UNITED STATES

DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

GEOHYDROLOGY AND POTENTIAL FOR CONTAMINATION OF OAK SPRING, BIG BEND NATIONAL PARK, TEXAS

PROGRESS REPORT, 1987

By

E. T. Baker, Jr., P. M. Buszka, D. G. Woodward, and T. A. Small
U.S. Geological Survey

Prepared for the National Park Service
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INTRODUCTION

This study is being done at the request of the National Park Service to investigate the source of water for Oak Spring with regard to the potential for contamination from Chisos Basin. Chisos Basin, which is about 1,000 feet higher in elevation than Oak Spring and is about two miles from the spring, is a major developed area of the park. Development consists of a restaurant, motel and cottages, horse corral, and large campground.

Sewage from Chisos Basin undergoes secondary treatment and is disposed into lagoons within the Basin. Oak Spring is outside of Chisos Basin and is the sole source of water for the Basin. The National Park Service is concerned that at some time in the future the water from Oak Spring may become contaminated by losses from the sewage lagoons to the aquifer that supplies the spring.

The major objectives are to describe the geohydrology of the aquifer supplying water to Oak Spring and the potential for contamination of the springflow. More specifically, information is needed on the source of water supplying the spring and if the source includes contributions from the sewage lagoons, the quality of water in the aquifer, the direction and rate of groundwater movement, the changes in water quality between the lagoons and Oak Spring, and the factors that influence the quantity and quality of the springflow and their significance.

METHODS AND RESULTS OF INVESTIGATIONS

Ground-Water Chemistry and Quality

The purpose of this section of the report is to (1) assess the past and current quality of ground-water at Oak Spring, (2) investigate the potential sources of the ground-water which discharges at Oak Spring and (3) to assess the relation of the aquifer system within the Chisos Basin to the Oak Spring aquifer system. The latter aspect includes the potential impact of contaminated seepage from the sewage lagoons on the current water quality at Oak Spring. Oak Spring is the sole source of drinking water for the restaurant, lodge, motel, campground and other facilities in the Chisos Basin.

Ground-water quality at Oak Spring and at wells and springs in the vicinity of the Chisos Basin has been monitored intermittently since 1953 by the U. S. Geological Survey and the National Park Service (NPS). These analyses have typically consisted of major elemental constituents and inorganic properties. The NPS also has analyzed Oak Spring discharge for two selected pesticides, mirex and silvex during the 1970's. A geochemical study of ground water (Sepulveda, 1984) in the Chisos Basin area concluded that Oak Spring discharge is typical of a fast flow system from the Chisos Mountains with recent recharge. These interpretations were based on the tritium content of the spring discharge and the stable temperatures observed during the winter and summer sampling of Oak Spring during 1983. This study expands the list of constituents used to evaluate water quality at Oak Spring and to investigate the impacts of Basin activities on that water quality.

Method of Investigation

Water-chemistry data consisting of laboratory analyses of ground-water samples were compiled from the files of the Geological Survey, the National Park Service, and from Sepulveda (1984). These data were supplemented by analyses within the Chisos Basin from the Lower CCC well, the lower sewage lagoon, and Window Spring, and outside the Basin from Oak Spring and Cattail Springs (Figure 1). These samples were collected during June, 1986 and August, 1987.

All water samples collected during this study were collected after pumping a minimum of one-half hour to ensure the collection of representative samples and minimize interferences from the pump and sample tubing. Measurements of pH, temperature, specific conductance and alkalinity were performed in the field according to the procedures outlined by Wood (1976). Dissolved oxygen measurements were performed at Oak Spring and the sewage lagoon using a YSI model 54A oxygen meter and probe. Water samples submitted for analysis of major element cations and minor elements were acidified immediately upon collection with 1 milliliter of nitric acid. Nutrient and nitrogen isotopic samples were preserved with mercuric chloride. All samples except the acidified and major anion samples were preserved by refrigeration between their collection and analysis.

Water samples submitted for analysis of volatile and semi-volatile organic compounds were collected using a submersible pump equipped with teflon and stainless steel fittings and teflon tubing to minimize sample contamination. These samples were spiked with a solution of surrogate

FIGURE 1. CHISOS BASIN AND OAK SPRING AREA SHOWING LO

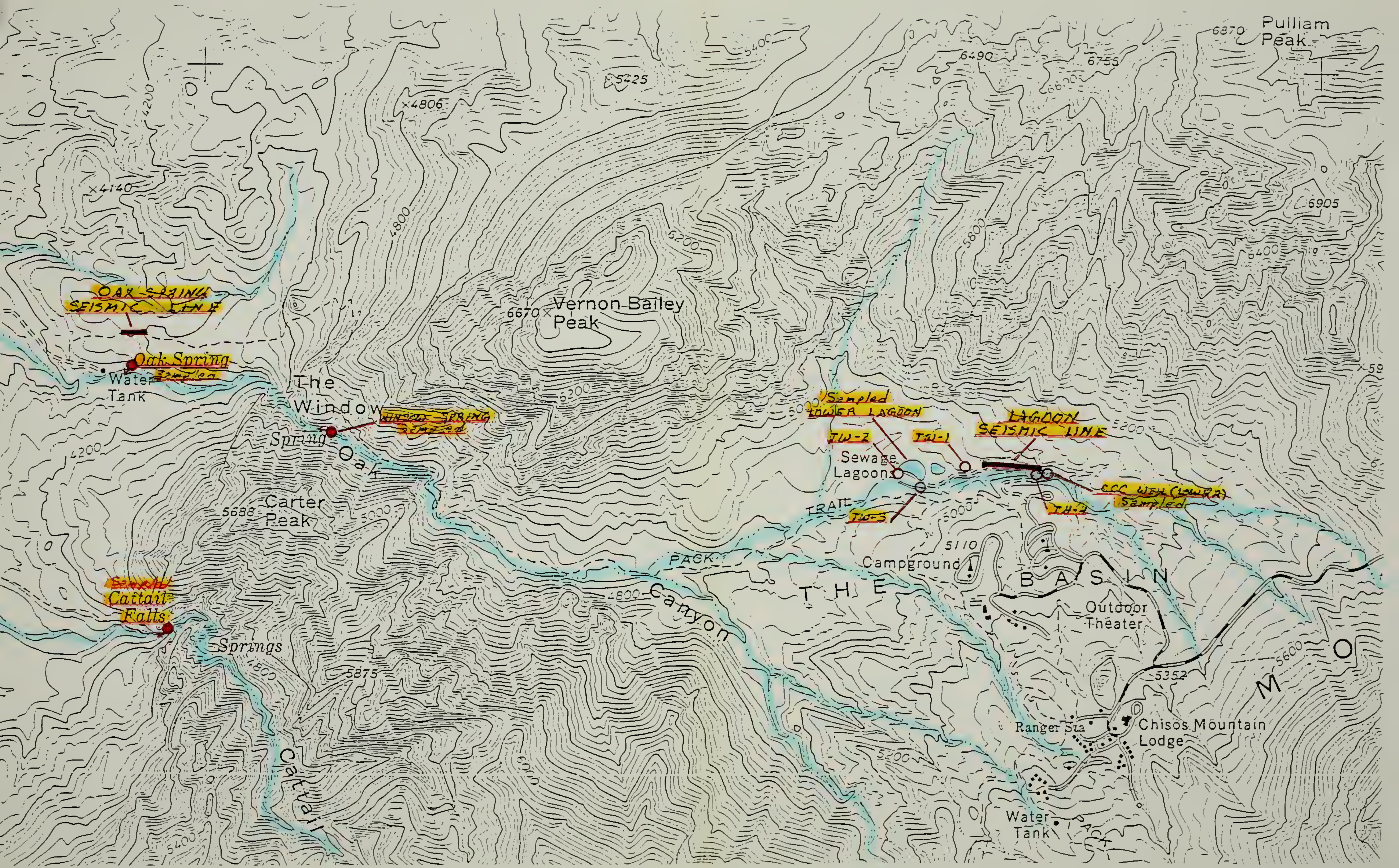


FIGURE 1. CHISOS BASIN AND OAK SPRING AREA SHOWING LOCATIONS OF SAMPLING SITES, DRILLING SITES, AND SEISMIC LINES

compounds to evaluate potential losses of volatile and semi-volatile compounds between collection and analysis.

Analyses of all water samples were performed either at the National Water Quality Laboratory in Arvada, Colorado or through official Geological Survey contract laboratories for isotopic analyses. Inorganic and nutrient analyses were performed according to procedures outlined in Friedman and others (1983). Organic analyses with the exception of determinations of semivolatile organic compounds were performed using procedures described by Wershaw and others (1987). The determinations of semivolatile organic compounds were performed using procedures outlined in Barber and others (1987).

Hydrogeologic Framework

The locations sampled for this study were defined as to their positions in a hypothetical hydrogeologic framework to represent the different potential sources of water to the Oak Springs aquifer. This framework is based on geologic observations by Maxwell and others (1967) and on the field observations of the investigators contributing to this study. The framework is meant as a working hypothesis to be modified by the results of this project.

Observations by previous investigators suggest the existence of three aquifers within the study area. The first aquifer, referred to in this section as the basin aquifer, consists of the saturated alluvium, colluvium deposits of the valley floor that is observed to discharge at Window Spring. It is unclear whether ground-water at the Lower CCC well represents the basin

aquifer or a deeper source such as saturated sandstones of the Pen Formation as encountered by Maxwell (written communication, 1947). The second aquifer system, as sampled at Cattail Springs, represents water which originates as precipitation on Ward Mountain, an igneous pluton. These deposits are thought to only have minor fracture permeability and respond rapidly to precipitation events. The third system, the Oak Spring aquifer, is thought to consist of the unconsolidated alluvium and permeable parts of the underlying basalt as observed along the ridge radiating from the Vernon Bailey and Amon Carter peak area. Within this framework, potential sources of recharge to the Oak Springs aquifer may consist of: (1) precipitation directly onto the aquifer and the exterior slopes of the igneous pluton, (2) discharge from the basin aquifer at Window Spring that reaches the Oak Spring aquifer via the "Pour-off", a waterfall located at The Window and (3) cross-formational flow from either the deeper, saturated formations within the Chisos Basin or an as yet unknown source.

The lower sewage lagoon was sampled to characterize potential tracers of sewage-impacted ground water as could be detected in samples from Oak and Window springs. The lower CCC well was considered to be upgradient of any sewage lagoon seepage impacts on ground-water chemistry and is intended to represent ground-water chemistry in the upper basin. Window Spring is thought to be typical of the chemistry of ground water discharging from the Basin. Cattail Springs was sampled to represent the chemistry of recent recharge from the Chisos Mountains.

Hydrochemical Data

The results of chemical analyses of 29 water samples from three springs, one well and the sewage lagoons in the Chisos Basin vicinity are shown in Table 1. These data are discussed in relation to their importance in defining potential sources of discharge from and in defining the water quality of Oak Spring.

Major and Minor Inorganic Constituents

The median concentration of dissolved solids observed at Oak Springs (210 milligrams per liter (mg/L)) is intermediate between the June, 1986 concentrations observed at Cattail Springs (76 mg/L) and Window Springs (270 mg/L). This pattern however is only repeated for alkalinity but is not repeated for any of the other major cations (calcium, magnesium, sodium and potassium) and anions (chloride, sulfate and fluoride). Examination of the data from Oak Spring shows no definite trend with respect to time for these data except for slight, recent increases in calcium and sulfate concentrations (Table 1). Variation in concentrations of these constituents however do not appear to relate to changes in discharge (Figure 2).

The minor elements with the largest concentrations in ground water were strontium, boron and barium. All three are thought to be mineralogic constituents of the Chisos Basin and Oak Spring aquifers.

Mineral saturation indicies were computed for water chemistry data from 1986 using the mass transfer-equilibrium speciation model PHREEQE (Parkhurst

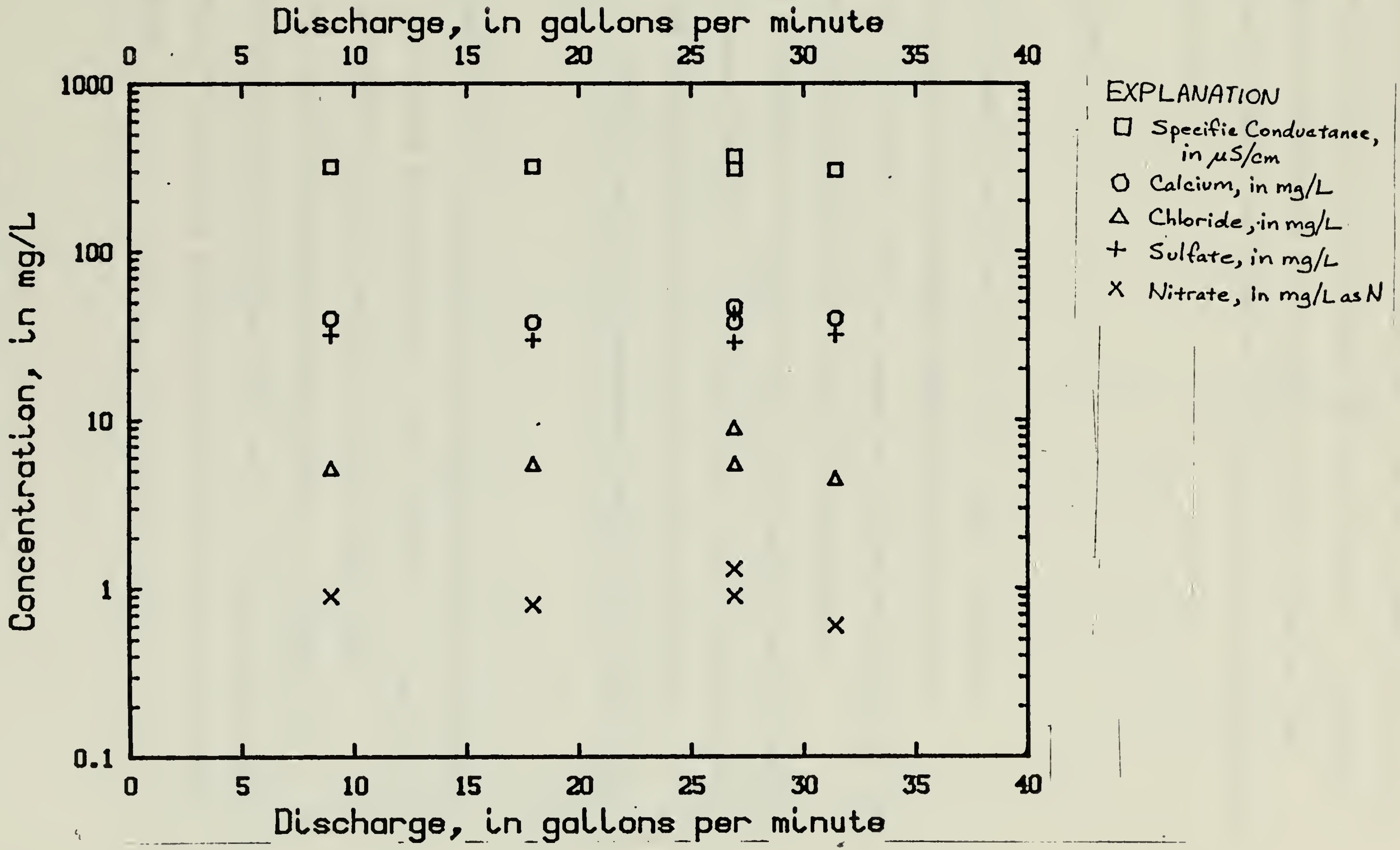


Figure 2:-- Relation of specific conductance values, and concentrations of calcium, chloride, sulfate and

