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# Chemical Changes in Groundwater of Northern Utah Valley, Utah

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# CHEMICAL CHANGES IN GROUNDWATER OF NORTHERN UTAH VALLEY, UTAH

by

Paul E. Fairbanks

A thesis submitted in partial fulfillment
of the requirements of the degree
of
MASTER OF SCIENCE
in
Geology

Approved:

UTAH STATE UNIVERSITY
Logan, Utah
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# ACKNOWLEDGEMENTS

This study was part of a larger research effort conducted by the U.S. Geological Survey in cooperation with the state of Utah. The research effort, under the supervision of David Clark, was directed towards evaluating the water resources in northern Utah Valley.

I would like to thank David Clark and Cindy Appel of the U.S. Geological Survey for their help and suggestions; Ken Thompson and Richard Fuller for their assistance in use of field equipment for the water sampling program; Jim Hood and Briant Kimball for advice on chemical analyses; and Dr. Robert Q. Oaks Jr., and Dr. Donald W. Fiesinger, of Utah State University, for reviewing this manuscript.

I would also like to express my appreciation to my major professor, Dr. Peter T. Kolesar for his help and encouragement, without which this study would be far from complete.

Finally I extend a husband's gratitude to Jetta, for her help and support.

Paul E. Fairbanks

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# ABSTRACT

## Chemical Changes in Groundwater of
## Northern Utah Valley, Utah

by

Paul E. Fairbanks, Master of Science
Utah State University, 1982

Major Professor: Dr. Peter T. Kolesar
Department: Geology

Northern Utah Valley is one of the fastest growing areas of Utah and has increasing needs for domestic, industrial, and agricultural water. To meet these needs, groundwater and surface water systems must be understood to maximize their use. Chemical studies of the sediment mineralogy and related water-chemistry give insight to the movement of the water.

There are three major aquifers present in the valley: shallow Pleistocene; deep Pleistocene; and Tertiary. They are composed of sands and gravels and are separated by confining layers (aquitards) composed mostly of clay. Along the flanks of the bordering mountains there are undifferentiated aquifers which act as conduits supplying water for aquifers in the valley.

Sediment samples from aquifers and confining layers were obtained by rotary and cable-tool drilling. X-ray diffraction analyses showed that the aquifers are mainly composed of quartz, calcite, and dolomite, whereas the confining layers contain illite and montmorillonite with some kaolinite, quartz and calcite. One hundred nine water samples were collected in this study from surface water, spring water, undifferentiated aquifer water, shallow Pleistocene aquifer water, deep Pleistocene aquifer water and Tertiary aquifer water.

Results show that the groundwater system has several geochemical cells in each aquifer, due to diverse areas of recharge. Three major water types can be identified in different areas of the shallow Pleistocene aquifer, three in different areas of the Tertiary aquifer, and four in different areas of the deep Pleistocene aquifer. The differences in these water types are related to the composition of the mountain recharge areas and positions of faults within the valleys. The aquifer composition exerts relatively little influence on the chemistry of the groundwater. Mountains of predominantly carbonate rocks produce recharge waters rich in calcium and bicarbonate. Mountains of predominantly granitic rocks produce recharge water low in mineral content. Valley sediments near major faults produce highly mineralized waters.

(82 pages)

# STATEMENT OF PROBLEM

Utah Valley is located on the eastern flank of the Basin and Range Province. It is an elongate basin comprising approximately 800 square miles. Water in this area of semi-arid climate is high in demand and one of the most important resources. This report analyzes the groundwater system in northern Utah Valley, an area embracing 150 square miles and including the towns of Alpine, American Fork, Lehi, and Pleasant Grove (fig. 1).

Northern Utah Valley is a growing area, with light industry and urban residences expanding into previously irrigated agricultural lands. Before 1947, most water wells were less than 200 feet deep and three inches in diameter and were mainly used for domestic irrigation and livestock watering. From 1947 to 1969, the number of wells five inches in diameter and greater increased drastically (Hyatt and others, 1969, p. 85). These wells include high withdrawal public-supply wells, industrial wells, and irrigation wells. As a result of these increases in water demand, a sound policy for future water usage is needed.

In order to supply adequate water for the present and future needs of this area the groundwater and interrelated surface-water system must be understood in terms of hydraulic properties of aquifers, movement of groundwater, and location of recharge areas. Such understanding will allow development of groundwater resources in strategic areas with little adverse influence on already allocated waters.

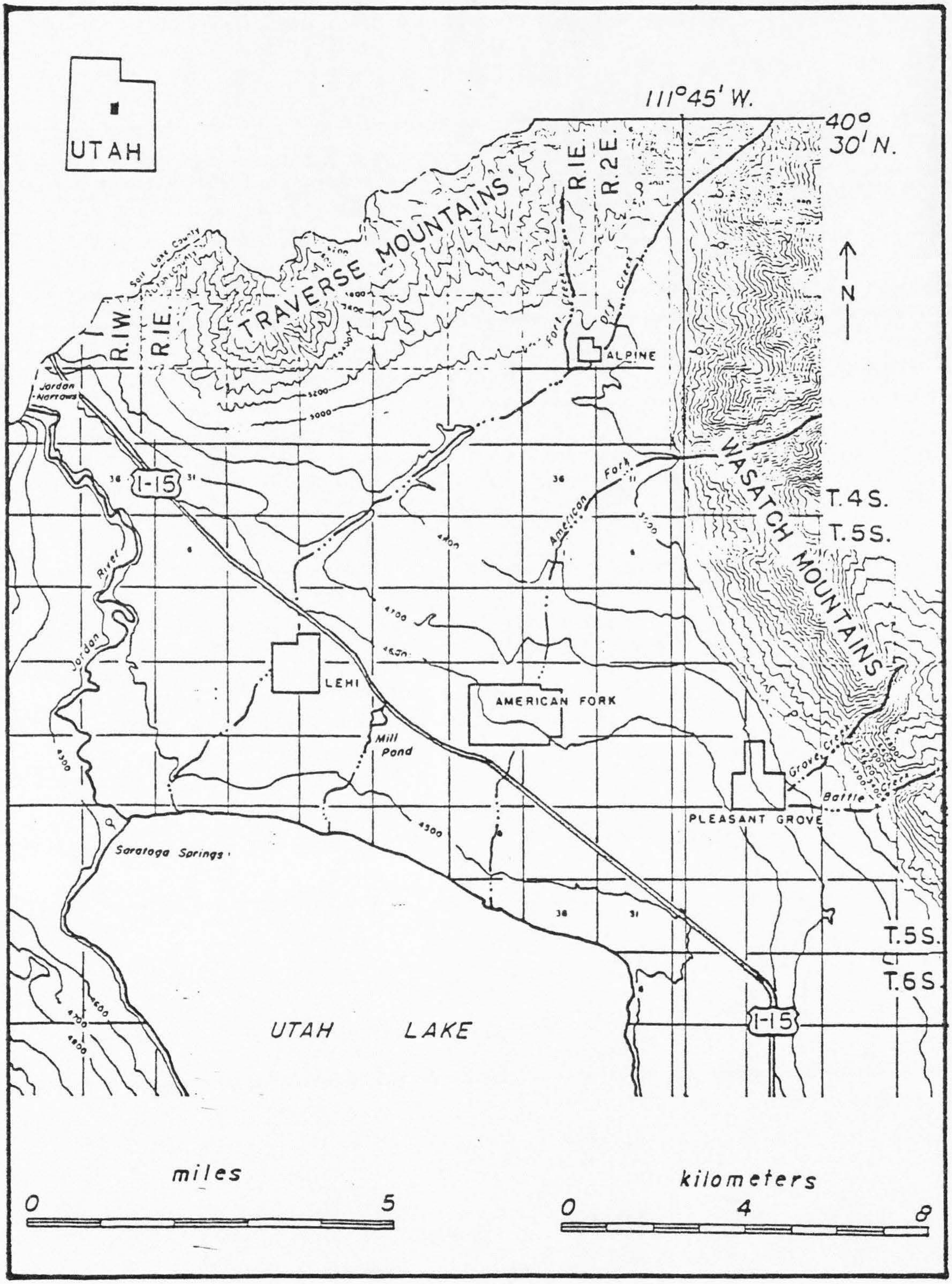


Figure 1.- Location map of the study area (from Subitsky, 1962)

Groundwater and surface-water are influenced chemically by rocks and sediments of the area. Chemical changes in the water, when correlated with the sediment composition of the aquifers, can be used to trace the groundwater flow path.

The U.S. Geological Survey (Water Resources Division, Investigations Section, Salt Lake City) is presently undertaking a large hydrologic study of northern Utah Valley. The expected results will be a sufficient understanding of the groundwater system to permit development of a predictive computer model. This study of the inorganic chemistry of the water, rocks, and sediments will be used in conjunction with the larger hydrologic study. Problems dealing with organic pollutants or insecticides are beyond the scope of this report.

The major objectives of this report are: 1) to correlate the mineralogy of the rocks and sediments with the chemistry of the water; 2) to identify the areas of recharge according to mineralogy and corresponding water chemistry; 3) to identify the areas of discharge based on the chemical characteristics of the sediments and water chemistry; 4) to observe the changes in water chemistry between recharge and discharge areas; and 5) to determine the flow paths of the water.

# GEOLOGIC SETTING

## General Statement

Northern Utah Valley is a typical area of the Basin and Range Province, characterized by normal block faulting. The valley is composed mostly of unconsolidated lacustrine sediments, interbedded fluvial fanglomerates and glacial outwash (Hunt and others, 1953). Three different mountain systems surround northern Utah Valley (fig. 2). The Traverse Mountains are composed of lava and tuff with some hydrothermally formed onyx, opal, and travertine. The Little Cottonwood Stock, to the northeast, is composed of granitic rock. The Wasatch Mountains are mostly limestone (Baker and others, 1949) with some sandstone and dolostone.

## Structures

### Laramide

Paleozoic limestones and sandstones of the Wasatch Mountains were highly deformed from Late Cretaceous to Early Tertiary time. Large recumbent folds and thrust faults resulted during several successive eastward movements (Spieker, 1946; Baker and others, 1949).

### Basin and Range

Normal block faulting of the Tertiary period is responsible for the landforms seen today in northern Utah Valley (Hunt and others, 1953). The most prominent of these faults are the Wasatch, Traverse, and Lake fault zones. The Little Cottonwood stock intruded at this time of normal block faulting (Smith, 1972). The stock has been

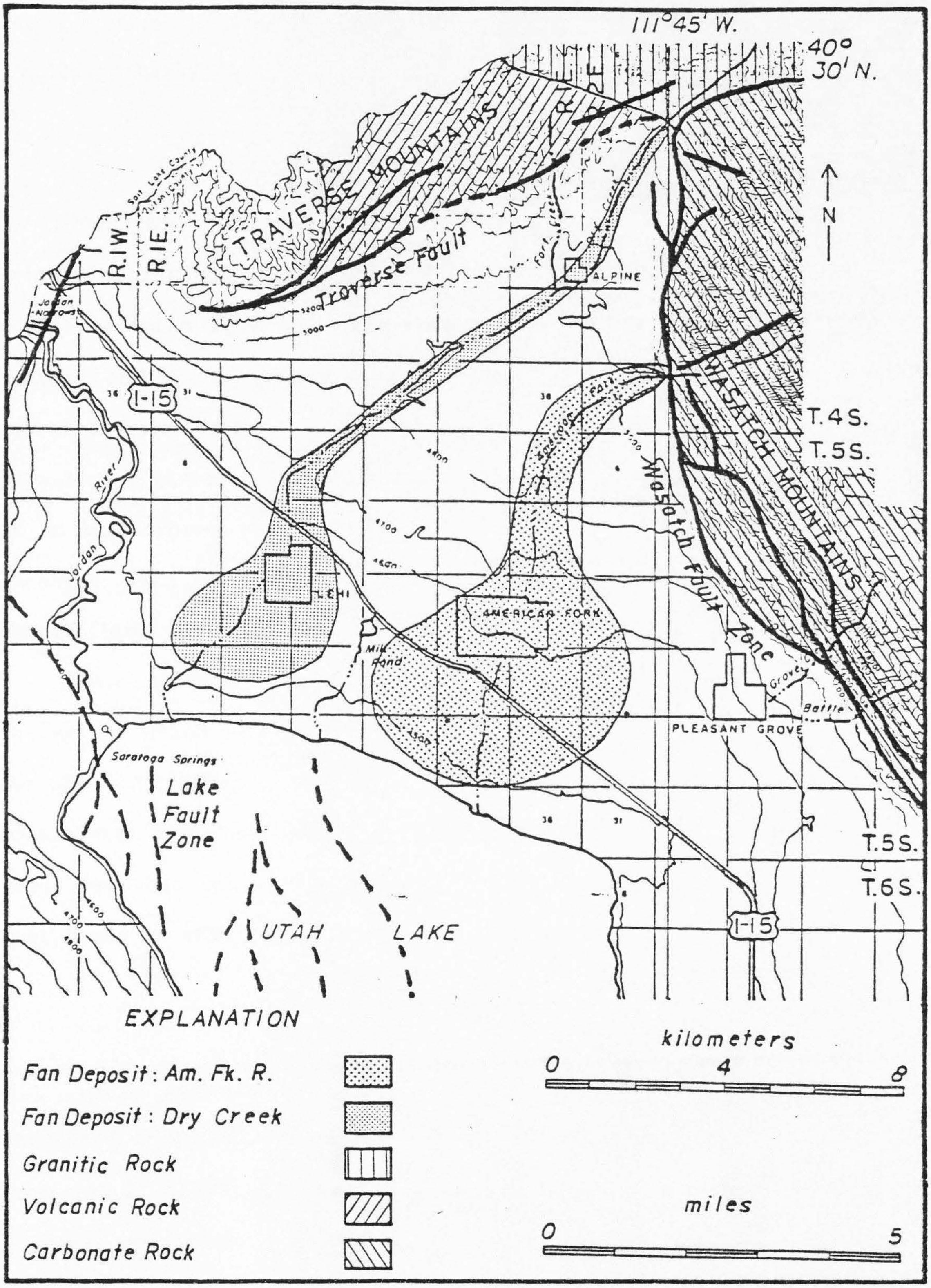


Figure 2.- Generalized geology of northern Utah Valley (modified from Hunt and others, 1953 and Brimhall and others, 1976)

radiometrically dated by Grant (1966) at 29 million years (K-Ar).

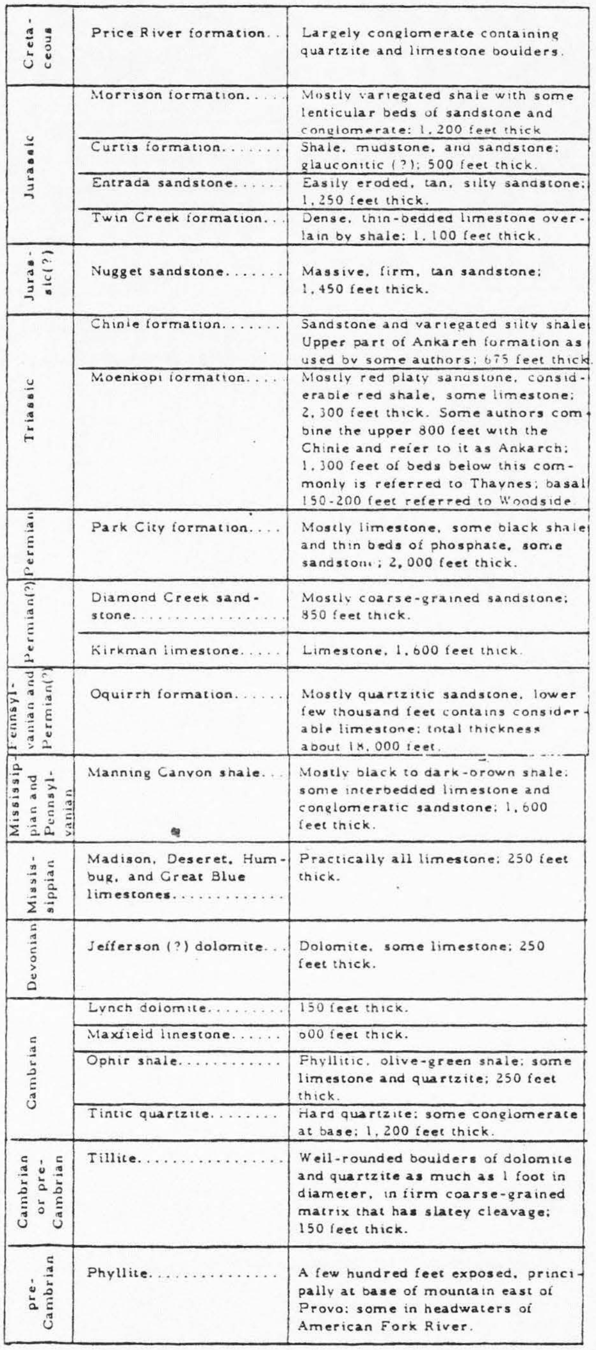
## Volcanic Rocks

Hunt and others (1953) found glassy and distinctly porphyritic lavas cropping out in the Traverse Mountains. Recent studies by Moore (1976) describe igneous rocks at Shaggy Peak in the Traverse Mountains. Laharic breccia deposits underlie latitic lavas, which are overlain by red-weathering tuffs and breccias. This study points out that the main period of eruptive activity in the Traverse Mountains was between 31 and 38 million years ago. In addition to the Traverse Mountains lava, northern Utah Valley was covered with volcanic ash and pyroclastic debris (Hunt and others, 1953).

Penecontemporaneous with the volcanism, lakes formed in Utah Valley in which well-stratified volcanic debris accumulated. Valley deposits identified by Hunt and others (1953) include conglomerates with interstratified tuffs and reworked ash. Dustin and Merritt (1980) concluded that volcanic deposits extended to depths greater than 20,000 feet based on drilling by Gulf Oil Corporation.

## Sedimentary Rocks

Large accumulations of limestone, sandstone and dolostone were deposited in Paleozoic epeiric seas (fig. 3). These sedimentary rocks crop out in the Wasatch Mountains, but are also present in parts of the Traverse Mountains. Stratigraphic studies of these rocks were reported by Baker (1947), and Baker and others (1949).



| | | |
|---|---|---|
| Cretaceous | Price River formation.. | Largely conglomerate containing quartzite and limestone boulders. |
| Jurassic | Morrison formation..... | Mostly variegated shale with some lenticular beds of sandstone and conglomerate: 1,200 feet thick |
| | Curtis formation....... | Shale, mudstone, and sandstone; glauconitic (?); 500 feet thick. |
| | Entrada sandstone...... | Easily eroded, tan, silty sandstone; 1,250 feet thick. |
| | Twin Creek formation... | Dense, thin-bedded limestone overlain by shale; 1,100 feet thick. |
| Jurassic(?) | Nugget sandstone....... | Massive, firm, tan sandstone; 1,450 feet thick. |
| Triassic | Chinle formation....... | Sandstone and variegated silty shale Upper part of Ankareh formation as used by some authors; 675 feet thick. |
| | Moenkopi formation.... | Mostly red platy sandstone, considerable red shale, some limestone; 2,300 feet thick. Some authors combine the upper 800 feet with the Chinle and refer to it as Ankarch; 1,300 feet of beds below this commonly is referred to Thaynes; basal 150-200 feet referred to Woodside. |
| Permian | Park City formation.... | Mostly limestone, some black shale and thin beds of phosphate, some sandstone; 2,000 feet thick. |
| Permian(?) | Diamond Creek sandstone................. | Mostly coarse-grained sandstone; 850 feet thick. |
| | Kirkman limestone..... | Limestone, 1,600 feet thick. |
| Pennsylvanian and Permian(?) | Oquirrh formation...... | Mostly quartzitic sandstone, lower few thousand feet contains considerable limestone; total thickness about 18,000 feet. |
| Mississippian and Pennsylvanian | Manning Canyon shale... | Mostly black to dark-brown shale; some interbedded limestone and conglomeratic sandstone; 1,600 feet thick. |
| Mississippian | Madison, Deseret, Humbug, and Great Blue limestones............ | Practically all limestone; 250 feet thick. |
| Devonian | Jefferson (?) dolomite... | Dolomite, some limestone; 250 feet thick. |
| Cambrian | Lynch dolomite......... | 150 feet thick. |
| | Maxfield limestone...... | 600 feet thick. |
| | Ophir shale............ | Phyllitic, olive-green shale; some limestone and quartzite; 250 feet thick. |
| | Tintic quartzite........ | Hard quartzite; some conglomerate at base; 1,200 feet thick. |
| Cambrian or pre-Cambrian | Tillite................ | Well-rounded boulders of dolomite and quartzite as much as 1 foot in diameter, in firm coarse-grained matrix that has slatey cleavage; 150 feet thick. |
| pre-Cambrian | Phyllite............... | A few hundred feet exposed, principally at base of mountain east of Provo; some in headwaters of American Fork River. |

Figure 3.- Generalized stratigraphic section of Paleozoic and Mesozoic rocks (from Baker, 1947).

