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Mineralized Springs in Utah and Their Effect on Manageable Water Supplies

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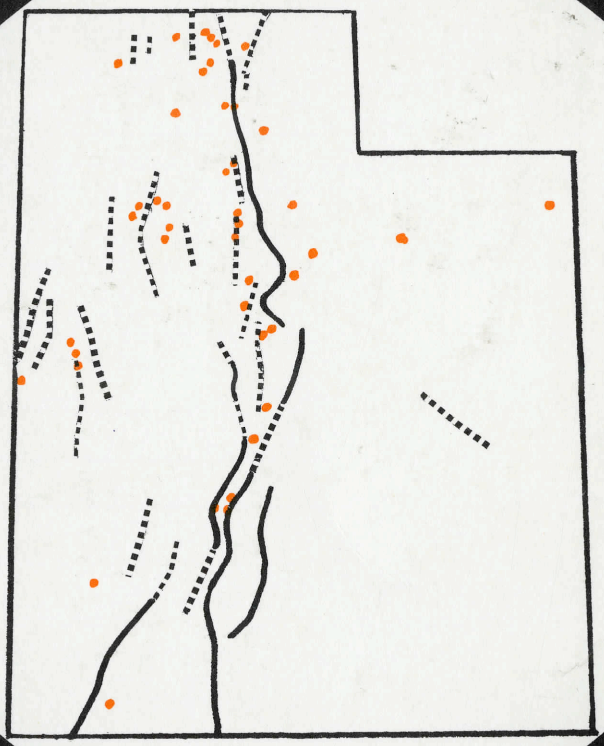

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and Their Effect on Manageable Water Supplies

DEVELOPING A STATE WATER PLAN — UTAH STATE UNIVERSITY — UTAH WATER AND POWER BOARD

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Utah Water Research Laboratory
Utah State University

In cooperation with the
Utah Water and Power Board

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FOREWORD

The work reported herein was accomplished during the summer of 1964. Because springs of the type under consideration are not generally subject to wide fluctuations in flow rate and quality, it was felt that a single extensive study and sampling would provide meaningful and useful information. Such an investigation certainly accomplishes a useful "sorting" of important and unimportant mineralized spring water sources in terms of their effect on major water supplies. It also reveals instances where management is critical and suggests possible management schemes. It is hoped that the results reported will constitute a significant element in planning for complete utilization of Utah's water supplies.

The project was suggested as a cooperative effort between staff of the Utah Water Research Laboratory and the Utah Water and Power Board. Jay M. Bagley conceived the project and gave general guidance throughout. James H. Milligan assumed major responsibility in the fieldwork of collecting samples and obtaining flow measurements. He also contributed heavily to the preparation of the manuscript. Mr. Milligan worked closely with Ray E. Marsell, who brought a wealth of geological understanding and experience to the project. Stewart Williams accompanied by the senior author on one field trip and added significantly to the general understanding. Likewise, Edwin Haycock participated in some of the fieldwork and advised generally as the work was brought to conclusion.

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INTRODUCTION

Need and Importance of Study

Water demands in Utah are continuously increasing. It is essential that these demands be met to insure the continued enhancement of the social and economic well-being of all sectors of our society. Since water needs must be met from a relatively fixed water supply it is imperative that supplies be managed for complete utilization in such a way that all legitimate requirements can be satisfied.

As our available water supplies are used more completely by making a given supply satisfy more than one use, water quality problems become more pronounced. The multiplicity of uses to which water may be put as it moves through a hydrologic system is limited only as its quality is reduced below acceptable standards of particular users, or as its quantity is reduced through evapotranspiration. Thus, a water supply may be reduced just as effectively by lowering its quality as if it is consumed or otherwise transported from a region.

In several areas of Utah, water quality problems are aggravated by contributions of highly mineralized springs. These feed into regular water supplies, thus impairing or completely destroying their usefulness — especially during periods of low streamflow. An inventory of sources of such mineralized springs, their quantities and qualities, along with an evaluation of their effects on natural waters, might suggest possible management and control measures which could materially extend the usefulness of certain water supplies in the state.

Specifically, the major objectives of this investigation were:

1. To obtain an inventory of mineralized spring waters with respect to location, hydrologic and geologic setting, and quantity and quality of water.

2. To make an appraisal of current and potential effects of these springs on important usable supplies.

3. To evaluate possible management and control measures aimed at extending the usefulness of principal water supplies.

Quality as a Dimension of Water

The ever enlarging spectrum of water demands places increasing emphasis on quality as an important and often critical dimension of water. Quality is a dynamic parameter inextricably associated with the hydrologic flow system. Many natural processes and human activities affect the quality of surface and subsurface waters. Quality becomes a term to describe the composite, chemical, physical, and biological characteristics of water with respect to its suitability for a particular use. Most interest in water quality still centers around supplies for ordinary household or domestic, agricultural, and industrial purposes. However, the spectrum of beneficial uses is extending rapidly beyond these.

A detailed discussion of water quality criteria, standards, or requirements is not appropriate here. Suffice it to say that the harmful effects of the kind of waters reported herein could extend to nearly all kinds of uses principally through their chemical and thermal properties. The high temperatures of most mineralized springs would make them unsuitable for many industrial uses and could injure aquatic life. The mineral content of such springs is commonly much higher than can be tolerated (without special treatment) in domestic, industrial, or agricultural use. Regardless of the current or potential water use, an understanding of the quality of these spring waters and the ability to predict the effect of their contributions at various down-stream points is essential to any overall quality management program.

General Location and Distribution of Mineral Springs

The location of the mineralized springs included in this study is shown in Fig. 1. For greater utility and compatibility with other hydrologic studies, the information and discussion has been organized according to the major hydrologic units outlined in this figure. The name and code numbers of these hydrologic units are: Columbia River (0), Great Salt Lake Desert (1), Bear River (2), Weber River (3), Jordan River (4), Sevier River (5), Cedar (6), Uinta (7), West Colorado (8), and South and East Colorado (9). Actually, no mineralized springs are reported in the Columbia River Unit which includes the Raft River drainage in the extreme northwestern corner of the state.

Most of the mineralized springs in Utah occur in the Great Basin drainage. Only a relatively few are found in the Colorado River drainage of Utah. This distributional pattern reflects the geologic differences between the two basins. There are, however, numerous seeps in the Colorado River drainage which are mineralized. These have been located and described in U.S. Geological Survey Professional Paper No. 442 (Iorns, 1964 [1]).

The principal river systems of Utah are also outlined in Fig. 1. The stream systems of greatest mineral spring occurrence are the Bear, Jordan, and Sevier. However, the size, location, and particular mineral constituents determine the extensiveness of any detrimental effect on any river system. Some springs may cause very localized water quality problems. In other instances mineralized spring waters may be used beneficially under proper management with no apparent problems. Others, of course, contribute significantly to the dissolved mineral content of downstream flows.

Some 48 mineral spring areas were analyzed and are reported herein. Only those springs having an electrical conductivity of 1200 micromhos or greater were selected for purposes of this study.

Previous Studies of Mineral Springs

The earliest interest in mineralized springs in the United States was in their use as health resorts. Several articles and books dealing with the medicinal value of these springs and their names, temperature, and locations were published at an early date. A treatise on the mineral springs of the United States entitled "Baths and Mineral Waters," written by John Bell (Peale, 1894) and published in 1831, gives ". . . a history of the chemical composition and medicinal properties of the chief mineral springs of the United States and Europe." This report listed only 21 localities for the United States but in a later publication in 1855 the list was increased to 181 localities. At these early dates very little was known about the Mountain West, and as more information became available the list of mineralized springs expanded rapidly.

In the latter part of the 1800's, geologists became interested in the study of mineralized springs because of the information these springs conveyed concerning the composition and structure of the earth's crust. In 1875 Gilbert compiled a table and map of thermal springs in the United States (Gilbert, 1875). Many of the data for his report were gathered from reports of exploring parties in the still little-known West.

Gilbert's work was a very thorough study considering the information then available. In fact, his map did not differ greatly from a later map published by Stearns, Stearns and Waring (1937) in a report entitled "Thermal Springs in the United States."

The geologists who studied these mineralized springs were generally interested in three problems – the source of the water, the source of the heat, and the mineral deposits. Although hydrologic data concerning these springs could have been collected with very little additional effort, this was rarely done. Consequently, early reports concerning mineralized springs contain very few data on flow rates and other hydrologic information.

The once popular health resorts, which were located at mineral springs, have now generally disappeared. Public health departments required and enforced chlorination of bathing and swimming waters. In many cases chlorination gave mineral waters an undesirable appearance and smell. The advancement of medical science also played a role in the decreasing popularity of the "magic mineral springs." The few surviving resorts generally have converted to fresh-water swimming pools and used the thermal spring water for heating the fresh-water pool either by mixing or by heat-exchange systems.

There have been a number of recent reports which have discussed quality of ground and surface waters of Utah. Thorne and Thorne (1951) prepared an extensive inventory of irrigation water quality and devised a system for classifying waters of the state in terms of their effects on soils and growing crops. In 1958 the State Engineer and the U.S. Geological Survey cooperatively published a compilation of ". . . all available information that exists on the quality of ground and surface water in Utah." (Connor, **et al.**, 1958.) The Bureau of Reclamation has made studies of water quality in some of their project areas and this information can be found in individual project reports. The Utah Geological and Mineralogical Survey at the University of Utah, working in cooperation with the U.S. Geological Survey, published a report on the "Dissolved Mineral Inflow to Great Salt Lake." (Hahl and Mitchell, 1963.) This report includes chemical and some hydrologic data for the mineralized springs around Great Salt Lake which discharge into the lake. The U.S. Geological Survey has also published basic data reports which cover most of the state and which contain some scattered chemical quality and hydrologic data for mineralized springs.

In nearly all water quality studies, however, sampling points below the vicinity of known mineralized springs, or below suspected inflow or contamination are generally avoided. Only in a few instances is specific information at such points obtained. With the exception of very recent Bureau of Reclamation projects these sources have never been evaluated in terms of their effect on available water supplies nor have the merits of management and control of these mineralized supplies been considered so as to extend the usefulness of the supplies which they contaminate.

[1] References are listed alphabetically at the end of the report.

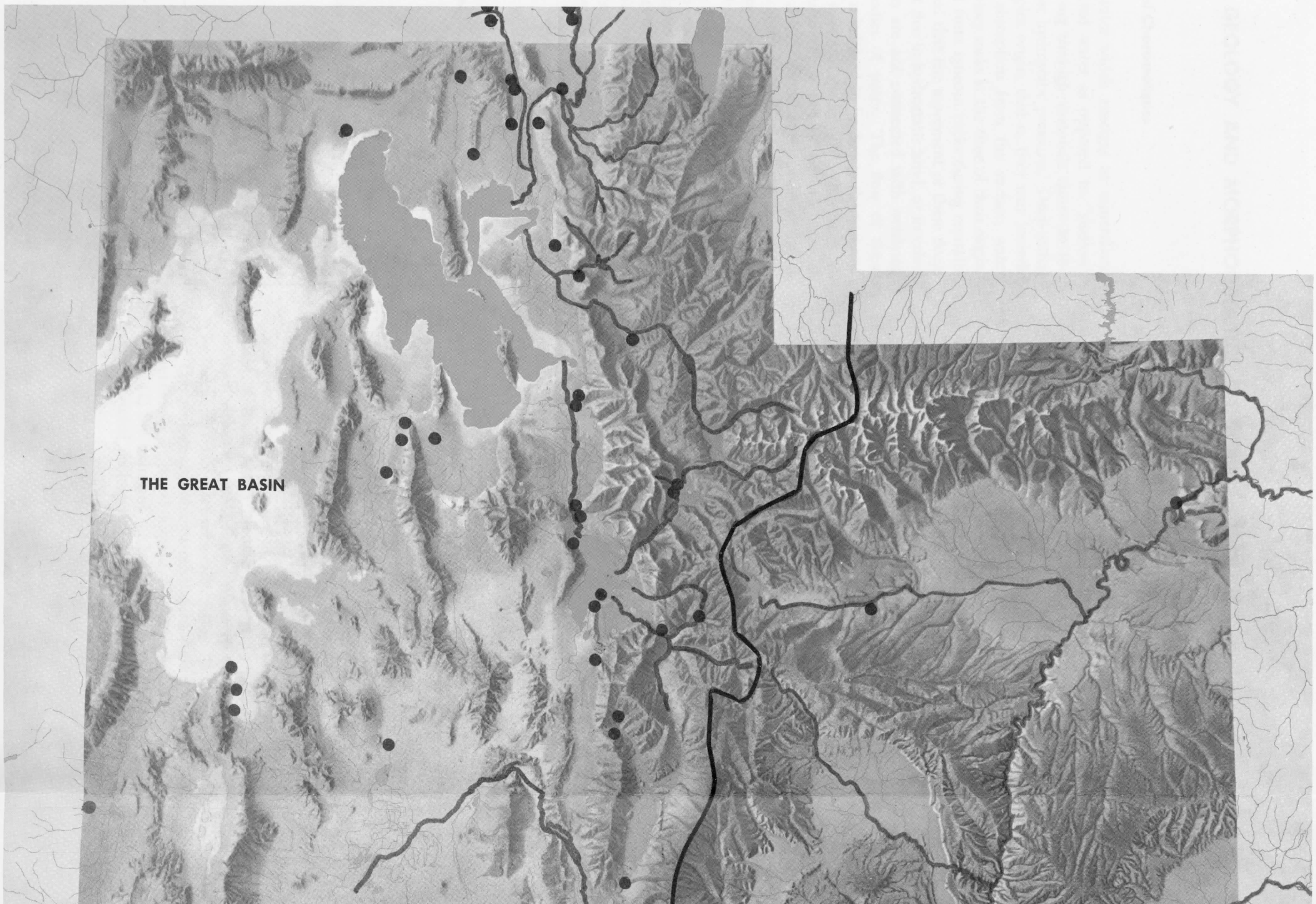

Fig. 1. General location and distribution of Utah's mineral springs.

GEOLOGY AND MORPHOGENETICS OF MINERAL SPRINGS

Origin and General Characteristics

Most ground water which emerges as mineralized springs is deep-seated water as opposed to "shallow" ground water moving through materials closer to the earth's surface under hydrostatic pressures. Deep-seated waters have a complex origin, that is, they may include water derived by absorption from the surface, water trapped in sedimentary rocks at the time of their origin, and water expelled from igneous rocks during crystallization. It is believed that the movement of these deep-seated waters is not due to hydrostatic head, or in other words, these waters are not connected with overlying and connecting bodies of water. The flow of these deep-seated waters is believed to be due to thermal and pressure gradients operative deep within the earth. A spring with a constant flow not subject to seasonal changes and with a high temperature probably has a deep-seated origin. Further evidence as to the deep-seated origin of mineralized spring water is the presence of important faults or other structures along which the water could rise.

Springs due to deep-seated water are sometimes divided into two classes according to their geographical location with respect to volcanic or tectonic disturbance. Three types of springs related to volcanic and tectonic disturbance and the probable character of the fissures which permit the water to rise are shown in Fig. 2.

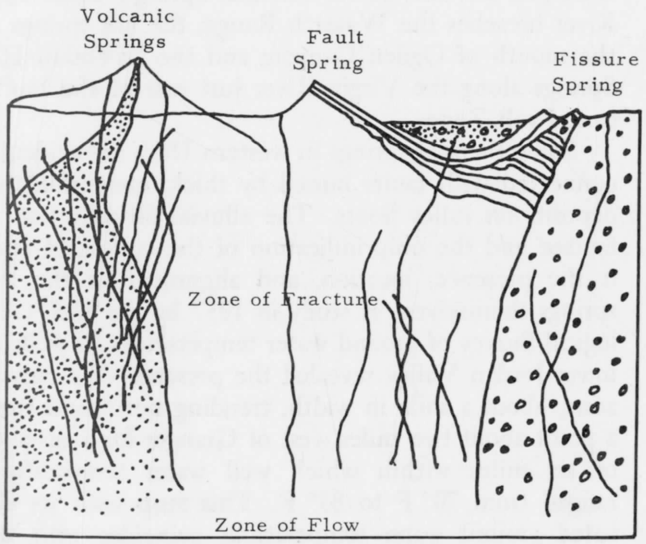

Fig. 2. Diagram showing origin of deep-seated springs.