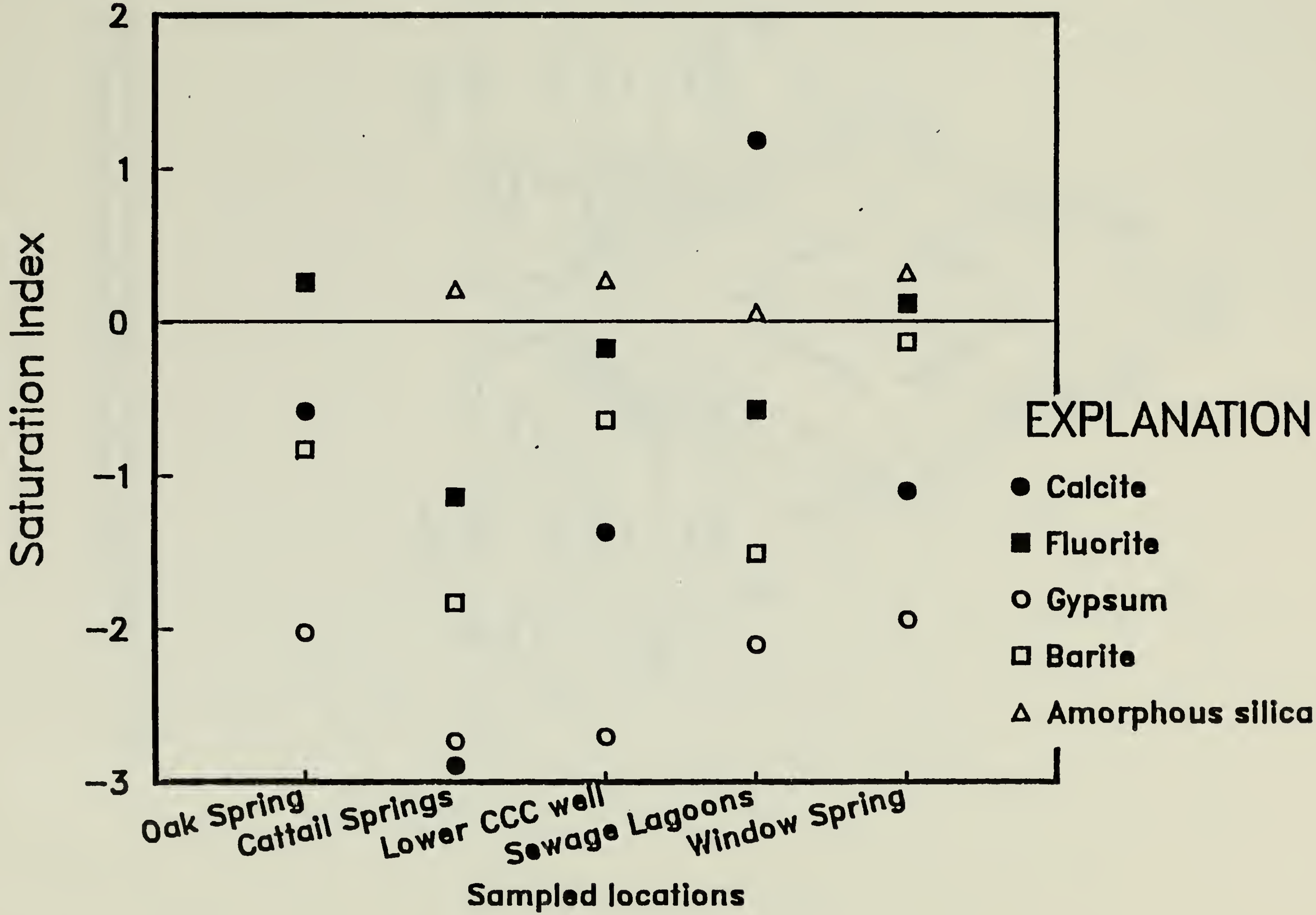
and others, 1980). Ground water is slightly supersaturated with respect to amorphous silica (chalcedony) in all 1986 samples and with respect to fluorite in water samples from Oak Springs and Window Springs (Figure 3). All ground-water samples were undersaturated with respect to calcite, dolomite, and gypsum. Barite was slightly undersaturated at Window Spring and undersaturated at all other locations.

Hydrochemical Facies

The term, hydrochemical facies was used by Back (1966) to denote a diagnostic characteristic of ground-water chemistry from the relative concentrations of major cations (calcium, magnesium, sodium and potassium) and anions (chloride, carbonate species, and sulfate) in ground water (Figure 4). The hydrochemical facies described in this section are the result of geochemical processes operating in the basin aquifer and in the aquifers discharging at Oak Spring and Cattail Springs. The facies may be used to define relative differences among the ground-water chemistry observed at each sampled location.

The hydrochemical face of ground-water discharging from Oak Springs and Window Springs is a calcium bicarbonate water type (Figure 5). In contrast, ground water at well BK-73-46-803 in the basin contains nearly equal proportions of calcium and sodium (as equivalent charge). The sample of discharge from Cattail Springs from August, 1986, was a calcium sulfate water type. The lagoon water sample had sodium as its principal cation but had no dominant anion type.

Figure 3:-- Mineral saturation indicies calculated by program PHREEQE (Parkhurst and others, 1980) for Chisos Basin area water samples, August, 1986.



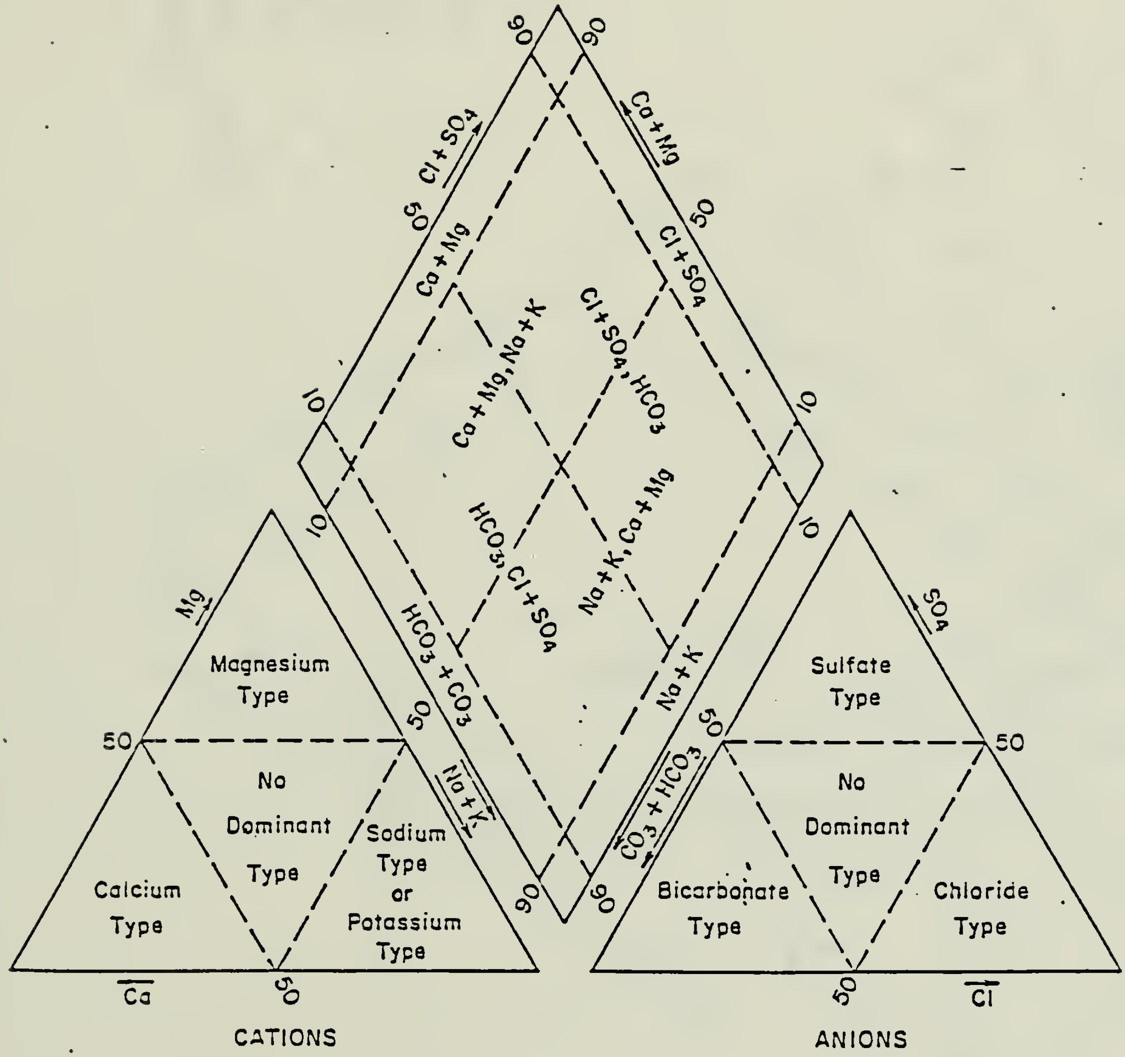


Figure 4. Hydrochemical facies diagram for waters according to major ion equivalent percentages (after Back, 1966).

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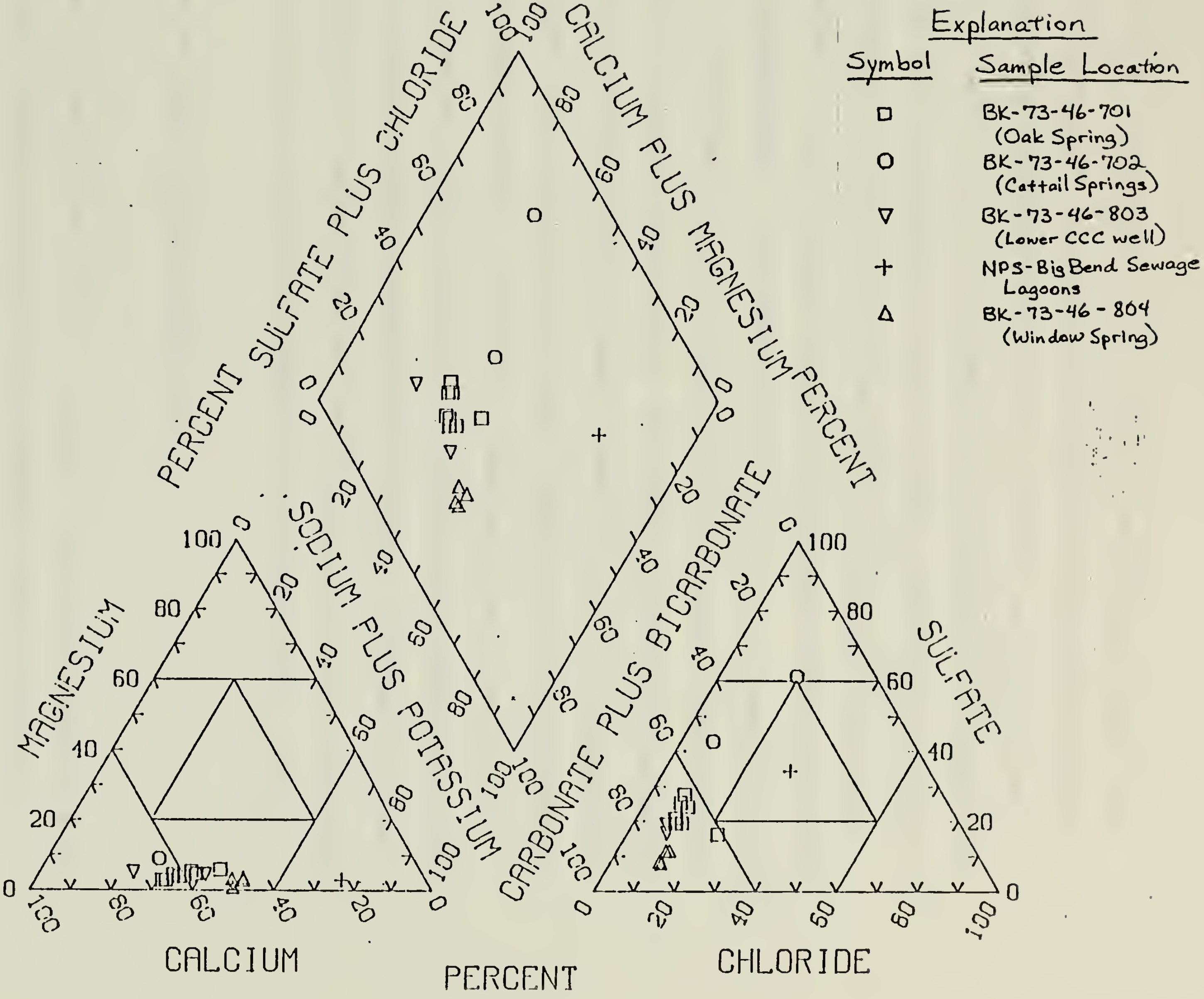
Figure 5:-- Hydrochemical facies for ground water and the sewage lagoon, Chisos Basin area, 1953-1986 water samples.



When viewed in the context of the regional hydrogeology, each of the sampled locations can be considered characteristic of a potential type of recharge to the Oak Springs aquifer system. From this perspective, the hydrochemical facies of Oak Springs appear to be intermediate in composition between that of Window Springs and Cattail Springs. This pattern suggests two different sources for ground water at Oak Spring, discharge from the basin aquifer system and recent recharge from precipitation onto the exterior slopes of the Chisos mountains. An alternate explanation for this composition is the evolution of precipitation-derived ground water by rock-water interaction to the composition observed at Oak Spring. The latter explanation is supported by the lack of variation in major element concentration with discharge at Oak Spring (Figure 2) and by the relatively small quantity of discharge observed from Window Spring (Table 1). Oak Spring ground water has a similar to slightly greater proportion of sodium than Window Spring, suggesting either a variation in sodium content of Window Spring discharge, differences between the mineralogy of the basin aquifer and the Oak Springs aquifer, or some type of sorptive exchange of calcium for sodium within the Oak Springs aquifer.

