.0	116.0	—	—	—
1955	2,223	49.4	370.4	110.0	—	—	—
1956	1,805	44.2	408.1	84.0	—	—	—
1957	1,066	29.6	462.8	53.0	277.0	224.0	2.1
1958	1,166	31.1	444.5	60.0	270.0	210.0	2.1
1959	1,599	40.7	424.2	71.0	303.0	232.0	1.8
1960	2,169	51.6	396.5	76.0	305.0	229.0	1.7
1961	2,149	44.4	344.3	101.0	313.0	212.0	1.6
1962	1,823	35.7	326.4	111.0	314.0	203.0	1.6
1963	1,999	40.7	339.3	127.0	332.0	205.0	1.7
1964	1,924	34.2	296.3	137.0	347.0	210.0	1.4
1965	1,911	39.8	347.1	121.0	330.0	209.0	1.7
1966	1,070	21.4	333.3	108.0	340.0	232.0	1.4
1967	238	4.9	343.1	78.0	304.0	226.0	1.5
1968	502	11.3	375.2	64.0	305.0	241.0	1.6
1969	155	3.8	408.6	50.0	297.0	247.0	1.7
1970	341	7.2	351.9	59.0	310.0	251.0	1.4
1971	1,787	31.8	296.6	88.0	318.0	230.0	1.3
1972	2,189	39.3	299.2	96.0	322.0	226.0	1.3
1973	2,625	46.7	296.5	106.0	334.0	228.0	1.3
1974	2,033	36.8	301.7	109.0	325.0	216.0	1.4
1975	2,310	40.2	290.0	103.0	320.0	217.0	1.3
1976	2,488	39.9	267.3	113.0	322.0	209.0	1.3
1977	2,775	42.5	255.3	118.0	314.0	196.0	1.3
1978	2,299	39.5	286.4	112.0	338.0	226.0	1.3
1979	1,353	26.2	323.0	75.0	316.0	241.0	1.3
1980	1,960	33.8	287.4	84.0	318.0	234.0	1.2
1981	1,991	34.4	300.0	94.0	336.0	242.0	1.2
1982	3,174	51.2	269.0	161.0	348.0	187.0	1.4
1983	2,752	54.5	330.0	121.0	321.0	200.0	1.6
1984	2,753	53.7	325.0	130.0	323.0	193.0	1.7
1985	2,027	37.1	305.0	112.0	291.0	179.0	1.7
1986	1,289	24.1	312.0	74.0	252.0	178.0	1.8
1987	2,619	39.6	252.0	129.0	319.0	190.0	1.3
1988	1,936	33.0	284.0	117.0	296.0	179.0	1.6
1989	2,647	43.2	272.0	141.0	329.0	188.0	1.4
1990	2,399	40.3	280.0	134.0	330.0	196.0	1.4

Appendix (Cont)

Well LA-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)
1947	1,476	64.9	732.8	—	—	—	—
1948	3,647	82.5	377.0	—	—	—	—
1949	1,505	41.7	461.8	—	—	—	—
1950	2,793	57.8	344.9	97.0	231.0	134.0	2.6
1951	3,554	66.9	313.7	116.0	233.0	117.0	2.7
1952	2,514	58.6	388.5	94.0	218.0	124.0	3.1
1953	3,104	69.7	374.2	103.0	229.0	126.0	3.0
1954	2,595	57.3	368.0	101.0	225.0	124.0	3.0
1955	2,195	48.7	369.8	91.0	226.0	135.0	2.7
1956	1,849	42.1	379.5	74.0	222.0	148.0	2.6
1957	1,080	26.1	402.8	56.0	219.0	163.0	2.5
1958	1,612	33.6	347.4	49.0	225.0	176.0	2.0
1959	1,821	35.0	320.3	54.0	231.0	177.0	1.8
1960	2,174	38.4	294.4	68.0	230.0	162.0	1.8
1961	1,939	34.7	298.3	85.0	189.0	104.0	2.9
1962	2,361	45.4	320.5	93.0	192.0	99.0	3.2
1963	2,128	42.5	332.9	81.0	197.0	116.0	2.9
1964	2,574	50.4	326.3	104.0	217.0	113.0	2.9
1965	1,961	43.3	368.9	79.0	220.0	141.0	2.6
1966	2,236	46.1	343.6	81.0	219.0	138.0	2.5
1967	2,274	47.4	347.4	86.0	218.0	132.0	2.6
1968	2,127	42.7	334.6	82.0	251.0	169.0	2.0
1969	2,072	40.1	322.6	58.0	246.0	188.0	1.7
1970	2,303	44.0	318.4	55.0	241.0	186.0	1.7
1971	2,556	45.4	296.0	77.0	250.0	173.0	1.7
1972	2,205	39.7	300.1	73.0	251.0	178.0	1.7
1973	977	20.3	346.3	65.0	248.0	183.0	1.9
1974	2,291	43.5	316.5	73.0	244.0	171.0	1.9
1975	2,306	43.3	313.0	80.0	253.0	173.0	1.8
1976	2,474	42.3	285.0	88.0	260.0	172.0	1.7
1977	2,779	47.3	283.7	89.0	248.0	159.0	1.8
1978	2,308	42.4	306.4	87.0	250.0	163.0	1.9
1979	1,343	28.1	348.1	58.0	243.0	185.0	1.9
1980	1,952	35.1	299.9	61.0	237.0	176.0	1.7
1981	2,297	41.5	301.1	70.0	240.0	170.0	1.8
1982	3,691	54.9	247.0	118.0	246.0	128.0	1.9
1983	949	14.7	258.0	89.0	203.0	129.0	2.0
1984	838	16.6	329.0	142.0	301.0	159.0	2.0
1985	2,078	41.9	336.0	104.0	280.0	176.0	1.9
1986	1,328	26.9	338.0	88.0	255.0	167.0	2.0
1987	2,710	50.9	313.0	118.0	289.0	171.0	1.8
1988	2,130	40.1	313.0	119.0	272.0	153.0	2.0
1989	2,808	51.9	308.0	122.0	298.0	176.0	1.8
1990	2,461	44.6	302.0	122.0	295.0	173.0	1.8