Volcanic springs are associated with past or present volcanism and derive their origin either in water expelled from the underlying magma or in surface water that has come in contact with highly heated rocks and has derived definite characteristics from this association. Generally, volcanic springs have relatively constant flows and are highly mineralized.

Fissure springs comprise the other group of springs which derive their water from deep-seated origins. These springs are much like volcanic springs in that they generally have constant flow not subject to annual variations and they are usually warm or hot and highly mineralized. These springs, however, appear to rise along major fractures in the earth's crust which appear to be very deep.

Some fissure springs lie along definite lines known to be recent faults involving earth blocks of great depth. Such springs are called fault springs. Faulting seems to produce the fractures which allow these deep waters to rise and carry the temperature and minerals of the deeper crust to the surface. This type of mineralized spring is especially common in the Great Basin where most of the mountain ranges have been formed by basin-and-range faulting. The classic example of springs of this type is found in the Great Basin in Utah just east of the Fish Springs Range in Juab County. The range has a distinct and recent fault running along the eastern flank and is evidenced by a fresh fault scarp in the alluvium near Fish Springs. Four groups of mineralized springs lie east of the range on a curved line close to the mountains and at the base of the alluvial slope. This group of springs definitely shows fault control. On the other hand, there are many fissure springs which show no structural evidence of origin and are not classified as fault springs. These are believed to have deep origin because of fairly constant flow, elevated temperatures, and high mineral content.

Some mineralized springs may not be due to deep-seated water. Most of the springs in this group would either be contact springs or artesian springs. These springs are due to meteoric and occasionally other waters moving as ground water under hydrostatic head; many of these fluctuate in flow with precipitation. Most of these waters become mineralized because of contact with old marine shales. Minerals are dissolved by the water on contact with salty shales.

The geological problems relating to thermal springs are generally centered around (1) the source of the water; (2) the source of the heat; and (3) the nature of the associated geologic structure. These are discussed briefly in the following paragraphs.

The source of water, for the most part, is probably surface water (meteoric water) originating in precipitation, which descends to depths in the earth, becomes heated, and rises again to issue at the surface as thermal springs. Some water may come from sedimentary rocks, the water having been entrapped in the original sediments at the time of their deposition. Such water is called "connate" water and it is generally highly saline. Still another source is water expelled by cooling bodies of igneous rock, either from relatively young, thick lava flows or from large, deeply-buried igneous intrusions. Water, in the form of superheated water-vapor, along with other volcanic gases, is condensed by contact with cooler rocks or ground water as it rises toward the earth's surface. In volcanic regions especially, at least some of the water, called "juvenile water," may be of magmatic origin, though even here it is often difficult to prove.

Thermal springs may derive their heat from several sources. The most important source is generally the normal increase in temperature of the earth in depth. Abundant data from deep mine workings and deeper bore holes drilled for oil indicate that there is a 1° F rise in temperature for every increase in depth of 60 to 100 feet. In volcanic areas the rise in temperature may be more rapid. Thus, surface water at 50° F upon descending 1,000 feet may have its temperature increased to 60° F and to 70° F at a depth of 2,000 feet. This rise in temperature with depth is referred to as the earth's geothermal gradient.

Another source of heat in volcanic regions is underlying bodies of hot or even molten rock. Meteoric water may be heated by contact with the hot rocks or by the hot water vapor expelled by them. Frictional heat of considerable magnitude is probably developed along active faults by recent movements and therefore some of the heat of thermal springs associated with faults may be of this origin.

Chemical reactions beneath the surface may also produce heat and some heat may come from the disintegration of radioactive elements.

Deep fractures, extending far into the earth's crust, provide the most common geologic structure for circulating ground water, either descending or ascending. Faulting is the process mainly responsible for producing the channelways along which many thermal springs reach the surface. This is especially the case in the Basin-and-Range province in Utah, Nevada, and Oregon where the typical "fault block" mountains are bordered by fault zones on one or sometimes both margins. These faults are often many miles in length and extend deep into the crust of the earth.

In regions of "folded" sedimentary rocks a downfold or "syncline" may carry water to depths where it can be heated and then returned to the surface. Examples of such mineral springs are found in the State of Virginia.

Relation to Fault Zones

Almost all of Utah's mineralized springs have elevated temperatures. When their locations are plotted on the state geological map, it is evident, at a glance, that they are closely associated with fault zones. This relation is shown in Fig. 3.

Relatively cool water (45° F to 55° F) enters the ground surface and descends under the force of gravity to great depths. As these waters come in contact with the fissures in fault zones they become heated and expand creating a convectional circulation, the denser cold water above forcing the less dense hot water below to rise much like that in the hot water tank at home. The hot water issues at the surface along the fault zone depending on the configuration on the channelways in the fractured rocks below the surface and also on the lowest topographic elevation where the fault zone intersects the ground surface. An example of the latter type is Beck's Hot Spring along the Wasatch front just north of Salt Lake City. Here the emerging water saturates the fault zone for a considerable distance and "spills over" at lowest topographic elevations.

Commonly the heated water finds freer avenues of escape to the surface along the more open fissures in the "footwall" of the fault than along the major fault plane itself. Thus many thermal springs issue at points several hundred feet back from the associated fault zone. Examples are: the Cutler Thermal Springs, where Bear River breaches the Wasatch Range; the hot springs at the mouth of Ogden Canyon; and the LaVerkin Hot Springs along the Virgin River just east of the Hurricane Fault Zone.

Some thermal springs in western Utah are evidently connected with faults buried by thick, unconsolidated deposits on valley floors. The alluvial fill may not be faulted and the only indication of the concealed fault is the presence, location, and alignment of the hot springs themselves. A study in 1957 by the U.S. Geological Survey of ground water temperatures in wells in lower Jordan Valley revealed the presence of a narrow zone, about a mile in width, trending northward from a point about two miles west of Granger for a distance of six miles within which well water temperatures ranged from 70° F to 83° F. This strip with its elevated ground water temperatures coincides with the position of a buried fault indicated by a gravity survey previously made of the area by the Geological Survey. Additional confirmation of the presence of a fault in

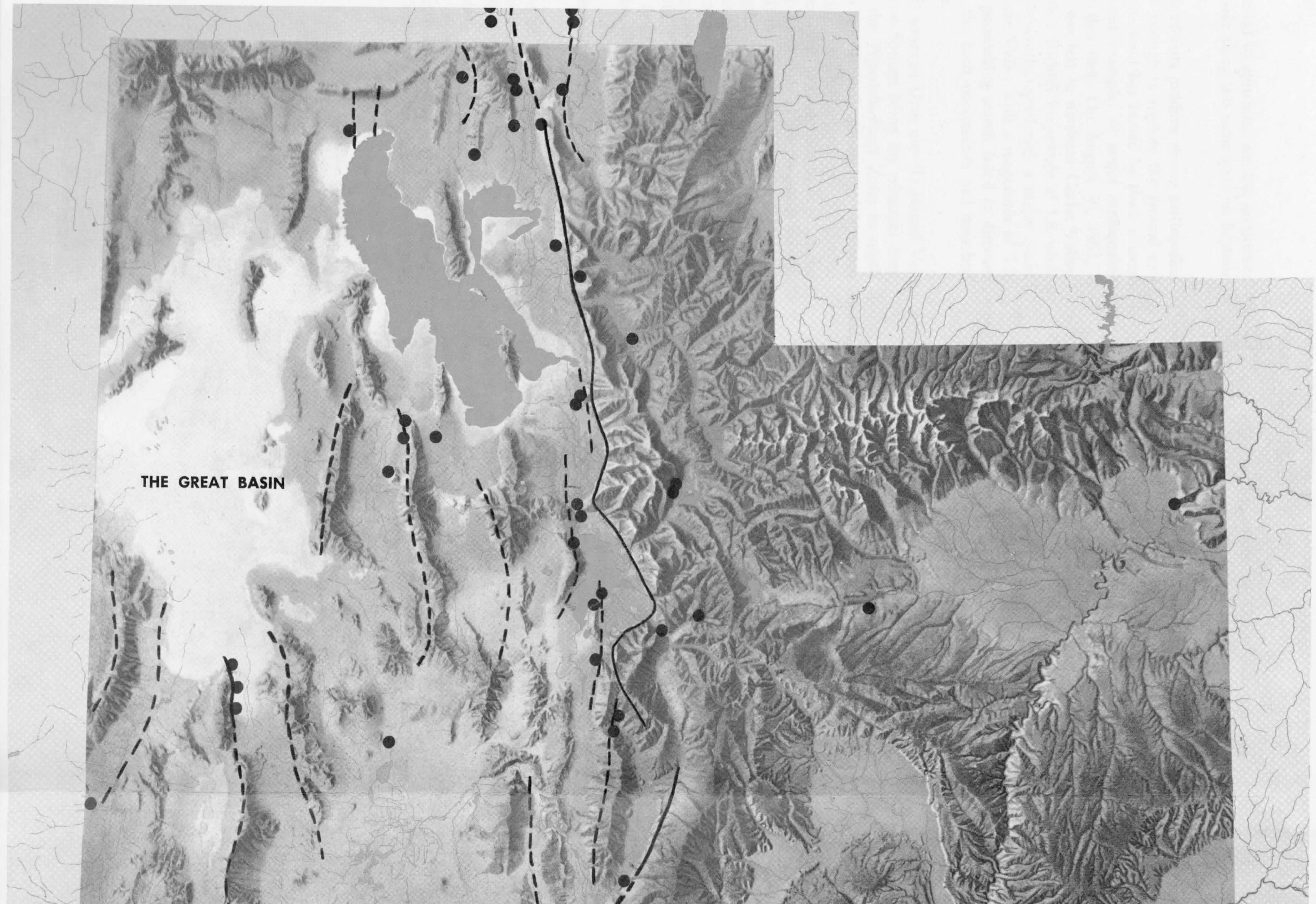

Fig. 3. Relation of mineral spring locations to major fault zones.

this locality, concealed by alluvium, was the occurrence of a major earthquake along this same zone on September 5, 1962.

Many fault movements produce strong earthquakes but are not severe enough to rupture the ground surface, especially if the fault lies buried by thick alluvial deposits. Two recent examples of major earthquakes in Utah illustrate this fact. On August 30, 1962, a strong earthquake was felt in northern Cache Valley, near Lewiston, with a Richter magnitude of 5.8, while six days later, as previously mentioned, a major quake occurred in Salt Lake Valley with a magnitude of 5.0. In both instances painstaking search failed to discover any evidence that the fault movements had breached the ground surface.

The major fault zones in Utah are: (1) Hansel Valley, with Locomotive Springs being the principal associated spring; (2) the Wasatch Fault Zone in north central Utah, with five thermal springs, namely (from north to south), (a) the Cutler Springs, (b) Crystal Springs, near Honeyville, (c) Utah Hot Springs, at the tip of the Pleasant View Spur of the Wasatch Range, north of Ogden, (d) the Ogden Canyon Hot Springs at the mouth of Ogden Canyon, and (e) Beck's Hot Spring, north of Salt Lake City; (3) the Sevier Fault Zone in south central Utah with two thermal springs, the Red Hill Spring, and the Monroe Hot Springs, both near Monroe; (4) the Elsinore (Tushar) Fault Zone in central Utah with one thermal spring, the Joseph Hot Spring; and (5) the Hurricane Fault Zone with one major spring, the LaVerkin Hot Springs on Virgin River in Washington County. These are indicated in Fig. 3.

The distribution of the thermal springs, associated with the fault zones mentioned above, discloses the puzzling fact that long segments of each fault zone are without springs, either hot or cold. For example, no thermal springs are known to occur along the Wasatch Fault Zone between Honeyville, north of Brigham City, and Pleasant View, north of Ogden, and none are present between the mouth of Ogden Canyon and Beck's Hot Spring, near Salt Lake City. From the latter locality to the southern end of the Wasatch Fault Zone, for a distance of over 80 miles, through Salt Lake, Utah, and Juab counties, no thermal springs are known in close association with the fault zone. To note their absence is one thing; to explain it is quite another. One possible explanation for the absence of thermal springs along the Wasatch Fault Zone south of Big Cottonwood Canyon in Salt Lake County, and farther south through Utah County, is the great thickness of unconsolidated "valley fill" bordering the fault zone that may absorb the thermal waters as they rise before they can reach the surface.

A similar long stretch along the Sevier Fault Zone from Monroe south to the Arizona line for a distance of over 120 miles is without known thermal springs. The Hurricane Fault Zone, which extends southward from near Cove Fort to the Arizona line and thence across the Arizona "strip" and the Grand Canyon, is singularly free of associated thermal spirngs. Only one extensive spring area is known, the LaVerkin Springs.

Many thermal springs associated with areas of ancient, as well as more recent volcanic activity, have now ceased to flow. An example is the Hatton Spring area in Pavant Valley, where (judging from the size and extent of the tufa and travertine deposits that remain) the former springs must have been large and in existence for a long period of time. A north-south linear belt of cinder cones and geologically recent basalt flows characterize this volcanic field, beginning at the north end with Pavant Butte, an extinct volcano, and trending south through the Fillmore Craters to a cinder cone south of Kanosh.

The hot springs north of Abraham in Millard County arise near Fumerole Butte, an old volcanic vent in the center of a lava field. The spring waters probably derive their heat from volcanic rocks that are slowly cooling at depth. The water, however, is mostly meteoric in origin.

CHEMICAL CHARACTERISTICS OF UTAH'S MINERAL SPRINGS

Measured Properties and Constituents

The properties and constituents commonly reported in water analyses will be discussed in some detail in this section in order to provide a better understanding of the nature of each constituent and to indicate possible sources from which it may be derived and the range of concentration normally expected. A major source of information for this discussion and further detail may be found in U.S. Geological Survey Water Supply Paper No. 1473 (Hem, 1959).

Specific electrical conductance. Electrical conductance is the ability of a substance to conduct electrical current. Specific electrical conductance (EC) is the conductance of a cube of the substance 1 cm. on a side. The conductivity of water solutions of mineral matter increases with temperature. For this reason, to make reported values comparable, they must be reported at the same temperature — usually 25° C.

Conductance is the inverse of resistance, so specific conductance is reported in reciprocal ohms, or "mhos." To avoid inconvenient decimals, water conductivity data are reported in micromhos (millionths of mhos). Before October 1, 1947, the specific conductance data reported by the U.S. Geological Survey were reported as mhos x 10^5, and to convert these values to micromhos they should be multiplied by 10.

Chemically pure water has a very low conductance. In simple dilute solutions of single-salt type a linear relation exists between dissolved-solids concentration and conductance. As the concentration increases, however, the relation becomes non-linear. Natural waters do not contain single-salt solutions. They are mixed-salt solutions containing some substances as dissolved solids which do not ionize or dissociate. These non-ionized substances are not conductors and tend to cause poorly defined dissolved solids-conductance relation in waters with high concentrations of dissolved solids. Ion mobility also changes with different solutions and also affects the relation between dissolved solids and conductance.

Because of these complexities no exact relation can be drawn between conductance and dissolved solids in natural waters. In the expression

$$\text{Dissolved solids (ppm)} = A \times \text{specific conductance (micromhos)}$$

the value of A may vary from 0.5 to 1.0 for natural waters but usually has a value between 0.55 and 0.75.

Specific conductance is easily determined either in the laboratory or field, and is, therefore, a valuable tool for screening and decision-making in the field. The determination is also a valuable index used in showing short-time quality changes in streamflow.

Conductance values may range from 0.05 micromho, for the purest water that can be made in the laboratory, to 195,000 micromhos, for water such as found in Great Salt Lake. Conductivity for ocean water is about 50,000 micromhos and for ordinary single-distilled water used in laboratory work about 1 to 5 micromhos. Conductivity of mineralized spring water is generally between 1,200 micromhos and 15,000 micromhos.

Hydrogen-ion concentration (pH). Hydrogen-ion concentration is expressed in terms of pH units. The pH of natural water is largely controlled by chemical reactions and equilibria among the ions in solution. The most important type of reaction affecting pH in natural water is hydrolysis.