Radioactive and Stable Isotope Geochemistry

Tritium is a radioactive isotope of hydrogen with an atomic mass of 3 and a half-life of 12.3 years. It occurs both naturally from the interaction of cosmic rays with the atmosphere and by addition from the solar wind and as a result of the atmospheric thermonuclear bomb testing between 1952 and 1960. Concentrations of tritium data are reported as a tritium ratio (TU) which is one atom of tritium per 10 (18) atoms of hydrogen. Tritium concentrations can

be used to classify ground water as:

(1) older in apparent age than 1952 if tritium ratios are less than 1 TU (Coplen, 1986),

(2) containing a significant proportion of post-1952 water if tritium ratios are greater than 50 TU (Coplen, 1986), or

(3) containing some portion of their recharge as post-1952 water if detectable tritium (greater than 1 TU) is present (Bower, 1978).

Results of a tritium analysis of ground water from Oak Spring collected during the winter of 1983 (Sepulveda, 1984; Table 1) suggest that some portion of that water is modern (post-1952) recharge. Comparison of the data with recent data on tritium in precipitation from Waco, Texas (Figure 6) further suggest the possibility that this recharge may well date from the last twenty years. Oak Spring ground-water samples collected during June, 1986 and August, 1987 by the Geological Survey for tritium analysis will be available for interpretation with the final report.

Carbon-14, a radioisotope produced both by cosmic ray bombardment of nitrogen nuclei and by the atmospheric testing of nuclear weapons, was also used by Sepulveda (1984) to interpret the age of ground water at Oak Spring. The activity of carbon-14 in samples collected at Oak Spring during winter of 1983 (Sepulveda (1984)) and June, 1986 are nearly identical at 99 and 99.9 percent modern carbon, respectively. These data support the interpretation that discharge from Oak Spring is modern in age.

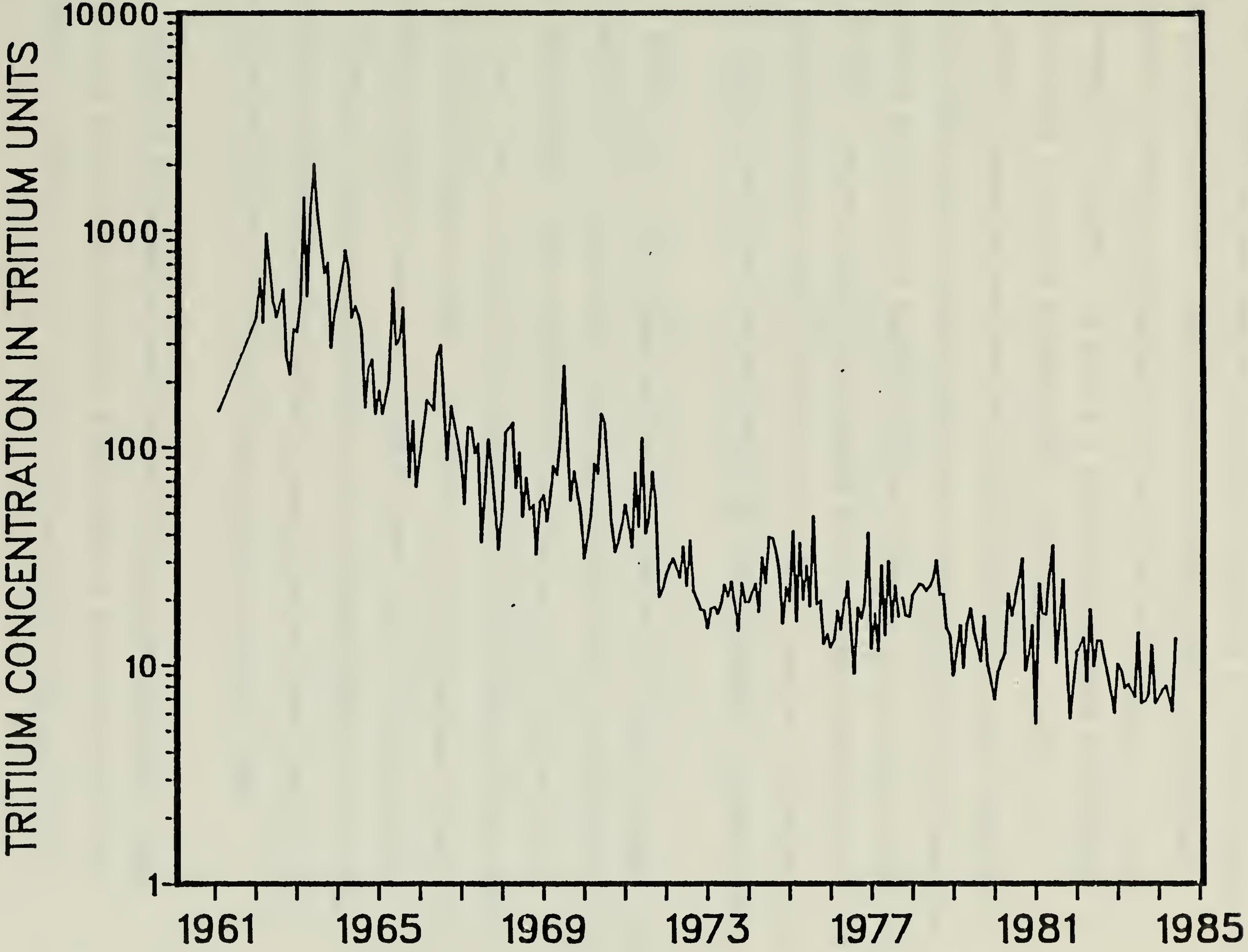


Figure 6:-- Concentration of tritium in precipitation, Waco, Texas airport, 1961-1935 data.

The ratio of the stable isotopes nitrogen-15 to nitrogen-14 in nitrate (del N-15-NO3) has been used to distinguish the source of nitrate nitrogen in ground water (Kreitler, 1975; Gormly and Spaulding, 1979). The primary sources of nitrate to ground water in the Chisos Basin area are: (1) soil nitrogen (del N-15-NO3 = +2 to +9 %) and (2) animal wastes (del N-15-NO3 = +10 to +23 %). The del N-15-NO3 values cited above are useful for qualitative comparison and have been found accurate for studies conducted in Runnels County, Texas (Kreitler, 1975) and in Nebraska (Gormly and Spaulding, 1979) but have also been found to overlap in other studies (Coplen, 1986). del N-15-NO3 ratios determined for Oak Spring (+5.5 %) and Window Spring (+5.2 %) suggest that the nitrate in ground water at these locations originates from the decomposition of soil organic matter and not from animal or human wastes.

Stable oxygen and hydrogen isotopes were used in this study to suggest the potential source or sources of ground water to Oak Spring. The concentrations of these isotopes (oxygen-18 and deuterium (hydrogen-2)) relative to each other can reflect the degree that ground water differs chemically from modern precipitation (meteoric water). The global relationship between oxygen-18 and deuterium in meteoric water, the "meteoric water line" is shown on Figure 7. Departures from this relationship, such as the enrichment of one isotope relative to the other, can be caused by evaporation or mineral precipitation and dissolution, such as through silicate hydrolysis (Coplen, 1986).

Oxygen-18 and Deuterium data from this study and from Sepulveda (1984) indicate a meteoric origin for all ground water in the Chisos basin area (Figure 8). The slight shift of Oak Spring and Cattail Springs isotopic

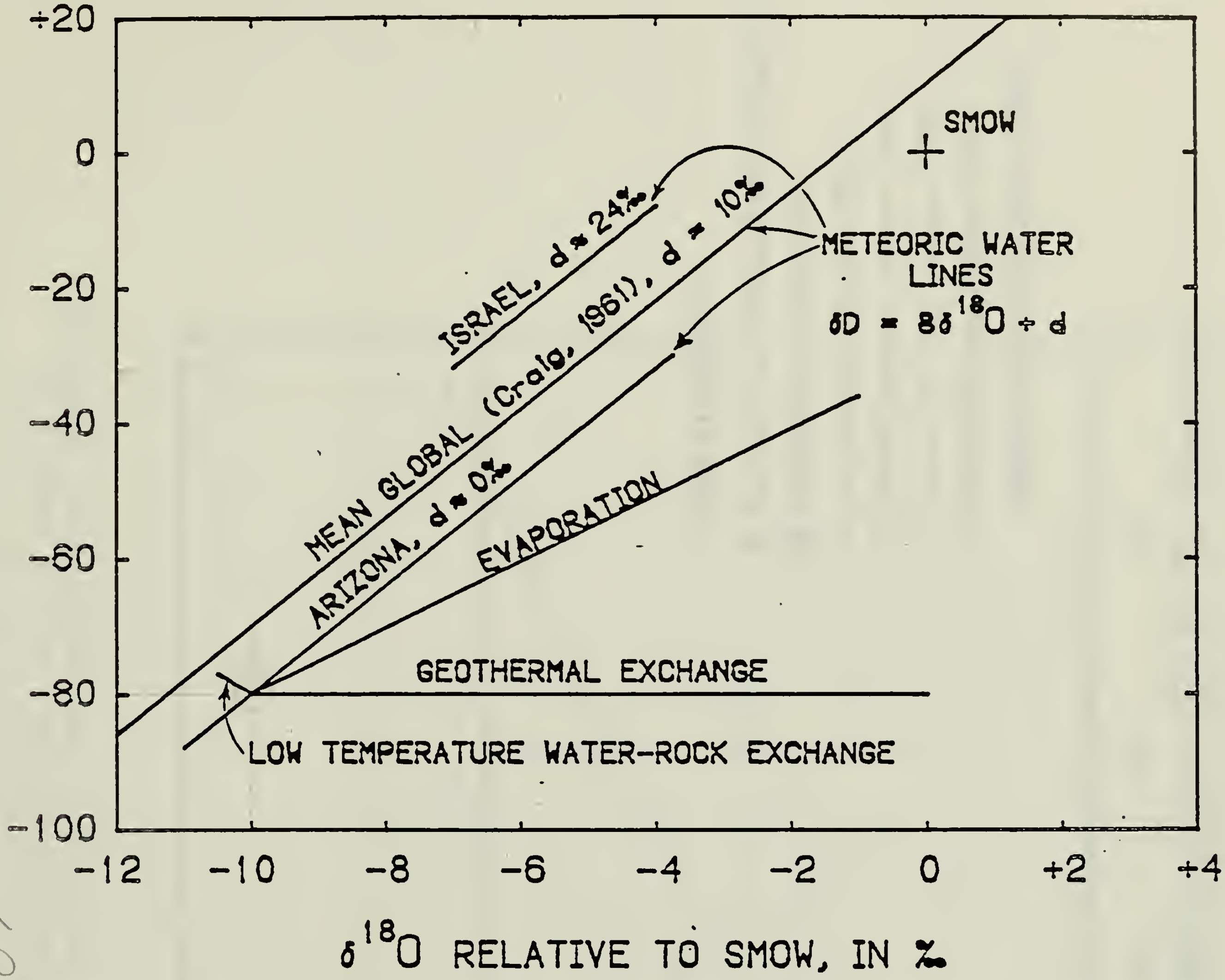


Fig. 7.-- The relationship between δD and $\delta^{18}O$ of meteoric water, evaporating water, and water interacting with rock (after IAEA, 1983b).

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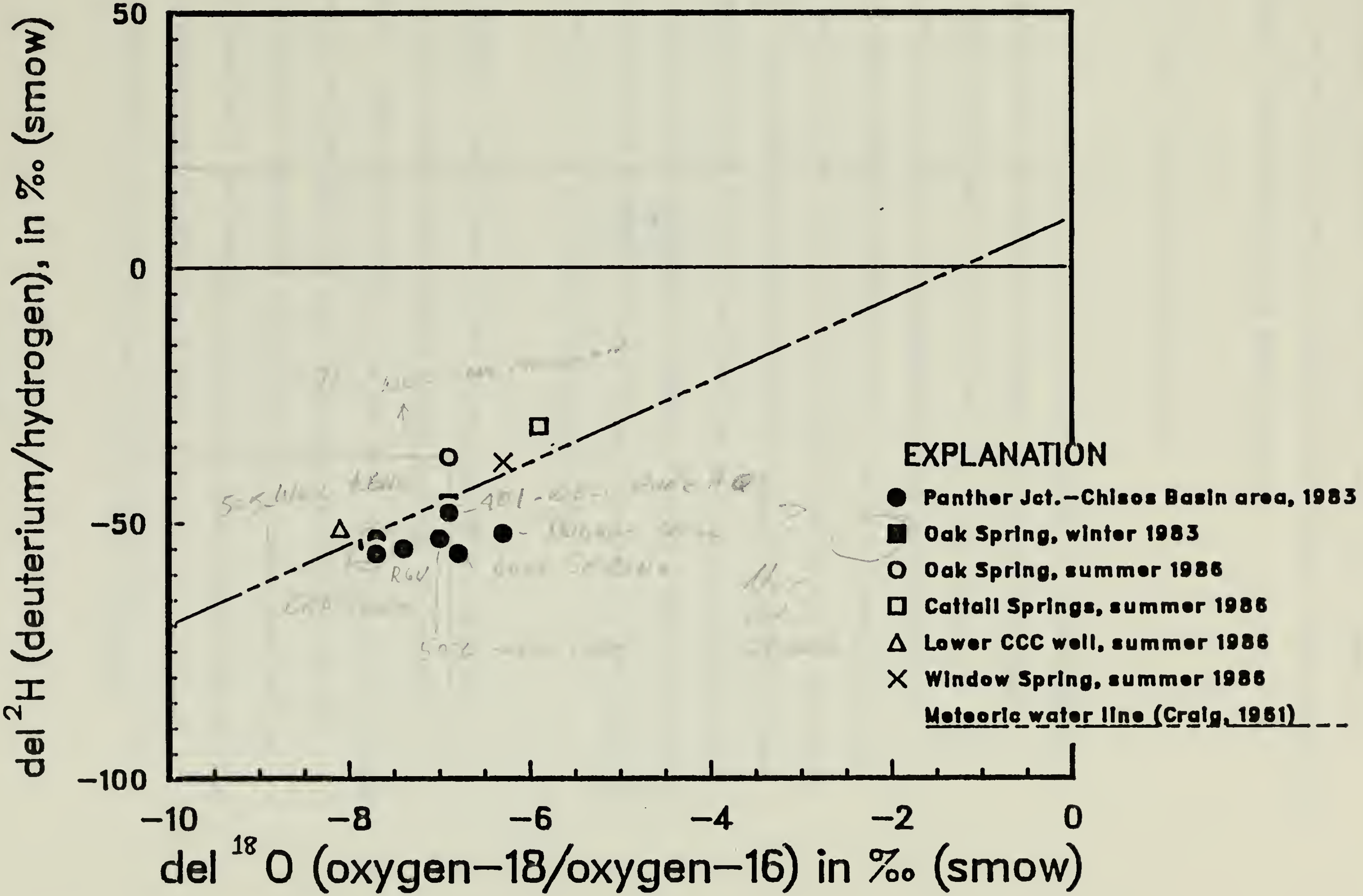
Figure 8:-- Relation of del-deuterium to del-oxygen-18 in ground water, Chisos Basin area, winter, 1983 (Sepulveda, 1984) and August, 1986 data.