## Unconsolidated Sediments

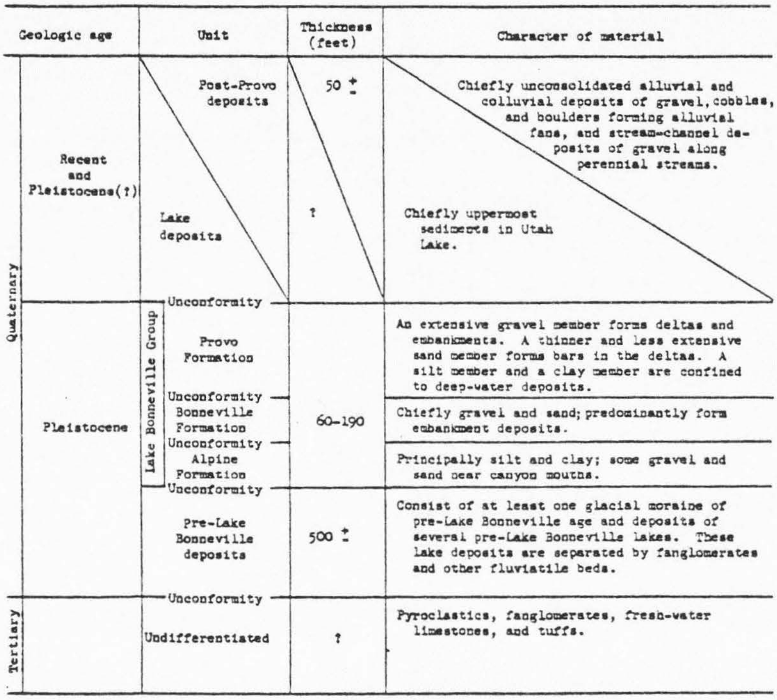
### Tertiary sediments

The Tertiary period began with deposition of coarse conglomerates followed by a time of relatively quiet deposition of fresh-water lake deposits (Hunt and others, 1953). At this time extensive deposits of volcanic debris formed and are now the Salt Lake Formation (fig. 4).

### Quaternary sediments

According to Hunt and others (1953) the early part of the Pleistocene epoch (pre-Lake Bonneville) was dominated by fluvial deposition of large alluvial fans far into the interior of the Utah Valley. Fans from the Traverse Mountains were derived largely from porphyritic and glassy lavas in that range. Fans from areas east of American Fork and Pleasant Grove were derived from Paleozoic marine deposits of the Wasatch Mountains and Tertiary quartz monzonites of the Little Cottonwood stock. Clay sequences deposited in glacial lakes separate the fan gravels and sands. These fans were subsequently eroded and weathered with the appearance of Lake Bonneville.

Atwood (1909) recognized and described glaciation (Early Pleistocene) of Dry Creek Canyon and American Fork Canyon in northern Utah Valley. The Dry Creek glaciers extended to the mouth of Dry Creek Canyon and deposited largely granitic material in the form of glacial moraines and outwash. The American Fork glaciers did not extend to the mouth of American Fork Canyon, but did contribute glacial outwash of limestone fragments to alluvial fans.



| Geologic age | | Unit | | Thickness (feet) | Character of material |
|---|---|---|---|---|---|
| Quaternary | Recent and Pleistocene(?) | | Post-Provo deposits | 50 ± | Chiefly unconsolidated alluvial and colluvial deposits of gravel, cobbles, and boulders forming alluvial fans, and stream-channel deposits of gravel along perennial streams. |
| | | | Lake deposits | ? | Chiefly uppermost sediments in Utah Lake. |
| | | | Unconformity | | |
| | Pleistocene | Lake Bonneville Group | Provo Formation | 60-190 | An extensive gravel member forms deltas and embankments. A thinner and less extensive sand member forms bars in the deltas. A silt member and a clay member are confined to deep-water deposits. |
| | | | Unconformity | | |
| | | | Bonneville Formation | | Chiefly gravel and sand; predominantly form embankment deposits. |
| | | | Unconformity | | |
| | | | Alpine Formation | | Principally silt and clay; some gravel and sand near canyon mouths. |
| | | | Unconformity | | |
| | | | Pre-Lake Bonneville deposits | 500 ± | Consist of at least one glacial moraine of pre-Lake Bonneville age and deposits of several pre-Lake Bonneville lakes. These lake deposits are separated by fanglomerates and other fluviatile beds. |
| | | | Unconformity | | |
| Tertiary | | | Undifferentiated | ? | Pyroclastics, fanglomerates, fresh-water limestones, and tuffs. |

Figure 4.- Generalized stratigraphic section of Tertiary and Quaternary formations (from Cordova and Subitsky, 1965)

Lake Bonneville formed during Middle Pleistocene time, and covered approximately 20,000 square miles, with a depth of 1000 ft at its maximum extent (Gilbert, 1890). Utah Valley was a bay on the eastern side of Lake Bonneville (fig. 5). This lake rose to a peak water level altitude of 5,135 feet. Below this elevation lacustrine landforms, including many shore terraces, bars, spits, and deltas, predominate. In contrast, above the peak water level, subaerial landforms are dominant (Bissell, 1963). The sediments of the lake constitute the Bonneville Group which is divided into three formations: Alpine (oldest), Bonneville, and Provo (youngest).

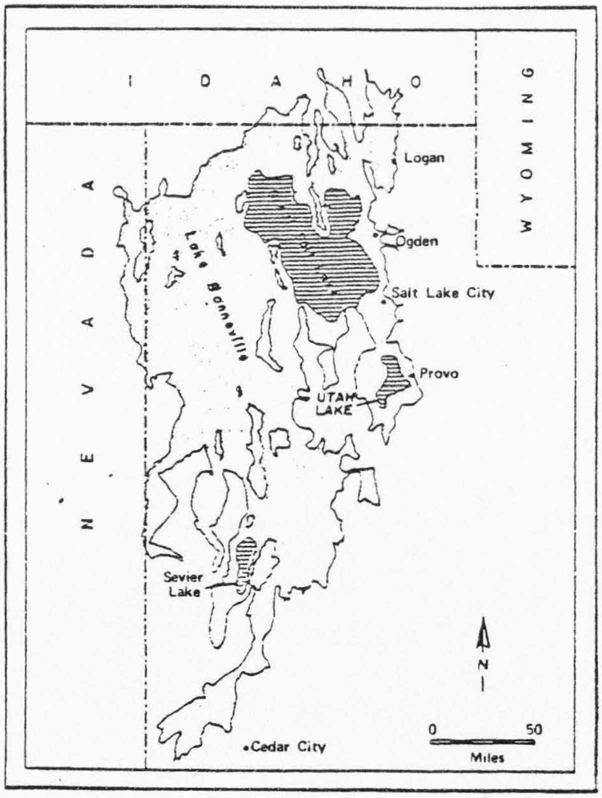


Figure 5.- Lake Bonneville at its maximum size (adapted from Bissell, 1963).

Lake Bonneville drained from its highest level (Bonneville level) to a lower level (Provo level) rapidly by way of Cache Valley, Red Rock Pass, and the Snake River Valley (Gilbert, 1890). From the Provo level the lake lowered through desiccation to the present level of the Great Salt Lake.

Utah Lake presently occupies the central part of northern Utah Valley. Little erosion has taken place since the time of Lake Bonneville due to the semi-arid climate. Post-Lake Bonneville deposits include fan and flood-plain deposits of the American Fork River and Dry Creek. Most noteworthy of these deposits are the fans of gravel and sand built on Lake Bonneville deposits where the American Fork River issues from the American Fork Canyon onto Highland bench. A similar fan, built by Dry Creek on deposits of Lake Bonneville, is located at Lehi.

## PREVIOUS HYDROLOGIC STUDIES

Richardson (1906) made the first extensive hydrologic study in northern Utah Valley. He noted that large numbers of artesian wells bottomed in Pleistocene (pre-Lake Bonneville) deposits, whereas some were in deeper Tertiary deposits. Richardson determined that the bulk of recharge to this groundwater system was through stream channels, irrigation ditches, underflow of creeks at mouths of canyons, seepage at the base of the mountains and some from precipitation in the valley.

Hunt and others (1953) studied the history of water utilization and the fluctuation in groundwater with respect to surface water supply. They noted and named four main aquifers: (1) unconfined surface water and water table; (2) confined shallow Pleistocene; (3) confined deep Pleistocene; and (4) confined Tertiary. By comparing potentiometric surface data from selected points in the valley, a hydraulic gradient was seen towards the lake. They noted that the general water quality decreased with depth, and concluded that large quantities of water pass upward from underlying aquifers and discharge into Utah Lake as seepage.

Taylor and Thomas (1939) studied the fluctuation of artesian water-levels by measuring pressure in water wells, and began a network of regularly measured water-levels that has grown extensively since 1939. Cordova and Subitsky (1965) collected general water-level data and water-chemistry data, identified water-bearing deposits, and measured and estimated recharge from streams and subsurface seepage. This information was compared to discharge from springs, drains, streams and the estimated subsurface inflow into Utah Lake to obtain an estimated water budget of northern Utah Valley. Dustin and Merritt (1980) studied the subsurface inflow of water to Utah Lake and determined that Cordova and Subitsky were much too conservative in their estimates of this inflow to the lake. They utilized a mass-balance model for water and salt (after Fuhriman and others, 1975) and concluded that inflow to the lake is three times that estimated by Cordova and Subitsky (1965).

Other large-scale reconnaissance-type studies have dealt with northern Utah Valley. Mundorff (1974) studied the quality of water flowing into Utah Valley. Hyatt and others (1969) inventoried waters of the Utah Valley drainage area. Also, the U.S. Bureau of Reclamation (1979) prepared an environmental-impact statement for the Central Utah Project which briefly discussed Utah Valley and its water budget.

# METHODS AND PROCEDURES

## Field Work

### Time interval

The field work on which this report is based was begun in March, 1980 and continued through September, 1981. Most sample collection took place, however, between April and September, 1981. Earlier work, performed between March, 1980 and March, 1981, was preliminary inventory work primarily to locate new water wells and obtain water-levels.

### Drilling

Drill-core samples were obtained from drill holes E-2 and A-4 by standard rotary methods. Both wells were drilled close to Utah Lake, where the aquifers and confining layers are easily differentiated. Drill-cutting samples were obtained from drill hole C-4 using standard cable-tool methods. This hole was located about equidistant from the lake and the mountains.

### Sediment sampling

All drill-core samples obtained (many were lost in the drilling process) from drill holes E-2 and A-4 were preserved by wrapping them in aluminum foil, then cheesecloth, and finally by sealing them in wax. Drill cuttings from hole C-4 were preserved in plastic bags. Two to four samples were obtained from each of the three artesian aquifers and the three associated confining layers (aquitards).

### Water sampling

Collection.- Water samples were collected between June and September, 1981. Seventy two water samples were obtained from groundwater and surface-water systems representing water in northern Utah Valley. Surface-water was sampled at progressive intervals downstream at Dry Creek and American Fork River. Also many of the springs along the Wasatch Mountain front were sampled. Groundwater was collected on a regular interval based on a sampling grid (fig. 6). Each grid section was approximately 10 square miles and was bounded by equipotential contours and flow lines. Thirty seven additional chemical analyses were obtained from samples taken by other personnel of the U.S. Geological Survey between 1949 and 1980 (see Appendix III for a complete listing of the chemical analyses).

Field analysis.- Temperature, pH, specific conductance, dissolved oxygen and alkalinity were measured in the field according to standard precedures (U.S. Geological Survey, 1979). The pH was determined using a Leeds and Northrup model 7417 pH/specific ion/mV portable meter. Specific conductance was determined with a Beckman Solu-Bridge RB-3 portable meter. Dissolved oxygen was determined with a Yellow Springs Instrument model 54 portable meter. The Winkler Titration (U.S. Geological Survey, 1979) was used to determine the alkalinity. At each location, 500 ml of water was filtered through 0.45$\mu$m filter paper and collected for later analysis. One bottle of water (250 ml) was acidified with reagent grade nitric acid (to prevent ion complexing) to below a pH of two, for analysis of calcium, iron, magnesium, potassium,

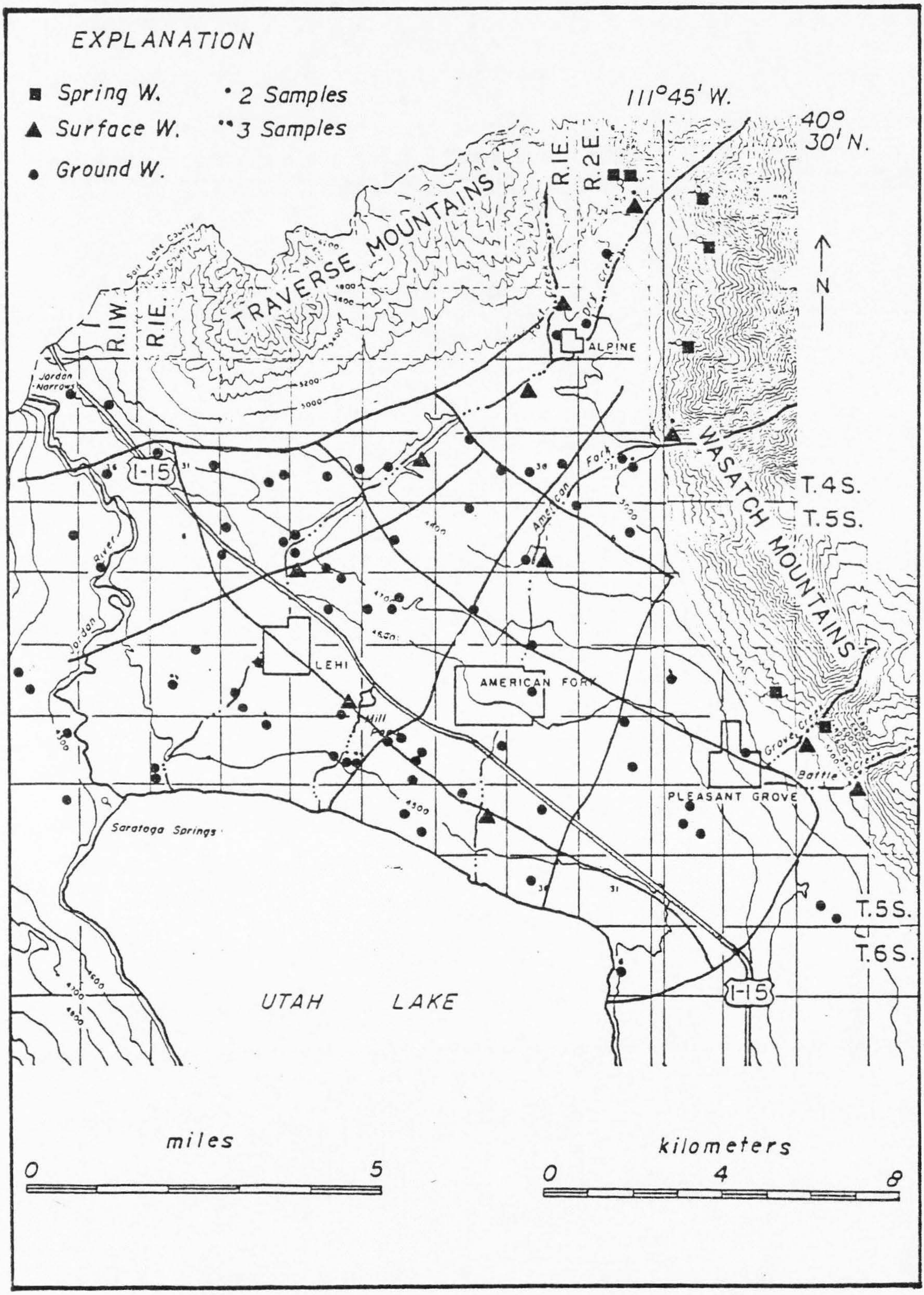


Figure 6.- Water-collection sites for spring, surface water, and groundwater (see Appendix IV). Groundwater was sampled at regular intervals according to the grid.

and sodium. The second bottle of water (250 ml) was used for analysis of boron, chloride, fluoride, and sulfate.

## Laboratory Work

### Sediment samples

*Grain-size analysis*.- The grain-size distribution was determined for each of the 20 samples. Dry-sieve methods were used for sand size and larger particles whereas pipet methods were used for silt size and smaller particles. Both methods were carried out according to standard procedures outlined by the U.S. Geological Survey (1971).

*Mineralogy*.- Forty x-ray analyses were made with a Siemens x-ray diffractometer. The operating conditions were as follows: a copper tube was operated at 35kV and 16mA with a nickel filter to produce Cu $K_{\alpha}$ radiation. The goniometer regulated the scanning range between 5 - 31° $2\theta$ at 2° $2\theta$/minute; the counter range was set at 2 or 4 x $10^4$ counts/min, with a statistical error of 4.0%.

Two grams of each of the 20 samples were dispersed in 50 ml of deionized water and 5 ml of 0.1 N sodium hexametaphosphate. The particles were disaggregated using an ultrasonic generator, and a portion of each dispersion was mounted (particles$\leq$2mm) on a glass plate and allowed to dry for x-ray analysis. Coarse sand and larger particles dropped out of suspension and were not analyzed, for it was assumed that these larger particles had little effect on the groundwater chemistry. The particular mounting used produces oriented clay samples, and subsequently allows for easy identification of these clays. The 20 dispersions were then left to settle for two hours, after which only suspended clay dispersions remained. A portion of this dispersion was then mounted (particles$\leq$0.002mm) as above, for x-ray analysis.

Cation-exchange capacity.- The cation-exchange capacity (CEC) was determined for the 20 samples according to standard procedures outlined by the U.S. Geological Survey (Crock and Severenson, 1980). The results give total CEC values, one based on the sum of calcium, magnesium, potassium, and sodium, and the other based solely on sodium. The procedure entailed mixing each sample with a solution of ammonium acetate (1.0 N at a pH of 7). All the exchangeable cation sites in the clays became saturated with ammonium while calcium, magnesium, potassium, and sodium went into solution. The solution was analyzed by a Perkin-Elmer model 303 atomic absorption spectrophotometer for each cation according to standard procedures. Each sample was then mixed with 1.0 N sodium acetate solution at a pH of 8.2. This process saturates all exchange sites with sodium. The samples were washed three times with reagent grade isopropyl alcohol, and the sodium was then extracted into a 1.0 N ammonium acetate solution. This solution was then analyzed for sodium, as described previously, using atomic absorption spectrophotometry. The sum of milli-equivalents (meq) for calcium, magnesium, potassium, and sodium found with the first solution should equal the meq of the sodium from the second solution and each is equal to the CEC total.

### Water samples

One hundred forty-four bottles of water (two bottles from each of the 72 sample sites) were sent to the Denver Central Laboratories of the U.S. Geological Survey for analysis. Dissolved calcium, iron, magnesium, potassium and sodium were analyzed using standard atomic absorption techniques. Dissolved boron, chloride, fluoride, and sulfate were analyzed by standard colorimetric techniques.

# RESULTS

## Delineation of Aquifers

The three aquifers described earlier in this report (shallow Pleistocene, deep Pleistocene, and Tertiary) can be differentiated in areas close to Utah Lake, and mostly below the 4700 foot elevation contour. Areas of higher elevation and close to the mountains, however, cannot be differentiated into these aquifers (fig. 7). The three aquifers (figs. 8, 9, 10, 11, and 12) are identified using drillers logs (which were reported by the same drilling company and assumed accurate). They are composed mostly of sand and gravel and allow water to flow, in many cases, very rapidly. The confining layers (aquitards) between the aquifers (number one being the uppermost, and number three being the deepest) are very discontinuous lenses of clay, clay and sand, and clay and gravel.

