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DOES LOCALIZED RECHARGE OCCUR AT A DISCHARGE AREA WITHIN THE GROUND-WATER FLOW SYSTEM OF YUCCA MOUNTAIN, NEVADA?

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ABSTRACT

Studies done in 1984, at a central site on Franklin Lake playa (also known as Alkali Flat, a major discharge area of the ground-water flow system that includes Yucca Mountain, Nevada, the potential site of a high-level nuclear-waste repository) yielded limited hydraulic-head and hydrochemical data from a 3-piezometer nest which indicated a slightly downward hydraulic gradient (-0.02) and decreasing concentrations of dissolved solids with increasing depth. Hydraulic-head measurements in June, 1989 made at the piezometer nest showed a substantially larger downward gradient (-0.10) and a 0.83-meter higher water level in the shallowest piezometer (3.29 meters deep), indicating the possibility of localized recharge. During the period of September-November, 1989, a multilevel sampler was used to obtain detailed hydrochemical profiles of the uppermost 1.5 m of the saturated zone. The sampler was installed in a fully screened, 7.8 centimeter-diameter, borehole that was drilled 4 meters into the saturated zone, and was used to examine the extent of hydrochemical stratification at the water table. Hydrochemical profiles were obtained for sodium, chloride, sulfate, and ¹⁸O using sampling intervals as small as 3 centimeters for periods of 8 and 30 days. Results implied the presence of a relatively fresher-water lens in the top 10 centimeters of the water table which may have been related to a localized recharge event. Salinity at the water table region increased after 30 days due to replacement of the fresh water lens by a more saline one and/or by concentration of the salt content through evaporation.

INTRODUCTION

Franklin Lake playa (Fig. 1) is a major discharge area of the ground-water flow system that includes Yucca Mountain, Nevada, the potential site of a repository for high-level nuclear waste (1,2,3). Ground-water discharges at Franklin Lake playa primarily as bare-soil evaporation of capillary water derived from the shallow saturated zone. The annual-average discharge rate is about 1.6 mm/d (3). As a result of this evaporation, salts concentrate in the ground water and form a salt crust on the surface. Hydrochemical sampling of water at a piezometer nest (wells GS-15, -16, and -17, Fig. 2) in October, 1984 indicated decreasing salinity with increasing depth. Paradoxically, the vertical hydraulic gradient derived from data at this piezometer nest was at or slightly less than 0.0 from 1983 to 1985 (4, Fig. 5f). A gradient of less than zero would imply recharge. This condition was in contradiction to results from all other piezometer nests on the playa which showed large vertically upward gradients. A possible cause for the inferred recharge may be intermittent stream flow in a shallow channel about 25 m west of the piezometer nest. Infrequent localized rain storms can produce surface water runoff to occur in otherwise dry braided-stream-channel surfaces.

In an effort to resolve this apparent contradiction, a well (FL) was constructed at the Central site (Fig. 2) about 15 m south of well GS-17 to facilitate the use of a multilevel sampler (5). The sampler had been tested and used in numerous field applications (6,7,8) to obtain detailed hydrochemical profiles of ground water.

Well FL was completed and developed by USGS personnel on July 24, 1989. The well was constructed by drilling a

7.6-cm diameter hole to a depth of about 6.1 m using a portable auger rig. Flush-joint, PVC screen (2.2 m length, 8.26 cm diameter) was driven by hand into the drill hole such that the lower end of the screen was 1.5 m below the water table. This screen was connected to a 1.5-m length of PVC which extended above land surface. Depth to water in well FL was 1.7 m. A plastic nose cone was used on the end of the screen to facilitate installation and to prevent sediment from entering the end of the screen. The sediments encountered during drilling consisted mostly of clay and silt sized sediments with occasional quartz and dolomite clasts up to 1-2 cm in length. Sediment color graded from reddish-brown silty clay in the first meter of the drillhole to grayish-green clay that had to be peeled off the auger flights during hole construction. No evidence of precipitation or surface water flow (for example, puddles or wet mudcracks) was observed at Franklin Lake playa between the time well FL was constructed and the time of deployment of the multilevel sampler.

In this paper, we present hydrochemical data obtained from the deployment of the multilevel sampler in well FL for periods of 8 and 30 days, and compare them to previous hydrochemical data obtained from a nearby three-piezometer nest. Also presented are hydraulic-head data from the piezometer nest, and preliminary interpretations of these data.