In natural water the hydrolysis due to carbonate and bicarbonate salts usually predominates. Other hydrolysis reactions in natural water are due to silicates, borates, phosphates, fluorides, and a few other less common salts. All these reactions tend to raise the pH above 7. In other words, they make the solution more basic than acidic. Substances giving an acid reaction upon hydrolysis are due to such salts as those of iron and ammonium, but these salts are rarely present in sufficient quantities to predominate in fixing the pH of natural waters. These salts occur more often, however, in thermal springs than in other waters.

Values of pH are often used as a measure of the solvent power of water or as an indicator of the chemical behavior which certain solutions may have toward rock minerals. In surface waters the supply of water is usually large in comparison with the solid material available for solution, so the pH of the water may not be much affected by the solution of all the available ions. The case for ground water is just the opposite since ground water occurs in an environment where the solids available for solution are present in excess of the solution capacity of the water. For this reason the pH of water that has been underground will more closely reflect the influence of the available solid material.

Most ground water in the United States has pH values ranging from 5.5 to 8 with some extreme values beyond these limits. Water which contains an excess of carbon dioxide will have pH values less than 7.0. Natural water with pH values lower than about 4.5 may contain free mineral acids added by volcanic gases or oxidation of sulfides. They may also contain the iron and ammonium salts which tend to give an acid reaction. Organic acids, due to the presence of organic material, may also give pH values lower than 7.0. Higher values of pH than 7.0 may be due to hydrolysis.

Dissolved solids. "Total dissolved solids" (TDS) and "dissolved solids content" are terms commonly used to describe the mineral content of water, but these terms lack standardization and are not really meaningful unless the method of determination is indicated. The terms may refer to the sum of the determined constituents or they may refer to the residue of a known quantity of a sample dried at 180° C or at 105° C. Some results may differ considerably; therefore, the method of determining dissolved-solids content is given with the analytical results.

The unit most commonly used to express dissolved solids content, and that is the basis of most quantitative expressions in this report, is parts per million (ppm). This unit expresses the number of milligrams of solute in 1 liter of solution. Ordinarily, in assuming that 1 liter of naturally occurring water weighs 1 kilogram, the error is small and is neglected.

Dissolved-solids content may also be described in milligram equivalents per million, commonly contracted to equivalents per million (epm). Equivalents per million are computed by dividing the concentration of an ion, in parts per million, by the combining weight (atomic or molecular weight divided by the balance) of the same ion. The term equivalents per million takes into account the concept of chemical equivalence and is useful in the analysis of water mixtures and in other chemical interpretations and evaluations. Because the number of equivalents per million of cations should balance or equal the number of equivalents per million of anions, a comparison of these data may indicate the accuracy or completeness of an analysis. In addition, the specific conductance divided by 100 is roughly equal to the total equivalents per million of anions or cations. If this relation does not hold for a particular analysis, the analysis may be inaccurate, or the analysis may not have been made for an abundant ionized constituent, or some ionized constituent which is heavy, although not abundant may not have been analyzed.

Major Constituents

Calcium. Calcium is present to some extent in nearly all waters because of its widespread occurrence in soils and rocks, and its ready solubility. Calcium is one of the alkaline-earth metals. Also included in this group are beryllium, magnesium, strontium, barium, and radium. Although the alkaline-earth metals have some common properties, the more important ones will be discussed separately since they may and often do have very different behavior in solution.

Calcium is a major constituent of many rock types and the precipitates contain especially large percentages. For example, limestone is essentially composed of calcium carbonate plus impurities. Since many of the rocks found in the Cordilleran geosynclinal area (western Utah is a part) are limestone and other precipitates, one would expect to find high concentrations of calcium in the ground waters of this area. Calcium may also be found in the clastic sedimentary rock because in sandstone and other detrital or clastic rocks redeposited calcium carbonate is usually one of the principal constituents of the cementing material holding the rock grains together. This cementing material may be redissolved as water moves through these rocks. Calcium is also present in soils as a carbonate and in other forms.

Large amounts of calcium and bicarbonate in solution are possible when a large amount of carbon dioxide is available. This solution is stable when there is sufficient pressure to prevent the escape of the carbon dioxide. Such conditions can exist in underground aquifers, but when the waters rise to the watertable or to the surface in a spring, they may be supersaturated with carbon dioxide at atmospheric pressures. Gas bubbles escaping from spring waters are often seen because of this, and when the carbon dioxide escapes, the equilibrium of the solution is altered and calcium carbonate precipitates until a new balanced condition is reached between the carbon dioxide in solution and the calcium carbonate. Travertine deposits at spring openings where water charged with carbon dioxide and calcium carbonate issue, result from this type of deposition.

The amount of calcium that might be expected in water has a wide range and depends largely on the amount of carbon dioxide available, the water temperature, and the presence of other salts in the water — especially salts of sodium and potassium. Water in soil containing 1 to 5 percent carbon dioxide could dissolve from 70 to 110 ppm of calcium from calcite. Waters from limestone may contain more than 160 ppm of calcium assuming that other salts are not present. Water saturated with gypsum can contain about 600 ppm of calcium at room temperature. Calcium sulfate is reportedly soluble to the extent of 2,400 ppm of calcium in a saturated solution of sodium chloride. This provides an explanation of high calcium concentrations in many of the mineralized springs.

Magnesium. Magnesium is abundant in the carbonate rocks and is a major constituent causing hardness in water. In ionic form, magnesium normally is present in solution. Once in solution, magnesium has a stronger tendency to remain in solution than does calcium. This is indicated by the comparatively high concentration of magnesium in sea water. Magnesium salts are among the last to be deposited in the evaporite sediments since some of the magnesium salts are very soluble.

The solubility of magnesium carbonate, like that of calcium carbonate, is increased by the presence of carbon dioxide. But this reaction is less readily reversible in the case of magnesium carbonate. The presence of other salts in solution also increases the solubility of magnesium carbonate.

In most waters of low to moderate dissolved-solids concentration, the magnesium content is considerably less than the calcium, even when expressed on an equivalent basis. The ratio of calcium to magnesium for most natural waters ranges from about 5 to 1 to about 1 to 1. The value of the ratio indicates the rock type being attacked. Higher values indicate relatively pure limestone or the availability of gypsum for solution, and the lower values indicate dolomitic rocks or magnesium silicate minerals. In some cases a low value of the ratio may indicate sea-water contamination since the ratio of calcium to magnesium for sea water is about 1 to 5. Where the concentration of magnesium is greater than that of calcium, contamination by connate brines may be indicated. This could also indicate that the water has been in contact with some of the magnesium silicate minerals.

The range of concentration of magnesium in natural waters is large. Waters that have been subject to natural base exchange may have little or no magnesium. Ocean water, on the other hand, is high in magnesium, having over 1,000 ppm. In closed basins where salts may accumulate and reach very high concentrations, magnesium brines may occur. For example, the magnesium concentration in Great Salt Lake waters is in the vicinity of 7,000 ppm. Concentrations of magnesium in mineralized spring waters in Utah range from a few ppm to over 1,000 ppm.

Sodium. Sodium is by far the most abundant and the most important of the alkali metals. It is an important constituent in igneous rocks and in the evaporite sediments. Ordinarily, there is very little sodium in carbonate rocks. Sodium, when leached from rocks, generally tends to remain in solution since nearly all sodium compounds are readily soluble in water. Sodium bearing waters may in some circumstances participate in "base-exchange" or "ion-exchange" reactions whereby sodium replaces other cations such as calcium or magnesium in clay minerals or other minerals. The range of concentration of sodium ions in water may vary from 1 or 2 ppm in water from pure limestones to 10,000 ppm in sea water to 100,000 ppm in some saturated salt brines. The range of concentration of sodium ions in Utah mineralized springs is from about 400 ppm to over 16,000 ppm.

Potassium. Sodium and potassium are both alkali metals, but their behavior in the process of chemical weathering from rock is different. Potassium is easily recombined with other products of weathering, particularly the clay minerals; therefore, potassium tends to appear in the sediments and not so much in the water. The chief source of potassium in water is probably in potassium-bearing feldspars and some micas.

Sodium-potassium ratios may sometimes be useful indications of the type of rock environments to which the waters have been subjected, but this computation has limited value since potassium may be easily lost from solution by absorption or other processes. Potassium concentrations, like sodium concentrations, may range from 1 or 2 ppm to several thousand ppm. Concentrations of potassium ions in Utah's mineralized springs range from about 20 ppm to over 1,000 ppm.

Carbonate and bicarbonate. Because of the relative abundance of carbonate minerals and because carbon dioxide is readily available, bicarbonate and carbonate are end products of chemical weathering of feldspars. Igneous rocks include about 50 percent feldspars, and sedimentary rocks may contain large amounts of carbonate and bicarbonate as a result of the weathering of igneous rocks. Carbonate and bicarbonate compounds precipitate easily, however, with changes in water temperature and pressure, and when CO_2 is released from the water.

Ordinarily, carbonate and bicarbonate concentrations in water might be expected to range from 50 ppm in water from terranes of insoluble rock to as high as

400 ppm in water from limestone terranes. In Utah's mineralized spring waters, the range of concentrations of carbonate and bicarbonate is from about 100 ppm to 6,630 ppm, with the carbonate concentration being much smaller than the bicarbonate concentration.

Sulfate. Sulfate commonly occurs in many of the waters of alluvial basins in Utah as a result of leaching of evaporites such as gypsum and anhydrite. Sulfate may also be provided by leaching or washing from marine shales.

Sulfate compounds with calcium and magnesium constitute permanent hardness in water. This type of hardness is much more difficult to remove than the temporary hardness of calcium carbonate and calcium bicarbonate. Sulfate concentrations of more than 250 ppm may have a laxative effect when combined with other ions, notably sodium or magnesium. Many of the mineralized springs in Utah contain more than 250 ppm of sulfate with the range being from about 50 ppm to about 1,500 ppm.

Chloride. The element chloride is a member of the halogen group of elements. Chloride-bearing igneous rock minerals are few and igneous rocks in general appear to be a very minor source of chloride. Much more important sources are associated with sedimentary rocks, especially the evaporites. Water from humid regions generally is low in chlorides, while water from arid regions generally is high in chlorides. Chloride is to be expected in any incompletely leached deposits laid down under the sea or in a closed basin where chloride was present. This is the situation to be expected in the Great Basin drainage section of Utah.

Although igneous rocks, as mentioned above, are generally low in chloride, volcanic gases and the water of many hot springs contain large amounts of chloride. White (1957) concluded that the chloride in waters of some hot springs areas is derived from a magmatic source and is transported from depth in a dense vapor solution. It is questionable whether most of the chloride in Utah's mineralized springs has a magmatic origin or whether it originates in the sediments laid down under the sea.

Chloride compounds are not to be expected in the alluvium down-gradient from the springs, since chloride generally is not precipitated but is carried in solution. This is one reason why chloride is the most abundant anion in sea water.

Chloride-ion concentrations that may be expected in natural waters may range from 5 ppm in the dilute waters of humid regions to as high as 155,000 ppm in saturated sodium chloride brines. The chloride content of sea water is about 19,000 ppm. The range of chloride concentrations in mineralized springs in Utah is from 120 ppm to about 27,000 ppm.

Minor Constituents

Iron. Although iron is usually found in natural waters in comparatively small amounts, the importance of determining these small amounts of iron in evaluating the usability of a supply for domestic and industrial purposes has led to the inclusion of this test in all complete water analyses. The amounts of iron found in many waters are usually so small that they are in the same range as trace minerals that are rarely determined.

The sources of iron in water are usually the silicate minerals of dark colored igneous rock, such as the amphiboles, the pyroxenes, and the dark ferromagnesian micas. Other important iron-bearing minerals in igneous rocks are sulfide minerals, such as pyrite and ferrous sulfide, and the oxides such as magnetite. In sandstones the iron oxides, iron hydroxides, and iron carbonates are often present as cementing materials. Iron is present in many carbonate rocks as a minor impurity.

The chemistry of iron in water is somewhat complex because of the two possible levels of oxidation of iron. Determinations for iron are usually reported in terms of dissolved iron. This determination is often not representative of conditions existing in the sample at the time of collection, because usually by the time the analysis is made, the ferrous iron has had some opportunity to oxidize and ferric hydroxide is precipitated. Thus, a report of dissolved iron in a sample may be somewhat less than the total iron in the water at the sampling site — the difference depending largely on the degree of oxidation since the sample was taken. Because of these inaccuracies, data pertaining to iron have only limited use for geochemical interpretation, but they are useful in evaluating the suitability of the waters for various uses.

The range of concentrations for iron varies from a trace to over 100 ppm. For high concentrations of iron to be possible, the pH must be less than about 3.0. Such waters may often be found in some thermal springs. For ground water subject to a reducing environment, concentrations of iron over 50 ppm rarely occur.

Manganese. Manganese resembles iron in its chemical behavior and in its occurrences in natural waters, although it is generally much less abundant. In igneous rocks, manganese is comparatively rare and exists most often as an impurity in the dark colored silicate minerals. Metamorphic and sedimentary rocks contain minerals with more manganese. There is also some tendency for manganese to build up in soils as they are formed from rock weathering. Manganese found in water is usually a result of solution of manganese from sediments as it complexes with organic materials. If manganese is carried by sediments to reservoirs and deposited there, the sediments may yield manganese to the water in storage. Since manganese in excess of about 0.3 ppm is objectionable in public supplies, this process of accumulation in reservoirs may give difficulty in water-supply reservoirs. The same reasoning holds, of course, for manganese contributed to the water supply system from mineralized springs.

In most natural waters the amount of manganese is less than 0.20 ppm and ranges generally from 0.05 to 0.25 ppm. Water which is strongly acidic and high in iron may contain concentrations of manganese as high as 1.0 ppm.

Boron. The element boron is a minor constituent of most rocks and of most natural waters, but boron is a significant constituent in the waters of many hot springs throughout the world. White (1957) and other writers agree that high concentrations of boron in thermal waters indicate a probable magmatic origin for at least part of the thermal waters. The occurrence of boron in water has been rather closely studied in the western United States because amounts of boron as small as 1.0 ppm in irrigation water and soil are damaging to certain crops. Most plants are more tolerant to boron than this, but many are damaged by concentrations of only 2.0 ppm. The effect of boron on plants has been covered in some detail in reports of the U.S. Department of Agriculture (Eaton, 1935).

The boron content of natural waters may range from less than 0.01 ppm to 30 ppm or more. Concentrations above 10 ppm are decidedly unusual, and most often occur in waters from hot springs or brines. Average sea water contains 4.6 ppm of boron. The range of concentrations of boron in mineralized springs in Utah is from 0.2 ppm to 12.0 ppm. Several springs have concentrations of boron over 2.0 ppm.

Lithium. Lithium is an alkali metal similar in many characteristics to sodium and potassium, although lithium probably does not participate extensively in base-exchange reactions. The element lithium is comparatively rare. It is concentrated in complex lithium minerals in granite and a few other igneous and metamorphic rocks. It may occur in deposits of evaporite sediments.

Data on lithium in the waters are meager; it is not often determined in routine water analyses. However, it has been found to be present in the waters of hot springs or of highly mineralized brines and is usually reported in concentrations of less than 10 ppm. Lithium concentrations in mineralized springs in Utah range from about 0.01 ppm to 24.0 ppm.

Strontium. The element strontium is a typical alkali-earth element, and it is similar chemically to calcium. Strontium is one of the most abundant minor elements found in igneous rocks and is important also in carbonate rocks.

Strontium is not often determined in routine water analyses, and data on strontium concentrations in water are scarce. Some authors feel that strontium may be available in water in amounts up to a few parts per million more often than the available literature indicates. An analysis of a chloride brine from Michigan indicates a strontium concentration of 2,730 ppm. Most analyses where strontium is indicated, however, show strontium concentrations of less than 1.0 ppm. The range of strontium concentrations found in Utah's mineralized springs is from about 2.0 ppm to 22.5 ppm.