## Mineralogy by X-Ray Diffraction

Minerals regarded as significant in the aquifers and confining layers show strong x-ray diffraction peaks, and are present in all three drill hole sediment sections. The shallow Pleistocene and Tertiary aquifers both have abundant quartz, whereas the deep Pleistocene aquifer is composed mostly of calcite. Quartz is abundant in all confining layer zones. Illite is dominant in the shallow and deep Pleistocene aquifers and in confining layers one and two (table 1). Montmorillonite is dominant in the Tertiary aquifer and confining layer three (refer to Appendix I for a complete listing of the x-ray diffraction analyses).

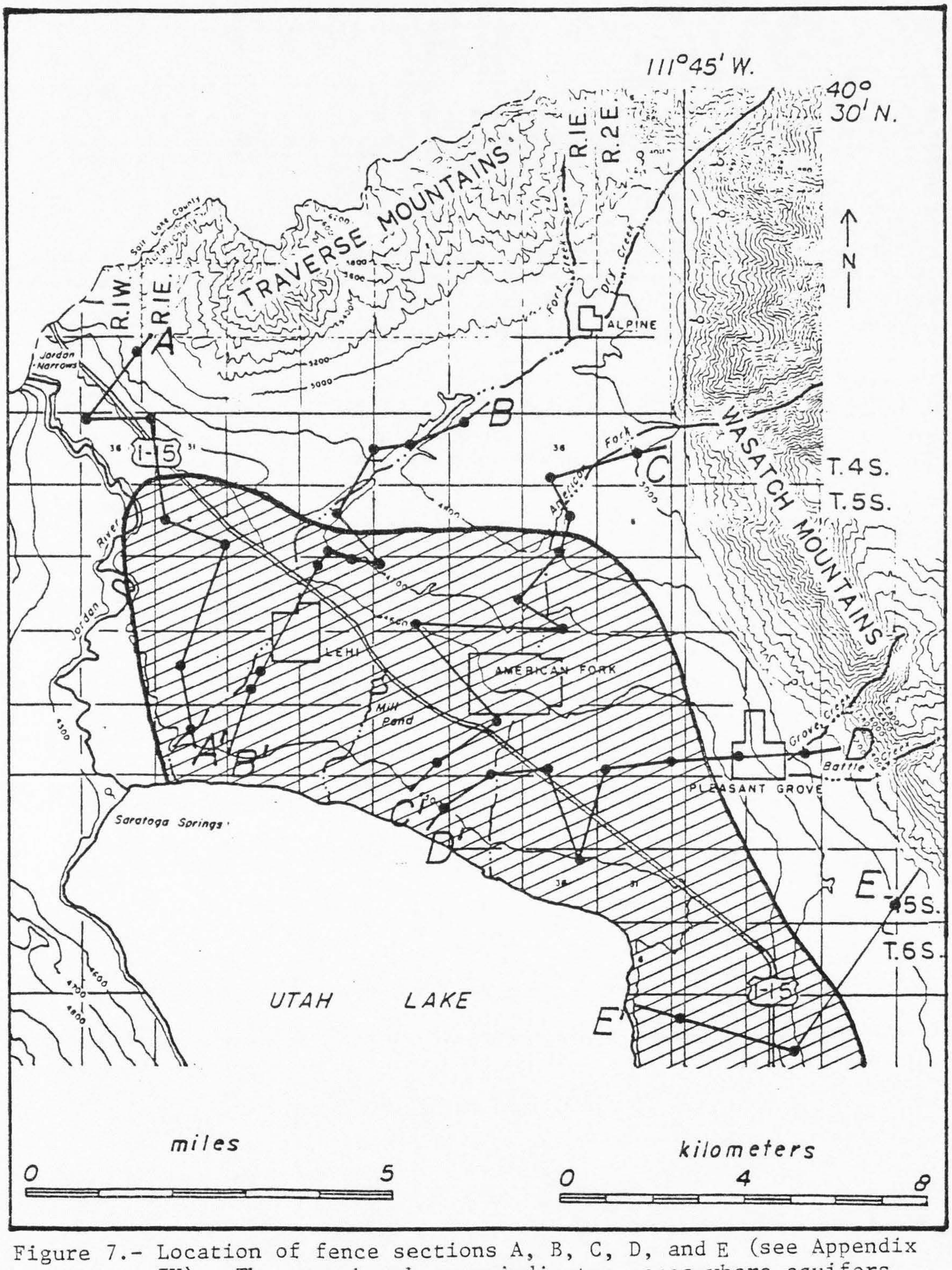


Figure 7.- Location of fence sections A, B, C, D, and E (see Appendix IV). The crosshatch area indicates zones where aquifers can be differentiated.

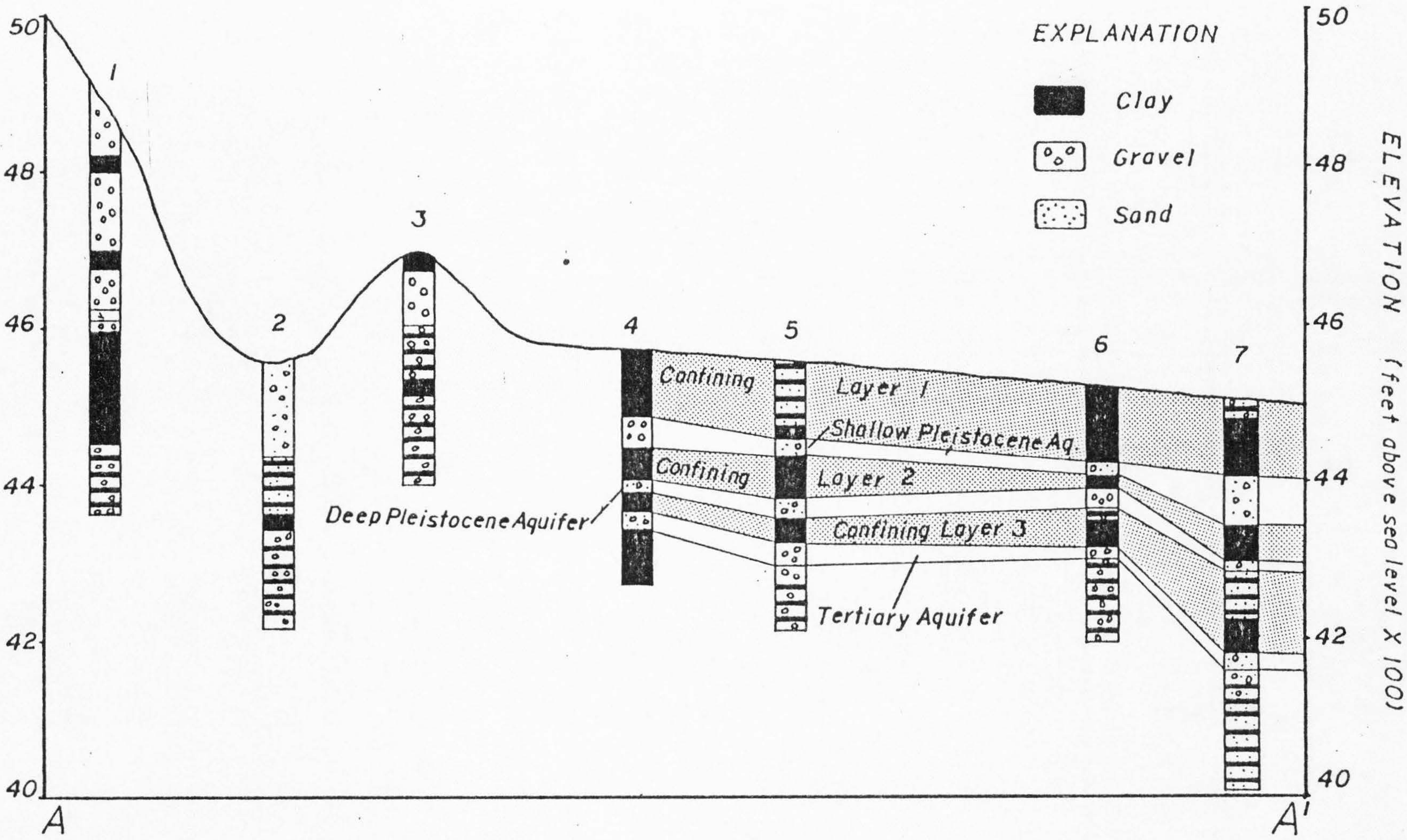


Figure 8.- Fence diagram of section A - A'.

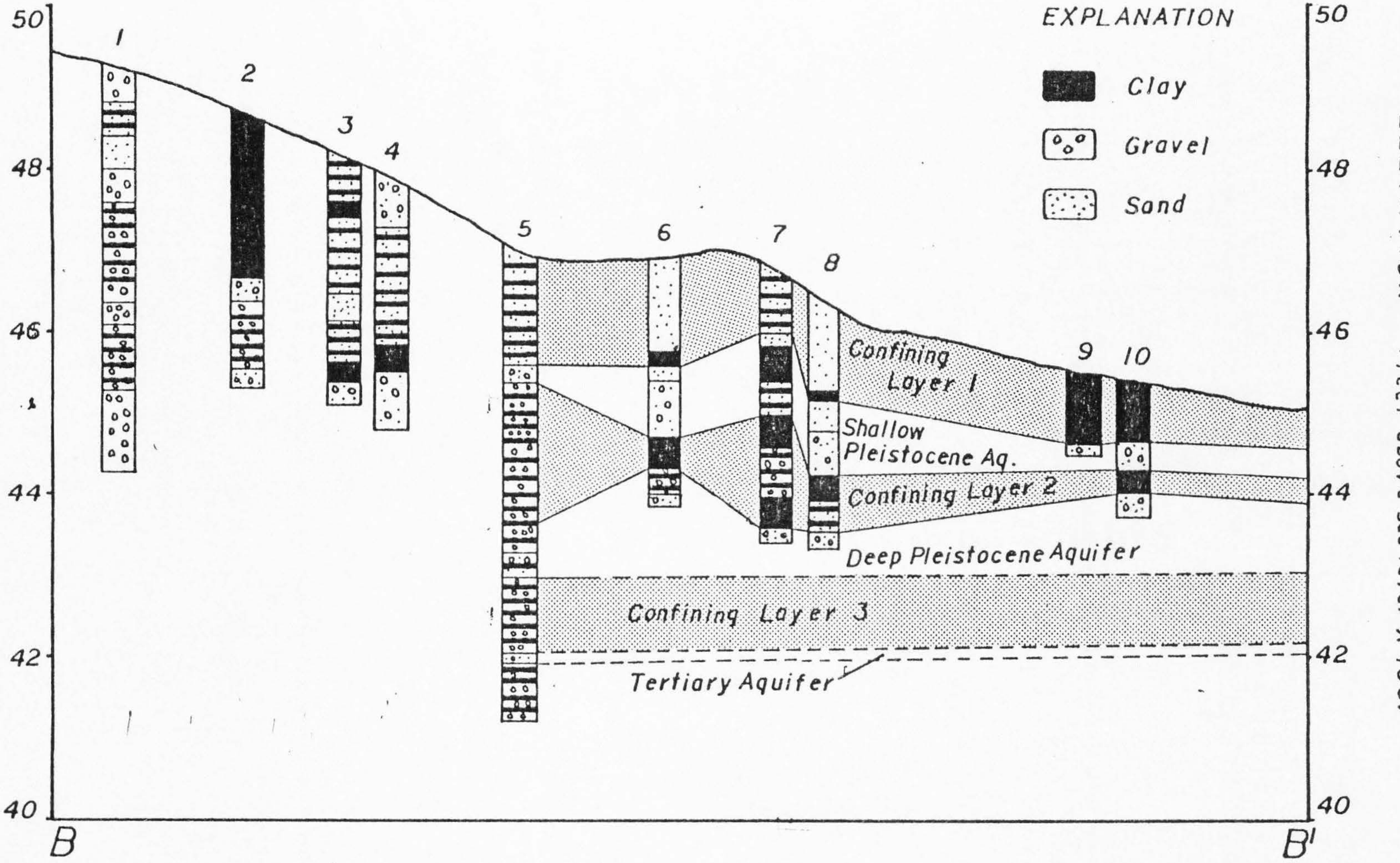


Figure 9.- Fence diagram of section B - B'.

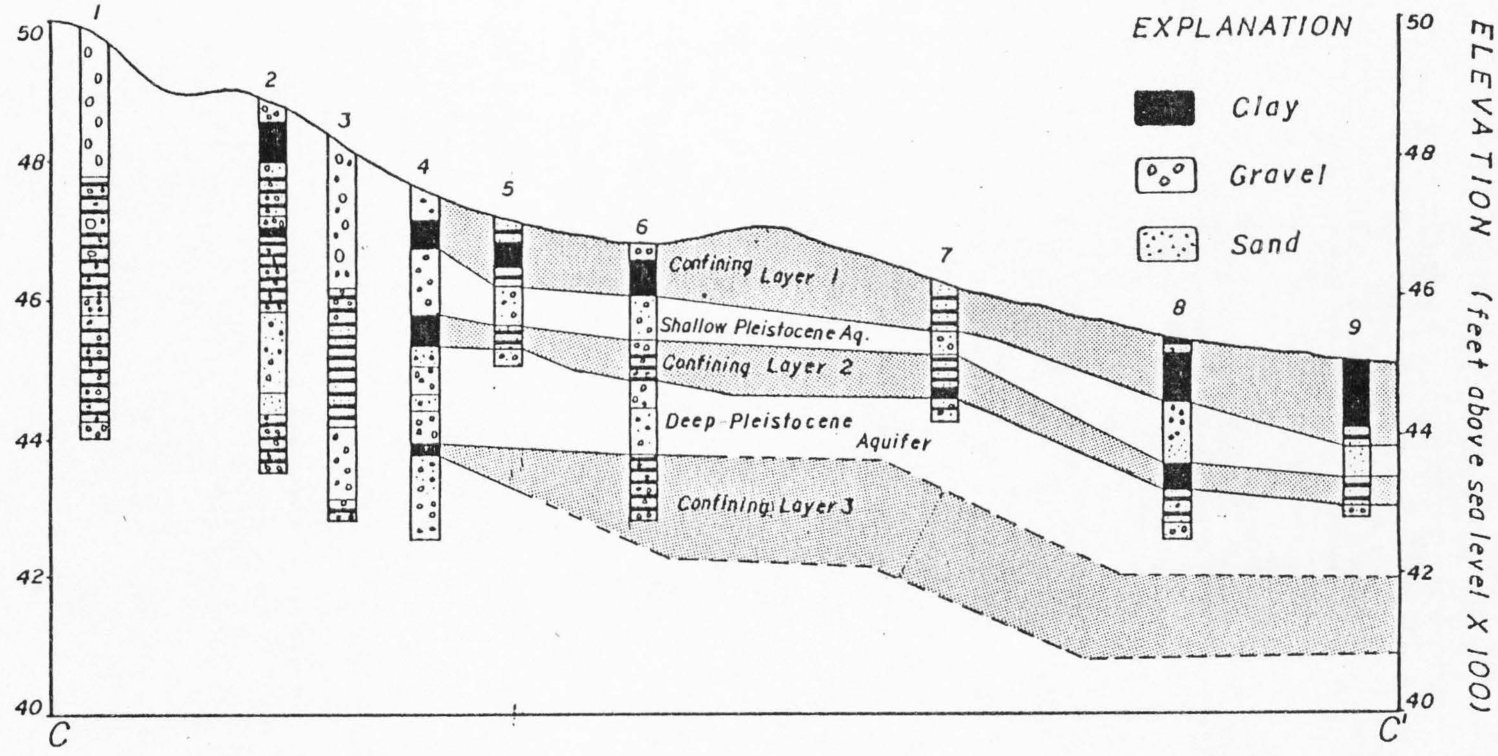


Figure 10.- Fence diagram of section C - C'.

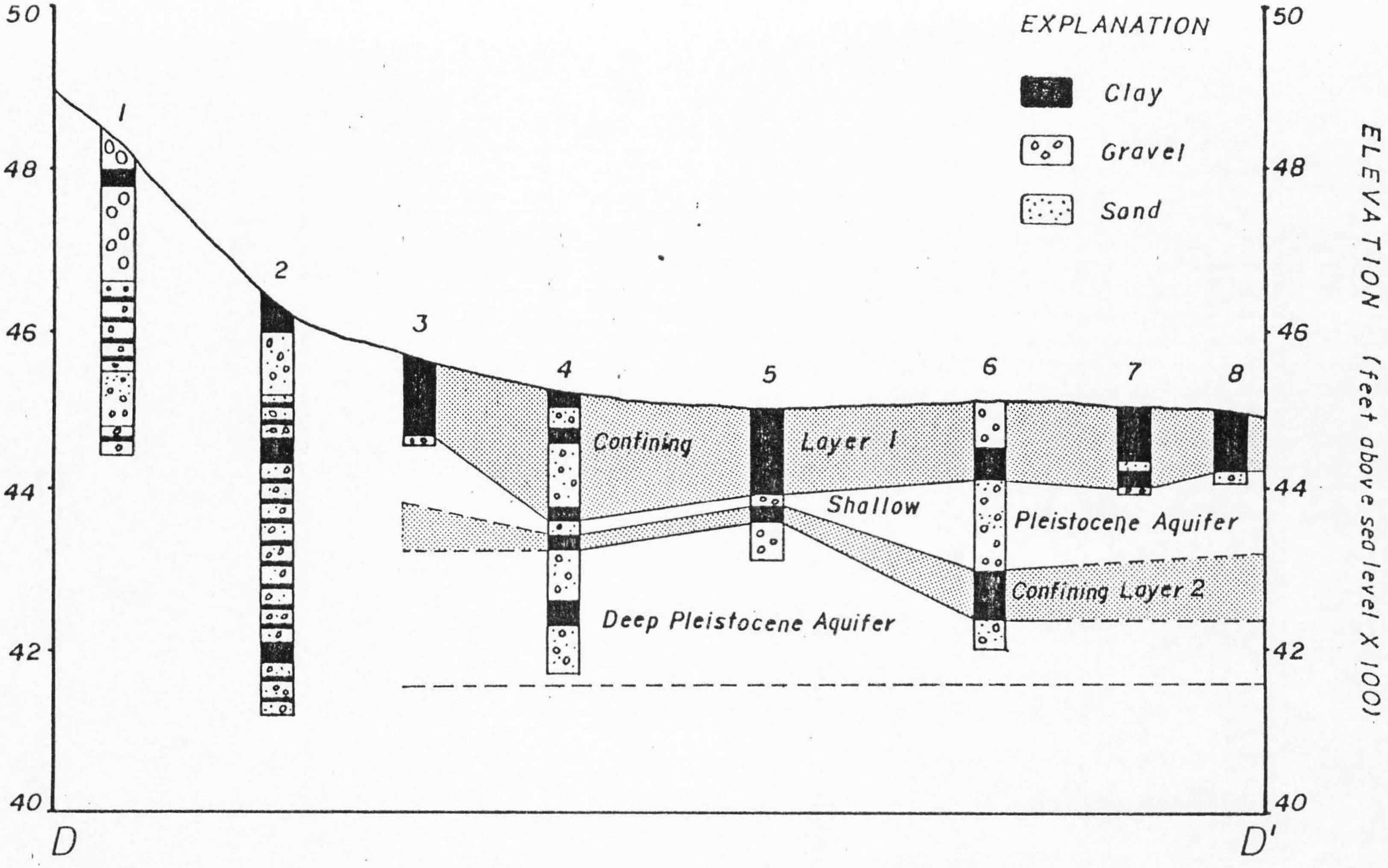


Figure 11.- Fence diagram of section D - D'.