Appendix (Cont)

Well LA-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)
1948	1,570	42.7	453.3	—	—	—	—
1949	940	37.5	664.9	—	—	—	—
1950	4,350	164.9	631.8	278.0	353.0	75.0	8.4
1951	4,909	173.6	589.4	285.0	357.0	72.0	8.2
1952	3,429	119.6	581.3	267.0	339.0	72.0	8.1
1953	3,034	109.1	599.3	264.0	335.0	71.0	8.4
1954	2,133	78.2	611.0	255.0	329.0	74.0	8.3
1955	2,647	94.5	595.0	268.0	341.0	73.0	8.2
1956	3,402	120.0	588.9	273.0	346.0	73.0	8.1
1957	2,844	105.4	617.7	270.0	345.0	75.0	8.2
1958	2,973	110.3	618.3	270.0	342.0	72.0	8.6
1959	3,084	113.5	613.4	275.0	346.0	71.0	8.6
1960	4,084	145.6	594.2	296.0	365.0	69.0	8.6
1961	3,687	129.7	586.3	296.0	365.0	69.0	8.5
1962	3,688	129.3	584.3	286.0	359.0	73.0	8.0
1963	3,718	130.5	585.0	280.0	351.0	71.0	8.2
1964	4,500	155.0	574.1	291.0	361.0	70.0	8.2
1965	3,110	111.4	597.0	279.0	349.0	70.0	8.5
1966	3,279	115.6	587.6	285.0	356.0	71.0	8.3
1967	2,127	77.1	604.1	278.0	350.0	72.0	8.4
1968	2,276	81.7	598.3	280.0	351.0	71.0	8.4
1969	1,694	61.8	608.0	282.0	358.0	76.0	8.0
1970	2,333	83.5	596.5	286.0	363.0	77.0	7.7
1971	2,519	89.0	588.9	287.0	373.0	86.0	6.8
1972	2,322	82.6	592.9	282.0	367.0	85.0	7.0
1973	2,616	92.4	588.7	294.0	377.0	83.0	7.1
1974	2,306	82.2	594.1	286.0	367.0	81.0	7.3
1975	2,319	82.3	591.5	272.0	355.0	83.0	7.1
1976	2,802	98.2	584.1	277.0	373.0	96.0	6.1
1977	2,741	96.4	586.2	278.0	374.0	96.0	6.1
1978	2,248	80.1	594.2	271.0	368.0	97.0	6.1
1979	2,964	104.6	587.9	280.0	376.0	96.0	6.1
1980	3,322	115.3	578.5	284.0	385.0	101.0	5.7
1981	2,573	89.4	579.1	289.0	393.0	104.0	5.6
1982	0	0	0	—	—	—	—
1983	1,840	61.5	577.0	287.0	392.0	105.0	5.3
1984	2,695	87.1	539.0	290.0	383.0	93.0	5.8
1985	2,667	86.4	540.0	292.0	378.0	86.0	6.3
1986	1,172	38.8	552.0	284.0	377.0	93.0	5.9
1987	38	1.6	—	269.0	357.0	88.0	—
1988	0	0.0	—	—	—	—	—
1989	0	0.0	—	—	—	—	—
1990	0	0.0	—	—	—	—	—