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composition above the meteoric water line may indicate the alteration of those ratios by rock-water interaction. This evidence tentatively supports the origin of Oak Springs ground water as precipitation-derived, rather than from cross-formational flow from the Chisos Basin aquifer.

Impact of Basin Activities on Ground-Water Quality

Several constituents of ground water were analyzed to investigate the presence in ground water of potential pollutants associated with human activities. These constituents can be grouped into three categories: (1) nutrient species such as nitrate and phosphorus, detergents measured as methylene blue active substances (MBAS) and boron which are associated with domestic wastewater (LeBlanc, 1983), (2) pesticides applied within the Chisos Basin, and (3) volatile and semi-volatile organic compounds, such as toluene and xylene, associated with both of the first two sources and with petroleum combustion. Concern about the impact of human activities within the basin on the quality of Oak Spring discharge arose principally because of the detection of the pesticide mirex in a 1976 sample from Oak Spring.

Of the category 1 constituents listed above, only MBAS suggested a potential association between Chisos Basin aquifer and Oak Spring water quality (Table 1). MBAS concentrations from the June, 1986 sampling of Window Spring (0.04 mg/L) and the Lower CCC well (0.05 mg/L) are similar to the concentration observed at Oak Spring (0.04 mg/L) and are less-than half the concentrations observed in the sewage lagoons (0.11 and 0.14 mg/L) during 1986 and 1987. A September, 1987 sample from Cattail Springs has been submitted for analysis to determine the concentration of MBAS from an unimpacted watershed.

Oak Spring was sampled during June, 1986 and August, 1987 for the analysis of organochlorine and organophosphorus insecticides and chlorphenoxy acid herbicides. Results of these analyses showed no incidence of these compounds above their analytical detection limits as indicated in Table 1.

The only volatile organic compound detected in samples extracted by purge-and-trap methods was chloroform (2.9 micrograms per liter (ug/L)) in a sample from the lower sewage lagoon in the basin (Table 1). Chloroform is a common byproduct of the chlorination of nutrient and organic carbon-rich wastewater. All other compounds extracted by this technique were not detected in concentrations above the analytical detection limit of 0.2 ug/L.

Semi-volatile and volatile organic compounds extracted by closed-loop stripping from Chisos Basin area water samples are shown in Table 2. Several monoaromatic compounds indicative of human activity, such as methyl benzene (toluene), an unidentified isomer of dimethyl benzene (xylene), and ethyl benzene were detected in the first CLS sample (8/23/87) collected from Oak Spring but not in a duplicate sample or in a sample collected two days later. Despite the presence of toluene and xylene in the sample collected from the sewage lagoon, these results do not draw a definite connection between waste disposal practices in the basin and ground-water quality at Oak Spring because of the poor reproducibility between samples. Alternate hypotheses for the intermittent occurence of the alkyl benzene compounds include their use as solvents in insecticide delivery or from unaccounted small spills of gasoline or petroleum products near the sampled sites.

Water Quality of Oak Spring and Chisos Basin Ground Water

The quality of water at the sites sampled during this study was evaluated by comparing the results of the chemical analysis (Tables 1 and 2) to the regulations enforced by the U. S. Environmental Protection Agency (EPA) as standards for public water systems (Table 3). The only dissolved constituent to consistently exceed its maximum contaminant level was fluoride. The only location where fluoride did not exceed the EPA maximum contaminant level was Cattail Springs during the 1966 and 1986 samplings (Table 1). The activity of gross alpha radiation at Oak Spring (21 picocuries per liter (pCi/L) was also found to exceed the maximum concentration permitted for drinking water by the Texas Department of Health. The occurrence of both fluoride and gross alpha radiation in ground water are thought to be related to the aquifer mineralogy and not to any human activities in the park. No other constituents were found to approach or exceed EPA enforcement standards or guidelines except mercury at Oak Spring (0.1 ug/L).

Drilling

The two most logical areas in terms of yielding hydrogeological information on possible aquifers supplying Oak Spring are the Chisos Basin and Oak Spring vicinity. Test drilling was judged to be vital in supplying such data in critical places due to the lack of existing wells or test holes.

The Chisos Basin was drilled first, because the potential for contamination--primarily the sewage lagoons--is centered here. If the lagoons are not contaminating the local ground-water system in Chisos Basin, then the influence of possible leakage of the lagoons on Oak Spring is essentially insignificant or non-existant.

Four test holes were drilled in August 1987 in Chisos Basin along Oak Creek (figure 9). Three of the holes were completed as monitoring wells.

The well-construction methods and materials are as follows: hole diameter is 6 inches; casing is nominal 2-inch PVC schedule 80 (1-7/8-inch inside diameter and 2-3/8-inch outside diameter); screen is mill-slotted 10-foot length PVC of the nominal size of the casing; well is gravel-packed opposite the screen with the top of the sand sealed with one sack of bentonite; hole is back-filled with cuttings; and a short section of 4-inch steel casing is set and cemented in the hole over the PVC casing for surface protection. The steel casing sticks up 2-3 feet above the land surface and has a hinged cap and lock.

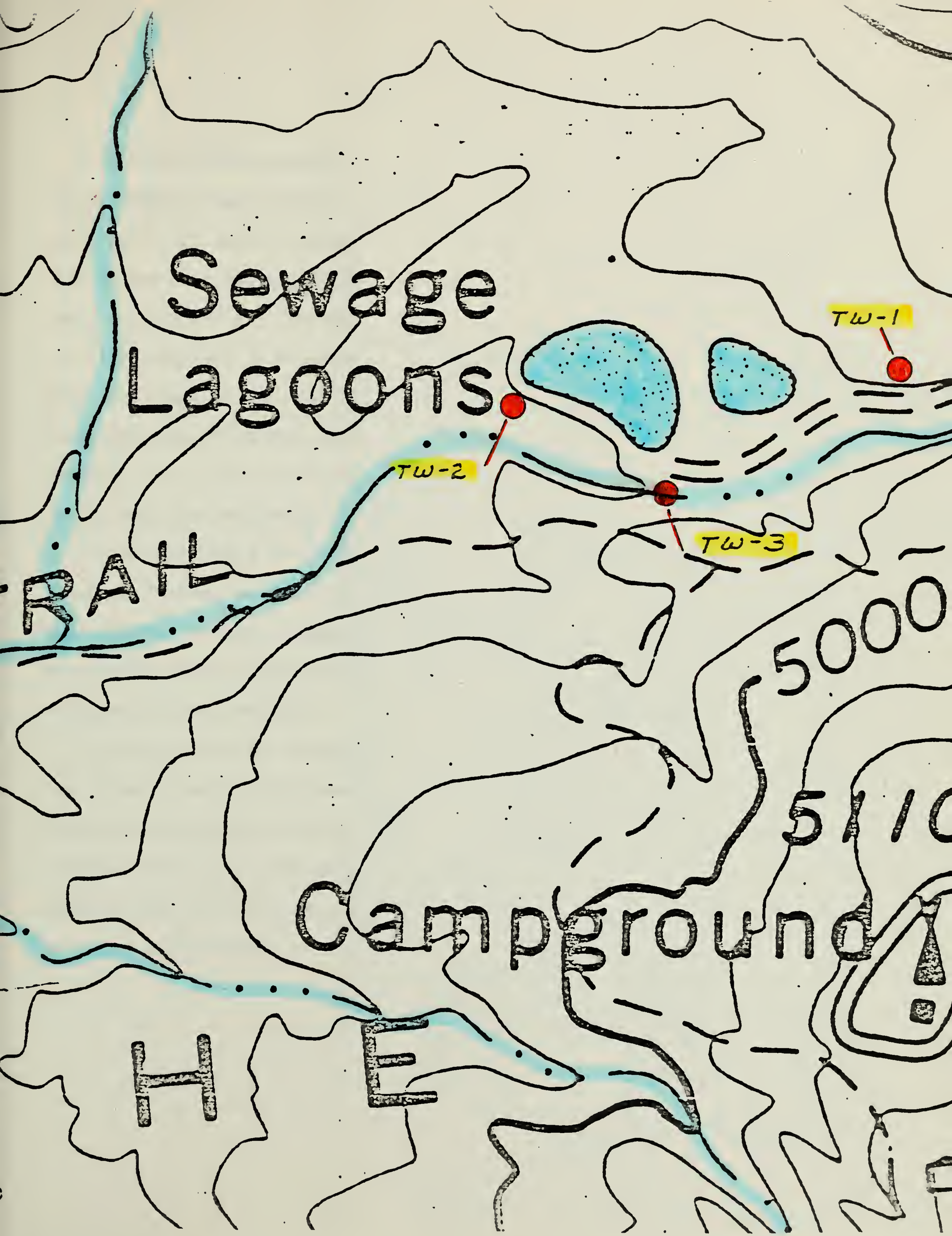


FIGURE 9.--OAK CREEK AREA IN CHISOS BASIN SHOWING LO

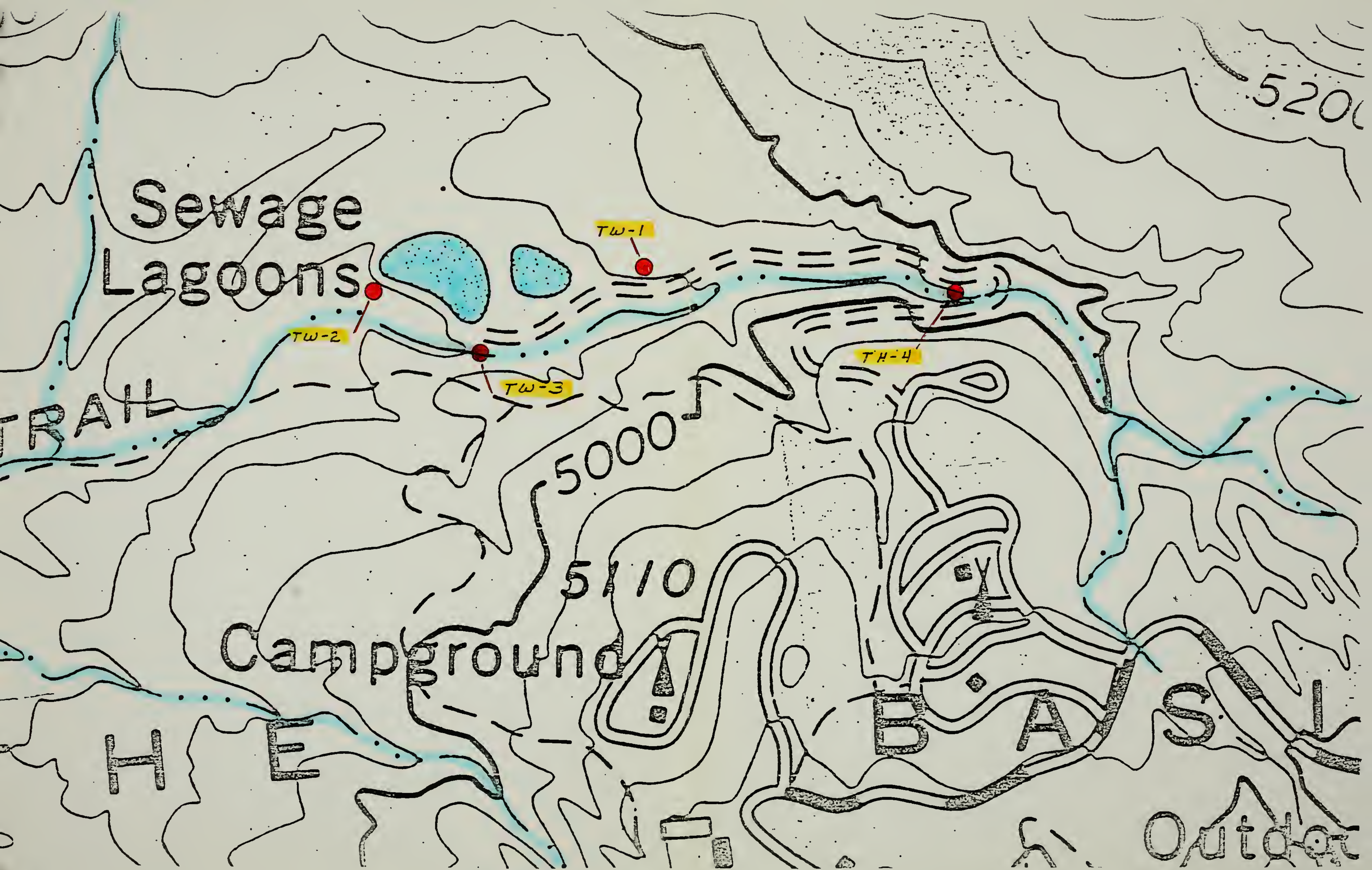


FIGURE 9.--OAK CREEK AREA IN CHISOS BASIN SHOWING LOCATIONS OF MONITORING WELLS AND TEST HOLE DRILLED

Test well TW-1 is about 750 feet west (down-creek) from the lower CCC well (BK-73-46-803), about 300 feet east of the small (upper) lagoon, and about 50 feet north of Oak Creek channel. The well depth is 46 feet with the bottom 5 feet in red clay (Aguja? bedrock). The unconsolidated fill material from the land surface to 41 feet was dry.

Test well TW-2 is at the western end of the large lower lagoon, 45 feet from the lagoon leeve, and 33 feet north of Oak Creek channel. The well depth is 56 feet with the bottom 23-24 feet in red clay and rhyolite stringers (Aguja? bedrock). The basin fill material from the land surface to 32-33 feet was dry with no moisture encountered.

Test well TW-3 is in the channel of Oak Creek about 300 feet up-creek (east) of TW-2 and southwest of the east end of the large (lower) lagoon. The well depth is 44 feet with the bottom 2 feet in red clay (Aguja? bedrock). Some minor moisture but no water was encountered in the basin fill material, and the well was dry when completed.