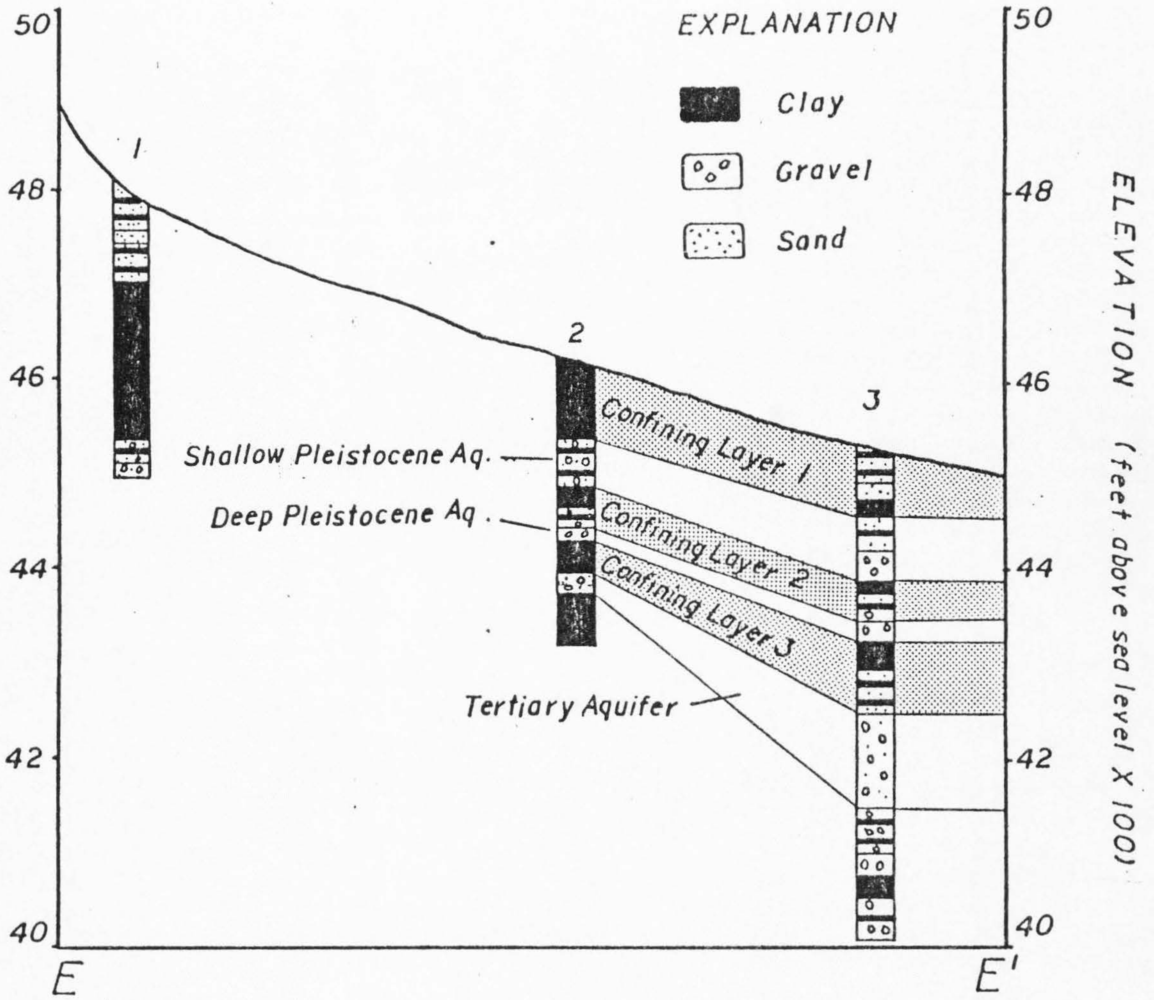


Figure 12.- Fence diagram of section E - E'.

Table 1.- Mineralogy of aquifers and confining layers, by x-ray diffraction.

| SEDIMENT ZONE | MINERALOGY* | |
|---|---|---|
| Confining layer 1 | Q C D | I K M |
| Shallow Pleistocene aquifer | Q C P | I K |
| Confining layer 2 | Q D | I K |
| Deep Pleistocene aquifer | C D | I |
| Confining layer 3 | Q C D | M Cl |
| Tertiary aquifer | Q D | M |

*Q=quartz, C=calcite, D=dolomite, P=plagioclase, I=illite, K=kaolinite, Cl=Chlorite, and M=montmorillonite.

## Cation-Exchange Capacity

Cation-exchange capacities (CEC) were calculated to meq/100 g of sediment. The results were adjusted to the grain-size (the results of grain-size analyses are in Appendix II) assuming that only clay and silt sized particles will contribute to the CEC, and the final results were used as a check on the x-ray diffraction results. According to Grim (1968) a CEC of 10 to 15 meq/100 g indicates the presence of kaolinite, 20 to 50 meq/100 g indicates illite, and 80 to 150 meq/100 g indicates montmorillonite (table 2).

Table 2.- Mineralogical comparison of aquifers and confining layers by cation-exchange capacity.

| SEDIMENT ZONE | MEAN CEC (Na adj.) meq/100g clay | CLAY MINERALS* |
|---|---|---|
| Confining layer 1 | 72.5 | I K M |
| Shallow Pleistocene aquifer | 188.5 | - |
| Confining layer 2 | 90.7 | I M |
| Deep Pleistocene aquifer | 666.8 | - |
| Confining layer 3 | 87.0 | I M |
| Tertiary aquifer | 152.4 | M |

*I=illite, K=kaolinite and M=montmorillonite.

Illite, kaolinite and montmorillonite are the major clay constituents for confining layer one, while illite and montmorillonite are dominant in confining layers two and three. The Tertiary aquifer is dominated by montmorillonite. CEC values according to calcium + magnesium + potassium + sodium (see Appendix II for individual CEC values) are anomalous, most probably because the ammonium acetate dissolved particles of calcite and dolomite, thus greatly increasing the calcium and magnesium concentrations in the ammonium acetate solution. Anomalous values are also encountered in sediments of some aquifer zones, which may be explained by the fact that perhaps more than the clay and silt sized particles contribute to the CEC. Aquifers have a very low clay content and have a larger relative error, based on the calculated CEC.

## Chemistry of the Water

Water of northern Utah Valley has basically three origins: waters of springs and streams; groundwater in undifferentiated aquifers; and groundwater in differentiated aquifers. In each of these major groups, subgroups in particular areas have been identified based on water chemistry. Mean values were calculated and used as characteristic values of the particular areas (see individual chemical analyses in Appendix III).

One hundred nine chemical analyses were obtained from surface water and groundwater systems in northern Utah Valley. Thirteen analyses were surface-water, seven were spring water, and 89 were groundwater. Of the 89 analyses of groundwater, 16 were shallow Pleistocene waters, 19 were deep Pleistocene waters, 13 were Tertiary waters, and 41 analyses were waters of undifferentiated aquifers.

Saturation indices were determined for waters in the major groups and their subordinate groups with respect to calcite, dolomite, siderite, gypsum, fluorite, chalcedony, quartz, sepiolite, sylvite, halite, magnesite, calcium dichloride, and anhydrite. These saturation indices are calculated using the log of the ion-activity product divided by the solubility product. Negative numbers show undersaturation, zero is saturation, and positive numbers show supersaturation. PHREEQE (pH-redox-equilibrium-equations), a computer program of the U.S. Geological Survey based on ion pairing in aqueous solutions, was used to calculate the indices. Input needed for this program are concentrations (mg/l) of calcium, magnesium, sodium, potassium, silica, sulfate, boron, fluoride, bicarbonate, and carbon dioxide along with pH, temperature, and redox potential.

Surface and spring water

Surface water discharging from the Alpine area (Dry Creek and Fort Creek) is very low in dissolved solids (as compared to most fresh-water streams and lakes) with only some calcium and bicarbonate present where the water comes out of the canyon mouth. It is, however, supersaturated with respect to calcite, dolomite, and quartz (table 3). Pleasant Grove surface-water (Grove and Battle Creeks) and American Fork River water contain mainly calcium and bicarbonate (fig. 13), and are supersaturated with respect to calcite and dolomite and quartz (table 3).

Table 3.- Saturation indices of surface water in the Alpine, American Fork, and Pleasant Grove areas.

| MINERAL | AREA | | |
|---|---|---|---|
| | Alpine | Am. Fork | Pl. Grove |
| calcite | .61 | 1.41 | 1.09 |
| dolomite | .53 | 2.33 | 1.82 |
| siderite | -.61 | -.03 | -.70 |
| gypsum | -3.01 | -2.02 | -1.98 |
| fluorite | -1.97 | -2.71 | -.98 |
| chalcedony | -.04 | -.34 | -.31 |
| quartz | .49 | .20 | .22 |
| sepiolite | -4.76 | -3.42 | -3.72 |
| sylvite | -9.39 | -9.95 | -9.83 |
| halite | -5.01 | -5.55 | -5.32 |
| magnesite | -3.75 | -2.76 | -2.92 |
| $CaCl_2$ | -1.07 | -1.30 | -1.03 |
| anhydrite | -3.65 | -2.69 | -2.60 |
| NO. OF SAMPLES | 4 | 2 | 2 |

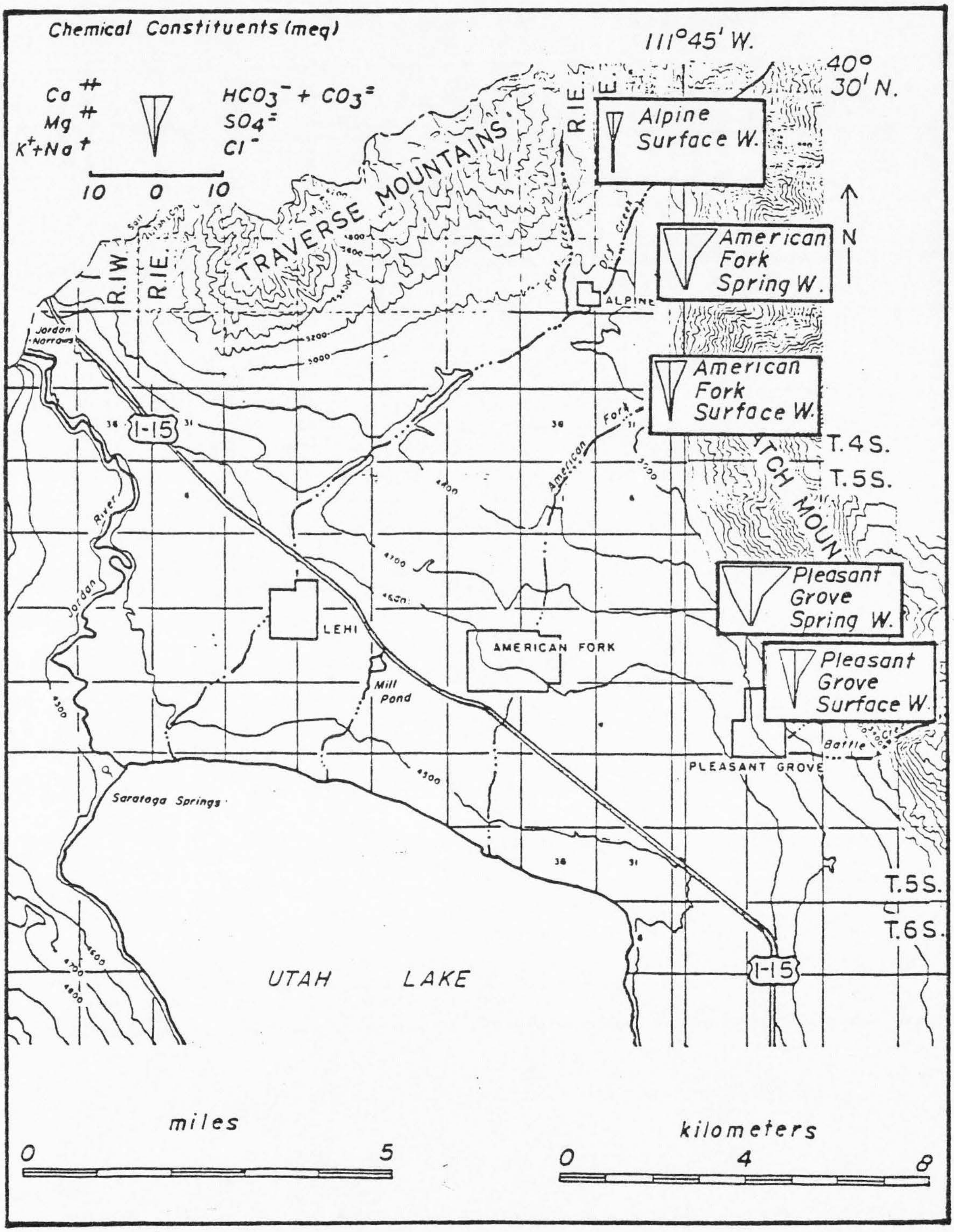


Figure 13.- Water chemistry of surface and spring water.

Springs along the Wasatch Mountain front (American Fork and Pleasant Grove areas) have relatively high concentrations of calcium and bicarbonate, and medium concentrations of magnesium and sulfate, and are supersaturated with respect to calcite, dolomite, quartz, and calcium dichloride (table 4). Springs in the Alpine area, however, are very low in dissolved solids, and therefore resemble the surrounding surface water (table 3).

Table 4.- Saturation indices of spring water in the American Fork and Pleasant Grove areas.

| MINERAL | AREA<br>Am. Fork | <br>Pl. Grove |
|---|---|---|
| calcite | .65 | .81 |
| dolomite | 1.03 | 1.04 |
| siderite | -1.18 | -.77 |
| gypsum | -1.53 | -1.36 |
| fluorite | -2.07 | -.82 |
| chalcedony | -.18 | -.20 |
| quartz | .36 | .32 |
| sepiolite | -4.13 | -4.00 |
| sylvite | -9.13 | -9.25 |
| halite | -4.54 | -4.43 |
| magnesite | -3.29 | -3.03 |
| $CaCl_2$ | .04 | .36 |
| anhydrite | -2.17 | -1.95 |
| NO. OF SAMPLES | 3 | 2 |

## Groundwater

Undifferentiated aquifers.- Waters discharging from areas not easily differentiated into shallow Pleistocene, deep Pleistocene, and Tertiary aquifers are of three major types: Jordan River; Traverse Mountains; and Wasatch Mountains. Waters of the Jordan River area have very high concentrations of all constituents, with particularly high values of chloride. Waters of the Traverse Mountains area show much variation. The waters of the Wasatch Mountains can be subdivided into American Fork, Pleasant Grove and Alpine areas (fig. 14). Wasatch Mountains water is high in calcium and bicarbonate, and is supersaturated with respect to quartz (table 5).

Table 5.- Saturation indices of water from undifferentiated aquifers in the American Fork, Pleasant Grove, and Alpine areas.

| MINERAL | AREA | | |
|---|---|---|---|
| | Am. Fork | Pl. Grove | Alpine |
| calcite | -.03 | .67 | .50 |
| dolomite | -.36 | 1.10 | .41 |
| siderite | -1.65 | -1.21 | -1.09 |
| gypsum | -1.54 | -1.50 | -2.31 |
| fluorite | -1.44 | -1.84 | -2.21 |
| chalcedony | .08 | -.09 | .02 |
| quartz | .46 | .43 | .56 |
| sepiolite | -5.98 | -3.26 | -4.11 |
| sylvite | -9.06 | -8.60 | -9.01 |
| halite | -4.54 | -3.83 | -4.74 |
| magnesite | -4.01 | -3.21 | -3.76 |
| $CaCl_2$ | -.14 | .81 | -.51 |
| anhydrite | -2.19 | -2.10 | -2.96 |
| NO. OF SAMPLES | 9 | 7 | 3 |

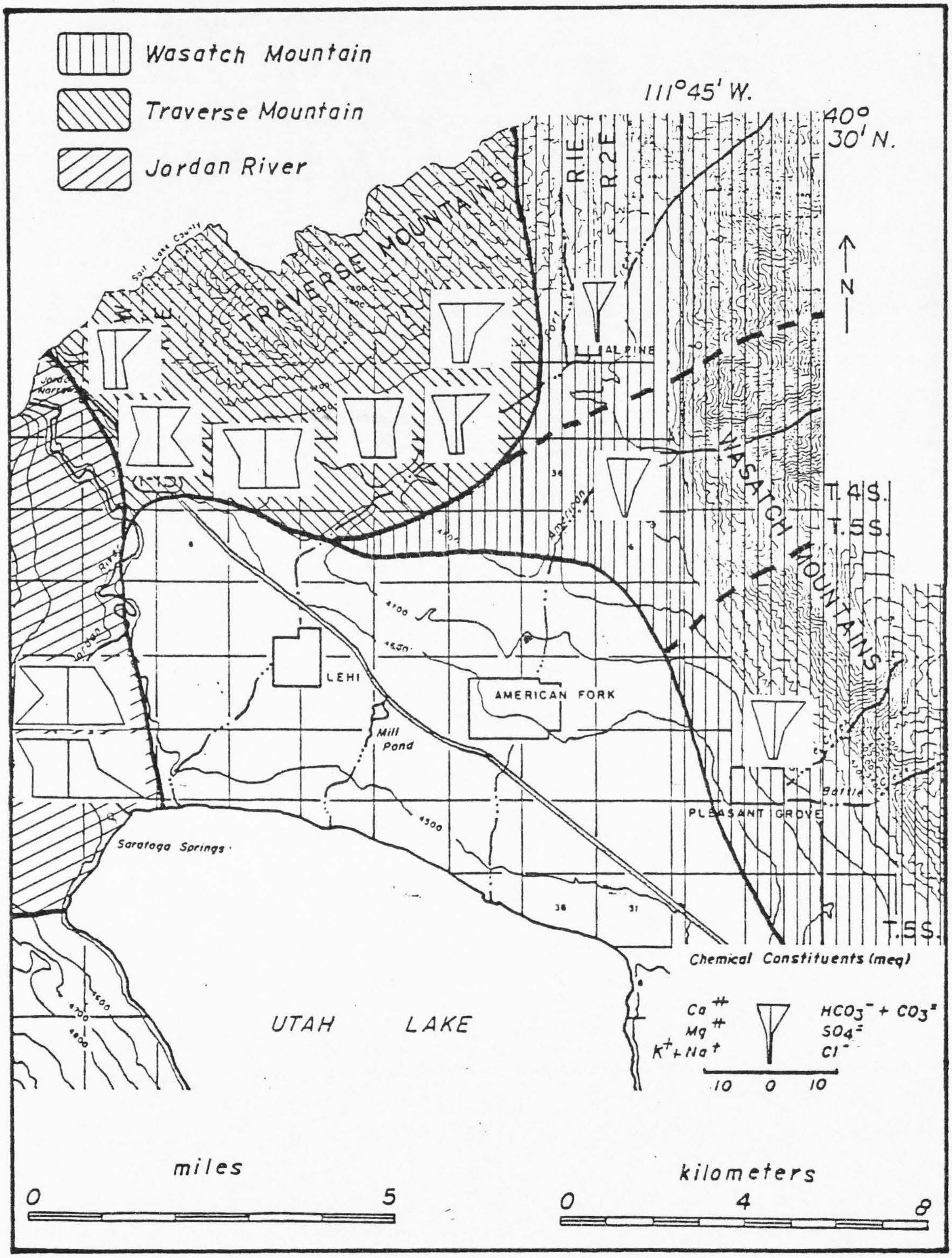


Figure 14.- Undifferentiated aquifer areas and corresponding water chemistry.

Shallow Pleistocene aquifer.- Three basic types of discharge water were encountered in different areas of the shallow Pleistocene aquifer (fig. 15a). Waters are all high in calcium and bicarbonate. In the Pleasant Grove area, however, there are higher values of magnesium and sulfate. Pleasant Grove and Alpine area waters are supersaturated with respect to calcite, dolomite, and quartz whereas American Fork water is supersaturated with respect to chalcedony and quartz (table 6).

