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P.O. Box 48, Viola, Idaho 83872 (208) 883-0153 (208) 875-0147

Hydrogeology • Mineral Resources Waste Management • Geological Engineering • Mine Hydrology

November 3, 1986
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Mr. Jeff Pohle
Division of Waste Management
Mail Stop 623-SS
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

RE: SALT

Dear Jeff:

A copy of the review of the following document is enclosed.

1. Dutton, A.R., 1985, Hydrologic Testing in the Salt-Dissolution Zone of the Palo Duro Basin, Texas Panhandle. Texas Bureau of Economic Geology, Austin, TX, OF-WTWI-1985-35.

Please contact me if you have any questions concerning this review.

Sincerely,

Gerry Winter/sl

Gerry V. Winter

GW:sl

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT #: OF-WTWI-1985-35

DOCUMENT: Dutton, A.R., 1985, Hydrologic Testing in the Salt-Dissolution Zone of the Palo Duro Basin, Texas Panhandle. Texas Bureau of Economic Geology, Austin, TX.

REVIEWER: Williams & Associates, Inc.

DATE REVIEW COMPLETED: October 31, 1986

ABSTRACT OF REVIEW: APPROVED BY: Roy Williams /pl

Hydraulic conductivities have been measured at two test wells located in the salt-dissolution zone below the Rolling Plains and the Canadian River Valley. Hydraulic conductivities are estimated to be 0.7 to 1.6 ft/day (0.2 to 0.5 m/day). Hydraulic conductivities measured at a test well located in the salt-dissolution zone below the Southern High Plains range from 0.0002 to 0.002 ft/day (0.00006 to 0.0006 m/day). The report states that groundwater velocities in the salt-dissolution zone below the Southern High Plains may be less than the groundwater velocities in the salt-dissolution zone below the Rolling Plains and Canadian River Valley. The difference in velocity is attributed to differences in hydraulic conductivity and hydraulic gradient. The inferred differences in flow rate correspond to observed differences in salinity. The report states that the coefficient of storage of the salt-dissolution zone ranges from approximately $10^{-3.5}$ to $10^{-4.6}$. The groundwaters found in the salt-dissolution zone below the Rolling Plains and the Canadian River Valley are stated to be approximately 10,000 to 20,000 years old. The salinity of the water found below the Rolling Plains and the Canadian River Valley ranges from 68,000 to 95,000 mg/L. The NaCl type of water is capable of dissolving halite.

The description of the construction techniques used for the test wells is not clear. Additional descriptions should be provided to clarify the construction of the test wells.

The hydrogeologic tests were affected by well bore storage effects. These single well tests were handicapped by the hydrogeologic properties of the materials being tested and the test techniques that were employed. Storativity was estimated based on the barometric efficiency of the wells. Calculation of specific storage is dependent upon an estimated porosity that was based on interpretation of geophysical logs.

Groundwater sampling for isotope analyses and age dating is subject to contamination from drilling fluids. A tracer was used in the drilling fluids to facilitate the evaluation of well development.

BRIEF SUMMARY OF DOCUMENT:

The authors cite previous studies which indicate that the solution of halite and anhydrite beds in the Rolling Plains, Pecos Plains and Canadian River Valley have caused local and regional subsidence of the land surface during the Cenozoic (p. 1). The report also states that evidence indicates that halite beds have dissolved during the Quaternary and that salt-dissolution is an active and dynamic hydrogeologic process. The purpose of the report is to characterize the hydrogeology of the salt-dissolution zone in the Palo Duro Basin. The report intends to present insights into the timing, rate, and mechanism of salt-dissolution processes (p. 2). Salt-dissolution zone refers to the rocks of the upper Permian (Guadalupian to Ochoan) age from which halite, anhydrite, and gypsum have been dissolved. The majority of the information used in the report was collected from four wells drilled for the purpose of testing salt dissolution zones. These wells are the Sawyer No. 2, Mansfield No. 2, Detten No. 2, and the Harman No. 1 wells. These wells were drilled by Stone and Webster Engineering Corporation (SWEC). Drill stem tests also were conducted in the salt-dissolution zones at the SWEC Holtzclaw No. 1 well.