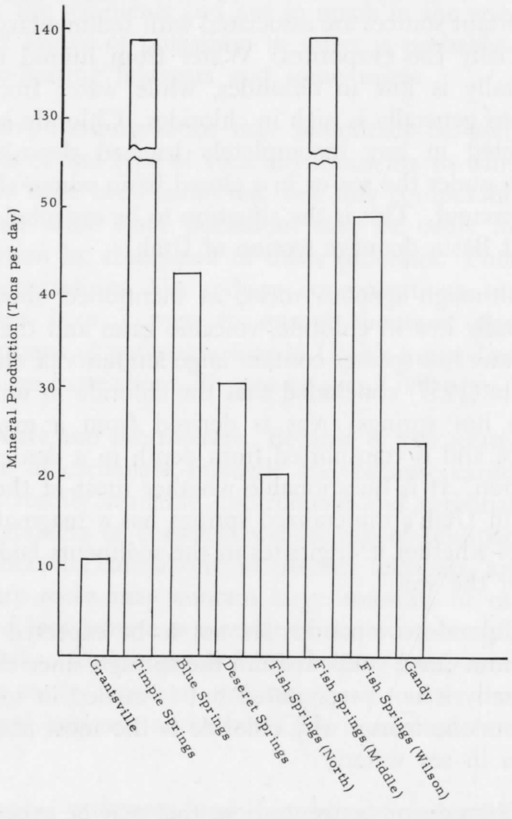

Fig. 4. Mineral production for springs in the Great Salt Lake Desert hydrologic unit.

Cesium. Cesium is a heavy alkali metal with behavior in rocks and in water very similar to that of potassium, but it is much more readily adsorbed and reconstituted in sedimentary minerals. This tendency for cesium to be adsorbed by hydrolyzate sediments is undoubtedly a major factor in keeping the concentration of cesium in water at a low level. Since cesium is a decidedly rare element, it should not normally occur in water in concentrations larger than traces.

Cesium concentrations in Utah's mineralized springs range from traces to 11 ppm.

Sample Data and Chemical Analyses

Water samples for chemical analyses were obtained from each of the mineralized springs shown in Fig. 3. Where pertinent, samples were also taken from the streams into which the mineralized spring waters flow. The results of the chemical analyses are given in Table 1.

The samples were analyzed in laboratories at Utah State University. Analyses of the cations were made for most of the samples at the Utah Water Research Laboratory by spectrophotometric methods. Analyses of the anions, and for some samples cations as well, were done by the Soil and Water Testing Laboratory.

The discrepancies in balances between anions and cations may be attributed to one or more of several factors. Such discrepancies may suggest errors in measurement or they may suggest interference by one ion in the determination of another. They may also suggest that some important constituent or constituents have not been determined in the analysis.

Information concerning flow of water from the various springs was obtained by actual stream measurement using stream gaging equipment, weirs, orfices, or flumes as appropriate. Some of the spring flows were measured several times during the course of this study.

Another meaningful way of expressing the problem hazard of mineralized waters is to combine the dissolved mineral concentration with the flow rate to obtain total tons per day produced. The tons per day mineral output of the springs included in this study are recorded in Table 1. The data are shown graphically according to hydrologic subdivision in Figs. 4 through 8.

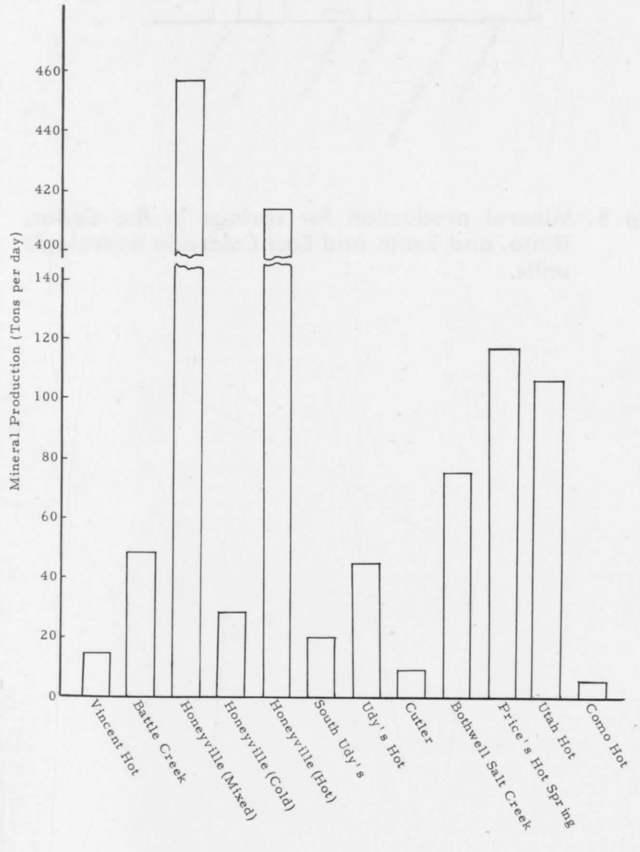

Fig. 5. Mineral production for springs in the Bear River and Weber River hydrologic units.

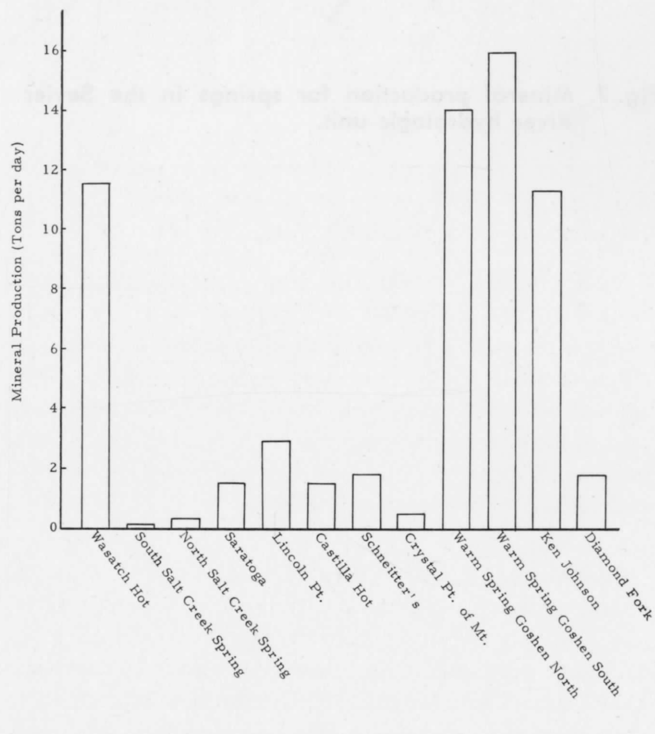

Fig. 6. Mineral production for springs in the Jordan River hydrologic unit.

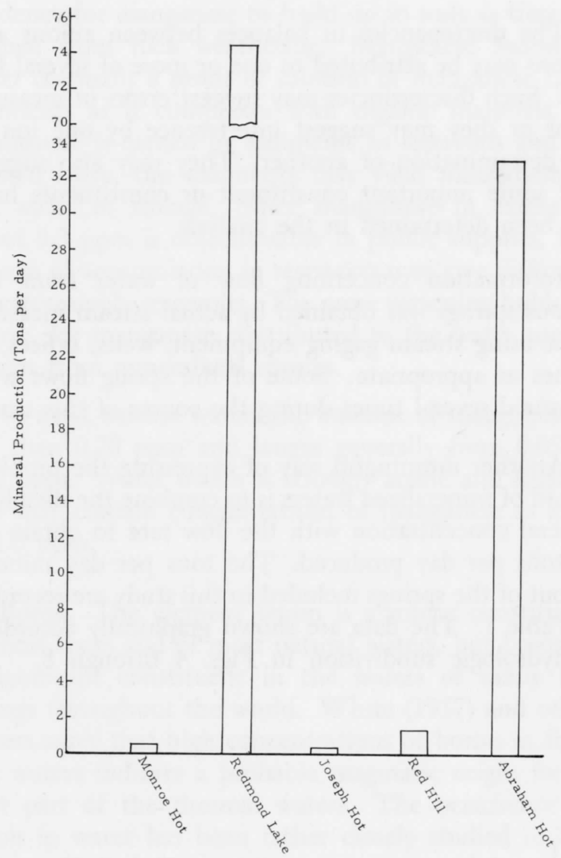

Fig. 7. Mineral production for springs in the Sevier River hydrologic unit.

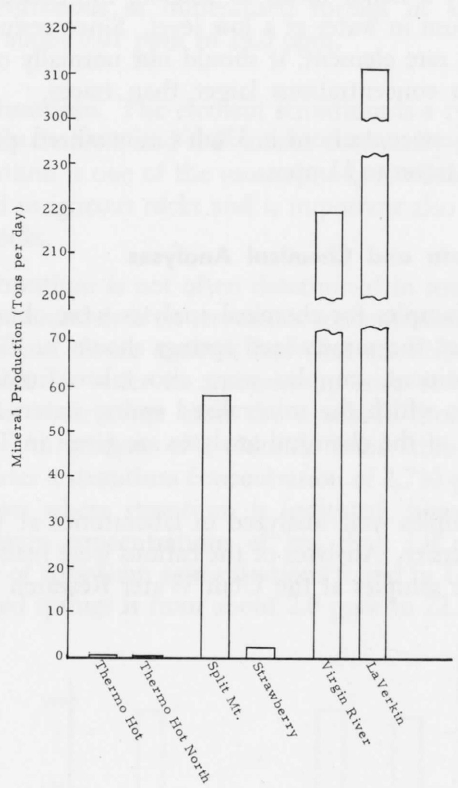

Fig. 8. Mineral production for springs in the Cedar, Uinta, and South and East Colorado hydrologic units.