Table 6.- Saturation indices of shallow Pleistocene water in the American Fork, Pleasant Grove, and south Pleasant Grove areas.

| MINERAL | | AREA | |
|---|---|---|---|
| | Am. Fork | Pl. Grove | S. Pl. Gr. |
| calcite | 1.07 | .46 | .53 |
| dolomite | 2.01 | .94 | .88 |
| siderite | -.57 | -1.30 | -.55 |
| gypsum | -1.53 | -1.19 | -1.59 |
| fluorite | -1.89 | -1.77 | -1.68 |
| chalcedony | .01 | .03 | .07 |
| quartz | .53 | .56 | .59 |
| sepiolite | -3.72 | -3.01 | -3.77 |
| sylvite | -8.45 | -7.99 | -7.49 |
| halite | -3.92 | -3.18 | -2.83 |
| magnesite | -2.68 | -3.17 | -3.27 |
| $CaCl_2$ | .60 | 1.44 | 1.78 |
| anhydrite | -2.11 | -1.81 | -2.17 |
| NO. OF SAMPLES | 6 | 7 | 3 |

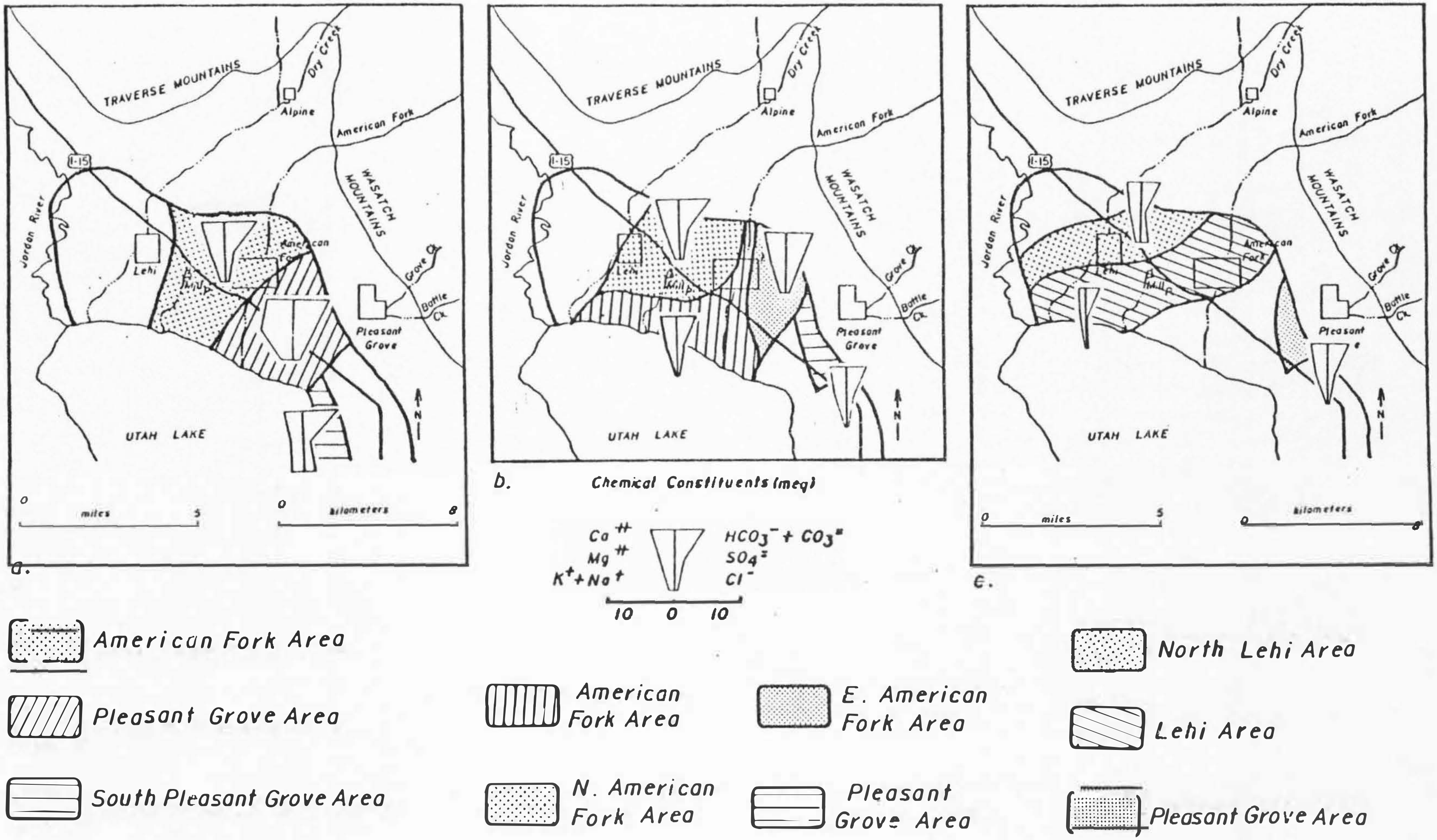


Figure 15.- Differentiated aquifer areas and corresponding water chemistry: a. shallow Pleistocene aquifer; b. deep Pleistocene aquifer; c. Tertiary aquifer.

Deep Pleistocene aquifer.- Four specific types of discharge water are found in different areas of the deep Pleistocene aquifer. Waters in the American Fork and Pleasant Grove areas have intermediate values for calcium and bicarbonate, whereas the waters of the north American Fork and east American Fork have distinctly higher values (fig. 15b). All waters are supersaturated with respect to quartz, and calcium dichloride and some with respect to calcite and dolomite (table 7).

Table 7.- Saturation indices of deep Pleistocene water in the American Fork, north American Fork, Pleasant Grove, and east American Fork areas.

| MINERAL | AREA | | | |
|---|---|---|---|---|
| | Am. Fork | N. Am. F. | Pl. Grove | E. Am. F. |
| calcite | .52 | .75 | -.01 | .59 |
| dolomite | .81 | 1.22 | -.27 | .94 |
| siderite | -.89 | -.95 | -1.16 | -1.05 |
| gypsum | -1.96 | -1.54 | -1.72 | -1.38 |
| fluorite | -2.14 | -2.06 | -2.04 | -1.99 |
| chalcedony | -.08 | .02 | -.10 | -.02 |
| quartz | .45 | .56 | .44 | .52 |
| sepiolite | -4.95 | -4.06 | -7.10 | -4.49 |
| sylvite | -8.69 | - | -8.91 | -8.68 |
| halite | -4.52 | - | -4.60 | -3.83 |
| magnesite | -3.36 | -3.19 | -3.92 | -3.29 |
| $CaCl_2$ | .22 | - | .09 | .67 |
| anhydrite | -2.58 | -2.17 | -2.36 | -2.01 |
| NO. OF SAMPLES | 11 | 5 | 1 | 2 |

*Tertiary aquifer*.- Three types of discharge water are found in different areas of the Tertiary aquifer (fig. 15c). Waters of this aquifer are all very low in mineral content. Waters of the Lehi area have some calcium and bicarbonate while the waters of the north Lehi area have fractionally higher values of sodium and chloride. These two waters are supersaturated with respect to calcite, dolomite and quartz. Waters of the Pleasant Grove area have intermediate values of calcium and bicarbonate and are supersaturated with respect to quartz and calcium dichloride (table 8).

Table 8.- Saturation indices of Tertiary water in the Lehi, north Lehi, and Pleasant Grove areas.

| MINERAL | | AREA | |
|---|---|---|---|
| | Lehi | North Lehi | Pl. Grove |
| calcite | .22 | .69 | -.16 |
| dolomite | .22 | 1.19 | -.55 |
| siderite | -.96 | -.94 | -1.90 |
| gypsum | -2.69 | -1.98 | -1.69 |
| fluorite | -2.04 | -.77 | -2.06 |
| chalcedony | -.06 | .07 | -.07 |
| quartz | .48 | .60 | .46 |
| sepiolite | -3.34 | -3.68 | -7.58 |
| sylvite | -8.91 | -8.05 | - |
| halite | -4.50 | -3.50 | -5.35 |
| magnesite | -3.67 | -3.14 | -4.04 |
| $CaCl_2$ | -.15 | 1.43 | .05 |
| anhydrite | -3.35 | -2.59 | -2.30 |
| NO. OF SAMPLES | 7 | 5 | 1 |

# CHEMICAL INTERPRETATION OF GROUNDWATER MOVEMENT

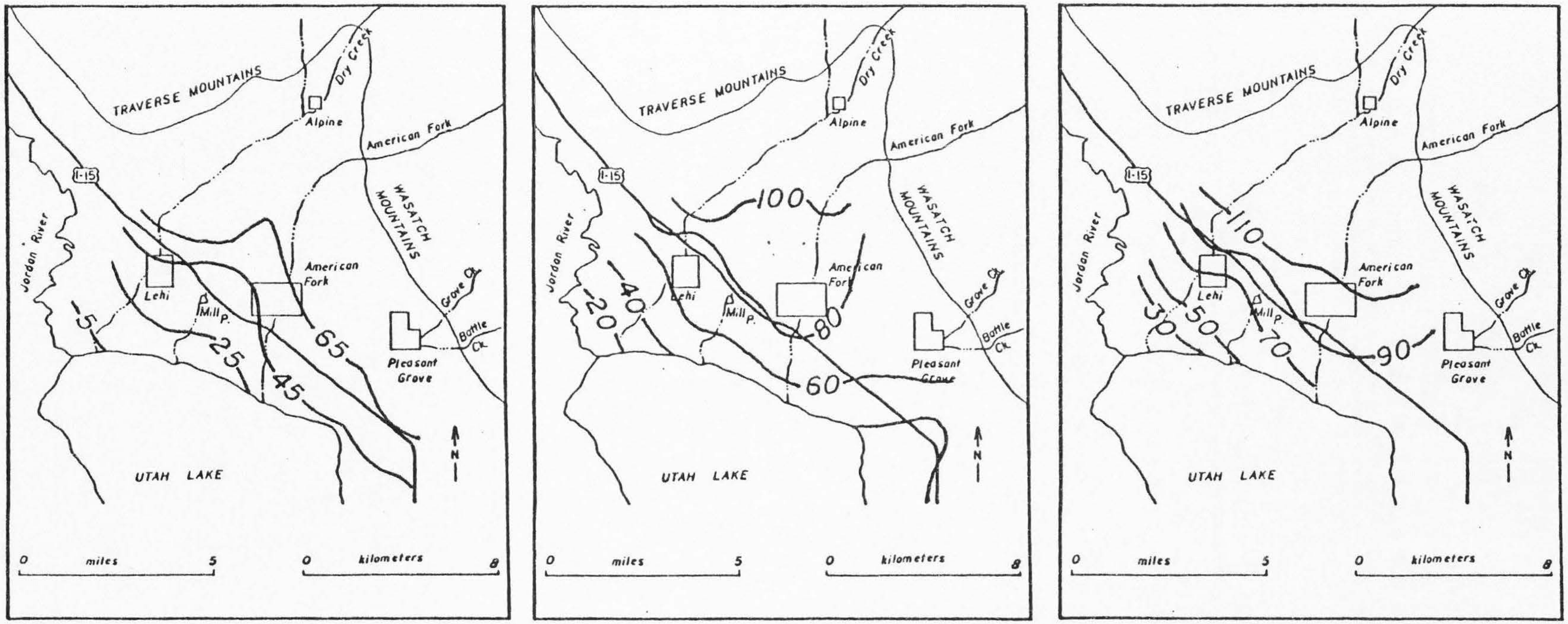
The overall movement of water in northern Utah Valley is from the mountain areas to the undifferentiated deposits which flank the mountains, to all the differentiated aquifers, and then to Utah Lake. Potentiometric surface contour maps of all three aquifers (fig. 16) show this basic trend. Contour maps of the specific conductance (a function of the dissolved solids) however, show complexities in the flow pattern, including several geochemical cells (fig 17).

## Shallow Pleistocene Aquifer

### American Fork area

Waters discharging from this area are possibly recharged by waters of undifferentiated aquifers of the American Fork area (fig. 18). The increase in ion concentration of the discharging water is likely due to dissolution or reactions of calcite, plagioclase and kaolinite in the aquifer (table 1). Calcite is undersaturated in the recharge waters (log IAP/K=-0.03 from table 5), and supersaturated in the discharge waters (log IAP/K=+1.07 from table 6).

Another possibility of recharge is upward leakage through confining layer two, from the deep Pleistocene aquifer. This vertical movement was seen in a pump test supervised by David Clark (personal communication, 1982). The test included pumping water from one aquifer and measuring water-levels from water wells in all aquifers. The results showed that water levels of all aquifers were affected.



a. b. c.

Figure 16.- Potentiometric surface maps (feet above sea level + 4500): a. shallow Pleistocene aquifer; b. deep Pleistocene aquifer; c. Tertiary aquifer.

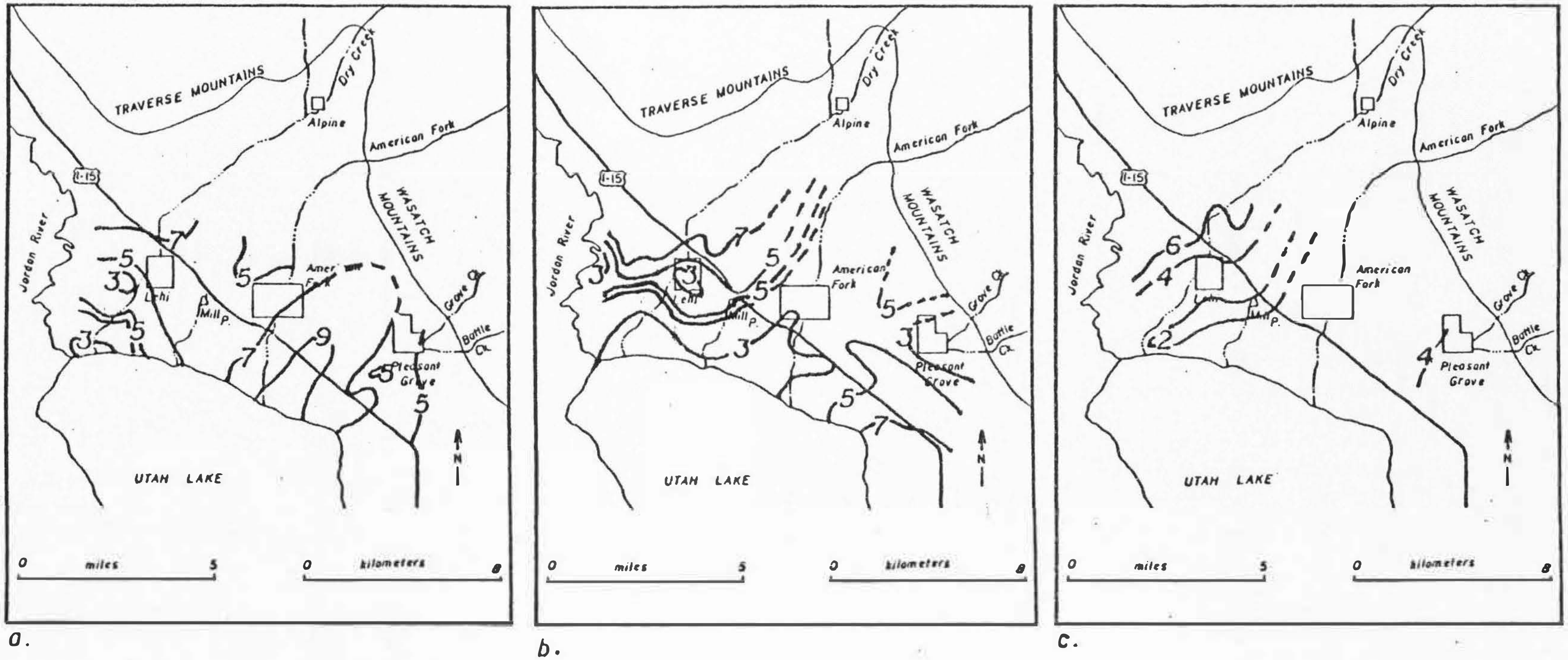


Figure 17.- Specific conductance contour maps (micromhos X 100): a. shallow Pleistocene aquifer; b. deep Pleistocene aquifer; c. Tertiary aquifer.

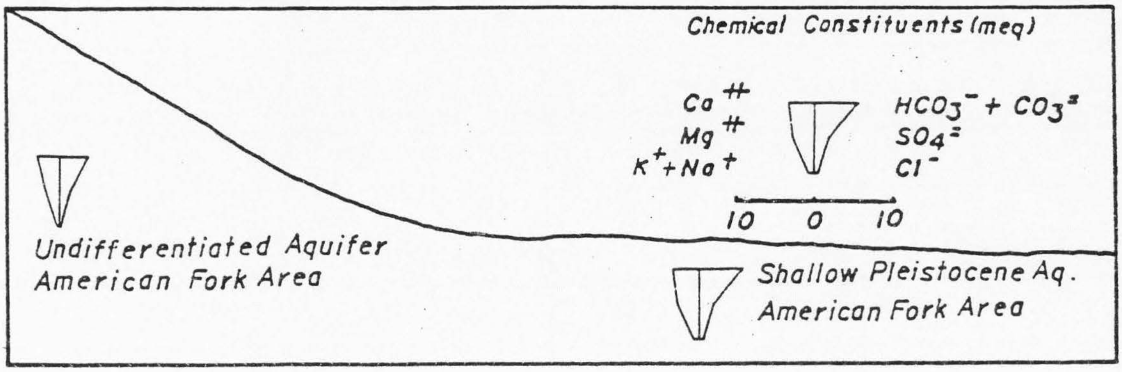


Figure 18.- A generalized section representing water movement in the shallow Pleistocene aquifer, American Fork area. Water from the undifferentiated aquifer of the American Fork area recharges the shallow Pleistocene aquifer of the American Fork area.

An additional source of ions could be exchange from clay minerals. A geochemical model can be constructed, using cation-exchange capacity, to see if the upward moving deep Pleistocene water can react with sediments of confining layer two and produce shallow Pleistocene water of this area. If one were to assume that one liter of water passes through a column five cm in diameter with an average length equal to the thickness of the confining layer (2815 cm), 442,000 g of sediment (at 2 $g/cm^3$) would be able to react with the one liter of water. There are 0.56 meq/l of ion added to the water, as the water passes through the confining layer. Because 245,000 meq are available, it is reasonable that water may move upward through the confining layer, and thereby add ions to the solution (table 9).

Table 9.- Geochemical CEC model calculating the feasibility of upward leakage from the deep Pleistocene aquifer to the shallow Pleistocene aquifer.

Cations in Solution

| Ion | Recharge Water meq/l | Discharge Water meq/l | Change meq/l |
|---|---|---|---|
| calcium | 3.43 | 3.33 | -0.1 |
| magnesium | 2.19 | 2.78 | 0.59 |
| sodium | 0.71 | 0.77 | 0.06 |
| potassium | 0.056 | 0.061 | 0.01 |
| TOTAL | | | 0.56 |

Cations in sediments of Confining Layer 2

CEC (Na )*: 55.4 meq/100g = 0.554 meq/g
Total amount of sediment: 442,000 g
Total exchangeable cations in sediment = 245,000 meq
Exchangeable cations in the sediment (mean values): 230·meq calcium /100g; 63.7 meq magnesium /100g; 7.4 meq potassium /100g; 26.3 meq sodium /100g.

*Note that CEC was determined using sodium saturated samples. The CEC based on the individual cations is greater than the CEC based on sodium because of the solution of calcite and dolomite.

Pleasant Grove area

Waters discharging in this area have relatively high values of sulfate. A very probable source of this water is from the Wasatch Fault zone. High sulfate waters possibly travel up along the fault and out into the valley. Such a mechanism is suggested by one local water sample found in a shallow undifferentiated aquifer east of the Pleasant Grove area (fig. 19). As the water travels farther into the valley, it is possibly diluted by undifferentiated aquifer water from the American

Fork area, or by water leaking upward from the deep Pleistocene aquifer. Springs along the Wasatch Mountain front are all relatively high in mineral content (fig. 13), which may be a result of upward migrating thermal waters. Using a geochemical mixing model (Truesdell and Fournier, 1977) with input of temperature and silica concentration, the spring waters are a possible mixture of thermal waters and between 50% and 90% surface waters.

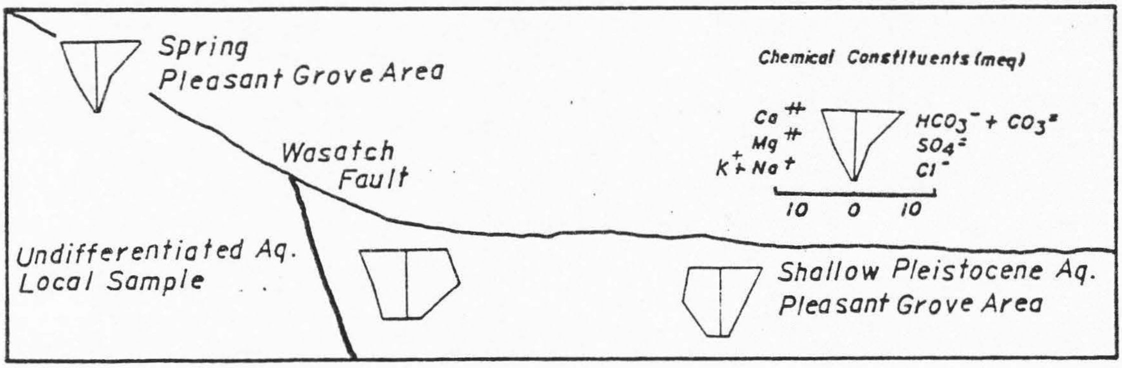


Figure 19.- A generalized section representing water movement in the shallow Pleistocene aquifer, Pleasant Grove area. Water from the Wasatch Fault recharges waters of the valley in the Pleasant Grove area and affects waters of the springs in the Pleasant Grove area.