The report states that the elevation and location of the deepest zones of salt dissolution vary. The uppermost salt bed is higher in the stratigraphic section toward the center of the Palo Duro Basin. The highest halite bed in the lower part of the San Andres Formation occurs at the Sawyer No. 2 well. The uppermost halite beds at the Mansfield No. 2, Detten No. 2, and Harman No. 1 wells occur at successively higher horizons in the Seven Rivers Formation and the Salado/Tansill Formations (p. 3).

The test wells were designed to obtain samples of water from near the zone of dissolution of salt. Geophysical logs and core were studied for selecting the test intervals. The bases of the test zones were within 7 to 49 feet of the upper surface of the bedded halite. The Sawyer No. 2, Mansfield No. 2, and the Detten No. 2 test wells were off-set by 100 to 200 feet from previously drilled hydrostratigraphic test wells. Well construction consisted of drilling to the top of the test interval. Geophysical surveys were run and the well was cased. The test zone, below the casing, was drilled or cored with an air-mist foam to minimize drilling fluid contamination. Thiocyanate (SCN^-) was dissolved in the drilling fluid to trace the degree of contamination in the test zones. The test zones were developed by blowing water from the well for several hours using compressed air. The Sawyer No. 2 and the Mansfield No. 2 wells yielded about 50 to 80 gpm with this well development procedure. The Detten No. 2 well did not yield water by this well development procedure.

The Harman No. 1 well was originally drilled to 3,041 feet below land surface using a salt based drilling mud. The well was converted for the dissolution zone test by placing a cement plug in the borehole below the zone of interest. A 148 ft interval was left open between the base of the casing and the top of the cement plug. This test zone was more contaminated with drilling fluid than were the test zones at the other three sites.

A submersible electric turbine pump was used at the Sawyer No. 2 and the Mansfield No. 2 wells. Water was bailed from the Detten No. 2 and the Harman No. 1 wells because the water yield was small.

Water level measurements were made using silicon strain gauge transducers which were connected to a microprocessor controlled data recorder. The transducer was calibrated before and after the test. Discharge rate was determined by measuring the time required to fill a calibrated 5-gallon bucket. Water level recorders (Stevens Type F, 8-day clock) were installed on the Sawyer No. 2 and the Mansfield No. 2 wells after the completion of sampling and testing. The recorders were used to measure water level fluctuations. Atmospheric pressure data were obtained from the records of the National Weather Service in Amarillo, Texas (p. 5).

Groundwater samples were obtained once tracer concentrations indicated that cleanup of the test interval was complete. Groundwater samples were collected for determinations of calcium, sodium, magnesium, potassium, strontium, iron, sulfate, bicarbonate, chloride, bromide, iodide, del-D, del-^{18}O, del-^{13}C, del-^{34}S, and ^{14}C. Wells were pumped until pH, Eh and temperature were stabilized. Temperature, pH, alkalinity and Eh were measured at the well site.

The Sawyer No. 2 well test zone consists of a highly porous, vuggy dolomite in the unit 4 carbonate of the lower part of the

San Andres Formation (p. 6). The test interval is limited to the top 22 ft of the unit 4 carbonate. No observation wells were available for this test or subsequent tests on other test wells. The initial recovery period extended from April 20, 1983, through April 21, 1983. A drawdown test was conducted from the 21st to the 22nd, and a second recovery period was monitored on the 22nd. Prior to the first recovery period the well had been pumped for seven days at 12 to 13 gpm and intermittently since March 29. The report states that the static water level was at a depth of approximately 249.8 ft (elevation 2,330.3 ft msl).