MULTILEVEL SAMPLER

The multilevel sampler used in well FL was based on the design of Ronen and others (5) and consisted of two 5-cm-diameter PVC-plastic rods, each 135 cm long, with sequential perpendicular holes drilled 3-cm apart to hold dialysis cells. The cells were separated by flexible rubber seals that fit

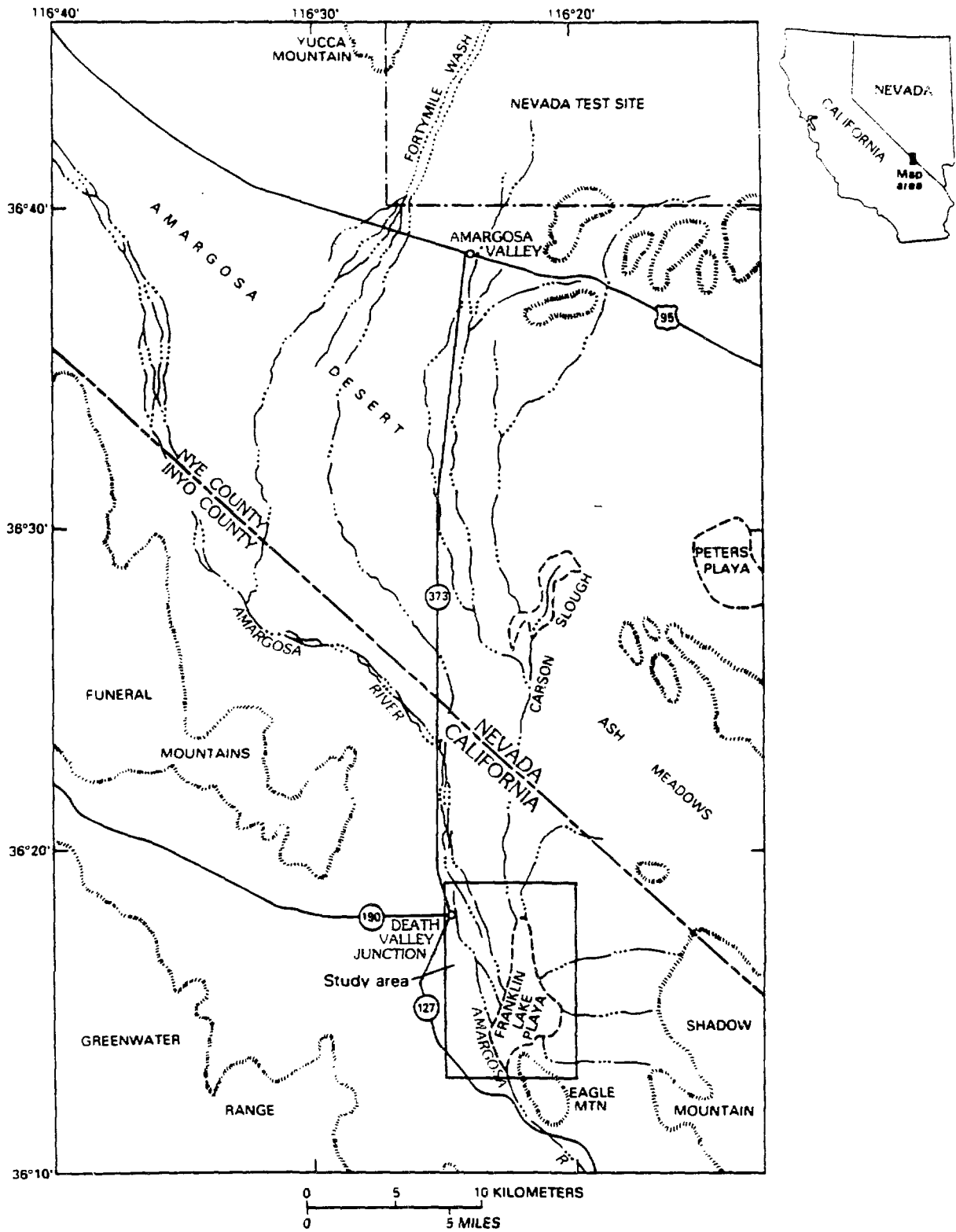


Fig. 1. Location of the study area.