South Pleasant Grove area

Water from this area resembles water of the undifferentiated aquifers of the Pleasant Grove area (fig. 20). It has a much higher concentration, however, of sodium and some chloride. Perhaps calcite is being dissolved from the aquifer (table 1). This would liberate calcium ions which could exchange with sodium and increase the concentration of sodium in solution.

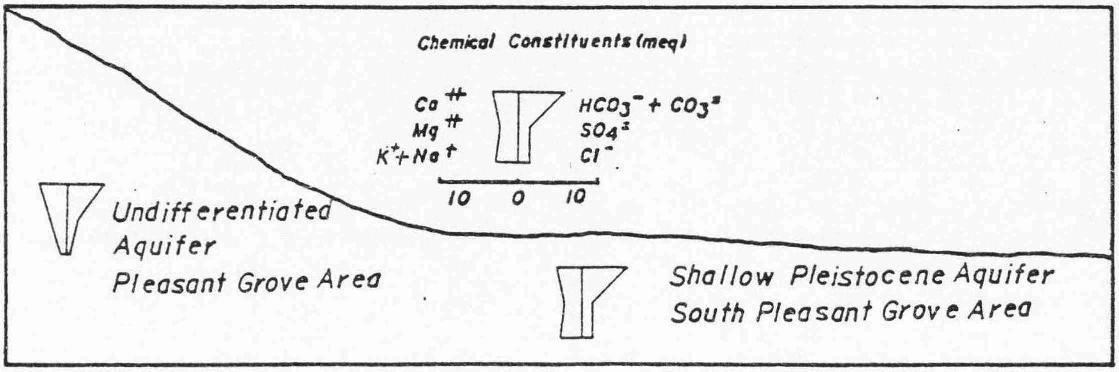


Figure 20.- A generalized section representing water movement in the shallow Pleistocene aquifer, south Pleasant Grove area. Water from undifferentiated aquifers of the Pleasant Grove area recharges the shallow Pleistocene aquifer in the south Pleasant Grove area.

## Deep Pleistocene Water

### American Fork area

The water discharging from this area is chemically so very close to undifferentiated aquifer water of American Fork, that water most likely flows relatively fast, approximately 1.41 m/day (table 10), from the recharge area to the discharge area. Hunt and others (1953), while mapping the geology of unconsolidated valley deposits, found many channel deposits flanking the American Fork River (fig. 2). Sediments of the deep Pleistocene aquifer are mostly composed of calcite and dolomite (table 1), being eroded from the carbonates of the American Fork Canyon. This indicates that perhaps the deep Pleistocene aquifer of the area is a combination of channel and fan deposits of the ancient American Fork River.

Table 10.- Velocity calculations of water movement in the deep Pleistocene aquifer.

| | AREAS<br>North American Fork | American Fork |
|---|---|---|
| Wells | C-7, B-5, B-6 | C-4, C-5, C-6 |
| Average Distance | 2,978 m | 2,897 m |
| Vertical Drop | 61 m | 61 m |
| Porosity* | 41.1% | 34.7% |
| Conductivity** | 9.54 m/day | 23.2 m/day |
| Velocity*** | 0.48 m/day | 1.41 m/day |

* Porosity is a function of grainsize (after Freeze and Cherry, 1979)

** Conductivity is a function of grainsize (after Mower, 1974)

*** Velocity = Conductivity X Vertical Drop / Porosity X Distance (after Todd, 1980)

Some water probably leaks upward from the Tertiary aquifer and mixes with water of the American Fork area. This may explain the fact that the recharge water is slightly more concentrated with respect to calcium and bicarbonate (fig. 21). Using the geochemical CEC model and assuming that one liter passes through a column of sediment five cm in diameter and having an average length equal in thickness to the confining layer (1636 cm), then 257,000 g of sediment could react with migrating waters. There are 1.54 meq/l of ion added to the water, most likely through a combination of dissolution of calcite and dolomite, and exchanging calcium and magnesium with sodium and potassium. Because 137,000 meq are available, it is feasible for upward moving water to react with the sediments of confining layer three and produce water of this area (table 11).

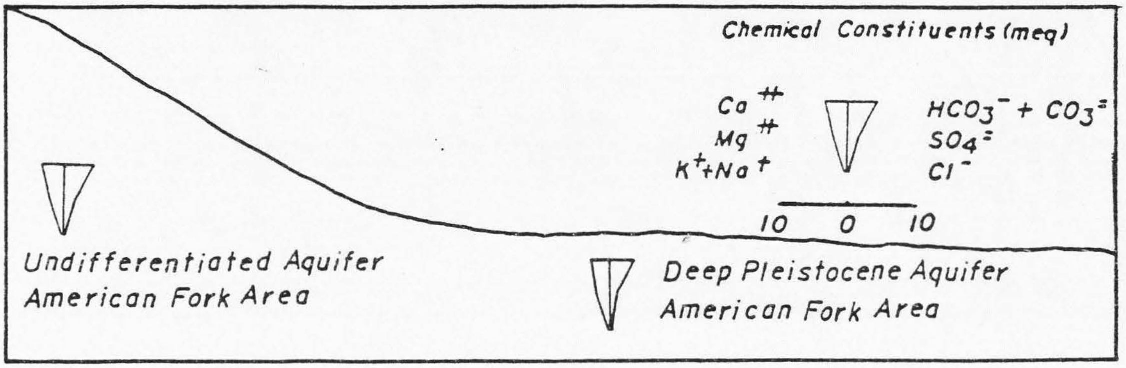


Figure 21.- A generalized section representing water movement in the deep Pleistocene aquifer, American Fork area. Waters from undifferentiated aquifers of the American Fork area recharge the deep Plesitocene aquifer of the American Fork area.

Table 11.- Geochemical CEC model calculating the feasibility of upward leakage from the Tertiary aquifer to the deep Pleistocene aquifer.

Cations in Solution

| Ion | Recharge Water meq/l | Discharge Water meq/l | Change meq/l |
|---|---|---|---|
| calcium | 1.05 | 1.97 | 0.92 |
| magnesium | 0.84 | 1.41 | 0.56 |
| sodium | 0.23 | 0.27 | 0.04 |
| potassium | 0.02 | 0.04 | 0.02 |
| TOTAL | | | 1.54 |

Cations in sediments of Confining Layer 3

CEC (Na)*: 53.4 meq/100 g = 0.534 meq/g
Total amount of sediment: 257,000 g
Total exchangeable cations in the sediment: 137,000 meq
Exchangeable cations in the sediment (mean values): 235 meq calcium /100g; 64.7 meq magnesium /100g; 8.0 meq potassium /100g; 36.2 meq sodium /100g.

* Note that the CEC was determined using sodium saturated samples. The CEC based on the sum of individual ions is greater than the CEC based on sodium because of solution of calcite and dolomite.

## North American Fork area

Waters discharged in this area are very much like the waters of the American Fork area with higher values of calcium, magnesium, and bicarbonate (fig. 15b). They are most likely recharged from the same source as the American Fork area. This water moves 0.48 m/day (table 10), which is slower than American Fork water. This water is also more supersaturated with respect to calcite and dolomite (log IAP/K=+0.75 and +1.22 from table 7) than is the water of American Fork (log IAP/K=+0.52 and +0.81 from table 7). The differences in water chemistry can be explained by the fact that movement is slower in northern American Fork water, leaving more time for reactions to take place. Perhaps this area represents flood-plain deposits of the ancient American Fork River.

## East American Fork area

Waters of this area are very similar to the waters of north American Fork (fig. 15b). They can be explained in the same way, as waters recharged from the undifferentiated aquifers of the American Fork area, and moveing slowly through flood-plain type deposits. The waters of this area, however, have higher sulfate content than the waters of north American Fork. Possibly there are some thermal waters present from the nearby Wasatch Mountain Fault zone, elevating the sulfate values.

## Pleasant Grove area

Pleasant Grove waters are very similar to American Fork waters. They are likely recharged, however, from the nearby Pleasant Grove surface waters, which represent an environment similar to American Fork water (fig. 22).

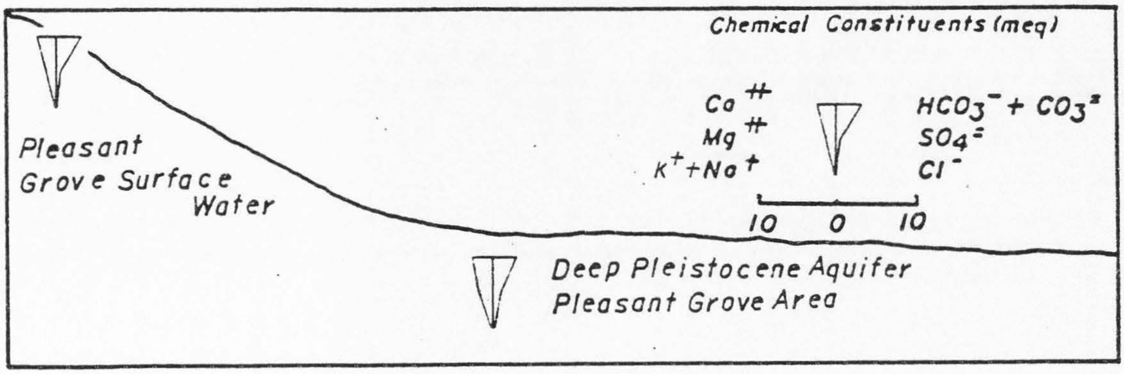


Figure 22.- A generalized section representing water movement in the deep Pleistocene aquifer, Pleasant Grove area. Surface waters from the Pleasant Grove area recharge the deep Pleistocene aquifer in the Pleasant Grove area.

## Tertiary Aquifer

### Lehi area

The waters discharging from this area are so low in mineral content that the most probable origin of the water is surface waters from the Alpine area. Recharge water probably travels very quickly along a section of the Wasatch Fault or through gravels and boulders of fluvial and glacial origin (fig. 23). The higher values of sodium and chloride in the aquifer can be explained in two possible ways: some water migrates upward from very deep saline deposits (Dustin and Merritt, 1980); or recharge water mixes with highly mineralized waters of the undifferentiated aquifers of the Traverse mountain area.

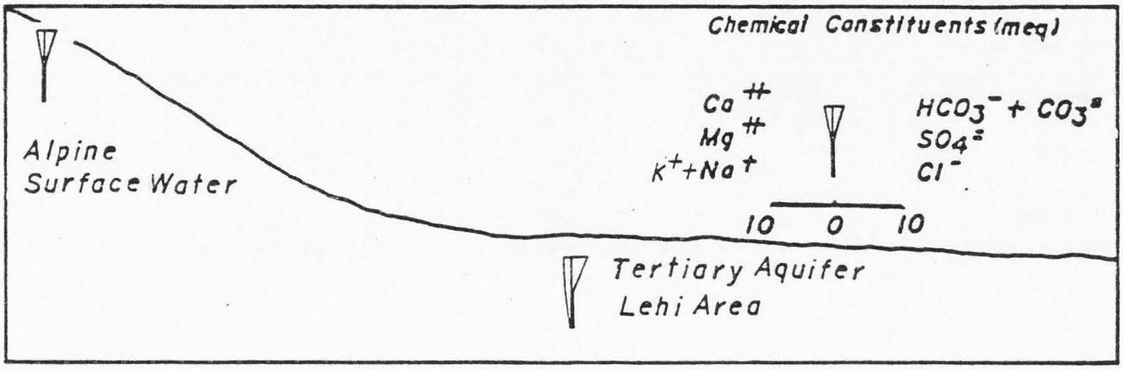


Figure 23.- A generalized section representing water movement in the Tertiary aquifer, Lehi area. Alpine surface water recharges the Tertiary aquifer in the Lehi Area.

### North Lehi area

The water discharging from this area is slightly more concentrated than Lehi water with respect to all major minerals (fig. 15c). Recharge most likely has the same source area as Lehi waters, and the difference in chemistry is explained in two possible ways: this water moves more slowly than waters of the Lehi area, allowing for more water-sediment reactions; or this water is mixing with highly concentrated waters of undifferentiated aquifers of the Traverse Mountains area.

### Pleasant Grove area

The water discharging in Pleasant Grove is almost identical to the water in the deep Pleistocene aquifer of Pleasant Grove (fig. 15c). Both of these waters are most likely recharged by waters of the Pleasant Grove surface-water system.

# SUMMARY

The data gathered in the course of this investigation indicate that the groundwater system in northern Utah Valley is very complex, with several geochemical cells in each of the three major aquifers. The mineralogy of the surrounding mountains controls the water chemistry of recharge water. Sediments of the valley affect the water mostly by increasing the dissolved mineral content. Major faults of the area may also change the water chemistry by adding highly mineralized thermal water.

The general movement of the water is from the mountains, through the undifferentiated aquifers and differentiated aquifers, to Utah Lake. Many times, however, water does not travel in a linear fashion or perpendicular to the mountains. Waters may move very rapidly in one area, and quite slowly in another area, even in the same aquifer. Waters also may move upward vertically because of the higher artesian pressures of the lower aquifers.

The overall mineralogy of the sediments shows very little varitation, with quartz, calcite and dolomite being the major constituents in most aquifers and confining layers.

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# APPENDICES

# Appendix I. X-Ray Diffraction Analyses

## DRILL HOLE E-2

| Zone | Depth (ft.) | (particles≤2mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Q | M | K | C | D | I | P | Z | Cl |
| Confining Layer 1 | 32 | S | W | S | S | W | S | W | - | - |
| Shallow Pleistocene Aq. | 73 | S | W | S | S | W | S | W | - | - |
| Confining Layer 3 | 206 | S | W | - | S | S | W | W | - | - |
| Tertiary Aquifer | 208 | S | S | W | - | S | W | S | W | - |
| Tertiary Aquifer | 220 | S | W | W | W | S | - | W | - | - |
| Tertiary Aquifer | 245 | S | S | W | S | S | - | S | - | - |

| Zone | Depth (ft.) | (particles≤0.002mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Q | M | K | C | D | I | P | Z | Cl |
| Confining Layer 1 | 32 | S | W | S | S | W | S | W | W | - |
| Shallow Pleistocene Aq. | 73 | S | W | S | S | W | S | W | - | - |
| Confining Layer 3 | 206 | S | S | W | S | S | W | W | - | - |
| Tertiary Aquifer | 208 | W | S | W | - | - | - | - | - | - |
| Tertiary Aquifer | 220 | W | S | W | W | - | - | - | - | - |
| Tertiary Aquifer | 245 | S | S | W | S | S | W | W | - | - |

## DRILL HOLE A-4

| Zone | Depth (ft.) | (particles≤2mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Q | M | K | C | D | I | P | Z | Cl |
| Topsoil | 12 | S | W | S | S | S | S | W | W | - |
| Topsoil | 13 | S | - | - | W | W | - | W | - | - |
| Confining Layer 1 | 78 | S | S | W | S | S | S | S | W | - |
| Shallow Pleistocene Aq. | 210 | S | W | S | S | W | S | S | S | - |
| Confining Layer 2 | 303 | S | - | - | W | S | S | S | - | - |
| Confining Layer 2 | 310 | S | - | W | S | W | W | W | - | - |
| Deep Pleistocene Aq. | 435 | S | - | W | S | W | W | W | - | - |
| Confining Layer 3 | 467 | S | - | - | S | S | - | W | - | W |

| Zone | Depth (ft.) | (particles≤0.002mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Q | M | K | C | D | I | P | Z | Cl |
| Topsoil | 12 | S | W | S | S | S | S | W | - | - |
| Topsoil | 13 | - | S | W | - | - | W | - | - | - |
| Confining Layer 1 | 78 | W | S | S | - | - | S | - | - | - |
| Shallow Pleistocene Aq. | 210 | W | W | W | - | - | W | - | - | - |
| Confining Layer 2 | 303 | W | W | W | - | - | S | - | - | - |
| Confining Layer 2 | 310 | S | S | S | S | W | S | W | W | - |
| Deep Pleistocene Aq. | 435 | W | W | W | W | - | W | - | - | - |
| Confining Layer 3 | 467 | W | - | - | W | W | - | - | - | S |

## DRILL HOLE C-4

| Zone | Depth (ft.) | (particles≤2mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Q | M | K | C | D | I | P | Z | Cl |
| Topsoil | 25 | S | - | W | S | S | S | S | W | - |
| Confining Layer 1 | 50 | S | W | W | S | S | S | W | W | - |
| Shallow Pleistocene Aq. | 125 | S | - | S | S | S | S | S | - | - |
| Confining Layer 2 | 180 | W | - | S | S | S | S | W | W | - |
| Deep Pleistocene Aq. | 240 | W | - | S | S | S | S | S | - | - |
| Deep Pleistocene Aq. | 255 | W | - | W | S | S | W | - | - | - |

| Zone | Depth (ft.) | (particles≤0.002mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Q | M | K | C | D | I | P | Z | CL |
| Topsoil | 25 | W | - | W | - | - | S | - | - | - |
| Confining Layer 1 | 50 | W | - | S | W | - | S | - | - | - |
| Shallow Pleistocene Aq. | 125 | W | - | W | S | W | S | - | - | - |
| Confining Layer 2 | 180 | W | - | S | W | W | S | - | - | - |
| Deep Pleistocene Aq. | 240 | W | - | W | W | W | W | - | - | - |
| Deep Pleistocene Aq. | 255 | W | - | W | - | - | W | - | - | - |

### EXPLANATION

Strong (S) and weak (W) x-ray diffraction peaks are shown of quartz (Q), montmorillonite (M), kaolinite (K), calcite (C), dolomite (D), plagioclase (P), zeolite (Z) and chlorite (Cl).

# Appendix II. Cation-Exchange Capacity Analyses

| SAMPLE (depth) | Ca | Mg | K | Na | CEC(1) | CEC(2) | CEC(3) | Clay+Silt % |
|---|---|---|---|---|---|---|---|---|
| E-2 | | | | | | | | |
| 32 | 267.8 | 97.8 | 11.2 | 35.2 | 412.0 | 56.8 | 59.5 | 95.5 |
| 73 | 308.0 | 185.5 | 12.8 | 31.8 | 501.1 | 59.0 | 59.8 | 98.7 |
| 206 | 267.8 | 104.2 | 11.8 | 49.5 | 433.3 | 57.0 | 76.4 | 74.6 |
| 208 | 144.0 | 141.5 | 11.2 | 41.8 | 338.5 | 64.2 | 103.4 | 62.1 |
| 220 | 193.8 | 14.5 | 5.2 | 35.0 | 248.5 | 44.8 | 211.3 | 21.2 |
| 245 | 242.8 | 149.5 | 11.8 | 42.0 | 446.1 | 63.2 | 93.0 | 67.5 |
| A-4 | | | | | | | | |
| 11 | 242.0 | 194.0 | 15.0 | 43.5 | 494.5 | 54.5 | 56.9 | 95.8 |
| 13 | 156.2 | 26.5 | 5.2 | 27.0 | 214.9 | 42.8 | 265.8 | 16.1 |
| 77 | 242.5 | 37.0 | 10.2 | 29.8 | 329.5 | 60.8 | 74.7 | 81.4 |
| 210 | 127.8 | 19.5 | 4.8 | 36.0 | 188.1 | 50.2 | 307.9 | 16.3 |
| 303 | 123.8 | 24.0 | 5.8 | 27.0 | 180.6 | 55.0 | 152.7 | 36.0 |
| 310 | 310.2 | 123.5 | 9.5 | 26.5 | 469.7 | 63.5 | 63.5 | 99.3 |
| 435 | 202.2 | 14.2 | 5.2 | 27.8 | 294.4 | 52.8 | 204.6 | 25.8 |
| 467 | 215.2 | 25.2 | 4.2 | 22.8 | 267.4 | 49.8 | 97.6 | 51.0 |

C-4

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 25 | 182.5 | 15.0 | 4.2 | 23.2 | 224.9 | 60.2 | 200.0 | 30.1 |
| 50 | 256.8 | 30.2 | 5.2 | 14.5 | 306.7 | 54.0 | 83.3 | 64.8 |
| 125 | 252.8 | 12.0 | 4.2 | 26.2 | 295.0 | 54.0 | 197.8 | 27.3 |
| 180 | 256.0 | 45.3 | 7.0 | 25.5 | 332.0 | 47.8 | 56.0 | 85.3 |
| 240 | 178.8 | 52.0 | 4.0 | 25.5 | 213.5 | 43.5 | 537.0 | 8.1 |
| 255 | 176.2 | 9.0 | 4.5 | 28.8 | 218.5 | 42.8 | 1258.8 | 3.4 |

## EXPLANATION

Individual cation exchange capacity (CEC) are shown for calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na). CEC (1) is based on the sum of calcium, magnesium, potassium, and sodium. CEC (2) is based on a sodium saturated solution. CEC (3) is a clay + silt adjusted cation exchange capacity in which CEC (2) is adjusted to 100% clay + silt. All CEC values are calculated to meq/100g.