Test hole TH-4 was not made into a well. It was drilled in the channel of Oak Creek about 110 feet downcreek (west) of the lower CCC well. The depth of the hole is 27 feet, and the bedrock surface of red clay and rhyolite is believed to be at a depth of from 21 to 26 feet. The unconsolidated basin fill material down to 21 feet was very moist in places, but the hole did not encounter any saturation.

The drilling results were surprising. We anticipated the presence of saturation in the unconsolidated fill material and assumed that it was a shallow aquifer that may have been receiving seepage outflow from the sewage lagoons. All of the holes drilled were dry; well TW-1 retains about 1 foot of water, but this may be residual drilling fluid that was used or water that was poured into the hole and remains trapped by the tight clay into which the hole was bottomed. The perplexing thing is that the lower CCC well which is about 30 feet deep and has about 18-20 feet of water in it probably represents the water table in the basin fill material at that site. Our last test hole TH-4 only about 110 feet down-creek, where the land surface has an elevation about equal to that of the water table in the CCC well, encountered no free water.

The drilling program in Chisos Basin indicates that a shallow aquifer does not exist in the fill material along that portion of Oak Creek where the lagoons are located. The deepest fill material is believed to be along the axis of Oak Creek, and this is where the test drilling was concentrated. Bedrock was shallower than expected, and the overlying unconsolidated fill material was not saturated at the sites drilled. A major reservoir of underground shallow water is not present, and Chisos Basin apparently does not and cannot supply a large amount of ground water to the only outlet of the Basin, namely the Window Pouroff. The source of water for Oak Spring may not be Chisos Basin but may be more locally centered near the spring. The fact that wells TH-2 and TH-3 are adjacent to the large sewage lagoon and encountered no saturation in the fill material in which the lagoons are located indicates little or no leakage is occurring and that no pollution plume has developed or is moving in the fill material toward the Window in Chisos Basin.

Seismic

Oak Spring Line

The Oak Spring line consists of one geophone spread located west of Chisos Basin on a hiking trail that parallels Oak Creek approximately 250 feet north of the creek (fig. 10). The line covers the distinct "green band" of vegetation thah brackets Oak Spring on the north slope of Oak Creek. For reasons of archeological integrity, the line was restricted to the hiking trail, and the precise location of the shot holes was inspected in the field and cleared by Mike Fleming, NPS.

The line configuration is composed of 12 geophones set 20 feet apart in a straight, approximately east-west line; shot points A and B are 95 feet and 25 feet, respectively, west of the westernmost geophone, and shot points C and D are 39 feet and 119 feet, respectively, east of the easternmost geophone. There was 50 feet of topographic relief in the line, with shot point A about 50 feet lower than shot point D.

The travel-time plot of first-break arrivals from the Oak Spring line suggests that a three-layer earth model should be assumed for the seismic interpretation. Layer 1 has an assigned velocity of 1,500 ft/s (feet per second) and corresponds to an unsaturated alluvium layer. Layer 2 has a velocity averaging about 4,100 ft/s, and, although that is a somewhat slow velocity, the layer is assumed to correspond to a saturated alluvium layer. Layer 3 has a velocity averaging about 7,400 ft/s and corresponds to bedrock. The interfaces between layers 1 and 2 and between layers 2 and 3 represent the water table and the bedrock surface, respectively.

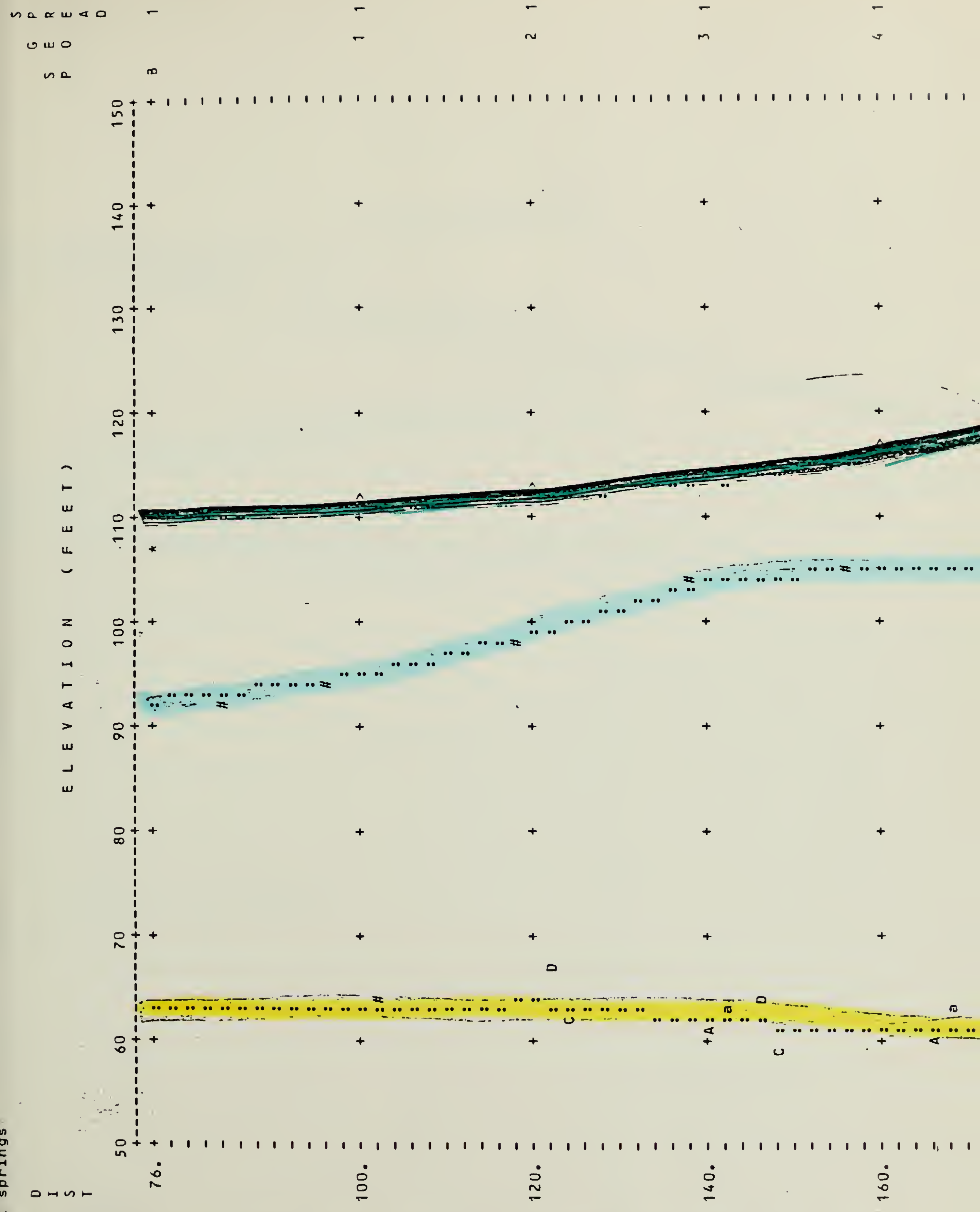


FIGURE 10.—SEISMIC DEPTH PROFILE SHOWING BEDROCK SURFACE, INTERPRETED WATER TABLE, AND LAND SURFACE IN OAK SPRING AREA

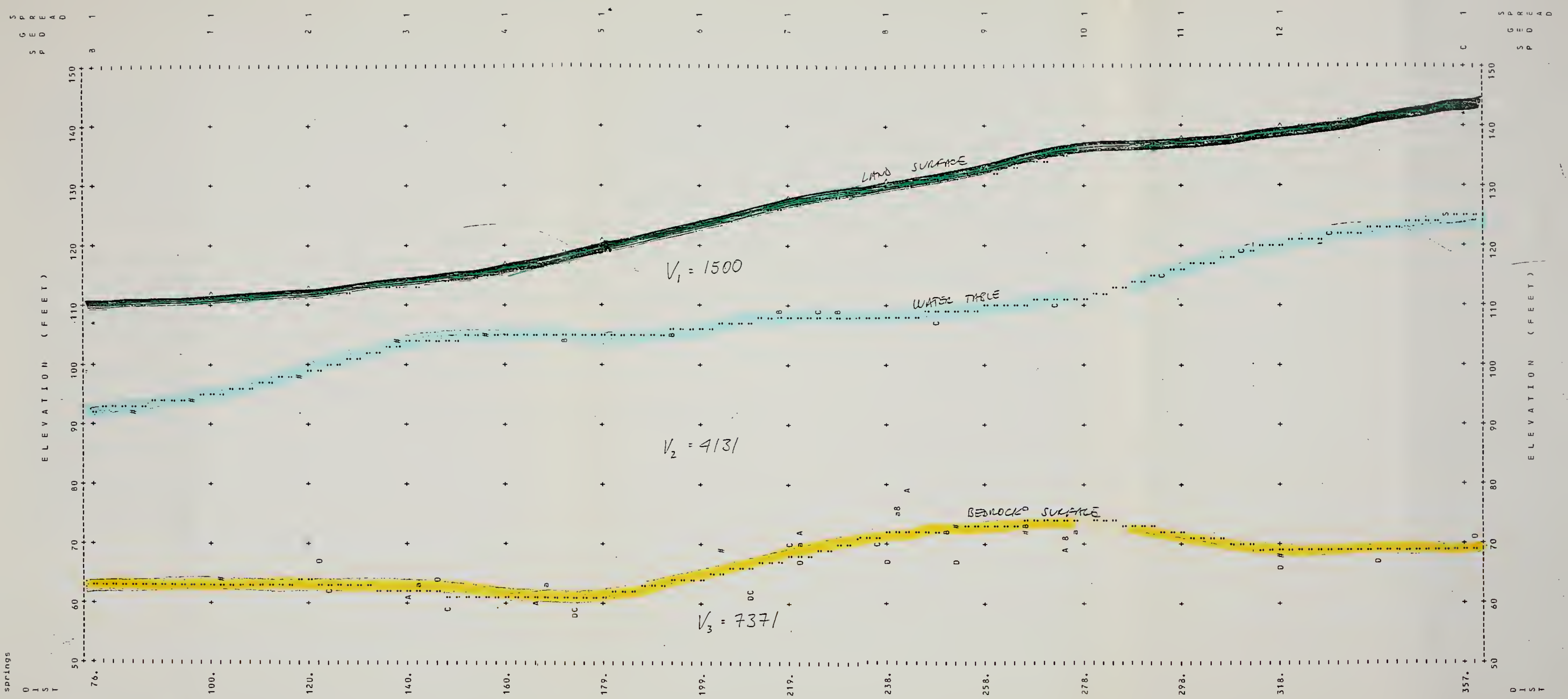


FIGURE 10.—SEISMIC DEPTH PROFILE SHOWING BEDROCK SURFACE, INTERPRETED WATER TABLE, AND LAND SURFACE IN OAK SPRING AREA

Interpretation of the Oak Spring line indicates that the bedrock surface is fairly regular and slopes gently to the west. Depth to the bedrock surface ranges from about 47 feet beneath shot point B to about 75 feet beneath shot point C (fig. 10). The water table roughly parallels the land surface at a depth from 18 to 24 feet, except beneath geophone 3 where the water table appears to be mounded to a depth of about 9 feet below the land surface (fig. 10).

Lagoon Line

The Lagoon line consists of three geophone spreads located on a service road thah leads to the sewage lagoons. The line extends from about 200 feet east of monitoring well TW-1 to about 90 feet west of the lower CCC well encasement, a line distance of 700 feet. See figure 11.

The line configuration is composed of three overlapping spreads, each spread consisting of 12 geophones set 20 feet apart in a generally straight east-west line. The easternmost geophone of the westerly spread became the westernmost geophone of the next successive spread, thus providing for overlapping coverage. Each spread was shot with four shot points. There was 55 feet of topographic relief in the line, with shot point A (the westernmost shot point) about 55 feet lower than shot point L (the easternmost shot point). Shot point L was located 5 feet west of the CCC well encasement.

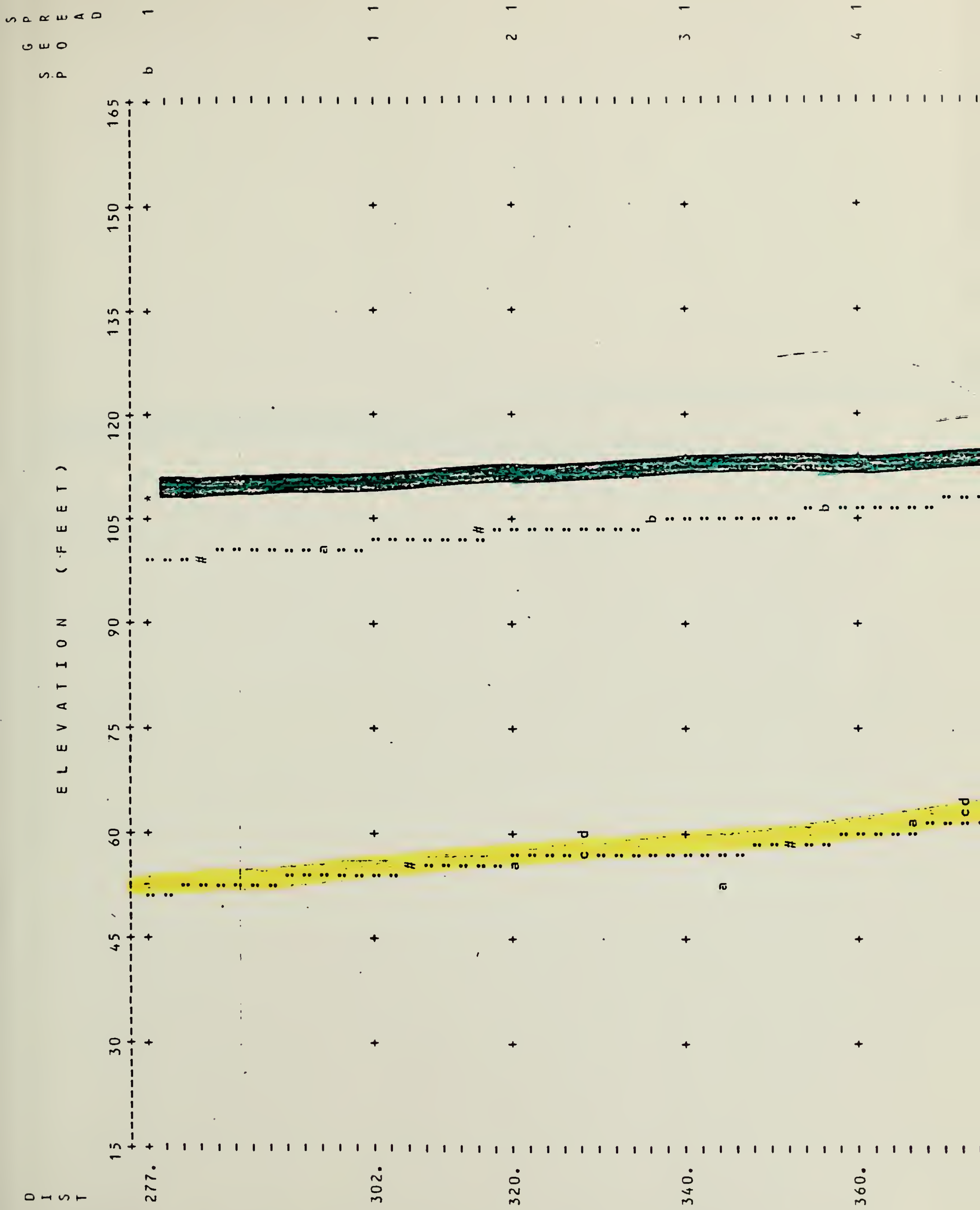


FIGURE *11.*—SEISMIC DEPTH PROFILE SHOWING BEDROCK SURFACE, INTERPRETED WATER TABLE, AND LAND SURFACE IN LAGOON AREA

The travel-time plot of first break arrivals from the Lagoon line suggests that a three-layer earth model should be assumed for seismic interpretation. Layer 1 has an average velocity of about 1,500 ft/s and corresponds to an unsaturated alluvium layer. Layer 2 has a velocity averaging about 2,700 ft/s, and is assumed to correspond to a higher velocity unsaturated alluvium layer. The average velocity for saturated, unconsolidated material ranges from 4,000 ft/s to about 6,000 ft/s. Layer 3 has a velocity averaging about 6,500 ft/s and corresponds to bedrock. The interface between layers 2 and 3 represents the bedrock surface.