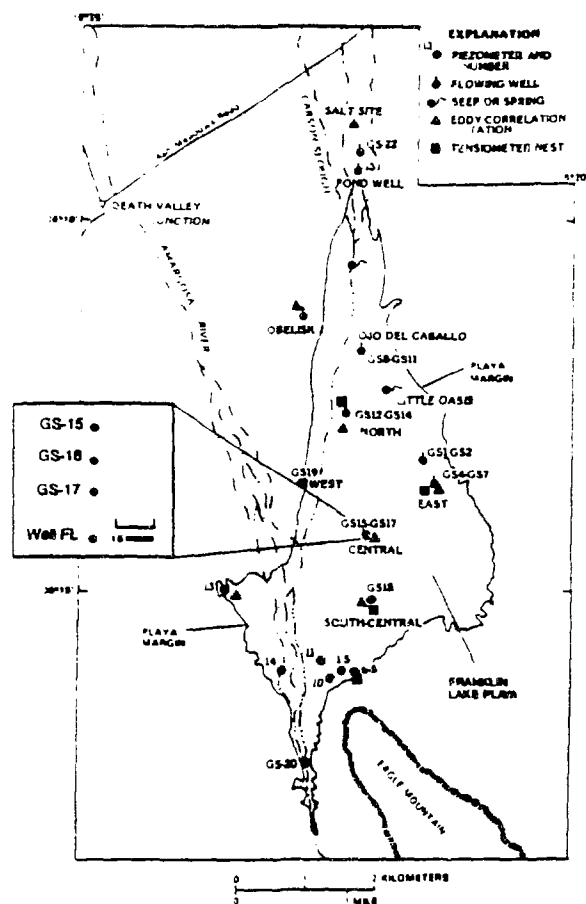


Fig. 2. Location of wells and study sites on Franklin Lake playa.

loosely in the inner diameter of the well screen to restrict vertical flow. The cells were filled with distilled water prior to deployment of the sampler. The sampler was lowered into the well by hand on September 26, 1989 and kept in place for 8 days, during which it was expected that the water in the cells would equilibrate with the ambient ground water. After retrieving the multilevel sampler, the cells were removed and their contents transferred at the field site to new glass bottles for subsequent laboratory analysis. Dialysis membranes with a pore size of 0.2 microns were used on the ends of each sample cell. Laboratory equilibration tests (5,7) which included waters of higher salinities than from Franklin Lake playa showed that for these dialysis membranes equilibration was obtained for Cl^- , SO_4^{2-} , NO_3^- , and $\delta^{18}\text{O}$ in 48 hours.

The resulting chemical profiles are referred to later in this report as MLS1. Because of the prototype nature of the deployment of the multilevel sampler, data obtained from its use will not be used for site characterization. Field analyses of pH, specific conductance, alkalinity and dissolved oxygen (DO) content for MLS1 showed minor variations with depth. A second set of profiles, MLS2, was obtained after installing the sampler again on October 4, 1989 and retrieving it after 30 days on November 3, 1989. Sealed 20-ml containers with the water samples were shipped to the laboratory for analysis of major ions and $\delta^{18}\text{O}$.

HYDROCHEMICAL ANALYSES

Chemical analyses are presented for Na^+ , Cl^- , SO_4^{2-} , and $\delta^{18}\text{O}$ in Figs. 3A-D and Tables I and II. Concentrations of each of these constituents for wells GS-15, GS-16, and GS-17 are plotted with data from MLS1. Ionic concentrations were analyzed by staff at the Weizmann Institute of Science with a Wescan 261 ion chromatograph with a precision of 4 percent. In general, all ions imply a lens of fresher water at the top of the profile in MLS1. Concentrations of Na^+ from MLS1 compare well with those obtained from well GS-16, 5 years prior; Cl^- and SO_4^{2-} are substantially lower in the MLS1 profile than for well GS-16, implying that fresher surface water may have infiltrated to the water table. Why the concentration of Na^+ from MLS1 was not substantially lower also is not known, but might be related to local variations in soil-salt content and the 5-year hiatus between sampling. Comparing MLS1 and MLS2, Cl^- and SO_4^{2-} concentrations (Figs. 3B-C) were higher in the second profile by 50 and 25 meq/L, respectively, indicating possible diffusion of the more saline-water ions into the fresher water lens combined with downward movement of the fresher water lens into the saline water.

Values of $\delta^{18}\text{O}$ in MLS1 (Fig. 3D) vary from -1.6 to -0.3 per mil to a depth of 12 cm below the water table. The range in values is less in the lower part of the profile. Values in the lower part of the MLS1 profile are similar to the value obtained from well GS-16 which is isotopically heavier than water in the top 12 cm, or from GS-15 and GS-17, probably as a result of evaporation.