# Appendix III. Water-Chemistry Analyses

## AMERICAN FORK SPRINGS

| WELL | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 16 | 430 | - | 10.0 | 60.0 | 31.0 | 6.6 | 1.3 | 40.0 | 7.5 | 20 | - | .1 | - | - |
| 2 | 7 | 345 | 7.6 | 5.1 | 51.0 | 13.0 | 2.5 | .2 | 22.0 | 2.7 | 0 | 8.1 | .2 | 202 | 8.5 |
| 3 | 11 | - | 7.7 | 9.6 | 99.0 | 41.0 | 13.0 | .9 | 130.0 | 13.0 | 20 | 12.1 | .2 | 378 | 8.5 |
| Mean | 11 | 387 | 7.6 | 8.2 | 70.0 | 28.3 | 7.4 | .8 | 64.0 | 7.7 | 13 | 10.1 | .2 | 290 | 8.5 |

## PLEASANT GROVE SPRINGS

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 16 | 675 | 7.8 | 8.5 | 88.0 | 31.0 | 7.3 | .6 | 90.0 | 7.5 | 20 | .9 | .9 | 354 | 7.6 |
| 2 | 16 | 760 | 7.3 | 9.2 | 93.0 | 39.0 | 11.0 | .7 | 81.0 | 9.3 | 20 | 31.6 | .5 | 376 | 5.4 |
| Mean | 16 | 717 | 7.6 | 8.8 | 90.5 | 35.0 | 9.2 | .6 | 85.5 | 8.4 | 20 | 16.2 | .7 | 365 | 7.0 |

## ALPINE SURFACE WATER

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 15 | 105 | 8.3 | 6.5 | 17.0 | 1.9 | 1.9 | .4 | .1 | 1.6 | 10 | .5 | .2 | 65 | 8.1 |
| 2 | 13 | 138 | 8.6 | 12.0 | 13.0 | 2.8 | 5.9 | 1.1 | 1.2 | 3.8 | 0 | .9 | .1 | 58 | 8.5 |
| 3 | 11 | 205 | 7.4 | 14.0 | 28.0 | 3.8 | 6.5 | 1.1 | 8.5 | 4.4 | 10 | 7.1 | .5 | 112 | 8.4 |
| 4 | 9 | 164 | 7.0 | 13.0 | 26.0 | 4.3 | 6.3 | 1.1 | 8.4 | 3.9 | 10 | 16.9 | .4 | 108 | 8.2 |
| Mean | 12 | 153 | 7.8 | 11.4 | 21.0 | 3.2 | 5.2 | .9 | 4.6 | 3.4 | 8 | 6.4 | .3 | 86 | 8.3 |

## AMERICAN FORK SURFACE WATER

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 11 | 326 | 8.5 | 6.5 | 46.0 | 12.0 | 2.6 | .3 | 38.0 | 2.6 | 10 | - | .1 | 160 | - |
| 2 | 10 | 280 | 7.9 | 4.7 | 42.0 | 10.0 | 2.2 | .5 | 23.0 | 1.8 | - | - | .1 | - | - |
| Mean | 11 | 303 | 8.2 | 5.6 | 44.0 | 11.0 | 2.4 | .4 | 30.5 | 2.2 | 10 | - | .1 | 160 | - |

## PLEASANT GROVE SURFACE WATER

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 12 | 325 | 8.4 | 5.4 | 43.0 | 13.0 | 2.7 | .5 | 18.0 | 1.7 | 0 | - | .6 | 200 | - |
| 2 | 14 | 410 | 7.5 | 7.3 | 53.0 | 17.0 | 4.6 | .5 | 41.0 | 3.3 | 10 | - | .5 | - | - |
| Mean | 13 | 368 | 8.0 | 6.4 | 48.0 | 15.0 | 3.6 | .5 | 29.5 | 2.5 | 5 | - | .6 | 200 | - |

## OTHER SURFACE WATER

| Well | T | Sc | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7 | 89 | 7.5 | 4.5 | 13.0 | 1.4 | 1.5 | .5 | 2.2 | .9 | - | - | .1 | 65 | - |
| 2 | 28 | 500 | 8.4 | 9.8 | 56.0 | 24.0 | 11.0 | 4.3 | 79.0 | 10.0 | 40 | .4 | .3 | 202 | - |
| 3 | 14 | 380 | 8.6 | 8.8 | 49.0 | 13.0 | 9.4 | 2.2 | 42.0 | 9.0 | 40 | .9 | .2 | 238 | - |
| 4 | 16 | 440 | 8.2 | 10.0 | 55.0 | 16.0 | 10.0 | 2.5 | 47.0 | 9.7 | 40 | .2 | .2 | 216 | - |
| 5 | 16 | 425 | 8.1 | 10.0 | 55.0 | 15.0 | 10.0 | 2.3 | 51.0 | 13.0 | 40 | 2.7 | .2 | 214 | - |
| 6 | 17 | 480 | 8.3 | 16.0 | 79.0 | 21.0 | 5.4 | 1.4 | 62.0 | 4.6 | 10 | 2.5 | .3 | 310 | - |

## SHALLOW PLEISTOCENE AQUIFER, AMERICAN FORK AREA

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 12 | 675 | 7.7 | 16.0 | 69.0 | 33.0 | 24.0 | 1.7 | 99.0 | 17.0 | 40 | 11.4 | .2 | 354 | 5.0 |
| 2 | 25 | 650 | 7.9 | 14.0 | 64.0 | 36.0 | 18.0 | 3.0 | 83.0 | 17.0 | 60 | .7 | .3 | 316 | 11.5 |
| 3 | 17 | 775 | 7.4 | 15.0 | 70.0 | 42.0 | 29.0 | 2.3 | 93.0 | 21.0 | 80 | 26.9 | .2 | 442 | 3.6 |
| 4 | 13 | 610 | 6.8 | 14.0 | 67.0 | 35.0 | 5.8 | 4.6 | 89.0 | 5.3 | 30 | 61.5 | .4 | 240 | 8.0 |
| 5 | 14 | 690 | 6.8 | 13.0 | 70.0 | 32.0 | 7.6 | 1.1 | 70.0 | 6.7 | 30 | 81.7 | .2 | 287 | 6.9 |
| 6 | 13 | 590 | 8.5 | 15.0 | 61.0 | 25.0 | 22.0 | 2.0 | 68.0 | 16.0 | 20 | - | .2 | - | - |
| Mean | 16 | 665 | 7.5 | 14.5 | 66.8 | 33.8 | 17.7 | 2.4 | 83.7 | 13.8 | 43 | 36.4 | .2 | 328 | 7.0 |

## SHALLOW PLEISTOCENE AQUIFER, PLEASANT GROVE AREA

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10 | - | 7.6 | 15.0 | 89.0 | 158.0 | - | - | - | 41.0 | - | - | - | 269 | - |
| 2 | 17 | 850 | 7.6 | 15.0 | 66.0 | 51.0 | 31.0 | 4.2 | 140.0 | 19.0 | 110 | 17.3 | .9 | 472 | 6.4 |
| 3 | - | 896 | 7.1 | 9.1 | 88.0 | 44.0 | - | - | 184.0 | 70.0 | - | - | - | 230 | - |
| 4 | 11 | 620 | 7.6 | 15.0 | 83.0 | 36.0 | 38.0 | 1.7 | 170.0 | 32.0 | 30 | 11.7 | .3 | 290 | 4.9 |
| 5 | 13 | 850 | 7.6 | 16.0 | 84.0 | 37.0 | 45.0 | 1.9 | 170.0 | 24.0 | 70 | 1.7 | .3 | 432 | 4.0 |
| 6 | - | 718 | 8.0 | 14.0 | 77.0 | 33.0 | - | - | 110.0 | 31.0 | - | - | - | 270 | - |
| 7 | 16 | 900 | 7.7 | 16.0 | 91.0 | 38.0 | 41.0 | 1.3 | 190.0 | 37.0 | 40 | 10.5 | .2 | 306 | 2.0 |
| Mean | 13 | 806 | 7.6 | 14.3 | 82.6 | 56.7 | 38.8 | 2.3 | 160.7 | 36.3 | 62 | 10.3 | .4 | 324 | 4.3 |

## SHALLOW PLEISTOCENE AQUIFER, SOUTH PLEASANT GROVE AREA

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | - | 787 | 7.2 | 12.0 | 65.0 | 27.0 | - | - | 62.0 | 64.0 | - | - | - | 326 | - |
| 2 | 16 | 775 | 7.7 | 21.0 | 65.0 | 28.0 | 60.0 | 6.2 | 70.0 | 37.0 | 170 | 11.5 | .3 | 370 | 2.5 |
| Mean | 16 | 781 | 7.4 | 16.5 | 65.0 | 27.5 | 60.0 | 6.2 | 66.0 | 50.5 | 170 | 11.5 | .3 | 348 | 2.5 |

## DEEP PLEISTOCENE AQUIFER, AMERICAN FORK AREA

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | - | 360 | - | - | 4.2 | 1.5 | 4.6 | 5.1 | 3.6 | 8.2 | 0 | - | - | 161 | - |
| 2 | 12 | 420 | 7.9 | 12.0 | 46.0 | 21.0 | 6.1 | 1.0 | 50.0 | 8.1 | 7 | 5.3 | .2 | 261 | 8.4 |
| 3 | - | 357 | 7.2 | 11.0 | 41.0 | 17.0 | - | - | 30.0 | 9.5 | - | - | - | 174 | - |
| 4 | 12 | 400 | 7.1 | 11.0 | 43.0 | 18.0 | 5.6 | 1.0 | 43.0 | 11.0 | 40 | - | .2 | - | - |
| 5 | 13 | 400 | 7.8 | 11.0 | 41.0 | 18.0 | 5.5 | .9 | 42.0 | 8.0 | 7 | 7.6 | .2 | 300 | 8.3 |
| 6 | - | 389 | 7.7 | 11.0 | 43.0 | 18.0 | - | - | 39.0 | 11.0 | - | - | - | 172 | - |
| 7 | 13 | 420 | 7.4 | 12.0 | 44.0 | 20.0 | 7.0 | 1.0 | 44.0 | 11.0 | 20 | - | .2 | - | - |
| 8 | - | 398 | 7.3 | 10.0 | 46.0 | 20.0 | - | - | 42.0 | 10.0 | - | - | - | 178 | - |
| 9 | 14 | 470 | 7.2 | 11.0 | 52.0 | 24.0 | 9.2 | 1.1 | 63.0 | 7.6 | 10 | 21.4 | .2 | 212 | 8.2 |
| 10 | - | 399 | 7.3 | 9.8 | 46.0 | 20.0 | - | - | 41.0 | 11.0 | - | - | - | 186 | - |
| 11 | - | 254 | 7.5 | 9.2 | 29.0 | 11.0 | - | - | 5.0 | 5.5 | - | - | - | 142 | - |
| Mean | 13 | 388 | 7.4 | 10.8 | 39.6 | 17.1 | 6.3 | 1.7 | 36.6 | 9.2 | 14 | 11.4 | .2 | 198 | 8.3 |

## DEEP PLEISTOCENE AQUIFER, NORTH AMERICAN FORK AREA

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 12 | 620 | 7.7 | 14.0 | 71.0 | 28.0 | 13.0 | 2.4 | 71.0 | 10.0 | 40 | 10.7 | .3 | 298 | 7.9 |
| 2 | 13 | 630 | 7.4 | 14.0 | 67.0 | 27.0 | 21.0 | 2.3 | 64.0 | 23.0 | 40 | 19.7 | .2 | 296 | - |
| 3 | - | 477 | 7.5 | 11.0 | 67.0 | 26.0 | - | - | 67.0 | 7.5 | - | - | - | 308 | 5.9 |
| 4 | 13 | 600 | 7.3 | 14.0 | 71.0 | 23.0 | 20.0 | 2.2 | 60.0 | 19.0 | 40 | 24.7 | .1 | 308 | 5.9 |
| 5 | 11 | 600 | 7.8 | 14.0 | 68.0 | 29.0 | 11.0 | 1.9 | 67.0 | 13.0 | 30 | 8.4 | .1 | 294 | 8.7 |
| Mean | 12 | 605 | 7.5 | 13.4 | 68.8 | 36.6 | 16.2 | 2.2 | 65.8 | 14.5 | 38 | 15.9 | .2 | 301 | 7.1 |

## DEEP PLEISTOCENE AQUIFER, PLEASANT GROVE AREA

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 12 | 380 | - | 10.0 | 49.0 | 21.0 | 5.2 | 1.1 | 52.0 | 9.3 | 0 | - | .2 | 186 | - |

## DEEP PLEISTOCENE AQUIFER, EAST AMERICAN FORK AREA

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 13 | 490 | 7.3 | 12.0 | 55.0 | 24.0 | 7.0 | 1.1 | 73.0 | 11.0 | 10 | 13.9 | .2 | 190 | 8.4 |
| 2 | 13 | 700 | 7.5 | 13.0 | 76.0 | 32.0 | 30.0 | 1.2 | 130.0 | 21.0 | 30 | 13.8 | .2 | 292 | 7.6 |
| Mean | 13 | 595 | 7.4 | 12.5 | 65.5 | 28.0 | 18.5 | 1.2 | 101.5 | 16.0 | 20 | 13.8 | .2 | 241 | 8.0 |

## TERTIARY AQUIFER, LEHI AREA

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | - | - | 8.2 | 11.0 | 27.0 | 11.0 | 7.1 | 1.1 | 18.0 | 8.3 | - | - | - | 112 | - |
| 2 | 13 | 332 | 7.8 | - | 23.0 | 17.0 | - | - | 8.2 | 25.0 | - | 4.1 | - | 162 | - |
| 3 | - | 218 | 8.0 | 13.0 | 23.0 | 8.5 | - | - | 5.0 | 6.0 | - | - | - | 121 | - |
| 4 | 12 | 260 | 8.2 | 13.0 | 23.0 | 9.9 | 7.5 | 1.0 | 6.0 | 7.9 | 5 | 1.2 | .2 | 124 | 8.4 |
| 5 | 12 | 292 | 7.8 | 16.0 | 24.0 | 13.0 | - | - | 9.5 | 19.0 | - | 3.8 | - | 148 | - |
| 6 | 2 | 325 | 7.9 | .2 | 2.4 | 1.3 | .2 | 0 | 8.9 | 2.1 | 50 | - | .4 | - | - |
| 7 | 13 | 260 | 7.9 | 9.9 | 25.0 | 11.0 | 6.8 | 1.4 | 12.0 | 5.8 | 9 | 2.6 | .2 | 122 | 7.3 |
| Mean | 10 | 281 | 8.0 | 10.5 | 21.1 | 10.2 | 5.4 | .9 | 9.6 | 10.6 | 21 | 2.9 | .3 | 131 | 7.8 |

## TERTIARY AQUIFER, NORTH LEHI AREA

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | - | - | 8.2 | 18.0 | 43.0 | 20.0 | - | - | 48.0 | 39.0 | - | - | - | 157 | - |
| 2 | - | 477 | 7.1 | 11.0 | 40.0 | 20.0 | - | - | 24.0 | 54.0 | - | - | - | 168 | - |
| 3 | 15 | 350 | 7.4 | 12.0 | 35.0 | 15.0 | 12.0 | 1.8 | 20.0 | 20.0 | 10 | 10.6 | .2 | 166 | 7.4 |
| 4 | 14 | 570 | 7.3 | 15.0 | 57.0 | 24.0 | 17.0 | 2.0 | 56.0 | 47.0 | 10 | 15.6 | .2 | 194 | 5.4 |
| 5 | - | 468 | 7.9 | 24.0 | 42.0 | 18.0 | - | - | 16.0 | 49.0 | - | - | - | 188 | - |
| Mean | 14 | 466 | 7.6 | 16.0 | 43.4 | 19.4 | 14.5 | 1.9 | 32.8 | 41.8 | 10 | 13.1 | .2 | 175 | 6.4 |

## TERTIARY AQUIFER, PLEASANT GROVE AREA

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 13 | 410 | 6.7 | 11.0 | 49.0 | 21.0 | 5.3 | 1.0 | 58.0 | 8.5 | 0 | - | .2 | 200 | - |

## UNDIFFERENTIATED AQUIFERS, AMERICAN FORK AREA

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 11 | 360 | 8.0 | 9.4 | 52.0 | 17.0 | 4.1 | .7 | 51.0 | 3.4 | 10 | 3.4 | .2 | 188 | 10.0 |
| 2 | 11 | 490 | 7.9 | 9.6 | 55.0 | 23.0 | 9.8 | 1.1 | 65.0 | 7.2 | 20 | 5.5 | .2 | 272 | 9.7 |
| 3 | 13 | 560 | 7.8 | 9.8 | 68.0 | 26.0 | 8.8 | 1.1 | 100.0 | 8.9 | 20 | 5.9 | 1.4 | 242 | 9.3 |
| 4 | 9 | 490 | 7.7 | 8.5 | 60.0 | 20.0 | 5.7 | .5 | 77.0 | 5.2 | 10 | 6.4 | .2 | 202 | 9.1 |
| 5 | 12 | 440 | 7.8 | 12.0 | 49.0 | 19.0 | 12.0 | 1.8 | 30.0 | 6.9 | 20 | 5.8 | .2 | 228 | 8.0 |
| 6 | 10 | 460 | 7.9 | 12.0 | 53.0 | 25.0 | 5.4 | .8 | 63.0 | 5.3 | 20 | 4.9 | .3 | 222 | 10.6 |
| 7 | - | 494 | 7.6 | 8.4 | 66.0 | 21.0 | - | - | 79.0 | 7.5 | - | - | - | 215 | - |
| 8 | 9 | 480 | 7.3 | 8.7 | 58.0 | 21.0 | 5.3 | .8 | 75.0 | 7.1 | 0 | - | .3 | - | - |
| 9 | 10 | 600 | 7.5 | 13.0 | 65.0 | 29.0 | 12.0 | 1.4 | 74.0 | 11.0 | 40 | - | .1 | - | - |
| Mean | 11 | 486 | 7.7 | 10.2 | 58.4 | 22.3 | 7.9 | 1.0 | 68.2 | 6.9 | 18 | 5.3 | .4 | 224 | 9.4 |

## UNDIFFERENTIATED AQUIFERS, PLEASANT GROVE AREA

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 13 | 650 | 8.3 | 11.0 | 72.0 | 31.0 | 14.0 | .9 | 91.0 | 11.0 | - | - | .2 | - | - |
| 2 | 13 | 750 | - | 17.0 | 92.0 | 29.0 | 25.0 | 2.9 | 82.0 | 32.0 | 60 | - | .2 | - | - |
| 3 | 13 | 580 | 7.7 | 9.8 | 70.0 | 24.0 | 15.0 | 1.0 | 51.0 | 10.0 | 10 | - | .1 | - | - |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | - | 455 | 7.8 | 8.9 | 58.0 | 21.0 | - | - | 47.0 | 10.0 | - | - | - | 225 | - |
| 5 | 20 | 565 | 7.7 | 11.0 | 59.0 | 26.0 | 20.0 | 1.1 | 59.0 | 18.0 | 40 | 8.9 | .4 | 278 | 7.2 |
| 6 | - | 664 | 7.6 | 10.0 | 87.0 | 29.0 | - | - | 61.0 | 13.0 | - | - | - | 336 | - |
| 7 | - | 662 | 7.2 | 10.0 | 73.0 | 31.0 | - | - | 84.0 | 17.0 | - | - | - | 286 | - |
| Mean | 15 | 455 | 7.7 | 11.1 | 73.0 | 27.3 | 18.5 | 1.5 | 67.8 | 15.8 | 37 | 8.9 | .2 | 281 | 7.2 |

## UNDIFFERENTIATED AQUIFERS, ALPINE AREA

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 10 | 350 | 7.8 | 11.0 | 45.0 | 15.0 | 6.7 | 1.2 | 14.0 | 4.6 | 0 | 5.1 | .2 | 202 | 8.6 |
| 2 | 10 | 280 | 7.6 | 14.0 | 41.0 | 4.7 | 6.6 | 1.6 | 13.0 | 4.3 | 10 | 6.1 | .3 | 152 | 6.3 |
| 3 | 11 | 300 | 7.8 | 13.0 | 45.0 | 8.3 | 7.0 | 1.7 | 12.0 | 5.4 | 10 | 4.3 | .1 | 172 | 9.6 |
| Mean | 10 | 310 | 7.7 | 12.7 | 43.7 | 9.3 | 6.7 | 1.5 | 13.0 | 4.7 | 7 | 5.2 | .2 | 175 | 8.2 |