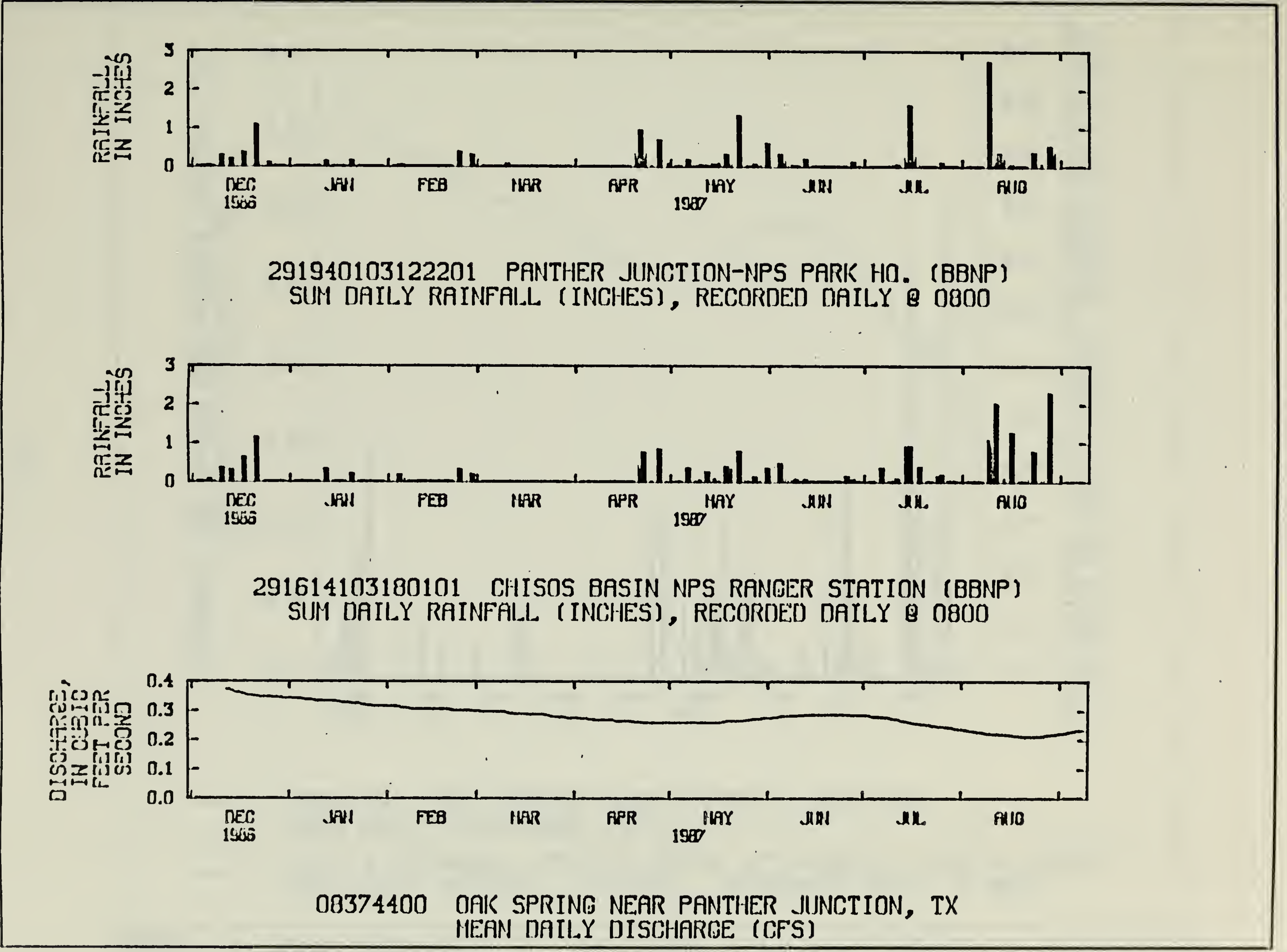
Interpretation of the Lagoon line indicates that the bedrock surface is fairly regular and slopes gently to the west. Depth to the bedrock surface ranges from about 58 feet at the western end of the line to about 30 feet at the eastern end (fig.). Monitoring well TW-1, about 200 feet west of the end of the line, encountered bedrock at a depth of about 41 feet. Although there is not a distinct indication of a saturated alluvial layer present, it is possible that a thin saturated layer could exist above the bedrock, as a thin intermediate layer can exist in the subsurface and yet not be detected by refraction techniques. The average velocity for saturated, unconsolidated material (4,000 ft/s to 6,000 ft/s) is close to the average velocity of the bedrock under the line (6,500 ft/s), and a saturated layer less than 10 feet thick overlying the bedrock could exist and remain undetected by our survey.

Continuous Springflow Monitoring

Continuous monitoring of the flow of Oak Spring began December 12, 1986 when the National Park Service installed a Stevens Type A recorder on a newly constructed concrete weir box at the spring site. From that time to the present, continuous flow rates have been recorded.

Figure 12 shows graphically the daily discharge of Oak Spring from December 1986 to September 1987 along with daily rainfall at the Chisos Basin and Panther Junction rainfall stations for the same time period. During the 9-month period of continuous springflow records, flow rates of Oak Spring declined from a high of 167 GPM (gallons per minute) December 12, 1986 to 115 GPM in late April 1987, recovered to 129 GPM in mid June, declined to a low of 94 GPM in late August, and finally started a sharp recovery to 105 GPM September 9 ~~snf~~ and 10, 1987.

The recorder chart was pulled September 10 at which time flow was still increasing. Figure 13, which shows (in expanded scale) the springflow at Oak Spring and the rainfall at the Chisos Basin ranger station from December 1986 to September 1987, provides conclusive evidence of the close relationship of springflow with rainfall. The high flow of 167 GPM in December 1986 is due to the record high rainfall earlier in 1986. (Some 33 inches were recorded in Chisos Basin in 1986.) Springflow continued to decline in 1987 from decreased rainfall (relative to 1986) until fairly heavy rainfall in April and May caused the flow to reach an interim peak in June. The rainfall-springflow relationship repeats itself from June to September, when very heavy August rainfall causes an upturn in flow beginning in late August and continuing to the end of the period of record in early September. A lag time of about one month appears to be normal, with the driving force behind springflow being local rainfall. The fairly rapid response of flow to rainfall indicates a shallow aquifer, effective recharge areas, and highly permeable aquifer material.



291940103122201 PANTHER JUNCTION-NPS PARK HQ. (BBNP)
SUM DAILY RAINFALL (INCHES), RECORDED DAILY @ 0800

291614103180101 CHISOS BASIN NPS RANGER STATION (BBNP)
SUM DAILY RAINFALL (INCHES), RECORDED DAILY @ 0800

08374400 OAK SPRING NEAR PANTHER JUNCTION, TX
MEAN DAILY DISCHARGE (CFS)

FIGURE 12-- DAILY DISCHARGE OF OAK SPRING AND DAILY RAINFALL IN CHISOS BASIN AND PANTHER JUNCTION, DECEMBER 1986 TO SEPTEMBER 1987

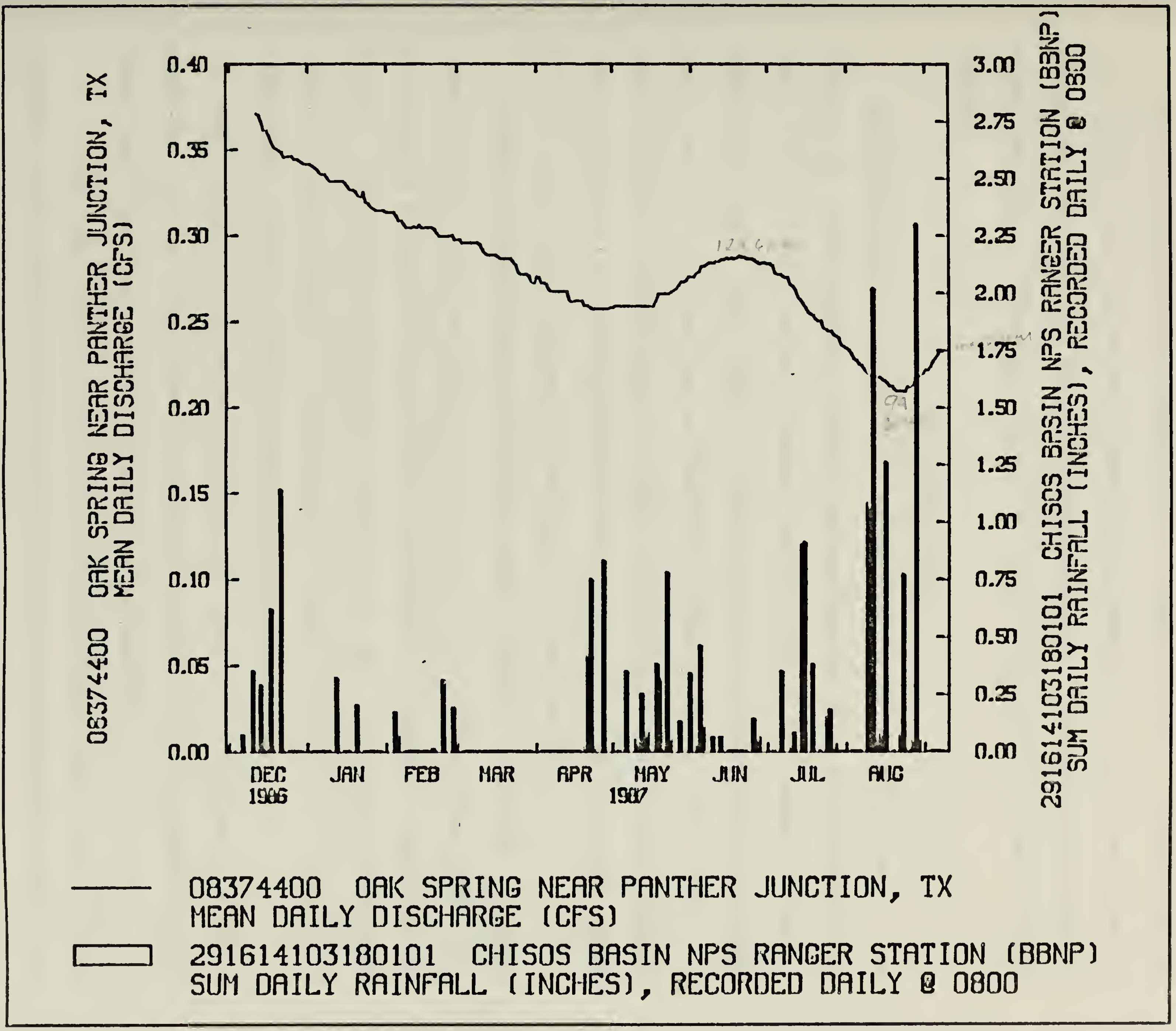


FIGURE 13.-- DAILY DISCHARGE OF OAK SPRING AND DAILY RAINFALL IN CHISOS BASIN, DECEMBER 1986 TO SEPTEMBER 1987

Close inspection of the recorder chart indicates diurnal fluctuations in flow every 24 hours during the warmer growing seasons with slight reductions in springflow from about 1200 hours to about 1600 hours. This may be attributed to evapotranspiration affecting the aquifer during this typically warmest part of the day.

Future Work Plans

Work activities in FY-88 will be concentrated in the Oak Spring area. The results of investigations in Chisos Basin primarily, along with secondary efforts at Oak Spring, provided valuable hydrologic data of the lagoon area and a chance to relate these data to the chemistry of the water and the flow Oak Spring and to the hydrogeology as revealed by seismic results. The lack of a shallow aquifer in Chisos Basin, at least in the vicinity of the sewage lagoons, shifts attention to the Oak Spring area and the possibility of an aquifer system of fairly local extent that may be the supplier of Oak Spring.

Detailed geologic mapping in the Oak Spring vicinity, followed by additional seismic work and finally the drilling of several test holes, which will be completed as monitoring wells, should delineate the aquifer supplying Oak Spring. Additional water-quality sampling of Oak Spring along with tracer studies using the network of monitoring wells should provide confirmation of the flow paths, velocity, and age of the Oak Spring water supply.

Much of the data collected through FY 87 and its significance will be presented in two brief open-file reports. One report will be centered around water quality and the other will present the hydrogeology.

A final comprehensive report in the USGS Water-Supply Paper series will be prepared early in FY 89 and will present all of the findings and the basic data generated during the project.

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Table 1.--Water-quality data for selected locations, Chisos Basin area, 1953-1987.