After retrieving MLS1, a ground-water sample was obtained by using a bailer which was lowered to a depth of about 75 cm below the water table. The chemistry of the bailed water (denoted by an open triangle in Figs. 3A-D) is similar to the average water concentration of the sampled water column (Table I) and was between the minimum and maximum concentrations for each of the constituents obtained from MLS1. If the deployment time of the sampler had been too short for full ionic and isotopic equilibration, the maximum concentration for each constituent measured in MLS1 would have been equal to or less than that obtained from the bailed sample. If the fresher-water samples in the upper part of MLS1 resulted from periodic submergence of the dialysis cells resulting from barometric fluctuations in the water table, then the bailed-sample-constituent concentrations should have been higher (that is, similar to the values obtained from samples collected in the lower half of MLS1).

HYDROLOGIC EVIDENCE OF LOCALIZED RECHARGE

Water-level-altitude data from wells GS-15, -16, and -17 are plotted against time in Fig. 4. Water-levels rose nearly uniformly for all three wells for the period from the beginning of 1985 to the middle of 1986. No measurements were made again until June 9, 1989, at which time water levels had changed substantially. The water level in the shallowest well (GS-16, 3.29-m deep) rose at least 0.83 m from 9/3/84, the last measurement prior to hydrochemical sampling. The water level in the deepest well (GS-17, 10.67 m deep) declined at least 0.26 m from the previously measured value. The vertical hydraulic gradient calculated by obtaining the slope of the line of best fit through the water-level altitudes of the three wells plotted against well depth gave a downward gradient of -0.10

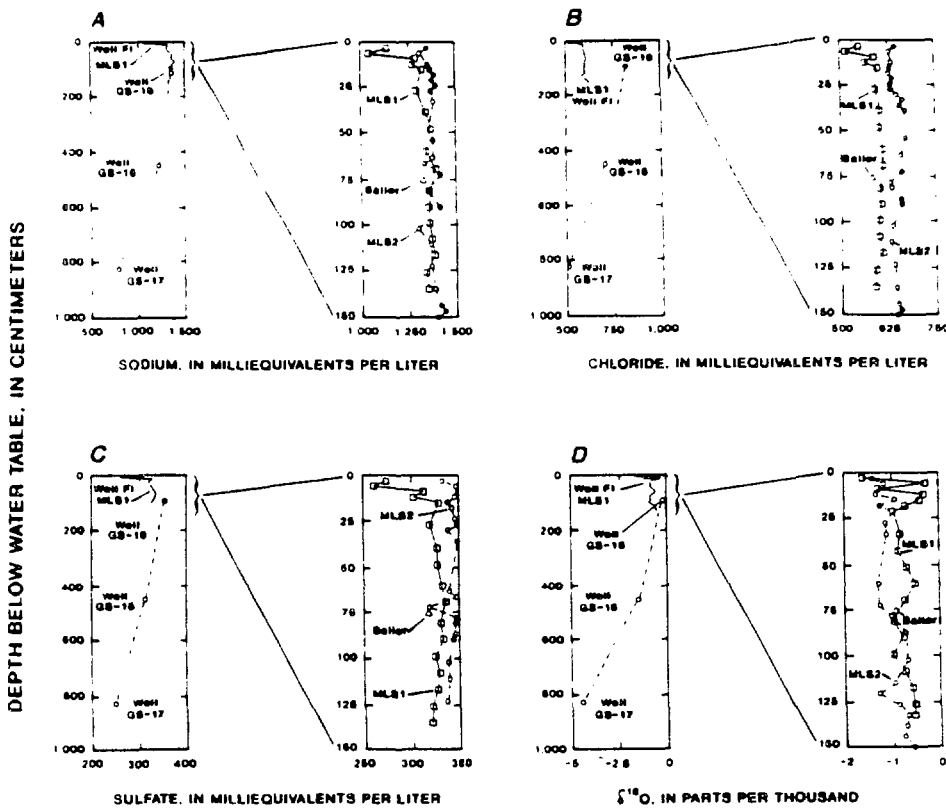


Fig. 3. Vertical hydrochemical profiles of (A) sodium; (B) chloride; (C) sulfate; and (D) oxygen-18.

for the 6/9/89 data, compared to a substantially smaller gradient of -0.02 on 9/3/84. If the hydraulic gradient were calculated using only piezometers GS-15 and GS-16, then the gradient is consistently positive (implying discharge) until 6/9/89.