The Mansfield No. 2 well test interval includes two poorly cemented beds of red, muddy, fine-grained sandstone. A portion of the 55 ft test interval consists of indurated red mudstone (p. 7). Three drawdown tests were conducted on this well. Recovery periods were monitored after the tests but only two recovery periods resulted in the collection of useful data. Static water level in the well was stated as being at a depth of 416 ft (3,232 ft msl). The specific weight of the water in the well was 0.459 psi/ft. This is the same specific weight as the fluid found in the Sawyer No. 2 well.

The Detten No. 2 well test interval lies in the uppermost strata of the Seven Rivers Formation. The pumping test data of the Detten No. 2 well are dominated by wellbore storage. A pumping rate as low as 0.5 gpm dewaters the well.

The Harman No. 1 well was constructed from a previously drilled well of much greater depth. The well was scraped and freshwater was flushed in the well to remove the salt-based drilling mud left in the borehole. The report states that the salt-based drilling mud had been tagged with SCN^- tracer. Unfortunately, the freshwater used in constructing the test zone lacked the SCN^- tracer (p. 9). The report states that wellbore storage dominates completely the water level changes during the pumping test of this well.

The Holtzclaw No. 1 well was used to conduct drill stem tests in the Salado/Tansill Formation and the Seven Rivers Formation. The report states that the data were analyzed to give estimates of fluid pressure and permeability.

The J. Friemel No. 1 well was constructed in the salt-dissolution zone of the Seven Rivers Formation. The report states that the shut-in pressure buildup period was too short; wellbore storage effects dominate the data. The data are inadequate for the determination of permeability or formation pressures.

The report states that the hydraulic conductivity of the salt-dissolution zone ranges from 0.0002 to 2.0 ft/day (0.00006 to 0.6 m/day). Table 2 from the report under review is appended to this review. The table summarizes the type of test conducted on each well and the results of the data analyses. Hydraulic conductivities are based on the assumption that the effective thickness of the transmissive zone is equivalent to the test interval thickness. It should be noted that the Sawyer No. 2 well tests were influenced strongly by wellbore storage during the drawdown and recovery periods of the tests. Recovery data in the Sawyer No. 2 well and in the Mansfield No. 2 wells were affected by the water draining out of the production tubing at the cessation of pumping. This drainage occurred because a check valve was not fitted to the production tubing. The drill stem tests conducted at the Holtzclaw No. 1 well apparently were not affected by wellbore storage effects.

Hydraulic heads were measured in open boreholes in the Detten No. 2 and the Harman No. 1 wells. The report states that these water level measurements may underestimate the true hydraulic head because of incomplete water level recovery after water production from the well. The report states further that the hydraulic heads at the Holtzclaw No. 1 well were determined by extrapolating pressure buildup curves from the drill stem test data; these heads are stated to reflect true hydraulic head in the tested zones. The report states that the hydraulic head in the salt-dissolution zone at the Sawyer No. 2 and Mansfield No. 2 wells varies daily by a few centimeters (p. 13). The report states that the close correspondence between the patterns of water level change and atmospheric pressure changes indicates that most of the variation is due to fluctuation of atmospheric pressure.

Barometric efficiencies of the Sawyer No. 2 well and the Mansfield No. 2 well were calculated. The barometric efficiency was estimated by comparing the ratio of standard deviations of the pressure histories. The calculated barometric efficiencies for the two wells are 0.58 and 0.37, respectively (p. 15).

Specific storage was not calculated based on pumping test data. Observation wells were not available for these tests. Specific storage was calculated using the barometric efficiency of the wells and the following relationship:

$$S_s = n\ \rho g / E_w\ B,$$

where S_s = specific storage, n = porosity, ρg = specific weight of the water, E_w = bulk modulus of compressibility of water, and B = barometric efficiency (p. 14). The specific storage of the salt-dissolution zone is estimated to be about 10^{-6} ft^{-1}. Specific storage was calculated using an assumed average porosity of 30%; average porosity was estimated based on neutron geophysical logs. The bulk modulus compressibility of the water was approximately 300,000 psi (p. 15). The calculated coefficient of storage (specific storage x aquifer thickness) is about $10^{-4.2}$ at the Mansfield No. 2 well; at the Sawyer No. 2 well it is estimated to be between $10^{-4.5}$ and $10^{-3.6}$.