Appendix (Cont)

Well LA-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)
1948	1,171	40.4	575.0	—	—	—	—
1949	1,763	58.5	553.0	—	—	—	—
1950	4,052	130.1	535.1	131.0	254.0	123.0	4.4
1951	6 004	187.4	520.2	162.0	272.0	110.0	4.7
1952	3,425	109.6	533.3	147.0	259.0	112.0	4.8
1953	3,278	103.9	528.3	141.0	257.0	116.0	4.6
1954	2,546	80.1	524.4	137.0	259.0	122.0	4.3
1955	3,158	97.3	513.5	145.0	267.0	122.0	4.2
1956	3,476	104.5	501.1	150.0	276.0	126.0	4.0
1957	2,868	86.0	499.8	150.0	277.0	127.0	3.9
1958	3,009	89.9	498.0	151.0	277.0	126.0	4.0
1959	3,088	93.5	504.6	155.0	280.0	125.0	4.0
1960	4,088	119.1	485.6	168.0	288.0	120.0	4.0
1961	3,534	100.3	473.0	165.0	288.0	123.0	3.8
1962	3,735	107.7	480.6	172.0	—	—	—
1963	3,726	105.0	469.7	171.0	—	—	—
1964	4,236	118.8	467.4	184.0	—	—	—
1965	1,740	50.5	483.7	180.0	—	—	—
1966	2,817	79.3	469.2	180.0	—	—	—
1967	2,533	73.7	484.9	168.0	—	—	—
1968	2,233	63.3	472.5	161.0	300.0	139.0	3.4
1969	2,402	68.5	475.3	161.0	298.0	137.0	3.5
1970	2,353	66.1	468.2	157.0	300.0	143.0	3.3
1971	2,659	74.4	466.3	155.0	302.0	147.0	3.2
1972	2,301	64.4	466.5	153.0	304.0	151.0	3.1
1973	2,476	68.3	459.7	156.0	308.0	152.0	3.0
1974	1,903	52.5	459.8	154.0	306.0	152.0	3.0
1975	2,318	63.9	459.4	149.0	309.0	160.0	2.9
1976	2,799	77.6	462.1	150.0	310.0	160.0	2.9
1977	2,665	74.8	467.8	147.0	303.0	156.0	3.0
1978	2,274	64.9	475.8	145.0	299.0	154.0	3.1
1979	2,964	84.0	472.4	149.0	301.0	152.0	3.1
1980	3,316	92.2	463.6	153.0	300.0	147.0	3.2
1981	3,523	96.5	456.5	158.0	304.0	146.0	3.1
1982	3,654	102.3	467.0	168.0	299.0	136.0	3.4
1983	2,842	78.1	458.0	154.0	295.0	141.0	3.2
1984	2,889	72.1	416.0	156.0	281.0	125.0	3.1
1985	2,153	55.8	432.0	174.0	308.0	134.0	3.2
1986	1,376	34.6	419.0	168.0	310.0	142.0	2.9
1987	1,148	27.9	405.0	167.0	314.0	147.0	2.8
1988	351	9.9	406.0	—	—	—	—
1989	1,074	26.5	411.0	—	—	—	—
1990	1,388	33.3	400.0	—	—	—	—

Appendix (Cont)