Corrections of the saline water heads to fresh water heads for the 9/3/84 head data resulted in the same head relation among the three wells as shown in Fig. 4. Lack of chemical analyses for other than the October, 1984 precluded correction of the other hydraulic head measurements.

The larger downward gradient and the substantially higher water level in well GS-16 imply that recharge may have occurred, probably as a result of surface water infiltration from a shallow stream channel located about 25 m west of well GS-15. Generally, data from all other piezometer nests at Franklin Lake playa had indicated an upward hydraulic gradient (4).

Hydraulic testing of well GS-17 (3, p. 23) resulted in a relatively small value of hydraulic conductivity ($< 2.5 \times 10^{-4}$ m/d) compared to those obtained from other sites on the playa. No tests were done in wells GS-15 or GS-16, but based on the similarity of cuttings observed during construction of all the observation wells, the hydraulic conductivity associated with these wells should be comparable. This is indicated by the hydrograph of the three wells (GS-15, GS-16, and GS-17, Fig. 4) in which the water levels move in parallel from 1984 through 1987.

SUMMARY AND CONCLUSIONS

Hydrochemical and hydrologic data at a central site at Franklin Lake playa implied the possible occurrence of localized recharge to the shallow water table. Using a multilevel

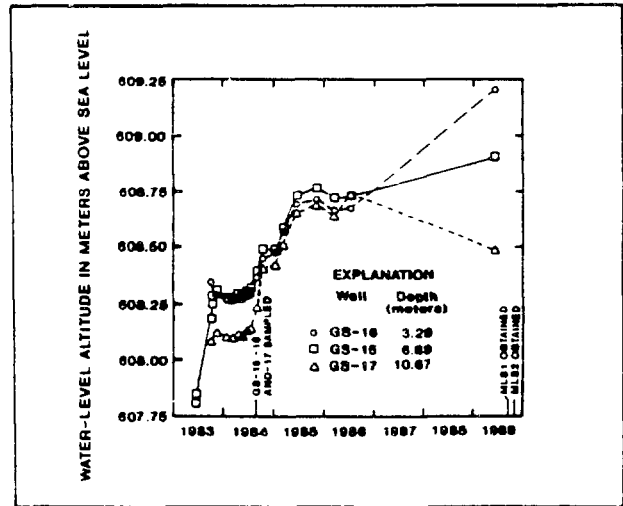


Fig. 4. Hydraulic-head data for wells GS-15, -16, and -17 from 1983 through 1989.

sampler to obtain hydrochemical samples at a 3-centimeter interval, a fresher-water layer or lens was observed in the top 10 cm of the saturated zone based on profiles of sodium, chloride, and sulfate ions. Sodium concentrations from the lower part of the multilevel-sampler profile were similar with values obtained at a comparable depth within the saturated zone from piezometer GS-16 obtained 5 years previously; sulfate, chloride, and $\delta^{18}O$ concentrations from MLS1 samples were less than those from the GS-16 samples, implying

TABLE I

Hydrochemical Data After 8-day Deployment of Multilevel Sampler in Well FL (MLS1) and from Analyses of Samples Obtained from Wells GS-16, GS-15, and GS-17