Table 1. CHEMICAL ANALYSES AND QUALITY OF MINERALIZED SPRINGS IN UTAH

Location Coordinate	Name of spring	Date of sampling	Temp. F°	Flow cfs	Sodium ppm	Sodium epm	Potassium ppm	Potassium epm	Calcium ppm	Calcium epm	Magnesium ppm	Magnesium epm	Lithium ppm	Lithium epm	Strontium ppm	Strontium epm	Cesium ppm	Iron ppm	Boron ppm	Chloride ppm	Chloride epm	Sulfate ppm	Sulfate epm	Carbonate ppm	Carbonate epm	Bicarbonate ppm	Bicarbonate epm	Total dissolved solids by evaporation at 105°C ppm	Total dissolved solids by sum of constit. ppm	EC (micromhos at 25°C)	Total hardness as $CaCO_3$	pH	Tons per day salt
Hydrologic Unit	**No. 1 — Great Salt Lake Desert**																																
		1964																															
(C-2-6)	Grantsville Warm Springs	7-29	86°	0.2	13,500	587.2	258	6.6										0.26	1.5	10,142	286.0	443	9.22	4.5	0.15	185	3.03	20,130	24,534	22,500		7.5	10.87
(C-1-7)9	Big Spring nr. Timpie	7-29	72°	7.6	2,300	100.0	170	4.3	390	19.5	320	26.3	3.60	0.52	6.8	0.16	2	0.29	0.9	4,539	128.0	360	7.49	3.6	0.12	188	3.09	8,960	8,335	12,900	2,291	7.6	183.86
(C-1-7)9	Big Spring nr. Timpie	8-17	72°	7.6	3,450	150.0	135	3.4	160	8.0	300	24.7	3.05	0.44	8.2	0.19	1	0.14	0.7	2,386	67.3	49.5	1.03	4.5	0.15	248	4.06	4,570	6,768	13,820	1,634	7.9	93.78
(B-13-5)	Blue Springs nr. Howell	9-10	80°	7.6	540	23.5	32.5	0.8	83	4.1	24	2.0	0.84	0.12	4.6	0.10	Trace	0.28	0.2	886	25.0	67.7	1.41	8.7	0.29	268	4.40	2,030	1,923	3,580	306	8.0	41.66
(C-3-8)	Deseret Springs--Skull Valley	8-17	74°	2.0	2,300	100.0	95	2.4	140	7.0	125	14.4	2.20	0.32	6.4	0.15	0.6	0.31	0.6	3,454	97.4	206	4.78	0.0	0.00	166	2.72	5,620	6,563	9,440	864	2.8	30.35
	Fish Springs Group																																
(C-11-14)26	North Springs	8-19	75°	2.6	700	30.4	68	1.7	88	4.4	105	8.6	1.50	0.22	4.6	0.10	Trace	0.25	1.0	1,284	36.2	345	7.18	5.4	0.18	251	4.11	2,880	2,861	4,460	652	7.9	20.22
(C-11-14)26	Middle & Thomas	8-19	72-78°	25.0	440	19.1	60	1.5	76	3.8	15	1.2	1.20	0.17	4.0	0.09	0	0.45	0.8	617	17.4	383	7.97	3.6	0.12	207	3.39	2,060	1,813	2,990	251	7.9	139.05
(C-11-14)3	Wilson's Hot Springs	8-19	95-140°	0.75	11,500	500.2	420	10.7										0.28	2.7	11,560	326.0	146	3.05	3.6	0.12	130	2.13	24,200	23,762	32,100	—	7.5	49.00
(C-15-19)31C	Gandy Warm Springs	8-19	80°	21.0	25	1.1	4.3	0.1	26	1.3	10	0.8	0.44	0.06	3.3	0.08	0	0.13	0.4	30.1	0.85	17.3	0.36	4.5	0.15	171	2.81	420	292	469	106	7.9	23.81
Hydrologic Unit	**No. 2 — Bear River**																																
(Idaho)	Vincent Hot Springs	7-30	180°	0.4	4,200	182.7	910	23.2	445	22.2	335	27.6	11.20	1.61	10.5	0.24	3	0.18	3.1	6880	194.0	38.9	0.81	0.0	0.00	372	6.10	13,190	13,200	18,500	2,490	7.3	14.24
(Idaho)	Battle Creek Hot Springs	7-30	173°	2.0	3,550	154.4	660	16.9	310	15.5	305	25.1	8.20	1.18	7.6	0.17	0	0.32	2.8	4,681	132.0	30.2	0.63	5.4	0.18	410	6.72	9,010	9,974	12,300	2,029	7.7	48.65
(B-11-2)29	Honeyville Crystal (Mixed)	9-11	90°	9.0	6,988	304.0	305	7.8	383	19.1	85	7.0					0	1.27	2.2	10,000	282.0	221	4.61	0.0	0.00	194	3.18	18,820	18,183	11,900	1,306	7.3	457.33
(B-11-2)29dac	Honeyville Crystal (Cold)	9-11	63°	5.5-	425	18.5	31	0.8	76	3.8	46	3.8					0	1.07	0.2	656	18.5	56.7	1.18	0.0	0.00	253	4.14	1,920	1,550	2,330	379	7.5	28.51
(B-11-2)29dab	Honeyville Crystal (Hot)	9-11	130°	3.5-	15,931	693.0	762	19.5	862	43.0	194	16.0					Trace	1.86	4.2	23,617	666.0	438	9.12	0.0	0.00	165	2.70	43,790	41,985	43,300	2,951	7.0	413.82
(B-13-3)	South Udy's Hot Springs	7-17	110°	0.8	2,050	89.2	180	4.6	355	17.7	335	27.6	4.40	0.63	8.6	0.20	2	0.38	0.9	4,823	136.0	110	2.30	1.8	0.06	154	2.53	9,070	8,075	12,900	2,265	7.4	19.59
(B-13-3)	South Udy's Hot Springs	9-11	104°	0.8	3,356	146	141	3.6	202	10.1	74	6.1					3	1.06	1.0	4,752	134	93.2	1.94	0.0	0.00	224	3.67	9,190	8,847	8,210		7.2	19.85
(B-13-3)	Udy's Hot Spring	7-17	93°	2.2	2,750	119.6	155	3.9	260	13.0	320	26.3	3.40	0.49	9.2	0.21	2	0.27	0.7	4,326	122.0	81.6	1.70	2.7	0.09	144	2.36	7,420	7,909	9,540	1,966	7.4	44.07
(B-13-3)	Udy's Hot Spring	9-11	93°	2.2	2,804	122	121	3.1	158	7.9	64	5.3					3	0.86	0.8	3,865	109	80.7	1.68	2.7	0.09	164	2.69	7,780	7,264	5,690		7.4	46.21
(B-13-2)27d	Cutler Springs	7-17	76°	0.7	1,850	80.5	83	2.1	205	10.2	305	25.1	2.10	0.30	4.6	0.10	1	0.26	0.4	2,511	70.8	68.2	1.42	2.7	0.09	159	2.60	4,960	5,220	7,220	1,767	7.2	9.37
(B-11-4)	Bothwell Salt Creek Springs	7-17	69°	17.0	600	26.1	37	0.9	86	4.3	190	15.6	0.75	0.11	2.45	0.05	0.5	0.28	0.3	748	21.1	79.7	1.66	5.4	0.18	289	4.74	1,590	2,050	2,990	997	7.7	72.98
(B-11-4)	Bothwell Salt Creek Springs	9-10	69°	16.0	425	18.5	325	8.3	82	4.1	24	2.0	0.75	0.11	4.6	0.10	Trace	0.29	0.2	734	20.7	66.8	1.39	5.4	0.18	267	4.38	1,800	1,941	3,180	304	7.9	77.76
(Idaho)	Prices Hot Springs	8-11	92°	6.0	2,200	95.7	180	4.6	200	10.0	200	16.4	3.90	0.56	7.5	0.17	1	0.31	0.6	2,961	83.5	60.0	1.25	0.9	0.03	170	2.78	5,810	6,024	8,855	1,322	7.4	94.12
(Idaho)	Prices Hot Springs	9-11	92°	6.0	1,000	43.5	105	2.7	170	8.5	135	11.1	2.60	0.37	6.8	0.16	0.6	0.23	0.9	4,504	127.0	317	6.61	5.4	0.18	192	3.14	8,680	6,453	7,940	980	7.7	140.62
Hydrologic Unit	**No. 3 — Weber River**																																
(B-7-2)4dc	Utah Hot Springs	8-4	136°	1.5	7,200	313.2	1,100	28.1	1,550	77.3	470	38.6	24.0	3.46	22.5	0.51	10	0.29	4.6	12,270	346.0	197	4.11	0.0	0.0	104	1.71	29,400	23,058	24,700	5,804	7.3	119.07
(B-7-2)4dc	Utah Hot Springs	9-2	135°	1.5	11,500	500.2	1,310	33.5										0.21	4.5	12,695	358.0	194	4.03	0.0	0.0	107	1.75	23,060	25,810	33,400	—	7.3	93.39
(A-4-2) 36b	Como Hot Springs, Morgan	8-27	82°	3.1	34	1.5	7.4	0.2	86	4.3	2.5	0.2	0.36	0.05	3.5	0.08	0	0.32	0.6	39.0	1.10	204	4.25	0.0	0.0	169	2.77	690	547	852	225	7.8	5.78
Hydrologic Unit	**No. 4 — Jordan**																																
(B-1-1)25	Wasatch Hot Springs	7-29	110°	0.7	1,950	84.8	118	3.0	500	25.0	240	19.7	4.0	0.58	8.0	0.18	1.5	0.32	1.1	3,149	88.8	850	17.7	2.7	0.09	192	3.14	7,380	7,055	10,100	2,236	7.4	13.95
(B-1-1)25	Wasatch Spring at Tunnel	8-18	110°	0.6	2,100	91.4	110	2.8	320	16.0	215	17.7	3.45	0.50	8.0	0.18	0.75	0.32	1.1	3,294	92.9	855	17.8	0.0	0.00	140	2.30	7,060	7,069	10,500	1,684	7.7	11.44
(B-1-1)25	Wasatch Spring at Resort	9-2	102°	0.6	1,950	84.8	168	4.3	300	15.0	190	15.6	3.65	0.52	6.4	0.15	1.1	0.22	1.3	3,213	90.6	840	17.5	0.0	0.00	143	2.34	7,230	6,673	9,950	1,531	7.6	11.71
(D-13-2)	South Salt Creek at Nephi	9-1	54°	0.01	820	35.7	10.4	0.3	86	4.3	86	7.1	0.90	0.13	5.5	0.13	Trace	0.08	0.2	1,145	32.3	393	8.19	2.7	0.09	131	2.14	2,690	2,688	3,280	569	7.6	0.07
(D-12-3)	No. Salt Creek Spring nr. Nephi	9-1	60°	0.002	16,500	717.8	71	1.8										0.75	0.5	26,986	761.0	2,992	62.3	2.7	0.09	140	2.30	52,440	46,693	64,200	—	7.4	0.28
(C-5-1)	Saratoga at Pool	8-5	118°	0.4	220	9.6	31.5	0.8	93	4.6	10	0.8	1.80	0.26	4.6	0.10	Trace	0.19	0.8	331	9.33	409	8.52	1.8	0.06	117	1.91	1,400	1,127	1,950	273	7.5	1.51
(C-5-1)	Saratoga North Spring	8-5	106°	0.01	210	9.1	31.0	0.8	96	4.8	15	1.2	1.80	0.26	2.1	0.05	0	0.18	0.9	310	8.75	422	8.79	0.0	0.00	126	2.07	1,410	1,221	1,860	301	7.6	0.04
(D-8-1)	Lincoln Point Spring	8-5	92°	0.17	940	40.9	185	4.7	330	16.5	210	17.3	3.90	0.56	4.7	0.11	0.7	0.26	1.9	2,429	68.5	879	18.3	0.0	0.00	159	2.60	6,230	5,163	9,300	1,688	7.4	2.86
(D-9-3)	Castilla Hot Spring	8-4	108°	0.08	1,600	69.6	160	4.1	430	21.4	190	15.6	4.60	0.66	4.7	0.11	0.75	0.23	2.0	2,426	68.4	1,575	32.8	0.0	0.00	164	2.68	7,040	6,579	10,100	1,856	7.5	1.52
(D-9-3)	Castilla Hot Spring Pt # 2	9-2	78°	0.01	2,150	93.5	200	5.1	300	15.0	305	25.1	0.12	0.02	9.8	0.22	1.2	0.08	1.5	3,195	90.1	2,036	42.4	1.8	0.06	933	1.53	8,900	8,326	13,300	2,004	7.3	0.24
(D-3-4)	Schneitter's Hot Pots Homestead	8-25	100°	0.4	132	5.7	34	0.8	182	9.1	51	4.2	1.45	0.21	2.3	0.05	0	0.26	0.9	122	3.45	764	15.9	3.6	0.12	173	2.83	1,690	1,468	2,060	664	7.5	1.82
(D-3-4)	Ken Johnson Hot Springs	7-23	114°	2.5	200	8.7	40	1.0	265	13.2	210	17.3	1.50	0.22	2.8	0.06	Trace	0.29	1.2	152	4.3	778	16.2	1.8	0.06	159	2.60	1,680	1,825	2,070	1,526	7.4	11.34
(C-4-1)	Crystal Spring Pt. of Mtn.	8-18	72°	0.13	230	10.0	58	1.5	88	4.4	6	0.5	1.65	0.24	4.0	0.09	0	0.31	0.8	560	15.8	53.3	1.11	2.7	0.09	140	2.30	1,410	1,149	2,370	244	7.6	0.49
(D-10-1)	Goshen Warm Spring North	8-5	74°	3.90	330	14.4	25.5	0.6	52	2.6	45	3.7	0.76	0.12	3.5	0.08	Trace	0.17	0.3	486	13.7	91.2	1.90	3.9	0.13	182	2.99	1,290	1,231	2,100	315	7.7	13.58
(D-10-1)	Goshen Warm Spring North	9-2	74°	3.90	380	16.5	25.0	0.6	29	1.4	29	2.4	0.64	0.09	4.6	0.10	0	0.30	0.2	511	14.4	87.9	1.83	0.0	0.00	251	4.11	1,370	1,322	2,210	192	7.8	14.43
(D-10-1)	Goshen Warm Spring South	8-5	74°	4.10	320	13.9	28.5	0.7	52	2.6	6	0.5	0.90	0.13	1.75	0.04	0	0.20	0.4	538	15.1	79.2	1.65	3.6	0.12	184	3.02	1,430	1,217	2,410	154	7.7	15.83
(D-10-1)	Goshen Warm Spring South	9-2	74°	4.10	360	15.7	24.0	0.6	37	1.8	37	3.0	0.63	0.09	5.0	0.11	Trace	0.08	0.2	542	15.3	70.6	1.47	2.7	0.09	206	3.38	1,450	1,274	2,320	245	7.8	16.05
(D-8-5)	Diamond Fork Warm Spring	9-3	69°	0.75	150	6.5	11.0	0.3	68	3.4	32	2.6	0.62	0.09	3.3	0.08	Trace	0.23	0.5	44	1.23	386	8.04	1.8	0.06	161	2.64	910	858	1180	302	7.8	1.84
Hydrologic Unit	**No. 5 — Sevier**																																
(C-25-3)11dbb	Monroe Hot Spring	8-7	140°	0.06	480	20.9	79	2.0	225	11.2	24	2.0	2.10	0.30	3.0	0.07	Trace	0.07	2.8	599	16.9	884	18.4	0.0	0.00	269	4.41	2,630	2,581	3,620	660	7.4	0.43
(C-25-3)11d	Monroe Hot Spring	7-15	112°	0.06	450	19.6	82	2.1	175	8.7	125	10.3	2.20	0.32	4.6	0.10	1.5	0.36	2.7	592	16.7	898	18.7	3.6	0.12	112	1.83	2,810	2,487	3,650	951	7.7	0.46
(C-21-1)11	Redmond Lake	8-6	72°	18.0	190	8.3	65	1.7	83	4.1	25	2.0	2.15	0.31	2.3	0.05	2.4	0.22	1.2	209	5.90	447	9.3	9.0	0.30	302	4.95	1,530	1,388	1,910	310	8.0	74.36
(C-25-4)23	Joseph Hot Springs	7-15	140-145°	0.02	960	41.8	85	2.2	265	13.2	230	18.9	4.15	0.60	3.8	0.09	0.75	0.25	3.6	1,585	44.7	1,239	25.8	3.6	0.12	118	1.94	5,210	3,520	6,630	1,608	7.6	0.28
(C-25-3)11	Red Hill Hot Spring	7-15	168°	0.17	420	18.3	86	2.2	205	10.2	150	12.3	2.10	0.30	10.8	0.25	0.5	0.32	3.6	620	17.5	893	18.6	2.7	0.09	90.9	1.49	2,780	2,500	3,620	1,129	7.5	1.28
(C-14-8)15	Abraham Hot Springs	9-1	150-175°	3.0	590	25.7	81.5	2.1	230	11.5	105	8.6	2.75	0.40	5.8	0.13	Trace	0.31	0.9	1,386	39.1	692	14.4	1.8	0.06	115	1.88	4,070	3,223	5,740	1,006	7.6	32.97
(C-14-8)15	Abraham Hot Spring at Bath	9-1	150°	0.2	820	35.7	78	2.0	210	10.5	175	14.4	2.50	0.36	6.8	0.16	Trace	0.17	0.9	1,390	39.2	975	20.3	0.0	0.00	123	2.01	4,000	3,796	5,580	1,244	7.6	2.16
Hydrologic Unit	**No. 6 — Cedar**																																
(C-30-12)28	Thermo Hot Springs	8-7	164°	0.05	440	19.1	6.4	0.2	54	2.7	1.2	0.1	0.27	0.04	2.3	0.05	Trace	0.26	0.4	180	5.08	87.8	1.87	7.2	0.24	148	2.43	570	943	969	139	7.9	0.07
(C-30-12)28	Thermo Hot Springs North	8-20	175°	0.01	440	19.1	60	1.5	76	3.8	15	1.2	1.20	0.17	4.0	0.09	0	0.26	1.0	205	5.77	434	9.03	2.7	0.09	276	4.53	1,600	1,521	2,020	251	7.9	0.04
Hydrologic Unit	**No. 7 — Uintah** UTAH																																
(D-4-24)	Split Mtn. Warm Springs	8-27	88°	20	145	6.3	17.5	0.4	87	4.3	60	0.5	0.54	0.08	3.6	0.08	0	0.31	0.3	288	8.11	194	4.03	2.7	0.09	140	2.3	1,080	888	1,560	464	7.8	58.32
U(C-4-7)	Strawberry Springs	8-28	58°	0.11	3,550	154.4	20.5	0.5	78	3.9	160	13.2	1.20	0.17	7.6	0.17	0.8	0.13	12.0	660	18.6	159	3.32	1203	40.1	4,417	72.4	7,130	10,292	9,410	853	9.5	2.12
Hydrologic Unit	**No. 9 — South and East Colorado**																																
(C-41-13)24	LaVerkin Hot Spring	8-21	108°	11.6	2,400	104.4	230	5.9	510	25.4	310	25.5	0.32	0.05	10.5	0.24	1.2	0.07	4.2	3,379	95.3	1,393	29.0	0.0	0.00	214	3.5	9,930	8,483	14,200	2,549	7.2	311.01

RESULTS AND COMMENTARY BY HYDROLOGIC SUBDIVISION

A brief description of the physical and geologic setting of each spring or group of springs along with interpretation and evaluation of this information follows and is organized according to hydrologic regions of the state.

The Great Salt Lake Desert Unit

Eight mineralized springs or groups of springs in the Great Salt Lake Desert area are included in this report. (Others are known to exist but their location precludes likelihood of any major detrimental effect on manageable supplies.) These are Grantsville Warm Springs, Big Spring near Timpie, Deseret Springs near Iosepa, Promontory Point Hot Spring, Blue Springs near Howell, the Fish Springs group, Locomotive Springs, and the Gandy Warm Spring.

Grantsville Warm Springs is a very small group of springs about five miles northwest of Grantsville, and north of Highway 50 in the SE ¼ of the NE ¼ of section 16, T2S, R6W, at an elevation of 4,245 feet. The springs altogether discharge about 0.2 cfs on the mud flat bordering the southern margin of Great Salt Lake. At one time there were six springs, a municipal bathhouse, and an open pool. The bathhouse is gone now and only the foundation of the pool remains. Temperatures have ranged from 74° F to 91° F. On July 29, 1964, a temperature of 86° F was measured on the main spring.

The controlling geologic structure is unknown, since the thermal water issues from alluvium. The nearest bedrock is an outcrop of the Mississippian Great Blue, Gardison, and Humbug formations.

Grantsville Warm Springs contribute water and salt directly to the Great Salt Lake as the water flows across the mudflat and into the Great Salt Lake. The water is not diverted for any use at the present time. The salt content is very high (TDS greater than 20,000 ppm) and precludes use for anything except, perhaps, for recovery of the salts.

Big Spring near Timpie is located at the northwestern tip of the Stansbury Range, near the southwest margin of Great Salt Lake and the northern end of Skull Valley. Actually, two large springs arise along a fault that borders the range. The springs are located in the SE ¼ of the SE ¼ of section 8, T1S, R7W, at an elevation of 4,221 feet. The combined flow of these springs was measured to be 7.6 cfs during most of the summer of 1964. The temperature was measured at 72° F.

The water from these springs is only about one-third as salty as the nearby Grantsville Warm Springs. The TDS content of the Timpie springs was just over 8,000 ppm. Although this is too saline for domestic, irrigation, or for most industrial uses, it is being used in a waterfowl management unit. Since there is no abundant supply of better quality water nearby for dilution, this seems to be about the best use for this water. Big Spring near Timpie is shown in the two photographs of Fig. 9. The photographs also show the salt flats of Great Salt Lake in the background.

Deseret Springs in Skull Valley consist of several warm springs which issue at intervals along a concealed north-south trending fault that lies west of the state highway leading to the Dugway Proving Grounds, between Timpie Warm Springs on the north and the Deseret or Iosepa Springs on the south. Deseret Springs are located about one mile north of Iosepa or the Deseret Land and Livestock Ranch. Several small springs discharge into a small reservoir in the SW ¼ of section 10, T3S, R8W, and in the W ½ of section 15, T3S, R8W, at an average elevation of 4,240 feet. Temperature measurements of 74° F were obtained. A combined flow of 2 cfs has been estimated for this group of springs. The water is used for stock watering and to irrigate salt-grass meadows. These waters eventually flow into Great Salt Lake, but do not have any effect on other stream systems.