The Sawyer No. 2 and the Mansfield No. 2 wells achieved approximately zero concentrations of the tracer (thiocyanate) prior to sampling. The thiocyanate concentrations in the Harman No. 1 and the Detten No. 2 wells were approximately 2 to 4 ppm; the slow rate of cleanup of these two wells is attributed to the low permeability of the test zones in these wells (p. 15). A summary table (#3) from the report under review is attached which outlines the chemical analyses and the isotopic analyses conducted on the samples obtained from the wells.

The report describes the groundwater from the unit 4 carbonate of the San Andres Formation in the Sawyer No. 2 well as a saline, sodium chloride type water. The total dissolved solids concentration is "94,924 mg/L" (p. 15). The report states that the water is undersaturated with respect to halite; the water is saturated with respect to gypsum. The del-D and del-^{18}O of groundwater from the Sawyer No. 2 well is about -50 0/00 and -7.2 0/00, respectively. These values lie along a line which is typical of worldwide precipitation and is consistent with values of rainfall and groundwater found in the Southern High Plains and Rolling Plains.

The groundwater in the Lower Seven Rivers Formation at the Mansfield No. 2 well is a saline, sodium chloride type water. The total dissolved solids concentration is "67,537 mg/L" (p. 16). The report states that the groundwater is undersaturated with respect to halite; the water is saturated with respect to gypsum. The groundwater is meteoric with a del-D of -60 to -70 0/00 and a del-^{18}O of -9.3 0/00. The report states that the del-D, del-^{18}O, del-^{13}C compositions of groundwater found in the salt-dissolution zones at the Mansfield No. 2 and the Sawyer No. 2 wells are similar to isotopic compositions of groundwater found in the Dockum Group aquifer.

Groundwater from the Harman No. 1 well is the most saline, sodium chloride type water sampled in the salt-dissolution zone. The total dissolved solids content is approximately 288,000 mg/L (p. 16). The report states that the groundwater is nearly at equilibrium with respect to halite and anhydrite. The magnesium concentration of the brine in the Harman No. 1 well is anomalous. The magnesium concentration of a brine in thermal dynamic equilibrium with halite, anhydrite, and dolomite would be only 24 mg/L; the molal ratio (Mg^{2+}/Ca^{2+}) would be about 0.03. The magnesium concentration in the Harman No. 1 well is approximately 4,000 mg/L; the molal ratio is approximately 4. The report states that magnesium may be derived by ion exchange from magnesium rich clay minerals in the Upper Permian shale.

Groundwater samples from the Detten No. 2 well must be evaluated with caution because of possible contamination by drilling fluid or by cement leachate (p. 17). The report states that the "Detten water plots along the meteoric water line near the SWEC Mansfield No. 2 sample" (p. 17). A considerable amount of dissolved gypsum and halite plus calcium and potassium is reported to be in the water.

The reported values of del-^{34}S of dissolved sulfate for the dissolution zone suggest that the source of the dissolved sulfate is mainly the dissolution of Permian age anhydrite. The value of del-^{34}S ranges from about +8 0/00 to +12 0/00.

The oxidation state of the groundwater at the Sawyer No. 2 and the Mansfield No. 2 wells is reported to be low relative to that of typical shallow groundwaters. The oxidation state (indicated by Eh) is similar to the oxidation state of the groundwaters found in the Dockum Group aquifer (p. 18).

The Br^-/Cl^- weight ratios for groundwaters from the four wells sampled in the salt-dissolution zone are between 1×10^{-4} and 4×10^{-4}. "These ratios reflect complete or congruent solution of marine halite and are distinct from ratios determined in oil field brines (Whittemore, 1984)" (p.18).