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10-21-87
MULTIPLE STATION ANALYSES

LOCAL IDENT- I- FIER	STATION NUMBER	GEO- LOGIC UNIT	DATE	TIME	TEMPER- ATURE WATER (DEG C) (00010)	STREAM- FLOW, INSTAN- TANEOUS (CFS) (00061)	SPE- CIFIC CON- DUCT- ANCE (US/CM) (00095)	OXYGEN, DIS- SOLVED (MG/L) (00300)	OXYGEN, DIS- SOLVED (PER- CENT SATUR- ATION) (00301)
BK-73-46-701 OAK SPRING	291655103200101	120IGNS	12-02-53	1200	20.5	0.06	310	--	--
		120IGNS	03-09-54	1200	--	0.04	322	--	--
		120IGNS	07-02-54	1200	--	--	328	--	--
		120IGNS	08-06-54	1200	--	--	315	--	--
		120IGNS	07-13-60	1200	--	--	301	--	--
		120IGNS	06-25-64	1200	--	0.07	305	--	--
		120IGNS	03-12-65	1200	--	0.02	320	--	--
		120IGNS	04-19-69	1200	--	--	336	--	--
		120IGNS	03-15-83	1200	19.0	--	--	7.8	8
		120IGNS	08-15-83	1200	19.0	--	--	7.2	7
		120IGNS	06-24-86	1300	19.5		368	--	--
		120IGNS	08-24-87	1400	--	--	--	--	--
		120IGNS	08-26-87	1045	--	--	--	--	--
BK-73-46-702 Cattail Falls	291624103200101		03-09-54	1200	--	--	569	--	--
		120IVIG	07-17-66	1200	--	0.11	115	--	--
		120IGNS	06-25-86	1630	19.5	5.0	91	--	--
		120IVIG	08-15-87	1200	--	--	--	--	--
BK-73-46-803	291642103180601	110ALVM	06-20-61	1200	--	--	235	--	--
		110ALVM	06-25-64	1200	--	--	221	--	--
		110ALVM	03-12-65	1200	20.0	--	240	--	--
		110ALUV	06-26-86	1330	20.5	--	246	5.3	--
		110ALVM	08-25-87	1000	21.5	--	226	--	--
		110ALVM	08-25-87	1430	--	--	--	--	--
NPS BIG BEND SEWAGE LAGOONS	291642103184601		06-24-86	1630	25.0	--	611	--	--
			08-26-87	1430	25.5	--	498	--	--
			08-26-87	1430	--	--	--	--	--
BK-73-46-804 WINDOW SPRING	291647103194401	110ALVM	05-10-72	0900	--	0.07	482	--	--
		110ALUV	06-25-86	1510	21.0	0.02	295	--	--
		110ALVM	08-25-87	1438	--	--	--	--	--

Table 1.--Water-quality data for selected locations, Chisos Basin area, 1953-1987--Continued

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY   PROCESS DATE 10-21-87
MULTIPLE STATION ANALYSES

LOCAL IDENT- I- FIER	BARO- METRIC PRES- SURE (MM OF HG) (00025)	PH (STAND- ARD UNITS) (00400)	ALKA- LINITY WH WAT TOTAL FIELD MG/L AS CACO3 (00410)	CARBON DIOXIDE DIS- SOLVED (MG/L AS CO2) (00405)	HARD- NESS (MG/L AS CACO3) (00900)	HARD- NESS NONCARB WH WAT TOT FLD MG/L AS CACO3 (00902)	CALCIUM DIS- SOLVED (MG/L AS CA) (00915)	MAGNE- SIUM, DIS- SOLVED (MG/L AS MG) (00925)	SODIUM, DIS- SOLVED (MG/L AS NA) (00930)
BK-73-46-701	--	7.80	114	3.5	110	0	38	2.7	--
	--	7.50	114	7.0	100	0	38	2.1	--
	--	7.60	113	5.5	97	--	--	--	--
	--	7.60	113	5.5	100	--	--	--	--
	--	7.20	110	13	100	0	37	1.8	
	--	7.00	112	22	110	0	40	1.5	--
	--	8.10	110	1.7	110	0	40	1.5	27
	--	7.30	116	11	110	0	42	2.0	--
	--	7.48	125	8.0	140	13	53	1.3	28
	--	7.57	127	6.6	130	4	51	1.3	28
	746	7.10	120	18	130	6	47	2.0	28
	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--
BK-73-46-702	--	8.00	150	2.9	190	38	70	3.3	--
	--	6.70	18	7.0	35	17	--	--	--
	--	6.54	8	4.5	31	23	11	0.93	4.6
	--	--	--	--	--	--	--	--	--
BK-73-46-803	--	6.90	93	23	59	0	22	1.0	--
	--	6.80	89	27	58	0	22	0.80	--
	--	7.60	97	4.7	61	0	24	0.20	27
	723	6.60	98	48	67	0	25	1.0	28
	--	7.30	100	9.7	--	--	--	--	--
	--	--	--	--	--	--	--	--	--
NPS BIG BEND SEWAGE LAGOONS	--	9.60	93	0.0	65	0	23	1.8	81
	--	9.50	107	0.1	--	--	--	--	--
	--	--	--	--	--	--	--	--	--
BK-73-46-804	--	7.60	190	9.2	150	0	57	2.8	--
	--	6.30	162	157	170	10	64	2.7	22
	--	--	--	--	--	--	--	--	--

Table 1.--Water-quality data for selected locations, Chisos Basin area, 1953-1987--Continued.

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10-21-87
MULTIPLE STATION ANALYSES

LOCAL IDENT-I-FIER	POTASSIUM, DIS-SOLVED (MG/L AS K) (00935)	SODIUM+POTASSIUM DIS-SOLVED (MG/L AS NA) (00933)	CHLORIDE, DIS-SOLVED (MG/L AS CL) (00940)	SULFATE DIS-SOLVED (MG/L AS SO4) (00945)	FLUORIDE, DIS-SOLVED (MG/L AS F) (00950)	SILICA, DIS-SOLVED (MG/L AS SIO2) (00955)	IODIDE, DIS-SOLVED (MG/L AS I) (71865)	BROMIDE DIS-SOLVED (MG/L AS BR) (71870)	SOLIDS, SUM OF CONSTITUENTS, DIS-SOLVED (MG/L) (70301)
BK-73-46-701	--	38	5.5	29	13	28	--	--	210
	--	28	5.5	30	3.6	28	--	--	210
	--	--	6.2	--	3.6	--	--	--	--
	--	--	5.5	--	3.6	--	--	--	--
	--	29	7.5	30	3.3	24	--	--	210
	--	26	4.5	32	3.5	27	--	--	200
	0.80	--	5.2	32	3.2	28	--	--	200
	--	--	5.1	35	--	--	--	--	--
	0.87	--	12	52	--	13	--	--	240
	0.69	--	12	47	--	13	--	--	230
	0.80	--	9.0	43	3.0	27	0.001	0.092	230
	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--
BK-73-46-702	--	54	5.8	120	6.0	49	--	--	410
	--	--	2.6	23	1.5	--	--	--	--
	1.4	--	3.5	24	1.1	25	--	<0.010	76
	--	--	--	--	--	--	--	--	--
BK-73-46-803	--	28	5.8	9.0	2.6	34	--	--	160
	--	28	5.2	13	3.0	30	--	--	160
	0.70	28	5.2	10	2.8	31	--	--	160
	0.50	--	6.5	14	2.4	30	--	0.074	170
	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--
NPS BIG BEND SEWAGE LAGOONS	17	--	56	89	2.0	32	--	<0.010	360
	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--
BK-73-46-804	--	49	11	41	3.5	37	--	--	320
	2.3	--	8.8	41	2.3	34	--	0.033	270
	--	--	--	--	--	--	--	--	--

Table 1.--Water-quality data for selected locations, Chisos Basin area, 1953-1987--Continued.

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10-15-87
MULTIPLE STATION ANALYSES

LOCAL IDENT-I-FIER	STATION NUMBER	DATE	TIME	NITRO-GEN, TOTAL (MG/L AS N) (00600)	NITRO-GEN, ORGANIC TOTAL (MG/L AS N) (00605)	NITRO-GEN, AMMONIA TOTAL (MG/L AS N) (00610)	NITRO-GEN, AM-MONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITRO-GEN, NITRITE TOTAL (MG/L AS N) (00615)	NITRO-GEN, NITRATE TOTAL (MG/L AS N) (00620)
BK-73-46-701	291655103200101	12-02-53	1200	--	--	--	--	--	--
		03-09-54	1200	--	--	--	--	--	--
		07-02-54	1200	--	--	--	--	--	--
		08-06-54	1200	--	--	--	--	--	--
		07-13-60	1200	--	--	--	--	--	--
		06-25-64	1200	--	--	--	--	--	--
		03-12-65	1200	--	--	--	--	--	--
		04-19-69	1200	--	--	--	--	--	--
		06-24-86	1300	--	--	<0.010	<0.20	<0.010	--
		08-24-87	1400	--	--	--	--	--	--
		08-26-87	1045	--	--	--	--	--	--
BK-73-46-702	291624103200101	03-09-54	1200	--	--	--	--	--	--
		07-17-66	1200	--	--	--	--	--	--
		06-25-86	1630	1.0	0.78	0.020	0.80	<0.010	--
		08-15-87	1200	--	--	--	--	--	--
BK-73-46-803	291642103180601	06-20-61	1200	--	--	--	--	--	--
		06-25-64	1200	--	--	--	--	--	--
		03-12-65	1200	--	--	--	--	--	--
		06-26-86	1330	1.3	0.28	0.020	0.30	<0.010	--
		08-25-87	1000	--	--	--	--	--	--
		08-25-87	1430	--	--	--	--	--	--
NPS BIG BEND SEWAGE LAGOONS	291642103184601	06-24-86	1630	7.6	4.3	0.160	4.5	0.450	2.65
		08-26-87	1430	--	--	--	--	--	--
		08-26-87	1430	--	--	--	--	--	--
BK-73-46-804	291647103194401	05-10-72	0900	--	--	--	--	--	--
		06-25-86	1510	--	--	<0.010	<0.20	<0.010	--
		08-25-87	1438	--	--	--	--	--	--

Table 1.--Water-quality data for selected locations, Chisos Basin area, 1953-1987--Continued.

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10-15-87
MULTIPLE STATION ANALYSES

LOCAL IDENT-I-FIER	NITRO-GEN, NO2+NO3 TOTAL (MG/L AS N) (00630)	PHOS-PHORUS, TOTAL (MG/L AS P) (00665)	PHOS-PHORUS, ORTHO, DIS-SOLVED (MG/L AS P) (00671)	PHOS-PHORUS, ORTHO, TOTAL (MG/L AS P) (70507)	CARBON, ORGANIC TOTAL (MG/L AS C) (00680)	CARBON, INOR-GANIC, TOTAL (MG/L AS C) (00685)	METHY-LENE BLUE ACTIVE SUB-STANCE (MG/L) (38260)	COLI-FORM, FECAL, 0.7 UM-MF (COLS./100 ML) (31625)	STREP-TOCOCCI FECAL, KF AGAR (COLS. PER 100 ML) (31673)
BK-73-46-701	0.900	--	--	--	--	--	--	--	--
	0.800	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--
	0.900	--	--	--	--	--	--	--	--
	0.600	--	--	--	--	--	--	--	--
	0.900	--	--	--	--	--	--	--	--
	0.900	--	<0.010	--	--	--	--	--	--
	1.30	<0.010	--	<0.010	0.1	26	0.04	8	9
	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	0.02	--	--
BK-73-46-702	<0.100	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--
	0.200	0.010	--	<0.010	--	--	--	--	--
	--	--	--	--	--	--	--	--	--
BK-73-46-803	0.400	--	--	--	--	--	--	--	--
	0.400	--	--	--	--	--	--	--	--
	0.400	--	--	--	--	--	--	--	--
	1.00	0.020	--	0.010	--	--	0.04	--	--
	--	--	--	--	--	--	0.02	--	--
	--	--	--	--	--	--	0.03	--	--
NPS BIG BEND SEWAGE LAGOONS	3.10	0.860	--	0.340	28	14	0.11	<1	700
	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	0.14	--	--
BK-73-46-804	0.600	--	--	--	--	--	--	--	--
	0.800	0.010	--	<0.010	2.2	28	0.05	--	--
	--	--	--	--	--	--	--	--	--

Table 1.--Water-quality data for selected locations, Chisos Basin area, 1953-1987--Continued.

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10-15-87
MULTIPLE STATION ANALYSES

LOCAL IDENT-I-FIER	STATION NUMBER	DATE	TIME	ARSENIC DIS-SOLVED (UG/L AS AS) (01000)	BARIUM, DIS-SOLVED (UG/L AS BA) (01005)	BORON, DIS-SOLVED (UG/L AS B) (01020)	CADMIUM DIS-SOLVED (UG/L AS CD) (01025)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR) (01030)
BK-73-46-701	291655103200101	03-12-65	1200	--	--	130	--	--
		06-24-86	1300	1	8	70	1	<10
BK-73-46-702	291624103200101	06-25-86	1630	--	--	20	--	--
BK-73-46-803	291642103180601	03-12-65	1200	--	--	210	--	--
		06-26-86	1330	2	34	120	1	<10
NPS BIG BEND SEWAGE LAGOONS	291642103184601	06-24-86	1630	--	--	550	--	--
BK-73-46-804	291647103194401	06-25-86	1510	<1	49	70	1	<10

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10-15-87
MULTIPLE STATION ANALYSES

LOCAL IDENT-I-FIER	COPPER, DIS-SOLVED (UG/L AS CU) (01040)	IRON, DIS-SOLVED (UG/L AS FE) (01046)	LEAD, DIS-SOLVED (UG/L AS PB) (01049)	MANGA-NESE, DIS-SOLVED (UG/L AS MN) (01056)	MERCURY DIS-SOLVED (UG/L AS HG) (71890)	SELE-NIUM, DIS-SOLVED (UG/L AS SE) (01145)	SILVER, DIS-SOLVED (UG/L AS AG) (01075)	STRON-TIUM, DIS-SOLVED (UG/L AS SR) (01080)	ZINC, DIS-SOLVED (UG/L AS ZN) (01090)
BK-73-46-701	--	--	--	--	--	--	--	--	--
	3	10	<5	<1	0.1	2	<1	350	40
BK-73-46-803	--	--	--	--	--	--	--	--	--
	4	13	<5	2	<0.1	1	<1	110	17
BK-73-46-804	4	8	<5	2	<0.1	1	<1	490	15

Table 1.--Water-quality data for selected locations, Chisos Basin area, 1953-1987--Continued.