## UNDIFFERENTIATED AQUIFERS, TRAVERSE MOUNTAIN 1

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 15 | 850 | 7.2 | 26.0 | 110.0 | 40.0 | 42.0 | 3.1 | 160.0 | 97.0 | 40 | 33.8 | .1 | 298 | 8.3 |
| 2 | 14 | 900 | 7.4 | 32.0 | 88.0 | 33.0 | 43.0 | 3.2 | 130.0 | 85.0 | 40 | 18.6 | .1 | 260 | 7.3 |
| 3 | 14 | 1090 | 7.6 | 33.0 | 96.0 | 42.0 | 51.0 | 4.4 | 120.0 | 160.0 | 40 | 9.6 | .1 | 238 | 5.7 |
| Mean | 15 | 947 | 7.4 | 30.3 | 98.0 | 38.3 | 45.3 | 3.6 | 136.7 | 114.0 | 40 | 20.6 | .1 | 265 | 7.1 |

## UNDIFFERENTIATED AQUIFERS, TRAVERSE MOUNTAIN 2

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 16 | 700 | 7.3 | 26.0 | 69.0 | 24.0 | 33.0 | 2.6 | 40.0 | 65.0 | 20 | 22.7 | .1 | 270 | 8.9 |
| 2 | 12 | - | 7.3 | 16.0 | 79.0 | 22.0 | 18.0 | 2.7 | 37.0 | 11.0 | 40 | 29.2 | .2 | 364 | 5.5 |
| Mean | 14 | 700 | 7.3 | 21.0 | 74.0 | 23.0 | 25.5 | 2.6 | 38.5 | 38.0 | 30 | 26.0 | .2 | 317 | 7.2 |

## UNDIFFERENTIATED AQUIFERS, TRAVERSE MOUNTAIN 3

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 18 | - | 7.0 | 19.0 | 85.0 | 29.0 | 8.9 | 4.4 | 63.0 | 8.5 | 50 | 58.6 | .3 | 358 | 2.2 |
| 2 | - | 902 | 7.5 | 13.0 | 98.0 | 25.0 | - | - | 129.0 | 35.0 | - | - | - | 391 | - |
| 3 | 14 | 740 | 7.5 | 51.0 | 57.0 | 22.0 | 67.0 | 3.8 | 66.0 | 20.0 | 130 | - | .3 | - | - |
| Mean | 16 | 821 | 7.3 | 27.7 | 80.0 | 25.3 | 38.0 | 4.1 | 86.0 | 21.1 | 90 | 58.6 | .3 | 374 | 2.2 |

## UNDIFFERENTIATED AQUIFERS, TRAVERSE MOUNTAIN 4

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 13 | 720 | 7.7 | 30.0 | 61.0 | 28.0 | 31.0 | 4.0 | 38.0 | 78.0 | 60 | 10.1 | .3 | 330 | 2.4 |
| 2 | 15 | 630 | 7.4 | 24.0 | 58.0 | 20.0 | 36.0 | 6.5 | 68.0 | 43.0 | 70 | - | .7 | - | - |
| 3 | 15 | 700 | 7.4 | 41.0 | 47.0 | 21.0 | 57.0 | 2.5 | 45.0 | 59.0 | 100 | - | .4 | - | - |
| Mean | 15 | 683 | 7.5 | 31.7 | 55.3 | 23.0 | 41.3 | 4.3 | 50.3 | 60.0 | 77 | 10.1 | .5 | 330 | 2.4 |

## UNDIFFERENTIATED AQUIFERS, TRAVERSE MOUNTAIN 5

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 14 | 1490 | 7.3 | 24.0 | 95.0 | 49.0 | 110.0 | 4.0 | 110.0 | 270.0 | 110 | - | - | - | - |
| 2 | - | 913 | 7.6 | 27.0 | 73.0 | 24.0 | - | - | 72.0 | 102.0 | - | - | - | 288 | - |
| Mean | 14 | 1201 | 7.4 | 25.5 | 84.0 | 36.5 | 110.0 | 4.0 | 91.0 | 186.0 | 110 | - | - | 288 | - |

## UNDIFFERENTIATED AQUIFERS, TRAVERSE MOUNTAIN 6

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 15 | 1380 | 7.3 | 35.0 | 119.0 | 53.0 | 67.0 | 4.6 | 210.0 | 180.0 | 100 | 24.1 | .2 | 300 | 6.2 |
| 2 | 15 | 1210 | 7.0 | 24.0 | 126.0 | 50.0 | 63.0 | 3.9 | 240.0 | 67.0 | 100 | 73.2 | .1 | 220 | 3.7 |
| 3 | - | - | 7.6 | 9.0 | 147.0 | 29.0 | - | - | 115.0 | 204.0 | - | - | .1 | 306 | - |
| 4 | 13 | 1900 | 7.3 | 26.0 | 132.0 | 62.0 | 150.0 | 5.2 | 310.0 | 270.0 | 200 | - | .6 | - | - |
| Mean | 14 | 1497 | 7.3 | 23.5 | 131.0 | 48.5 | 93.3 | 4.6 | 218.2 | 180.2 | 133 | 48.6 | .2 | 338 | 5.0 |

## UNDIFFERENTIATED AQUIFERS, JORDAN RIVER 1

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 21 | - | 6.9 | 26.0 | 182.0 | 55.0 | - | - | 438.0 | 352.0 | - | - | - | 233 | - |
| 2 | 24 | - | 7.7 | 39.0 | 130.0 | 43.0 | - | - | 264.0 | 210.0 | - | - | - | 278 | - |
| 3 | - | 2300 | 6.9 | 26.0 | 182.0 | 55.0 | - | - | 438.0 | 352.0 | - | - | - | 233 | - |
| 4 | - | 1180 | 7.4 | - | 100.0 | 31.0 | - | - | 167.0 | - | - | - | - | 206 | - |
| Mean | 23 | 1740 | 7.2 | 30.3 | 148.5 | 46.0 | - | - | 326.5 | 304.7 | - | - | - | 237 | - |

## UNDIFFERENTIATED AQUIFERS, JORDAN RIVER 2

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | - | 1040 | 7.8 | 34.0 | 58.0 | 28.0 | - | - | 110.0 | 176.0 | - | - | - | 206 | - |
| 2 | - | 2760 | 7.2 | 27.0 | 263.0 | 106.0 | - | - | 322.0 | 640.0 | - | - | - | 156 | - |
| Mean | - | 1900 | 7.5 | 30.5 | 160.5 | 67.0 | - | - | 216.0 | 408.0 | - | - | - | 181 | - |

## UNDIFFERENTIATED AQUIFER, LOCAL SAMPLE EAST OF PLEASANT GROVE

| Well | T | SC | pH | Si | Ca | Mg | Na | K | SO | Cl | B | CO | F | HCO | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | - | 602 | 7.8 | 13.0 | 76.0 | 29.0 | 13.0 | .5 | 80.0 | 20.0 | 60 | - | .2 | 280 | - |

## EXPLANATION

T=Temperature (°C), SC=Specific Conductance (micromhos), Si=dissolved silica (mg/l), Ca=dissolved calcium (mg/l), Na=dissolved sodium (mg/l), K=dissolved potassium (mg/l), SO=dissolved sulfate (mg/l), Cl=dissolved cloride (mg/l), B=dissolved boron (ug/l), CO=dissolved carbon dioxide (mg/l), F=dissolved fluoride (mg/l), HCO=dissolved bicarbonate (mg/l), O=dissolved oxygen (mg/l).

Missing values used in the body of the report were obtained by assuming values from similar waters, and adjusting reported sodium+potassium values. Redox potential was calculated using dissolved oxygen values.

# Appendix IV. Sample Locations and Dates of Collection

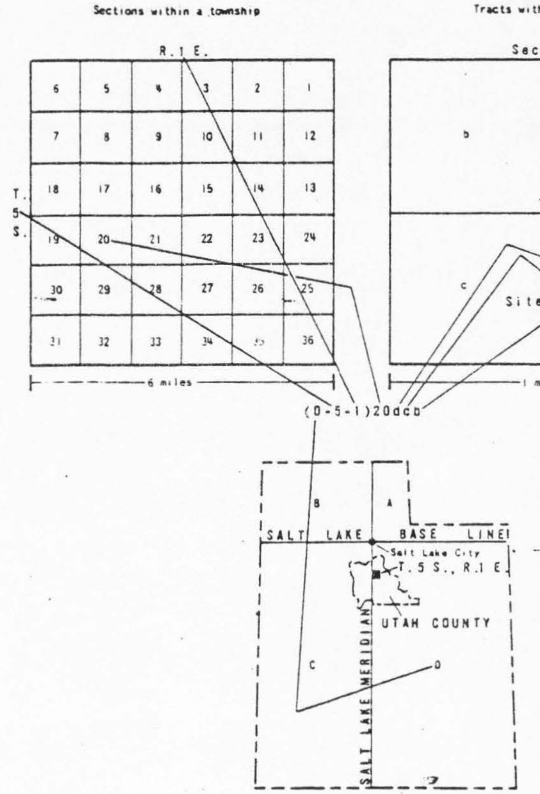

Figure 24.- System of location of water collection sites, and wells for fence diagrams. Note that any numbers after the location letters are sequence numbers only.

American Fork Springs

| | | |
|---|---|---|
| 1 | (D-4-2)20CAB-S1 | 7/81 |
| 2 | (D-4-2)17BAD-S1 | 6/81 |
| 3 | (D-4-2) 8CAD-S1 | 6/81 |

## Pleasant Grove Springs

| | | |
|---|---|---|
| 1 | (D-5-2)22BBB-S1 | 7/81 |
| 2 | (D-5-2)16DAB-S1 | 7/81 |

## Alpine Surface Water

| | | |
|---|---|---|
| 1 | (D-4-3)18ADC | 6/81 |
| 2 | (D-4-2)13ABB | 6/81 |
| 3 | (D-4-2) 7DBA-S1 | 6/81 |
| 4 | (D-4-2) 7DBA-S2 | 6/81 |

## American Fork Surface Water

| | | |
|---|---|---|
| 1 | (D-4-3)32BBD | 6/81 |
| 2 | (D-4-3)32BBD | 6/80 |

## Pleasant Grove Surface Water

| | | |
|---|---|---|
| 1 | (D-5-3)22DDC | 9/81 |
| 2 | (D-5-3)22BBD | 9/81 |

## Other Surface Water

| | | |
|---|---|---|
| 1 | (D-4-3)18ADC | 6/80 |
| 2 | (D-5-1)35AAB | 8/81 |
| 3 | (D-5-1)12CBA | 7/81 |
| 4 | (D-5-1) 8ADA | 7/81 |
| 5 | (D-5-1) 4ABA | 7/81 |
| 6 | (D-4-1)34ACC | 7/81 |

## Shallow Pleistocene Aquifer, American Fork Area

| | | |
|---|---|---|
| 1 | (D-5-1)21DBA-2 | 7/81 |
| 2 | (D-5-1)16DDD | 8/81 |
| 3 | (D-5-1)16DCD-1 | 7/81 |
| 4 | (D-5-1)12CCD-1 | 7/81 |
| 5 | (D-5-1)11BDD-1 | 7/81 |
| 6 | (D-5-1)17CBC-1 | 7/81 |

## Shallow Pleistocene Aquifer, Pleasant Grove Area

| | | |
|---|---|---|
| 1 | (D-5-1)22CCC | 12/57 |
| 2 | (D-5-2)19DDB-1 | 7/81 |
| 3 | (D-5-1)35ADA-1 | 12/57 |

| | | |
|---|---|---|
| 4 | (D-5-1)27DAA-1 | 7/81 |
| 5 | (D-5-1)26BAD-1 | 7/81 |
| 6 | (D-5-1)21DBA-2 | 1/58 |
| 7 | (D-5-1)36BDB-1 | 7/81 |

### Shallow Pleistocene Aquifer, South Pleasant Grove Area

| | | |
|---|---|---|
| 1 | (D-6-2) 6ACC-1 | 12/57 |
| 2 | (D-6-2) 6ACC-1 | 7/81 |

### Deep Pleistocene Aquifer, American Fork Area

| | | |
|---|---|---|
| 1 | (D-5-1)23CAB-2 | 7/49 |
| 2 | (D-5-1)22DDC-1 | 7/81 |
| 3 | (D-5-1)21DDA-2 | 12/57 |
| 4 | (D-5-1)21DDA-2 | 8/80 |
| 5 | (D-5-1)21DDA-2 | 7/81 |
| 6 | (D-5-1)21DDA-3 | 1/58 |
| 7 | (D-5-1)21DDA-3 | 8/80 |
| 8 | (D-5-1)23BDB-2 | 11/57 |
| 9 | (D-5-1)23ABC-1 | 7/81 |
| 10 | (D-5-1)23BAC-1 | 12/57 |
| 11 | (D-5-1)19CCC-1 | 12/57 |

### Deep Pleistocene Aquifer, North American Fork Area

| | | |
|---|---|---|
| 1 | (D-5-1) 3CAA-1 | 7/81 |
| 2 | (D-5-1)17ACB-5 | 7/81 |
| 3 | (D-5-1)10BAD-2 | 8/58 |
| 4 | (D-5-1) 9ABA-1 | 6/81 |
| 5 | (D-5-1) 2BAA-1 | 7/81 |

### Deep Pleistocene Aquifer, Pleasant Grove Area

| | | |
|---|---|---|
| 1 | (D-5-2)29DBD-13 | 8/81 |

### Deep Pleistocene Aquifer, East American Fork Area

| | | |
|---|---|---|
| 1 | (D-5-2)19CCC-1 | 7/81 |
| 2 | (D-5-2)18ABA-1 | 7/81 |

## Tertiary Aquifer, Lehi Area

| | | |
|---|---|---|
| 1 | (D-5-1)20ABA-6 | 9/81 |
| 2 | (D-5-1)18CAB-2 | 8/69 |
| 3 | (D-5-1)20ABA-6 | 4/58 |
| 4 | (D-5-1)17CDD-5 | 7/81 |
| 5 | (D-5-1)18CAB-2 | 3/68 |
| 6 | (D-5-1)18CAB-2 | 6/65 |
| 7 | (D-5-1)14BDC-1 | 8/81 |

## Tertiary Aquifer, North Lehi Area

| | | |
|---|---|---|
| 1 | (D-5-1) 9DBB-1 | 7/52 |
| 2 | (D-5-1)12ADD-1 | 11/57 |
| 3 | (D-5-1)10BCC-1 | 8/81 |
| 4 | (D-5-1) 4CDD-1 | 7/81 |
| 5 | (D-5-1) 4BCC-1 | 7/58 |

## Tertiary Aquifer, Pleasant Grove Area

| | | |
|---|---|---|
| 1 | (D-5-2)29CAA-1 | 8/81 |

## Undifferentiated Aquifers, American Fork Area

| | | |
|---|---|---|
| 1 | (D-4-2)31BDA-1 | 7/81 |
| 2 | (D-5-1) 1CDC-1 | 7/81 |
| 3 | (D-5-2) 6ACD-1 | 7/81 |
| 4 | (D-5-1) 1AAA-1 | 6/81 |
| 5 | (D-4-1)35DAA-1 | 7/81 |
| 6 | (D-4-1)36ADC-1 | 7/81 |
| 7 | (D-4-2)31ACD-1 | 8/58 |
| 8 | (D-4-2)31ACD-1 | 8/81 |
| 9 | (D-4-2)36CAB-1 | 9/81 |

## Undifferentiated Aquifers, Pleasant Grove Area

| | | |
|---|---|---|
| 1 | (D-5-2)21CBA-1 | 7/81 |
| 2 | (D-5-2)34CCD-1 | 7/81 |
| 3 | (D-5-2)34CAC-1 | 8/81 |
| 4 | (D-5-2)29BDA-4 | 5/58 |
| 5 | (D-5-2)27BAA-1 | 7/81 |
| 6 | (D-5-2)29ABB-1 | 5/58 |
| 7 | (D-5-2)21CBA-1 | 8/58 |

### Undifferentiated Aquifers, Alpine Area

| | | |
|---|---|---|
| 1 | (D-4-2)19CCB-1 | 7/81 |
| 2 | (D-4-2)18BDD-1 | 7/81 |
| 3 | (D-4-1)24DCD-1 | 7/81 |

### Undifferentiated Aquifers, Traverse Mountain 1

| | | |
|---|---|---|
| 1 | (D-4-1)33DDA-1 | 7/81 |
| 2 | (D-4-1)32DAA-1 | 6/81 |
| 3 | (D-4-1)33CAA-1 | 6/81 |

### Undifferentiated Aquifers, Traverse Mountain 2

| | | |
|---|---|---|
| 1 | (D-4-1)34BDC-1 | 7/81 |
| 2 | (D-4-1)35BAA-1 | 7/81 |

### Undifferentiated Aquifers, Traverse Mountain 3

| | | |
|---|---|---|
| 1 | (D-5-1)10BDD-1 | 7/81 |
| 2 | (D-5-1) 4CBC-1 | 7/58 |
| 3 | (D-4-1)32DBB-1 | 8/81 |

### Undifferentiated Aquifers, Traverse Mountain 4

| | | |
|---|---|---|
| 1 | (C-5-1) 1CDC-1 | 7/81 |
| 2 | (C-4-1)26AAD-1 | 8/81 |
| 3 | (D-4-1)31ADD-2 | 9/81 |

### Undifferentiated Aquifers, Traverse Mountain 5

| | | |
|---|---|---|
| 1 | (C-4-1)36DAA-1 | 9/81 |
| 2 | (C-4-1)25CAC-1 | 5/59 |

### Undifferentiated Aquifers, Traverse Mountain 6

| | | |
|---|---|---|
| 1 | (D-5-1) 5CBC-1 | 7/81 |
| 2 | (D-5-1) 5DAA-1 | 7/81 |
| 3 | (D-5-1) 5BBC-1 | 5/54 |
| 4 | (D-4-1)31CBB-2 | 8/81 |

Undifferentiated Aquifers, Jordan River 1

| | | |
|---|---|---|
| 1 | (C-5-1)23BDA-1 | 5/58 |
| 2 | (D-5-1)24CDC-1 | 4/60 |
| 3 | (C-5-1)23BDA-1 | 5/58 |
| 4 | (C-5-1)25ABC-1 | 4/58 |

Undifferentiated Aquifers, Jordan River 2

| | | |
|---|---|---|
| 1 | (C-5-1)14CAA-1 | 5/58 |
| 2 | (C-5-1)14BCC-1 | 4/58 |

Undifferentiated Aquifer, Local Sample

| | | |
|---|---|---|
| 1 | (D-5-2)29CBC-1 | 5/59 |

## LOCATIONS OF WELLS USED FOR FENCE DIAGRAMS

### Section A - A'

1. (C-4-1)26ADD
2. (C-4-1)36BBB-1
3. (C-4-1)36AAA
4. (D-5-1) 6BCD
5. (D-5-1) 5CBB
6. (D-5-1)18CBC-1
7. (D-5-1)19ACC

### Section B - B'

1. (D-4-1)35BAA
2. (D-4-1)34BDC
3. (D-4-1)33DDA-1
4. (D-4-1)33DAD-1
5. (D-5-1) 4BCC
6. (D-5-1)10BBB
7. (D-5-1) 9ABA-1
8. (D-5-1) 4CDD-1
9. (D-5-1) 9BBA
10. (D-5-1)17CCB
11. (D-5-1)17CBC

### Section C - C'

1. (D-4-2)31ACD-1
2. (D-4-1)36DAB
3. (D-5-1) 1BCD
4. (D-5-1) 1CDC-1
5. (D-5-1)11DAA
6. (D-5-1)12DCC-1
7. (D-5-1)10CCB
8. (D-5-1)23AAB
9. (D-5-1)22DDC

### Section D - D'

1. (D-5-2)21DAC-1
2. (D-5-2)20DBB
3. (D-5-2)19DDB
4. (D-5-2)19CCC
5. (D-5-1)36ACA
6. (D-5-1)24CCD
7. (D-5-1)26BAD

8 (D-5-1)27DAA

Section E - E'

1 (D-5-2)34DAA
2 (D-6-2) 9CCC-1
3 (D-6-2) 8BCD-4