The isotopic compositions (del-D, del-^{18}O, and del-^{13}C) of groundwaters in the Mansfield No. 2 and Sawyer No. 2 wells and the Dockum Group aquifers are similar. The similarity suggests that groundwater "Flow in the Dockum Group has a large influence on dissolution of salt beds in and around the Palo Duro Basin. The hydraulic head in the Ogallala and Dockum Group aquifers is above the hydraulic head in the salt dissolution zone. The distribution of hydraulic heads indicates that groundwater can flow downward into the salt dissolution zone" (p. 18-19).

The amount of carbon-14 (^{14}C) in groundwater in the dissolution zone at the Sawyer No. 2 and the Mansfield No. 2 wells is only a small percentage of modern ^{14}C (p. 21). The del-^{13}C value is approximately -2 0/00 to -3 0/00; the del-^{13}C is more enriched than the groundwater found in the unsaturated zone of the Ogallala Formation (-17.9 0/00). This enrichment suggests that biologic or lithologic reactions have added carbon to the water. The groundwater age, based on ^{14}C values for the Sawyer No. 2 well, is approximately 10,000 years. The ^{14}C age at the Mansfield No. 2 well is approximately 19,000 years. The report concludes that the younger age of the Sawyer No. 2 groundwater suggests that Holocene groundwater or a mixture of Holocene and Pliestocene groundwaters may be moving through the salt dissolution zone east of the caprock escarpment.

Groundwaters found at the Sawyer No. 2 and the Mansfield No. 2 wells are undersaturated with respect to halite; these groundwaters are capable of dissolving salt beds. The report states that although the groundwaters may be 10,000 to 20,000 years old they are still capable of dissolving halite during modern time.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

The report is important to the Waste Management Program because it discusses the salt-dissolution zone. Little testing and information was available on the salt-dissolution zones prior to the tests conducted by the Department of Energy. The hydraulic conductivity values and the chemical and isotopic analyses indicate the genesis of the salt-dissolution zones. The data suggest that the salt-dissolution zones may be active at this time. Salt dissolution is important to the program because it potentially can remove soluble confining beds located within the evaporite aquitard sequence. The dissolution of the soluble strata within the evaporite aquitard sequence could lead to an early exposure of the radioactive wastes to the groundwater flow systems. Such exposure could reduce groundwater travel time to the accessible environment.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The report states that the salt-dissolution zones tested in the various wells are at different stratigraphic locations as well as areal locations (p. 2-3). The comparison of hydrogeologic data collected from different stratigraphic and probably hydrostratigraphic units is problematic. The point should have been discussed in greater detail in the report.

The report does not state clearly how the wells were constructed (p. 3). It is necessary to refer to the attached figures to ascertain whether or not the wells were screened and whether a gravel pack was installed in the wells.

The report states that it is assumed that the effective thickness of the transmissive zone in the test interval is equivalent to the flow test interval thickness. This practice is consistent with practices used by most hydrogeologists in the evaluation of pumping test data. Unfortunately, this practice is not consistent with proper scientific procedures; the transmissivity should be appropriately proportioned among the units included in the test interval. This correct procedure is now being used at the BWIP site. The procedure used in the report results in the calculation of nonconservative hydraulic conductivities because the transmissivity is spread over the entire test interval thickness. The determination of the effective or producing intervals within the test interval results in the calculation of higher hydraulic conductivities than are calculated by the method employed in the report.

Specific storage is calculated based on the relationship of barometric efficiency to specific storage. Calculation of specific storage by this method requires the estimation of effective porosity from the interpretation of neutron geophysical logs. The neutron geophysical logs yield a value which more closely reflects total porosity than effective porosity. The calculation of specific storage by this method also requires the determination of the bulk modulus of compressibility of water; the water in this case is a high density fluid, which makes the accuracy of the estimation of the bulk modulus of compressibility questionable. The approach used to estimate the specific storage coefficient and hence coefficient of storage is appropriate considering the fact that observation wells were not available for the pumping tests at each of the wells. The calculated specific storage is an estimate; this point is not stated adequately in the report.