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10-15-87
MULTIPLE STATION ANALYSES

LOCAL IDENT-I-FIER	STATION NUMBER	DATE	TIME	URANIUM DIS-SOLVED, EXTRAC-TION (UG/L) (80020)	RADIUM 226, DIS-SOLVED, RADON METHOD (PCI/L) (09511)
BK-73-46-701	291655103200101	06-24-86	1300	9.9	0.06

LOCAL IDENT-I-FIER	GROSS ALPHA, DIS-SOLVED (UG/L AS U-NAT) (80030)	GROSS ALPHA, SUSP. TOTAL (UG/L AS U-NAT) (80040)	GROSS BETA, DIS-SOLVED (PCI/L AS CS-137) (03515)	GROSS BETA, SUSP. TOTAL (PCI/L AS CS-137) (03516)	GROSS BETA, DIS-SOLVED (PCI/L AS SR/YT-90) (80050)	GROSS BETA, SUSP. TOTAL (PCI/L AS SR/YT-90) (80060)
BK-73-46-701	21	<1.0	4.2	1.4	3.5	1.4

Table 1.--Water-quality data for selected locations, Chisos Basin area, 1953-1987--Continued.

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10-21-87
MULTIPLE STATION ANALYSES

LOCAL IDENT-I-FIER	STATION NUMBER	DATE	TIME	C-13 / C-12 STABLE ISOTOPE RATIO PER MIL (82081)	H-2 / H-1 STABLE ISOTOPE RATIO PER MIL (82082)	N-15 / N-14 STABLE ISOTOPE RATIO PER MIL (82084)	O-18 / O-16 STABLE ISOTOPE RATIO PER MIL (82085)	CARBON 14 PERCENT MODERN (82172)	TRITIUM IN WATER MOLE-CULES (TU) (07012)
BK-73-46-701	291655103200101	03-15-83	1200	-11.1	-46.0	--	-6.9	99.0	35.0
		06-24-86	1300	-11.2	-37.0	5.5	-6.9	99.9	6.3
BK-73-46-702	291624103200101	06-25-86	1630	--	-31.0	--	-5.9	--	--
BK-73-46-803	291642103180601	06-26-86	1330	--	-51.0	--	-8.1	--	--
BK-73-46-804	291647103194401	06-25-86	1510	--	-38.0	5.2	-6.3	--	--

Table 1.--Water-quality data for selected locations, Chisos Basin area, 1953-1987--Continued.

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10-15-87
MULTIPLE STATION ANALYSES

LOCAL IDENTIFIER	STATION NUMBER	DATE	TIME	PCB, TOTAL (UG/L) (39516)	NAPHTHALENES, POLYCHLOR. TOTAL (UG/L) (39250)	ALDRIN, TOTAL (UG/L) (39330)	CHLORDANE, TOTAL (UG/L) (39350)
BK-73-46-701	291655103200101	06-24-86	1300	<0.1	<0.10	<0.010	<0.1
		08-24-87	1400	<0.1	<0.10	<0.010	<0.1

LOCAL IDENTIFIER	DDD, TOTAL (UG/L) (39360)	DDE, TOTAL (UG/L) (39365)	DDT, TOTAL (UG/L) (39370)	DIAZINON, TOTAL (UG/L) (39570)	DIELDRIN TOTAL (UG/L) (39380)	ENDOSULFAN, TOTAL (UG/L) (39388)	ENDRIN, TOTAL (UG/L) (39390)	ETHION, TOTAL (UG/L) (39398)
BK-73-46-701	<0.010	<0.010	<0.010	<0.01	<0.010	<0.010	<0.010	<0.01
	<0.010	<0.010	<0.010	<0.01	<0.010	<0.010	<0.010	<0.01

LOCAL IDENTIFIER	HEPTACHLOR, TOTAL (UG/L) (39410)	HEPTACHLOR EPOXIDE TOTAL (UG/L) (39420)	LINDANE TOTAL (UG/L) (39340)	MALATHION, TOTAL (UG/L) (39530)	METHOXYCHLOR, TOTAL (UG/L) (39480)	METHYL PARATHION, TOTAL (UG/L) (39600)	METHYL TRITHION, TOTAL (UG/L) (39790)	MIREX, TOTAL (UG/L) (39755)
BK-73-46-701	<0.010	<0.010	<0.010	<0.01	<0.01	<0.01	<0.01	<0.01
	<0.010	<0.010	<0.010	<0.01	<0.01	<0.01	<0.01	<0.01

LOCAL IDENTIFIER	PARATHION, TOTAL (UG/L) (39540)	PERTHANE TOTAL (UG/L) (39034)	TOXAPHENE, TOTAL (UG/L) (39400)	TOTAL TRITHION (UG/L) (39786)	2,4-D, TOTAL (UG/L) (39730)	2, 4-DP TOTAL (UG/L) (82183)	SILVEX, TOTAL (UG/L) (39760)	2,4,5-T TOTAL (UG/L) (39740)
BK-73-46-701	<0.01	<0.1	<1	<0.01	<0.01	<0.01	<0.01	<0.01
	<0.01	<0.1	<1	<0.01	<0.01	<0.01	<0.01	<0.01

Table 1.--Water-quality data for selected locations, Chisos Basin area, 1953-1987--Continued.

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10-15-87
MULTIPLE STATION ANALYSES

LOCAL IDENT-I-FIER	STATION NUMBER	DATE	TIME	DI-CHLORO-BROMO-METHANE TOTAL (UG/L) (32101)	CARBON-TETRA-CHLO-RIDE TOTAL (UG/L) (32102)	1,2-DI-CHLORO-ETHANE TOTAL (UG/L) (32103)	BROMO-FORM TOTAL (UG/L) (32104)	CHLORO-DI-BROMO-METHANE TOTAL (UG/L) (32105)	CHLORO-FORM TOTAL (UG/L) (32106)
BK-73-46-701	291655103200101	08-24-87	1400	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
BK-73-46-803	291642103180601	08-25-87	1000	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
NPS BIG BEND SEWAGE LAGOONS	291642103184601	08-26-87	1430	<0.20	<0.20	<0.20	<0.20	<0.20	2.9
BK-73-46-804	291647103194401	08-25-87	1438	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10-15-87
MULTIPLE STATION ANALYSES

LOCAL IDENT-I-FIER	TOLUENE TOTAL (UG/L) (34010)	BENZENE TOTAL (UG/L) (34030)	CHLORO-BENZENE TOTAL (UG/L) (34301)	CHLORO-ETHANE TOTAL (UG/L) (34311)	ETHYL-BENZENE TOTAL (UG/L) (34371)	METHYL-BROMIDE TOTAL (UG/L) (34413)	METHYL-CHLO-RIDE TOTAL (UG/L) (34418)	METHYL-ENE CHLO-RIDE TOTAL (UG/L) (34423)	TETRA-CHLORO-ETHYL-ENE TOTAL (UG/L) (34475)	TRI-CHLORO-FLUORO-METHANE TOTAL (UG/L) (34488)
BK-73-46-701	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
BK-73-46-803	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
NPS BIG BEND SEWAGE LAGOONS	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
BK-73-46-804	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20

Table 1.--Water-quality data for selected locations, Chisos Basin area, 1953-1987--Continued.

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10-15-87
MULTIPLE STATION ANALYSES

LOCAL IDENT-I-FIER	1,1-DI-CHLORO-ETHANE TOTAL (UG/L) (34496)	1,1-DI-CHLORO-ETHYL-ENE TOTAL (UG/L) (34501)	1,1,1-TRI-CHLORO-ETHANE TOTAL (UG/L) (34506)	1,1,2-TRI-CHLORO-ETHANE TOTAL (UG/L) (34511)	1,1,2,2 TETRA-CHLORO-ETHANE TOTAL (UG/L) (34516)	1,2-DI-CHLORO-BENZENE TOTAL (UG/L) (34536)	1,2-DI-CHLORO-PROPANE TOTAL (UG/L) (34541)	1,2-TRANSDI CHLORO-ETHYL-ENE TOTAL (UG/L) (34546)	1,3-DI-CHLORO-PROPANE TOTAL (UG/L) (34561)	1,3-DI-CHLORO-BENZENE TOTAL (UG/L) (34566)
BK-73-46-701	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
BK-73-46-803	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
NPS BIG BEND SEWAGE LAGOONS	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
BK-73-46-804	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY PROCESS DATE 10-15-87
MULTIPLE STATION ANALYSES

LOCAL IDENT-I-FIER	1,4-DI-CHLORO-BENZENE TOTAL (UG/L) (34571)	2-CHLORO-ETHYL-VINYL-ETHER TOTAL (UG/L) (34576)	DI-CHLORO-DI-FLUORO-METHANE TOTAL (UG/L) (34668)	TRANS-1,3-DI-CHLORO-PROPENE TOTAL (UG/L) (34699)	CIS 1,3-DI-CHLORO-PROPENE TOTAL (UG/L) (34704)	1,2-DIBROMO ETHYL-ENE TOTAL (UG/L) (39082)	VINYL CHLO-RIDE TOTAL (UG/L) (39175)	STYRENE TOTAL (UG/L) (77128)	TRI-CHLORO-ETHYL-ENE TOTAL (UG/L) (39180)	XYLENE WATER WHOLE TOT REC (UG/L) (81551)
BK-73-46-701	<0.20	<0.20	<0.20	<0.20	<0.20	<0.2	<0.20	<0.2	<0.2	<0.2
BK-73-46-803	<0.20	<0.20	<0.20	<0.20	<0.20	<0.2	<0.20	<0.2	<0.2	<0.2
NPS BIG BEND SEWAGE LAGOONS	<0.20	<0.20	<0.20	<0.20	<0.20	<0.2	<0.20	<0.2	<0.2	<0.2
BK-73-46-804	<0.20	<0.20	<0.20	<0.20	<0.20	<0.2	<0.20	<0.2	<0.2	<0.2

Table 2 : Concentrations of volatile and semi-volatile organic compounds in CLS-extracted water samples, Chisos Basin area, August, 1987
(concentrations in nanograms per liter)

	Oak Spring			Window Spring	Lower CCC Well	Sewage Lagoon #2
	BB87-1	BB87-1.2	BB87-5	BB87-3	BB87-4	BB87-6
	(8/23/87)	(8/23/87)	(8/25/87)	(8/24/87)	(8/24/87)	(8/26/87)
Compound Name						
Methyl benzene (Toluene)	53	--	--	--	14	109
Ethyl benzene	10	--	--	--	--	--
Dimethyl benzene (Xylene)	30	--	--	--	--	56
Trimethyl benzene	--	--	--	--	--	32
Nonanal	23	--	--	--	--	--
Decanal	49	--	--	--	--	--
Tridecane	36	--	--	--	--	--
Tetradecane	23	--	--	--	--	--
2,6-bis(1,1-dimethylethyl)-2,5-cyclohexadiene-1,4-dione	--	--	29	--	--	--
1-dodecanol	--	--	--	--	--	64
Heptadecane	--	--	--	--	--	204
Methyl N-(2,4-dimethyl-1-napthyl)carbamate	--	--	--	--	15	--

Table 3.--Summary of regulations for selected water-quality constituents and properties for public water systems

DEFINITIONS

Contaminant----------Any physical, chemical, biological, or radiological substance or matter in water.

Public water system---------A system for the provision to the public of piped water for human consumption, if such system has at least 15 service connections or regularly serves at least 25 individuals daily at least 60 days during the year.

Maximum contaminant level----The maximum permissible level of a contaminant in water which is delivered to the free-flowing outlet of the ultimate user of a public water system. Maximum contaminant levels are those levels set by the U.S. Environmental Protection Agency (1976) in the National Interim Primary Drinking Water Regulations. These regulations deal with contaminants that may have a significant direct impact on the health of the consumer and are enforceable by EPA.

Secondary maximum contaminant level----The advisable maximum level of a contaminant in water which is delivered to the free-flowing outlet of the ultimate user of a public water system. Secondary maximum contaminant levels are those levels proposed by EPA (1977) in the National Secondary Drinking Water Regulations. These regulations deal with contaminants that may not have a significant direct impact on the health of the consumer, but their presence in excessive quantities may affect the esthetic qualities and discourage the utilization of a drinking water supply by the public.

INORGANIC CHEMICALS AND RELATED PROPERTIES

Contaminant	Maximum contaminant level	Secondary maximum contaminant level
Arsenic (As)	50 µg/L	--
Barium (Ba)	1,000 µg/L	--
Cadmium (Cd)	10 µg/L	--
Chloride (Cl)	--	250 mg/L
Chromium (Cr)	50 µg/L	--
Copper (Cu)	--	1,000 µg/L
Iron (Fe)	--	300 µg/L
Lead (Pb)	50 µg/L	--
Manganese (Mn)	--	50 µg/L
Mercury (Hg)	2 µg/L	--
Nitrate (as N)	10 mg/L	--
pH	--	6.5 - 8.5
Selenium (Se)	10 µg/L	--
Silver (Ag)	50 µg/L	--
Sulfate (SO_4)	--	250 mg/L
Zinc (Zn)	--	5,000 µg/L
Dissolved solids	--	500 mg/L

Fluoride-------The maximum contamination level for fluoride depends on the annual average of the maximum daily air temperatures for the location in which the community water system is situated. A range of annual averages of maximum daily air temperatures and corresponding maximum contamination level for fluoride are given in the following tabulation.

Average of maximum daily air temperatures (degrees Celsius)	Maximum contaminant level for fluoride (mg/L)
12.0 and below	2.4
12.1 - 14.6	2.2
14.7 - 17.6	2.0
17.7 - 21.4	1.8
21.5 - 26.2	1.6
26.3 - 32.5	1.4

Table 3.--Summary of regulations for selected water-quality constituents and properties for public water systems--Continued

ORGANIC CHEMICALS

Contaminant	Maximum contaminant level (µg/L)
Chlorinated Hydrocarbons	
Endrin	0.2
Lindane	4
Methoxychlor	100
Toxaphene	5
Chlorophenoxys	
2,4-D	100
Silvex	10

Proposed Maximum Contaminant Levels
(U.S. Environmental Protection Agency, 1985)

Compound	Proposed maximum contaminant level (mg/L)
Trichloroethylene	0.005
Carbon tetrachloride	.005
Vinyl chloride	.001
1,2-Dichloroethane	.005
Benzene	.005
1,1-Dichloroethylene	.007
1,1,1-Trichloroethane	.20
p-Dichlorobenzene	.75

NOTE: The maximum contaminant level for tetrachloroethylene will be proposed later.

The total dissolved-solids concentration is a major limiting factor in the use of water. The following is a general classification of water based on dissolved solids (Winslow and Kister, 1956, p. 5).

Description	Dissolved-solids content, in milligrams per liter
Fresh	Less than 1,000
Slightly saline	1,000 to 3,000
Moderately saline	3,000 to 10,000
Very saline	10,000 to 35,000
Brine	More than 35,000