Well LA-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)
1948	116	4.9	704.0	—	—	—	—
1949	2,451	95.8	651.4	—	—	—	—
1950	4,490	167.9	623.2	83.0	136.0	53.0	11.8
1951	5 882	201.6	571.2	115.0	160.0	45.0	12.7
1952	3,168	110.3	580.3	108.0	151.0	43.0	13.5
1953	3,177	113.8	597.0	95.0	139.0	44.0	13.6
1954	2,894	107.1	616.8	92.0	135.0	43.0	14.3
1955	2,911	108.0	618.3	97.0	140.0	43.0	14.4
1956	3,438	125.8	609.9	106.0	149.0	43.0	14.2
1957	2,833	102.4	602.4	107.0	152.0	45.0	13.4
1958	2,957	106.9	602.5	108.0	131.0	43.0	14.0
1959	3,096	108.3	583.0	115.0	158.0	43.0	13.6
1960	4,084	138.6	565.6	130.0	172.0	42.0	13.5
1961	3,284	112.5	571.0	129.0	171.0	42.0	13.6
1962	3,886	129.4	555.0	135.0	175.0	40.0	13.9
1963	2,953	102.9	580.8	125.0	171.0	46.0	12.6
1964	4,244	138.3	543.1	132.0	172.0	40.0	13.6
1965	3,145	103.8	550.1	120.0	160.0	40.0	13.8
1966	3,173	104.0	546.3	129.0	169.0	40.0	13.7
1967	2,511	85.4	566.8	118.0	158.0	40.0	14.2
1968	2,111	71.6	565.3	109.0	150.0	41.0	13.8
1969	2,402	81.6	566.2	109.0	151.0	42.0	13.5
1970	2,337	79.1	564.1	106.0	149.0	43.0	13.1
1971	2,472	82.5	556.2	119.0	160.0	41.0	13.6
1972	2,317	79.2	569.7	117.0	155.0	38.0	15.0
1973	2,638	90.6	572.4	118.4	155.0	37.0	15.5
1974	2,337	79.8	569.1	120.0	156.0	36.0	15.8
1975	1,571	51.9	550.6	113.0	151.0	38.0	14.5
1976	175	5.1	485.7	96.0	—	—	—
1977	—	—	—	82.0	—	—	—
1978	33	1.1	572.7	77.0	142.0	65.0	8.8
1979	6	0.2	555.6	80.0	146.0	66.0	8.4
1980	4	0.1	520.8	82.0	142.0	60.0	8.7
1981	2.3	0.08	579.8	84.0	141.0	57.0	10.2
1982	—	—	—	90.0	—	—	—
1983	—	—	—	81.0	—	—	—
1984	—	—	—	83.0	—	—	—
1985	—	—	—	92.0	—	—	—
1986	—	—	—	—	—	—	—
1987	—	<0.1	—	—	—	—	—
1988	—	<0.1	—	—	—	—	—
1989	—	<0.1	—	—	—	—	—
1990	—	—	—	—	—	—	—

Appendix (Cont)

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

Appendix (Cont)

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

Appendix (Cont)

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

Appendix (Cont)

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	—	—	—	—	—	—	—

Appendix (Cont)

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

Appendix (Cont)

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

Appendix (Cont)

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

Appendix (Cont)

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

Appendix (Cont)

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

Appendix (Cont)

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

Appendix (Cont)

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

Appendix (Cont)

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	—	—	—	—
1988	1,754	128.6	1,221	—	—	—	—
1989	1,184	86.2	1,213	—	—	—	—
1990		121.0	1,252	—	—	—	—

Appendix (Cont)

Water Canyon Gallery

Year	Time (h)	Production (10^6 gal.)	Discharge Rate (gpm)
1947	8,760	84.0	159.8
1948	8,784	97.0	184.0
1949	8,760	92.0	175.0
1950	8,760	54.0	102.7
1951	8,760	39.0	74.2
1952	8,784	48.0	91.1
1953	8,760	39.0	74.2
1954	8,760	40.0	76.1
1955	8,760	33.0	62.8
1956	8,784	23.0	43.6
1957	8,760	40.0	76.1
1958	8,760	60.0	114.2
1959	8,760	54.0	102.7
1960	8,784	48.0	91.1
1961	8,760	54.0	102.7
1962	8,760	67.0	127.5
1963	8,760	51.0	97.0
1964	8,784	45.0	85.4
1965	8,760	72.0	137.0
1966	8,760	82.0	156.0
1967	8,760	56.0	106.5
1968	8,784	65.0	123.3
1969	8,760	80.0	152.2
1970	8,760	65.0	123.7
1971	8,760	37.0	70.4
1972	8,784	40.0	75.9
1973	8,760	49.0	93.2
1974	8,760	35.0	66.6
1975	8,760	42.0	79.9
1976	8,784	41.0	77.8
1977	8,760	57.0	108.4
1978	8,760	45.0	86.2
1979	8,760	44.0	83.7
1980	8,784	32.0	60.7
1981	8,760	45.5	86.6
1982	8,760	45.9	94.9
1983	8,760	38.2	72.7
1984	8,784	34.0	65.4
1985	8,760	36.6	69.6
1986	8,760	28.2	53.6
1987	8,760	34.2	65.1
1988	8,784	34.5	65.5
1989	8,760	23.0	43.8
1990	8,760	9.3	—[a]

[a]Industrial use the rest bypassed.

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