The report discusses the isotopic composition of the groundwaters found at the test wells. The report does not discuss the potential effects of small amounts of drilling fluid contamination on the isotopic data. The report should discuss this issue. The thiocyanate tracer concentration in the wells was measured and does reflect some contamination of the groundwater samples.

REFERENCES CITED:

Whittemore, D.O., 1984, Geochemical Identification of Salt Water Sources. in French, R.H., ed., Salinity in Watercourses and Reservoirs. Proceedings, 1983 International Symposium on State-of-the-Art Control of Salinity, Salt Lake City, Utah, Butterworth, p. 505-514.

Table 2. Summary of Hydrologic Tests

Test Period	Q (m^3/day)	b (m)	P_D	ΔP (psi)	s/cycle (m)	T m^2/day	K m/day	Method
				Sawyer #2 Well				
drawdown #1	58.875	6.71	1.0	5.25 & 3.36	-	2.4 to 3.6	0.4 to 0.5	type-curve match
recovery #2	58.875	6.71	1.0	5.43 & 3.42	-	2.3 to 3.7	0.3 to 0.6	type-curve match
				Mansfield #2 Well				
drawdown #1	49.55	16.76	1.0	3.3	-	3.2	0.19	type-curve match
	"	"	-	-	2.83	3.2	0.19	Jacob approximation
recovery #1	49.55	16.76	1.0	3.7	-	2.8	0.17	type-curve match
	"	"	-	-	3.32	2.7	0.16	Theis approximation
drawdown #3	53.73	16.76	1.0	4.15	-	2.7	0.16	type-curve approximation
	"	"	-	-	3.25	3.0	0.181	Jacob approximation
drawdown #4	58.57	16.76	1.0	4.95	-	1.5	0.09	type-curve approximation
	"	"	-	-	3.38	3.2	0.189	Jacob approximation
recovery #4	58.57	16.76	1.0	2.47	-	5.0	0.3	type-curve approximation
	"	"	-	-	3.102	3.5	0.19	Theis approximation
				Holtzclaw #1 Well: Seven Rivers Formation				
test #1	0.37	14.04	10.0	25.0	-	0.1	0.007	type-curve approximation
				Holtzclaw #1 Well: Salado/Tansill Formations				
test #2	0.62	14.04	1.0	46.2	-	8×10^{-4}	6×10^{-5}	type-curve approximation

Q - flow rate; b - test-zone thickness; P_D - type-curve pressure match-point; ΔP - data match point; s/cycle - straight-line slope on semi-log plot; T - transmissivity; K - hydraulic conductivity

Table 3

Results of Chemical Analyses
(concentrations in mg/L unless noted otherwise)

Sample date	Sawyer #2 4/27/83	Mansfield #2 6/9/83	Detten #2 2/4/84	Detten #2 6/16/84	Detten #2 8/14/84	Detten #2 3/19/85	Detten #2 5/29/85
Ca^{2+}	1,860	1,460	850	610	680	481	457
Mg^{2+}	480	388	<0.5	<0.2	<0.4	1	<0.2
Na^{+}	33,000	23,850	8,010	3,750	5,150	2,970	3,130
K^{+}	30.3	31.9	347	163	220	116	101
Sr^{2+}	27.8	23.1	25.6	12.6	17.2	8.8	7.43
SiO_2	5.69	4.23	<0.54	<0.63	0.73*	1.1*	--
Fe	0.773	0.091	1.41	--	--	--	--
SO_4^{2-}	4,725	5,610	3,780	2,820	3,180	2,130	2,070
Cl^{-}	54,700	36,120	9,330	3,770	5,680	3,410	3,640
titrated alkalinity	72.6	41.53	--	--	--	9.4meq/L	7.9meq/L
Br^{-}	21.4	6.2	2.9	<0.2	<0.2	2.42	1.87
I^{-}	bdl	bdl	3.7	0.58	2.48	0.43	--
H_2S	bdl	bdl	--	--	--	--	--
pH	6.3	7.2 to 7.55	11.2	--	--	11.72	11.55
Eh(v)	-0.185	-0.325	--	--	--	--	--
T°C	23.5	22.9	17.5	--	--	--	23.0
t.d.s.	94,924	67,537	23,988	11,986	15,708	9,130	8,950
δD[1,4]	-47.7%	-60.5%	--	--	--	--	--
δD[2,4]	-52.0%	-72.0%	--	--	--	--	--
δD[8,4]	--	--	--	--	--	-62%	--
$\delta^{18}O$[1,4]	-7.3 °/oo	-9.2 °/oo	--	--	--	--	--
$\delta^{18}O$[2,4]	-7.18 °/oo	-9.40 °/oo	--	--	--	--	--
$\delta^{18}O$[8,4]	--	--	--	--	--	-8.8%	--
$\delta^{34}S$[2,5]	+11.92 °/oo	+9.07 °/oo	--	--	--	--	--
$\delta^{34}S$[8,5]	--	--	--	--	--	+8.7%	--
$\delta^{13}C$[3,6]	-1.9 °/oo	-3.1 °/oo	--	--	--	--	--
$\delta^{13}C$[8,6]	--	--	--	--	--	--	--
^{14}C[3,7]	3.3 ±0.4	1.7 ±0.13	--	--	--	--	--