It is interesting to note that the fault along which the Skull Valley springs are aligned is not the main fault that borders the west base of the Stansbury Range, but is an unnamed fault that lies well out from the mountain front. Salt Mountain, a prominent hill of Paleozoic rocks, rises from the valley floor between the two fault zones as a fault block spur of the range. Deseret Springs lie at the base of Salt Mountain.

Promontory Point Hot Spring is a small thermal spring rising on the east side of Promontory Point along a minor fault in Precambrian Mineral Fork Tillite. A temperature of 84° F has been recorded but no flow measurements or analyses are included for this spring. The water from this spring apparently is not used as it flows directly to Great Salt Lake.

Locomotive Springs consist of several springs in a fairly widespread area with a large combined flow. These springs emerge from alluvium near the boundary between the moist salt flat and the drier mud flat on the north end of Great Salt Lake. Aerial views of two of the principal springs are shown in Fig. 10. The spring area is part of the Locomotive Springs National Wildlife Refuge. The springs are located in the vicinity of

Fig. 9. Big Spring near Timpie with salt flats of Great Salt Lake in the background.

Townships 11 and 12 North, and Ranges 9 and 10 West. The swamp area of the refuge varies between 4,220 and 4,225 feet in elevation. Paleozoic rocks, the Pennsylvania Oquirrh formation, outcrop five miles to the east of the springs, which are believed to be associated with a buried fault.

Additional information regarding the Locomotive Springs group and other mineralized inflows to the Great Salt Lake can be found in Water Resources Bulletin No. 3 of the Utah Geological and Mineralogical Survey (Hahl and Mitchell, 1963) as well as in Technical Publication No. 10 of the Utah State Engineer's Office (Connor, 1958).

Blue Spring near Howell arises from alluvium in section 29, T13N, R5W, at the head of a "spring-sapped" gully in Lake Bonneville sediments. Paleozoic rocks outcrop nearby. The water, with a temperature of 86° F, is probably associated with a concealed fault. A flow of 7.56 cfs was measured on September 10, 1964. Water from the spring is impounded in Howell Reservoir and the water is used for irrigation. When the Howell Reservoir is filled the spring orifice is submerged. The setting of Blue Spring as it arises in the stream bed of Blue Creek is shown in Fig. 11.

Fish Springs consist of a group of thermal springs occurring at the northeastern end of the Fish Springs Range. Fish Springs Range is a typical north-south trending fault block mountain tilted to the west and bordered along the eastern flank by a fault zone that is still active as indicated by a fresh scarp in the alluvium near Fish Springs.

Four groups of springs in the Fish Springs area lie immediately east of the Fish Springs Range. The northernmost spring area, Hot Springs or Wilson's Hot Springs, issues at the extreme northern tip of the range; Big Spring is a mile to the southeast, and Middle and Thomas Springs are a group three miles south of Big Spring. These three groups are located in T11S, R14W. The fourth, known as Cane Spring, is located seven miles to the south in T12S, R14W.

The elevated temperatures of these springs and their mineralized character suggest a deep-seated source of water, but the fluctuations in flow and the fact that the temperatures are not excessive suggest that there is meteoric water mixing and intermingling in the alluvium with the hot mineralized water from a deep source.

Cane Spring is situated at the margin of the central valley flat or "playa," and at the toe of an alluvial fan. The nature of its mineral content and its small flow suggests that most of the mineral or thermal water gets into the fan from the now buried southern extension of the same fault that feeds the northern group of springs. The flow from Cane Spring is all evaporated and used on the site by tules and other phreatophytes. No samples for chemical analyses were taken from this spring.

Wilson's Hot Spring at the extreme north tip of the range is the hottest spring in the Fish Springs group with temperatures as high as 140° F. Views of this spring are shown in Fig. 12. The small flow, 25 gpm, from Wilson's Hot Spring is used for baths and spreads out over the desert to evaporate, leaving highly colored deposits.

The other springs in the Fish Springs group are of lower temperature, 72° F to 78° F, and have much larger flows. The combined flow of the other springs is about 25 cfs in the latter part of the summer, but is reported as high as 43 cfs during earlier parts of the season. These waters are managed by the Fish and Wildlife Service as a National Wildlife Refuge. Extensive diking and ponding of the water has been completed recently in an effort to more fully develop the water for the refuge. Problems in growing proper plants as feed have been encountered due to the poor quality of the water. Preliminary experiments seem to indicate that some birds cannot live in the environment at Fish Springs due to the salty nature of the water. Management of the Fish Springs water for other uses does not seem likely at the present time.

Gandy Warm Spring consists of several large warm springs which issue from fissures in Paleozoic limestones at the western margin of Snake Valley in the NW ¼ of the NE ¼ of section 4, T16S, R19W, at an elevation of about 4,980 feet. The springs flow together into Gandy Warm Creek which is used for irrigation. The temperature of these waters was found to be 80° F and the flow 21 cfs. Both are very constant throughout the year. Although the mineral content of the water is not extremely high as is common for most thermal springs, tufa deposits are very conspicuous in the area and in the streambed. The large flow from the springs makes Gandy Warm Spring a large salt producer, producing over 16 tons of salts per day. The water is used on pervious soils, however, and deleterious effects on crops have not been reported. The rather interesting setting of the Gandy Warm Spring is illustrated in the Fig. 13 photographs.

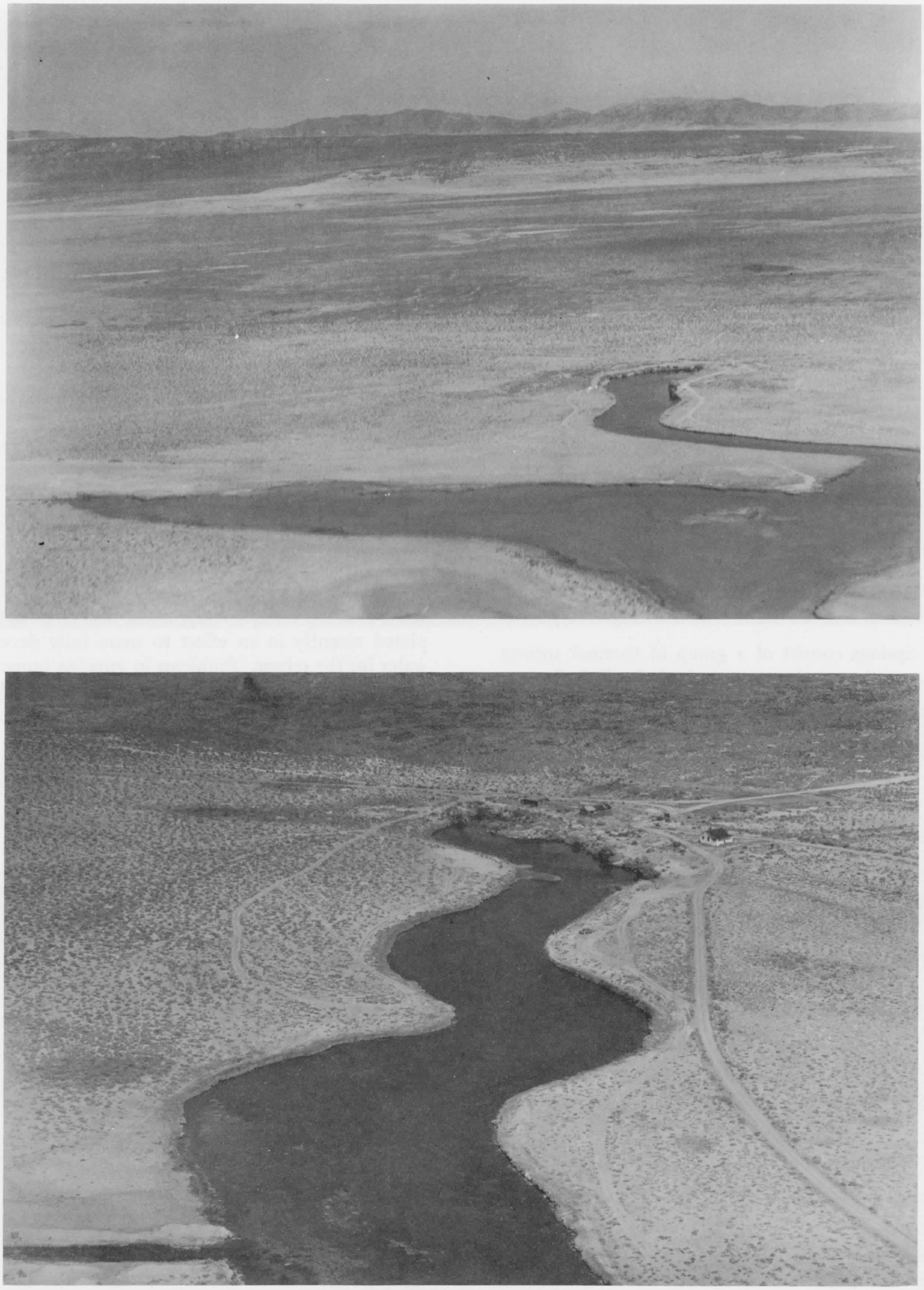

Fig. 10. Typical springs in the Locomotive Springs Wildlife Refuge.

Fig. 11. Blue Spring near Howell as it arises in the streambed of Blue Creek.

Fig. 12. Views of Wilson Hot Springs, typical of the Fish Springs area.

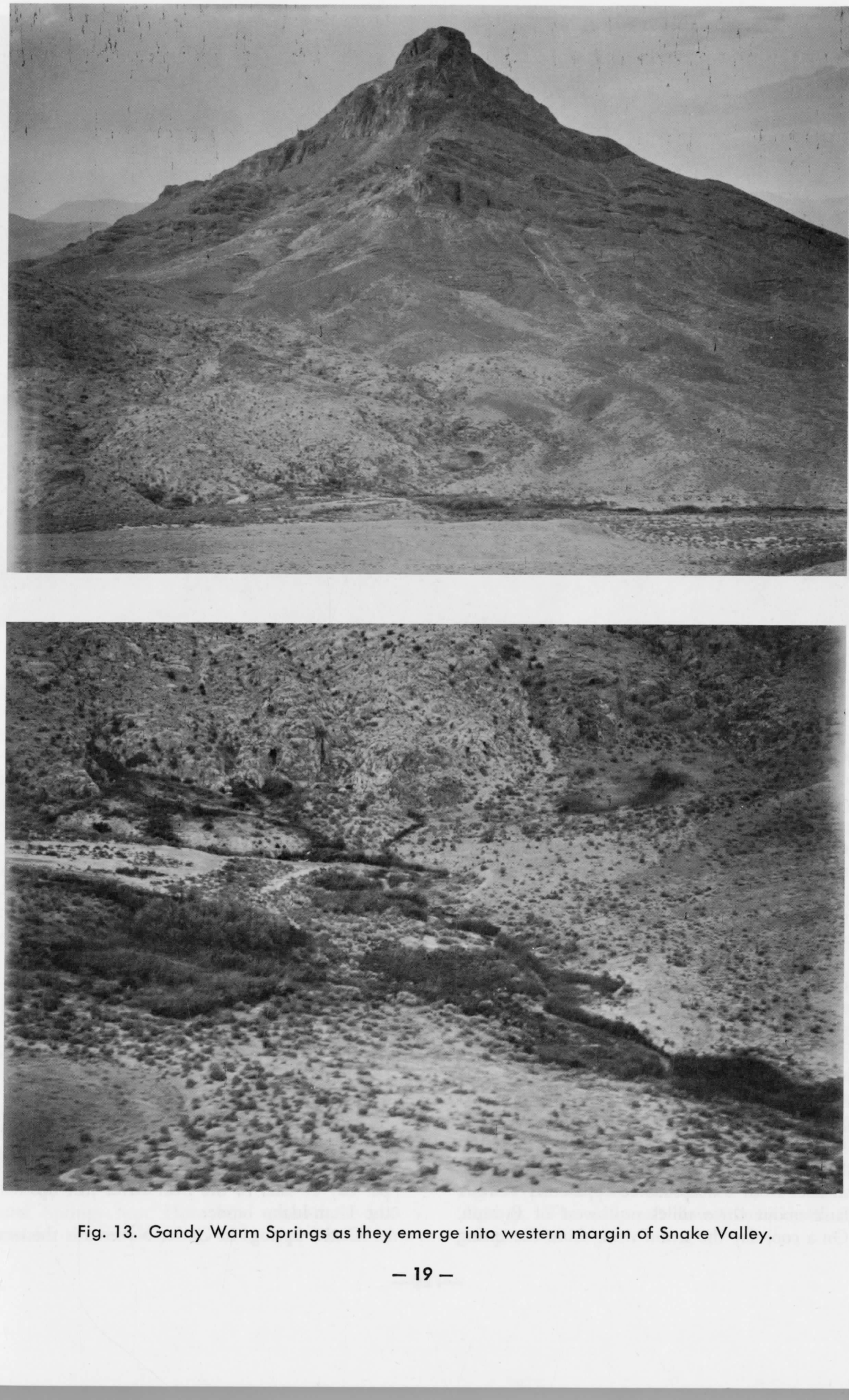

Fig. 13. Gandy Warm Springs as they emerge into western margin of Snake Valley.

Fig. 14. Idaho mineral springs on the Bear River include Battle Creek Hot Spring.

Bear River Unit

In the Bear River unit there are eight mineralized springs or groups of springs reported herein. Of these, three are in Idaho just across the Utah-Idaho state line. The Bear River has several other hot and mineralized springs flowing into it along its course, but these are farther north in Idaho and beyond the scope of this report. The springs included for the Bear River unit consist of Battle Creek Hot Spring and Vincent Hot Spring, both in Idaho northwest of Preston, Cutler Springs near Cutler Dam, and Crystal Springs near Honeyville, all directly tributary to the Bear River itself. On the Malad River are Price's Hot Spring near Woodruff, Idaho, and the Udy's Hot Springs group near Plymouth, Utah. Miscellaneous springs in the Bear River unit are Magic Mineral Spring near Little Mountain, and Salt Creek Spring near Bothwell. A summary of information concerning each of the above springs follows.

Battle Creek Hot Spring is a very hot spring (173° F) which rises from a deep source apparently along a buried fault about three miles northwest of Preston, Idaho. On a cool day the steam rising from the spring is readily visible from U.S. Highway 91 from Preston to Swan Lake. The hot, mineralized water from this spring pours 2 second-feet of water out over a small tufa mound and empties it directly into the Bear River, increasing the total salt load in the Bear River considerably. The setting of Battle Creek Hot Spring on a bend of the Bear River is shown in Fig. 14.

Vincent Hot Springs is a small group of very hot springs (180° F) about one mile south of Battle Creek Hot Spring and apparently lying along the same buried fault. The total flow of 0.4 cfs is much less than that of the spring to the north.

The hot water is used for heating a house and for temperature control of a pigpen; thence the water runs directly into Bear River. The combined effect of these springs on the water quality of Bear River, with Battle Creek Hot Spring, is to increase the TDS in the river from about 400 ppm to about 800 ppm during the latter part of the season. The effect of these springs is reduced, of course, during periods of high flow, but the springs continue to contribute approximately 60 tons per day of salts to the Bear River just upstream from the Utah-Idaho border.

Cutler Springs in Cutler Narrows is the next group

Fig. 15. Aerial view of Bear River just below Cutler Dam where mineral springs discharge from bed and banks.

of warm mineralized springs on the Bear River. Several small thermal springs and seeps issue from the banks and rise in the bottom of the channel of Bear River below Cutler Dam in section 26, T13N, R2W, at the mouth of Bear River Canyon where the river has cut through the Wasatch Range. The springs issue from nearly vertical fissures in Ordovician and Silurian limestones about a mile upstream from the inferred position of the frontal Wasatch fault.