Well Name	Depth* (cm)	Na ⁺ (meq/L)	Cl ⁻ (meq/L)	SO ₄ ⁻ (meq/L)	δ18 _o (o/oo)
FL	3	1142	550	274	-1.61
FL	6	1048	516	261	-0.29
FL	9	1290	590	313	-1.29
FL	12	1275	568	303	-0.32
FL	15	1322	599	329	-0.41
FL	18	--	--	--	-0.71
FL	21	--	--	--	-0.97
FL	24	--	--	--	--
FL	27	1290	593	343	--
FL	30	--	--	--	--
FL	33	--	--	--	-0.83
FL	36	--	--	--	--
FL	39	1341	603	327	--
FL	42	--	--	--	-0.87
FL	45	--	--	--	--
FL	48	1365	600	327	--
FL	51	--	--	--	-0.69
FL	54	--	--	--	--
FL	57	--	--	--	--
FL	60	1341	610	332	-0.52
FL	63	--	--	--	--
FL	66	--	--	--	--
FL	69	1394	610	336	-0.74
FL	72	--	--	--	--
FL	75	--	--	--	--
FL	78	--	--	--	--
FL	81	1360	601	331	-0.97
FL	84	--	--	--	--
FL	87	--	--	--	--
FL	90	1355	606	333	-0.76
FL	93	--	--	--	--
FL	96	--	--	--	--
FL	99	1355	599	325	-0.98
FL	102	--	--	--	--
FL	105	--	--	--	--
FL	108	1371	596	329	-0.73
FL	111	--	--	--	--
FL	114	--	--	--	--
FL	117	1384	606	327	-0.58
FL	120	--	--	--	--
FL	123	--	--	--	--
FL	126	1337	589	321	-0.54
FL	129	--	--	--	--
FL	132	--	--	--	-0.55
FL	135	1350	587	320	--
MLS1av	--	1313	590	320	-0.75
FLb	75	1324	584	318	-0.92
GS-16	94	1347	819	354	-0.2
GS-15	449	1217	706	312	-1.5
GS-17	825	782	508	250	-4.4

*Depth is depth below water table; meq/L, milliequivalents per liter; o/oo, parts per thousand; --, no analysis performed; MLS1av, arithmetic average of MLS1 values; FLb, bailed sampled from well FL.

TABLE II

Hydrochemical Data After 30-day Deployment of Multilevel Sampler in Well FL (MLS2)

Depth* (cm)	Na ⁺ (meq/L)	Cl ⁻ (meq/L)	SO ₄ ⁻ (meq/L)	δ18 _o (o/oo)
3	1352	645	333	-1.40
6	1316	630	348	-1.14
9	1334	624	339	-1.02
12	1358	636	346	-1.33
15	1370	632	339	-0.92
18	1389	629	343	-1.25
21	1378	637	351	-0.96
24	1397	634	346	--
27	1370	633	349	-1.13
30	--	648	338	--
33	1383	664	354	-1.11
36	--	656	349	--
39	--	671	355	--
42	--	--	--	--
45	--	--	--	--
48	1360	--	356	--
51	--	--	--	--
54	1381	671	355	--
57	--	--	--	--
60	--	--	--	-1.30
63	1380	659	340	--
66	1337	--	347	--
69	--	--	--	--
72	1418	661	319	-1.26
75	--	--	--	--
78	--	631	347	-1.02
81	1351	633	347	--
84	--	--	--	--
87	--	659	346	-0.73
90	1415	661	344	--
93	--	--	--	--
96	--	--	--	--
99	--	--	--	--
102	1299	634	338	-0.68
105	--	--	--	--
108	--	--	--	--
111	1363	629	339	--
114	--	--	--	-0.95
117	--	--	--	--
120	--	--	--	-1.29
123	1370	638	337	--
126	--	--	--	-0.87
129	--	--	--	--
132	--	--	--	-0.69
135	1386	642	356	--
138	--	--	--	-0.72
141	--	--	--	--
144	1413	648	369	-0.76
147	1438	655	368	--
150	1401	645	356	-0.57
153	--	652	344	-0.77

*Depth is depth below water table; meq/L, milliequivalents per liter; o/oo, parts per thousand; --, no analysis performed.

possible recharge from surface water. Water from the lower part of the profile is likely a mixture of ambient saline water and fresher recharge water from a nearby intermittent-stream channel. Hydraulic-head data from a 3-piezometer nest indicated a downward hydraulic gradient (-0.10), and a substantial rise in water level (0.83 m) from 1984 to 1989 in a 3.29-m deep piezometer (GS-16). The water level in the deepest piezometer (GS-17, 10.67 m deep) declined 0.26 m from the previously measured value. This decline may have even been greater prior to the last measurement, and may have also occurred in wells GS-15 and GS-16 prior to the recharge event.

Results from this study are preliminary and may effect ground-water discharge calculations and future studies in the vicinity of Franklin Lake playa. Surface water runoff likely results in some infiltration through the poorly transmissive sediments at the playa. The presence or infiltration of surface water would slow the rate of evaporation of ground water at Franklin Lake playa. Frequently monitored and widely distributed piezometer nests along ephemeral stream channels might delimit areas of recharge. In addition, further deployment of the multilevel sampler in a 30-50 m deep borehole located away from stream channels could provide chemical-concentration-gradient data that might contribute to long-term estimates of evaporation and a better understanding of the hydrochemistry and hydrology of the playa.

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