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Table 3 (cont.)

Sample date	Harman #1 8/1/84 (a)	8/1/84 (b)	9/14/84	3/19/85	5/29/85 (a)	5/29/85 (b)
Ca^{2+}	1,640	1,540	1,470	1,570	1,466	1,731
Mg^{2+}	3,370	3,810	3,450	3,830	3,923	4,040
Na^{+}	96,420	101,600	94,390	100,300	108,700	110,700
K^{+}	1,150	1,250	1,130	1,290	1,218	1,293
Sr^{2+}	32	29.5	29	27.3	28.5	31.5
SiO_2	0.73*	1.75	0.83*	--	--	--
Fe	--	--	--	--	--	--
SO_4^{2-}	6,060	6,230	8,070	5,880	75,760	5,700
Cl^{-}	151,600	158,900	152,500	161,140	166,800	170,400
titrated alkalinity	?	?	?	?	?	?
Br^{-}	43	46	47	44.6	52	58
I^{-}	2.0	1.1	4.9	6.8	--	--
H_2S	--	--	--	--	--	--
pH	--	--	6.1	5.9	6.3	--
Eh(v)	--	--	--	--	--	--
$T^{o}C$	--	--	22	22	23	--
t.d.s.	260,318	273,471	261,104	274,177	287,899	293,954
$\delta D^{1,4}$	--	--	--	--	--	--
$\delta D^{2,4}$	--	--	--	--	--	--
$\delta D^{3,4}$	--	--	--	51%	--	--
$\delta^{18}O^{1,4}$	--	--	--	--	--	--
$\delta^{18}O^{2,4}$	--	--	--	--	--	--
$\delta^{18}O^{8,4}$	--	--	--	-7.3%	--	--
$\delta^{34}S^{2,5}$	+11.92 o/oo	+9.07 o/oo	--	--	--	--
$\delta^{34}S^{8,5}$	--	--	--	+7.9%	--	--
$\delta^{13}C^{3,6}$	-1.9 o/oo	-3.1 o/oo	--	--	--	--
$\delta^{13}C^{8,6}$	--	--	--	-2.4%	--	--
$^{14}C^{3,7}$	3.3 ±0.4	1.7 ±0.13	--	--	--	--

1 - reported by Knauth, L. P., Arizona State University
2 - reported by Mankiewicz, P. J., Global Geochemistry Corp.
3 - reported by Long, A., University of Arizona
4 - SMOW standard
5 - Canyon Diablo meteorite standard
6 - PDB standard
7 - % Modern
8 - reported by Winters, Ken, Coastal Science Laboratories, Inc.
bdl - below detection limit
* - at detection limit
a - Harman water sample from top of water column
b - Harman water sample from bottom of water column

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