Since many of the springs of this group rise from the bottom of the channel it is very difficult to say what the total flow of these springs must be. A flow of 0.7 cfs was measured in small springs issuing from the banks of the channel, but a much larger flow evidenty arises in the bottom of the channel — perhaps as high as 6 to 10 cfs. Although the temperature of these springs is not highly elevated (76° F), the mineral content is rather high, being about 8,000 ppm. Under flow conditions in the middle of July 1964, the mineral content of the Bear River was increased by the springs from 660 ppm to 1,475 ppm. The reach of river in which this discharge takes place is illustrated in Fig. 15.

Crystal Springs near Honeyville consists of two springs which rise very close to each other but which have very different characteristics. One spring is hot (130° F) with a very high mineral content (TDS = 42,000 ppm), while the other is a relatively cold spring (63° F) with a relatively low mineral content (TDS = 1,550 ppm). These springs issue at the toe of the Honeyville spur of the Wasatch Range, one and one-half miles north of Honeyville, Utah. The spur is terminated by a fault which is part of the Wasatch Fault Zone. Paleozoic rocks of Cambrian and Ordovician age make up the nearby bedrock outcrops. The springs are located in the NE ¼ of the SE ¼ of section 29, T11N, R2W. The elevation of the springs is approximately 4,285 feet, 90 feet above Great Salt Lake.

Part of the water from the two springs is mixed and used in a bathing resort, after which all of the water is comingled to form Salt Creek which ultimately reaches Bear River several miles to the south. The twin springs can be seen flowing in a westerly direction from the resort in Fig. 16. The flow on the left is the "cold" spring, while the one on the right is the "warm" spring. The mineral content of the Bear River near Corinne is up to about 2,800 ppm TDS, largely as a result of large flows (9.0 cfs) of mineralized water from Crystal Springs. The daily salt flow from Crystal Springs is about 450 tons.

Fig. 16. Crystal Springs near Honeyville, Utah.

Price's Hot Spring near Woodruff, Idaho, is a rather large mineralized spring which flows directly into the Malad River. The spring orifices are nearly always submerged by the Malad River so that direct measurements of the flow from the spring are very difficult to obtain. The owner of the property adjacent to the spring reports that such a measurement has been made at extremely low flow periods of the Malad River and that the flow is 6.0 cfs. The temperature of the spring is 92° F and the mineral content is over 6,000 ppm TDS. A view of this spring is shown in Fig. 17. The spring issues from fissures in a limestone outcrop at the base of a low-lying hill about two miles north of Woodruff, Idaho. The quality of the Malad River is not greatly affected by this spring since the mineral content of the river above the spring is approximately the same as that of the spring. In the headwaters of the Malad River, mineralized springs feed into the stream, hence the name "Malad," which means "bad."

Udy's Hot Springs are a series of hot springs which emerge along the base of a low bluff at the western margin of the flood plain of the nearby Malad River in section 14, T13N, R3W, about two miles southwest of Plymouth, Utah. These springs, with a temperature of 93° F, are located practically in the center of Malad Valley, which here has an average width of about seven miles. The Wasatch Fault Zone is about four miles to the east. Paleozoic limestone outcrops at the base of the low scarp where the springs emerge. No associated calcareous deposits of tufa or travertine are present. A north-south trending fault is probably responsible for the location of the springs and the exposure of bedrock. Two smaller springs in the group lie just to the south of the main spring and in line with it. The spring orifices of all the springs in the group are submerged deeply under pools of water, and the water from the pools overflows into the Malad River.

An aerial view of the main pool fed by Udy's Hot Springs is shown in the Fig. 18 photograph. The discharge from the pond can be seen emptying into an oxbow of the Malad River in the foreground. Agricultural areas can be seen on the bench immediately above Udy's Springs in the background. The two pools to the south of the main pool have a higher temperature by a few degrees (110° F and 104° F).

With a TDS content of between 7,000 ppm and 9,000 ppm the Udy's Hot Springs contribute a considerable amount of salt to the Malad River, although the

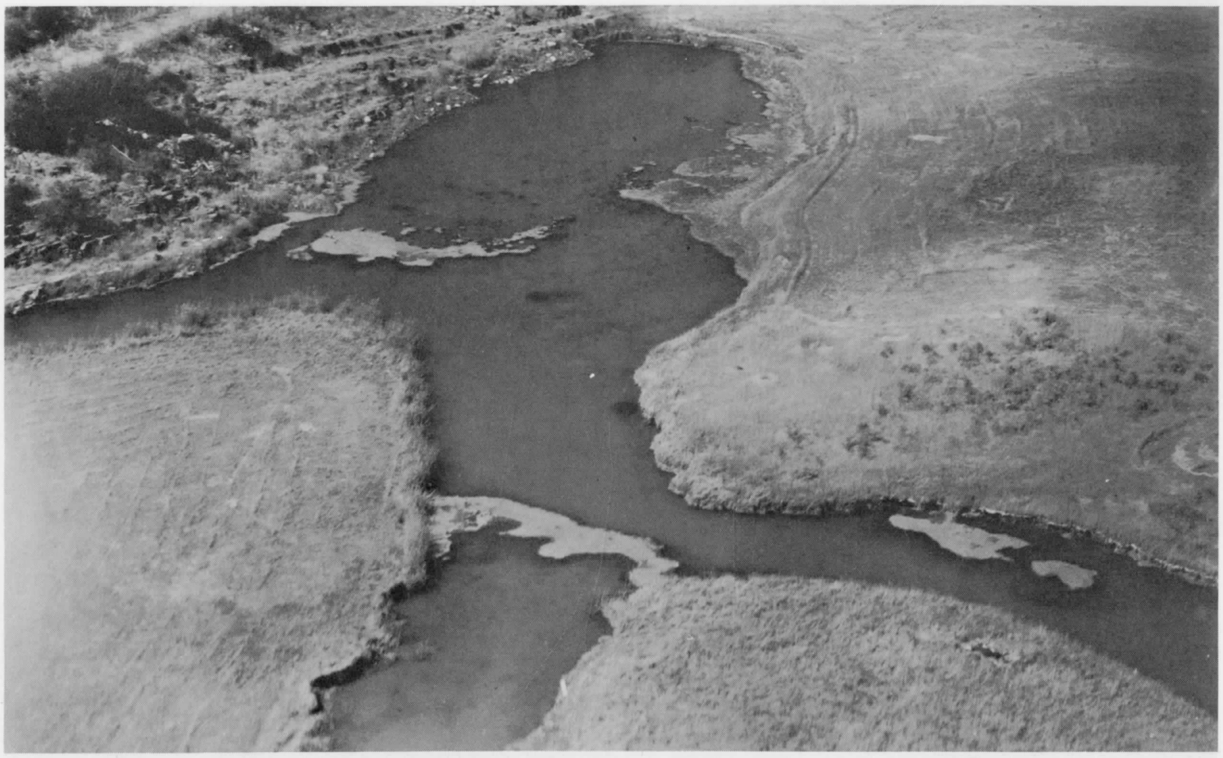

Fig. 17. Price's Hot Spring near Woodruff, Idaho, which flows directly into Malad River, tributary to the Bear River in Utah.

Fig. 18. Udy's Hot Springs near Plymouth, Utah, showing one of the main pools emptying directly into the Malad River.

Fig. 19. Salt Creek Springs near Bothwell, Utah, looking south in direction of flow.

change in quality is not great because of the already high mineral content of the river. Together the springs contribute about 3 cfs to the Malad River at this point along with over 60 tons of salts per day.

Magic Mineral Spring, also called Stinking Spring, is a small thermal spring which issues at the base of a limestone butte at the southern tip of Little Mountain in the NW. ¼ of the NW ¼ of section 30, T10N, R3W, at the north edge of Highway 83 (called Promontory Road). The spring drains across the highway and over the mud flat to the south where the water is evaporated. The limestone back of the spring is probably the Lodgepole limestone of lower Mississippian age. The strong odor of hydrogen sulfide gas being liberated from the hot water is probably responsible for the local name of the spring. The ground elevation at the spring is 4,261 feet. The total flow was estimated on June 22, 1964, as 0.1 cfs. No samples for chemical analyses were taken from this spring.

Salt Creek Spring near Bothwell and west of Tremonton is a large warm spring (69° F) which issues from fissures in a limestone outcrop at the head of the spring area in section 2, T11N, R4W. The limestone is probably a part of the Oquirrh formation, which makes up most of the West Mountains and whose southern end is about three miles NNE of the spring. The mineral content is not excessive (TDS = 1,500 to 2,000 ppm), but the flow ranges from 16 to 32 cfs, so that the total salt output of the spring is large. The flow of this spring fluctuates greatly during the season, indicating that much of the flow is not of deep-seated origin. A flow of 32 cfs was measured on June 22, 1964, but the flow had decreased to 16 cfs by September 10, 1964.

No use is made of this water near its source, but the water eventually enters duck shooting preserves and then spreads out on the mud flats north of Great Salt Lake. Although the salinity hazard of this water is very high, the alkali hazard is low, and with proper management on the proper soils the water likely could be used beneficially for irrigation.

The Bothwell springs and the resulting channel are shown in Fig. 19. The springs emerge in the area of the poplar trees in the right center of the photograph and flow southward toward the Salt Creek Waterfowl Management area. An idea of the magnitude of flow from the springs is indicated in Fig. 20, which shows the stream as it emerges from a road culvert.

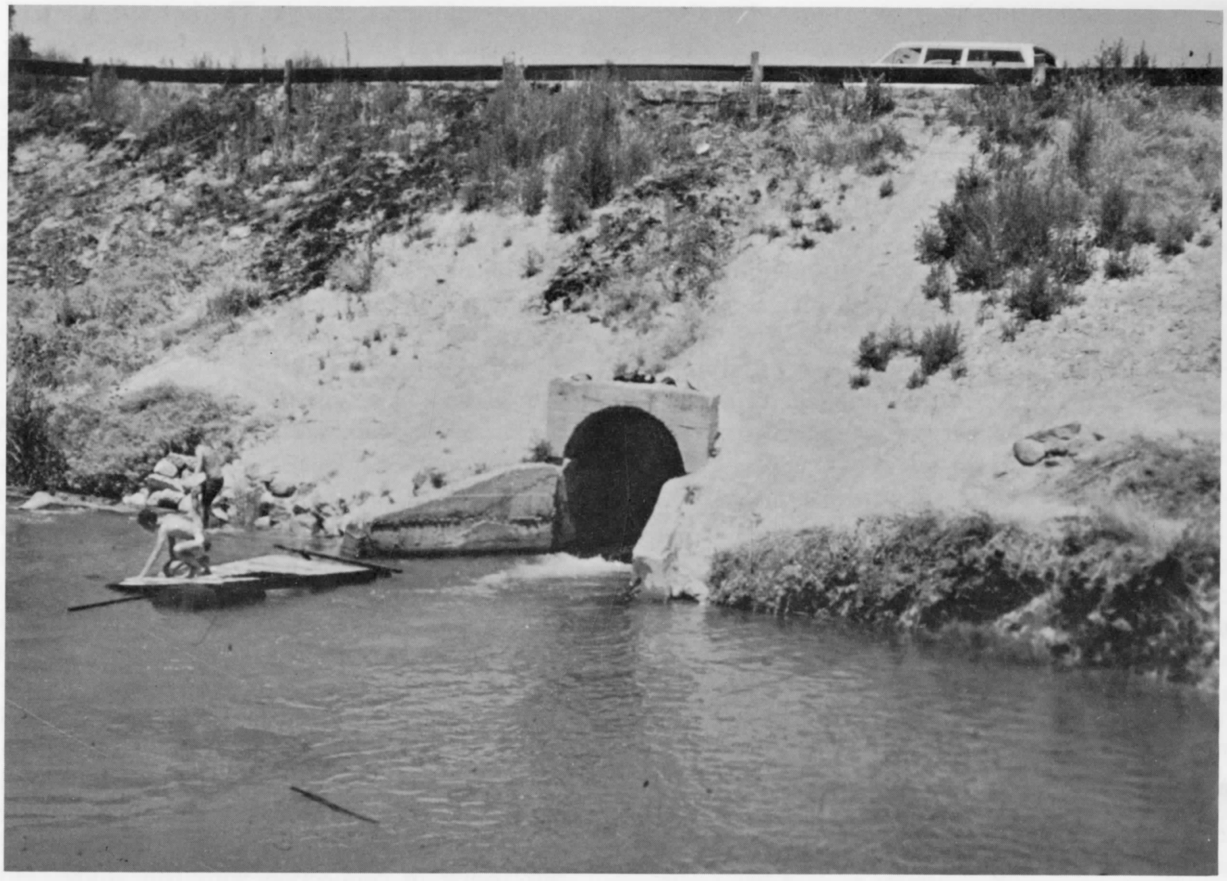

Fig. 20. The stream of water from Salt Creek Spring near Bothwell.

Weber River Unit

Only two mineralized springs are included in this report for the Weber River hydrologic unit. These are Utah Hot Springs near Pleasant View and Como Hot Springs near Morgan. A third mineralized spring, Elmonte Spring or Ogden Hot Spring, was not sampled or measured during this project. Ogden Hot Spring is located in the mouth of Ogden Canyon, section 23 of T6N, R1W. Additional information regarding this spring is available in Technical Publication No. 10 of the Utah State Engineer's Office (p. 189). The mineral content of Ogden River is increased very slightly due to low flow contribution of this spring although its mineral content is known to be high.

Utah Hot Springs is a group of hot springs having temperatures of 135° F which issue from the western base of the Pleasant View spur of the Wasatch Range about eight miles northwest of Ogden, Utah. The bedrock that outcrops just east of the spring area consists of lower Paleozoic quartzite, shales, and limestones of Cambrian age. For a long time the Pleasant View spur has been regarded as a down-faulted block spur along the Wasatch Fault Zone. More recently Eardley (oral communication) has re-examined the area and now considers the spur to be a surficial rock slide mass.

The spring zone straddles the boundary between Box Elder and Weber Counties in the SE ¼ of section 14, T7N, R2W just west of the highway. The resort and bathing pools are about 1,000 feet northwest of the springs. Cold water springs are also present in the vicinity. The thermal waters are both saline and iron-bearing, but most of the iron seems to be deposited at the site as the samples taken indicated only small amounts of iron. This spring has relatively large amounts of lithium, strontium, and cesium.

Only a small amount of the spring water is used at the resort. Just enough of this water is mixed with the cold water to bring the mixed water up to a comfortable swimming temperature. The waters from the springs and from the resort are carried west in a ditch and into a drainage channel which carries the water to the Great Salt Lake. Utah Hot Springs produce about 100 tons per day of salts.

Water from Utah Hot Springs empties into an open drain which bypasses Willard Bay Canal and is conveyed directly to Great Salt Lake. Consequently, these springs have essentially no effect on usable water supplies. However, much of the land area surrounding the springs has been made practically sterile by the salts in the water.

Como Hot Springs are thermal springs about one mile east of the town of Morgan. These springs rise along a north-south trending fault where the fault crosses the flood plain of the Weber River in the NW ¼ of section 36, T4N, R2E. The water is collected as it rises along the fault and used in a bathing resort on the south side of the Weber River and then it is discharged into the river. About half of the 3.1 cfs flow is used in the bathing pool before it is discharged into the river. The temperature of the spring water is 82° F. There is no noticeable increase in mineral content of the Weber River due to the salt contribution of this hot spring, especially since the mineral content of the spring itself is not high.

The fault at Como Hot Springs cuts limestones of Middle Cambrian and Devonian ages, and its position is indicated on the north side of the state highway by a prominently stained and hydrothermally altered fault breccia. A conspicuous fault-line erosion scarp also trends north-northwest from the river bottom.

Jordan River Unit

The relatively high mineral content of the Jordan River along its entire length, along with the intensive use of the water, has prompted a detailed study of the chemical quality of the waters of Utah Lake by the U.S. Bureau of Reclamation in connection with its Central Utah Project. (The information collected in this study is not yet publicly available.)

Eleven mineralized springs or groups of springs have been examined in the Jordan River hydrologic unit. The springs included and discussed are Beck's Hot Springs, Wasatch Hot Springs, Crystal Hot Springs, Camp Williams Warm Springs, Goshen Warm Springs, Castilla Hot Springs, Diamond Fork Warm Spring, South Salt Creek Spring near Nephi, North Salt Creek Spring near Nephi, Utah Lake Hot Springs (includes hot springs at Saratoga, Lincoln Point, and Bird Islands), and Midway Hot Springs.

Beck's Hot Springs issue at the contact of the fault plane of the Warm Springs fault and the alluvium of the valley floor at the tip of a bedrock spur, called the Salt Lake Salient of the Wasatch Range, in northwestern Salt Lake County. Beck's Hot Springs are located in section 14, T1N, R1W. The spring issues at an elevation of 4,230 feet, which is the lowest point in elevation along the fault zone.

In the past thermal waters have issued at various points for a distance of two miles along the base of the prominent fault scarp that terminates the western end of the Salt Lake Salient. Scattered tufa deposits mark the sites of former springs. The hot waters are of meteoric origin and rise along the fault zone and either come to the surface directly or discharge from the distal end of small alluvial fans that border the fault zone. A canal excavation 5,000 feet west of the fault zone exposed tufa deposits under 10 feet of late Lake Bonneville clay-silts. For a distance of one-half mile south of Beck's Spring, and bordering the railroad tracks, thermal waters maintain several pools and swamps, some of which have names such as: Mullen Springs, Hobo Springs, and Veedol Wells. Clouds of steam mark these spring sites on cold winter mornings. A strong odor of hydrogen sulfide gas is always present.

These thermal waters associated with the Warm Springs Fault have been exploited for bathing purposes for more than a century. Several bathing resorts have been in operation off and on with both indoor and outdoor pools. For many years some of the hot water was piped into Salt Lake City to a natatorium on west Broadway called the Sanitarium. The Wasatch Plunge is the only one currently in operation and there the hot water is used only to heat fresh water.

In recent years the water from Beck's Hot Springs has been collected and piped to the salt flats in order to remove the water from highway areas and industrial complexes. Since the water is now somewhat inaccessible, no flow measurements or samples were taken from this spring in connection with this study. However, some analyses are reported in connection with Wasatch Hot Springs and are given in Table 2. Additional information can be found in Technical Publication No. 10 of the Utah State Engineer.

Wasatch Hot Springs is another group of hot springs associated with the Warm Spring Fault and located in section 25, T1N, R1W. As mentioned above, Wasatch Hot Springs is the only bathing resort still in operation in the vicinity. Only part of the water from the Wasatch Hot Springs is actually used at the Wasatch Plunge. All of the water is eventually piped from the area to the salt flats near the Great Salt Lake.

In attempting to increase the flow of the thermal springs, a series of six short tunnels has been driven from time to time into the cemented alluvium and tufa deposits adjacent to the fault plane. After a few years the flow from a given tunnel would diminish until the supply was inadequate and then a new tunnel was driven, each, in turn, farther north along the fault zone. Tunnel No. 6 was started July 23, 1924, and completed September 26, 1924, with a length of 204 feet at a total cost of $4,208.05. The tunnel cross-section is 5 feet wide at the base and 6 feet in height, tapering to a width of 4 feet at the top. It was necessary to timber the tunnel for its entire length. Because of high temperature and excessive amounts of noxious gases pres-

Table 2. Chemical analyses of thermal waters along Warm Springs Fault.

	Wasatch Springs Collection Date							Beck's Hot Springs Collection Date		
	11-4-24	3-15-34	11- -34	5- -35	1- -37	3-16-40	5-19-42	5-19-42	8-29-47	11-3-51
SiO_2 (ppm)	40	30	30	62	41	26	22	32	35	36
Fe (ppm)	3									0
Ca (ppm)	1,069	1,380	719	469	414	461	538	653	688	720
Mg (ppm)	151	136	143	98	58	65	103	134	136	125
Na (ppm)	3,113	2,660	2,300	1,940	1,870	1,400	2,110	4,040		4,050
Na + K (ppm)									4,100	
K	180	552	1,210	163	194	62	211	444		262
HCO_3		307	310	293	293	278	260	239	235	227
SO_4	1,380	1,330	1,370	1,020	1,470	982	912	875	800	879
Cl	6,055	5,800	5,170	3,390	2,780	2,070	3,690	7,670	7,210	
F										2
Total Dissolved Solids	11,991	12,195	11,252	7,435	7,120	5,344	7,846	14,087	13,204	13,500
Total Hardness as ($CaCO_3$)	*3,290	3,990					1,750	2,180	2,280	2,310

Note: All analyses but the last three were made by Nephi E. McLachlan, Salt Lake City Chemist. The remainder were made by the U.S. Geogolical Survey, Quality of Water Laboratory. See Table 1 for analysis of Wasatch Hot Springs in connection with this study.

* A correction from apparent error in original table showing 191.85 for total hardness.

ent, it was necessary to provide artificial ventilation by means of a blower and vent pipe. In this tunnel the first major flow of hot water was encountered at a point 189 feet in from the portal, which measured 1.05 cfs. The temperature of the water was 106° F on October 1, 1924.

On March 7, 1927, a short crosscut was started on the west side of tunnel No. 6 at a point 35 feet from the face, for by this time the flow had diminished to 0.82 cfs. The crosscut was about 15 feet long and restored the flow of hot water which issued then from a northwest trending fissure cut at the southwest base of the face of the crosscut. By April 21, 1927, the total flow from tunnel No. 6 was 2.17 cfs, which was deemed sufficient. The flow from the tunnel has maintained itself quite well since this construction. In the summer of 1964, a flow was measured at the resort of 0.6 cfs and 0.6 cfs was flowing at the overflow for a total of 1.2 cfs.

Contrary to common opinion, the flows of thermal waters in the vicinity of Beck's Hot Springs and Wasatch Hot Springs show marked seasonal fluctuations, indicating that a good part of the water must be meteoric waters mixing with the waters of magmatic origin. Measurements indicate that the flows reach a high usually late in March or early in April, and a low point in the fall, in late November or early December. Careful measurements of the flow at Wasatch Hot Springs were made by a hydrologist of the Salt Lake City Engineer's staff through the years 1924 to 1943. A typical example of the annual variation in flow for tunnel No. 6 was a high of 1.97 cfs on March 26, 1931, and a low flow of 0.79 cfs on December 1 of the same year.

As indicated by the analyses presented in Table 2, the thermal waters of the springs that rise along the Warm Springs Fault in Salt Lake County are highly saline and high in sulfate.

A comparison of the concentration of dissolved mineral salts with the corresponding total flows for the same dates is of interest. For example, the total dissolved solids in the water at tunnel No. 6 in November, 1934, was 12,100 ppm, while at the same time the flow was at the all time low of 0.69 cfs. It is significant that this was the climax of the 1934 drought. On the other hand, on March 16, 1940, when the concentration was at its lowest, 5,590 ppm, the flow was 1.47 cfs, or more than double that of 1934. This again is in support of the conclusion that the hotter, more mineralized water rising from great depths is diluted by the cooler, fresher water that enters the conduit at shallow depths and at a time closely following the peak of the snow melt period for the adjacent Salt Lake Salient with elevations below 7,000 feet. The seasonal variation is more likely a function of the shallow meteoric water entering the circulation than variation in the amount of water rising from great depths.

On May 19, 1942, the flow of thermal water from tunnel No. 6 was again at a low point, 0.93 cfs, and the TDS was correspondingly high at 7,770 ppm on the same date. Although no record of flow at Beck's Hot Springs for this same date is known, the analysis of a sample taken at the same time shows nearly double the concentration of dissolved solids as compared with

Fig. 21. Mineral spring area southwest of Utah State Prison known as Crystal Hot Springs.

the tunnel water. This is especially true for both sodium and chloride. Since it is known from temperature measurements that the water at Beck's Hot Springs averages 20° F higher than the water from tunnel No. 6, the difference both in temperature and dissolved mineral content may be due to a lesser dilution at the Beck Spring. From these considerations, one may surmise that the plumbing system of a fault zone is anything but simple. Some previous results of chemical analysis are given in Table 2. Those analyses in connection with this study are given in Table 1.

Crystal Hot Springs consists of a small group of hot springs issuing from the valley alluvium near the southern end of Salt Lake Valley in the SW ¼ of the NW ¼ of section 12, T4S, R1W, and 1,100 feet southwest of the Utah State Prison boundary line. The combined flow of these springs was estimated in August 1964 as 45 gpm and again in September of the same year as 60 gpm. The temperatures were found to range from 122° F to 137° F. The elevation of the easternmost spring is 4,466 feet. The water was formerly used to supply an artificially-dug bathing pool. At present, the water is used for beaver culture and for irrigation. During the period of investigation there was no apparent surface drainage from these springs reaching the canals below or the Jordan River itself which is only a short distance away. The water seems to be completely infiltrated or evaporated before flowing very far. There is a strong likelihood that the water eventually reaches the river through seepage. Evidently the flows and water quality of these springs have remained fairly constant over the years, as a 1934 analysis of these waters is practically identical to that of 1964 shown in Table 1. An aerial view of the Crystal Springs area is shown in Fig. 21.

The associated geologic structure is unknown, but a buried fault is indicated. One can note in Fig. 3 that this spring area is on a line with the Crystal Springs north of Brigham City, Utah Hot Springs northwest of Ogden, Beck's Hot Springs at North Salt Lake, Wasatch Hot Springs at Salt Lake City, the Camp Williams Hot Springs in the Jordan Narrows, the Saratoga and Crater Springs at the northwest corner of Utah Lake, and the Lincoln Point Springs on the south shore of Utah Lake. It seems most significant that in this narrow strip, about 100 miles in length, seven of the major thermal spring areas in the north-central part of Utah occur. A deeply buried fault zone control seems likely. The four northernmost spring areas are definitely associated with the Wasatch Fault Zone along the western base of the Wasatch Range, but the three remaining areas are several miles west of the Wasatch front.

Camp Williams Warm Springs issue from the base of a low cliff that forms the western margin of a large tufa and travertine mound in the area familiarly known as the Jordan Narrows. The size of the tufa deposit suggests that thermal waters have issued here for many thousands of years. The spring water issues at a point 200 feet southeast of the west ¼ corner of section 23, T4S, R1W, at an elevation of 4,440 feet. On July 21, 1950, an average temperature reading of 71° F was obtained. A sample of the spring water showed only 350 ppm of total dissolved solids, which along with the relatively low temperature and a high water table at the site, seems convincing that the thermal water is diluted to a considerable extent by cooler, fresher waters before it reaches the surface. The water from the Camp Williams Springs is pumped by pipeline to the Camp Williams Military Reservation nearby. Because of the relatively good quality of this water, no analyses are included in this report, but the apparent association of this spring with nearby mineralized springs warrants some discussion.

Thermal water with a temperature of 80° F was encountered farther south in the Jordan Narrows area where the Provo Reservoir Canal crosses the Jordan River in a double siphon. The stilling basin is located in the NW ¼ of the NE ¼ of section 26, T4S, R1W. The hot water was encountered 6 feet below the surface (ground elevation 4,480 feet) in swamp muck.

It appears that the Jordan Narrows have been the site of continuous hot spring activity since late Tertiary time. On the west side of Jordan River, just below the Bonneville shoreline and north of Beef Hollow, a large remnant of a spring-built terrace of travertine occurs. Because of the purity of the limestone, the travertine was quarried and shipped to nearby sugarbeet factories. Some of the rock has also been shipped to Los Angeles for building purposes, such as floor tile. At present the deposit covers but a few acres and the springs have ceased to flow. However, the mound-like shape of the travertine deposit is still evident. The top is flat, showing truncation by wave action of ancient Lake Bonneville.

The hot water that deposited the travertine evidently issued from north-south trending fault fissures, for veins and lens-shaped masses of manganese oxide occur in the travertine with similar trends. One major vein has a bearing of N 42° W and dips 28° to the northeast. Nowhere has the concentration of manganese been sufficient, it seems, to form a body of commercial ore. Similar manganese veinlets occur in the Red Hill Hot Spring mound north of Monroe, in Sevier County, and also at the Abraham Hot Springs northwest of Delta (Fumerole Butte). Manganese deposits of hot spring origin, resembling those in the Jordan Narrows, have been reported at Cleveland, Idaho, in the southern end of Gentile Valley.

The great age of the hot spring activity in the Jordan Narrows is confirmed by the recovery of a well-preserved jaw of a fossil horse of late Pliocene age, which is now on display in the University of Utah geology museum.

Goshen Warm Springs consist of four large warm springs which issue from talus at the western base of Warm Spring Mountain, north of Long Ridge in southwestern Utah County. The springs rise in the south ½ of section 8, T10S, R1E, about two miles east of Goshen, Utah, and are the source of Warm Creek in Goshen Valley. The total flow of the group of springs was measured in August and September of 1964 at 8.0 cfs. The flow is divided, nearly equally, and part of it is diverted to the north and part of it to the south. Springs typical of the area are shown in Fig. 22. The upper photograph shows an abandoned ore reduction plant, which at one time used the water from the Goshen Warm Springs in the ore reduction process.

Since the water is not exceptionally salty (TDS about 1,400 ppm), it seems to be a good water supply for irrigation of the grass meadows found in the bottomlands of Goshen Valley. The chemical analyses of these spring waters would indicate, however, that the sodium hazard is very high. The salinity hazard is high to very high. There is a possibility that these hazards are reduced by sufficient early-season leaching and mixing with better-quality surface waters.

The Geologic Map of Utah (Stokes, 1960) shows the rocks adjacent to the springs to be lower Cambrian quartzites, shales, and limestones. A typical basin and range fault zone borders Warm Spring Mountain on the west and probably provides channelways for the thermal waters. No associated tufa deposits were observed near these springs, probably because of the large amounts of sodium and the relatively low total hardness.

Castilla Hot Springs are undoubtedly responsible for the name of Spanish Fork River which was known as Rio de Aguas Calientes meaning River of Hot Waters. In Spanish Fork Canyon three small thermal springs were formerly present east of the Spanish Fork River near the base of cliffs of Diamond Creek Sandstone of Permian age. In the last decade of the nineteenth century and the first decade of the twentieth century enough hot water was available to support a flourishing bathing resort. Special Sunday excursion trains on the D & R G railroad left Salt Lake City early in the morning, returning late in the evening, thus providing

Fig. 22. Typical springs of the Goshen Warm Springs group east of Goshen, Utah.

Fig. 23. Diamond Fork Warm Spring at the base of the road fill.

an opportunity for family picnics and a swim at the hot springs. The temperature of the water in those decades ranged from 111° to 145° F. Today the resort is gone and the springs have almost dried up.

Investigations in 1960 revealed that the spring was discharging 1.0 cfs at 110° F with a TDS concentration of 6,422 ppm which would yield about 7½ tons of salts per day. On July 3, 1960, the specific conductance of the Spanish Fork River above the spring was 380 micromhos and below the spring was 420 micromhos when the river was flowing at about 100 cfs.

Diamond Fork Warm Spring consists of two small warm springs which issue near the northern edge of the road in Diamond Fork Canyon in T8S, R5E, about 13 miles from its junction with Spanish Fork Canyon. The warm water issues from fissures in conglomerate, the Benny Creek Formation, formerly called the Price River Conglomerate. A flow of 0.75 cfs was measured on September 3, 1964, and the temperature of the water at this time was 69° F. The springs have a strong odor of hydrogen sulfide and the water is similar to the hot water obtained in an oil well test hole east of Mt. Pleasant, Utah. The Diamond Fork Spring waters probably rise through conglomerates, sandstones, and shales, rather than limestones. At any rate, no tufa or travertine has been deposited around the orifice of the springs or in the channels below the springs. The springs are shown in Fig. 23 as they emerge at the base of the road fill.

The springs at Diamond Fork flow into Diamond Fork Creek and have a slight effect on the water quality of that stream. The spring waters themselves have an electrical conductivity of 1180 micromhos, and at the time of sampling Diamond Fork Creek above the springs had an EC of 350 micromhos and below the springs the EC was 500 micromhos. Diamond Fork Creek flow at this time was estimated at 15 cfs. The waters from Diamond Fork Creek eventually flow into the Spanish Fork River, which in turn drains into Utah Lake.

South Salt Creek Spring near Nephi is a small contact spring which issues near the top of a shale formation on the south side of Salt Creek Canyon above Nephi, Utah. The salts in the water are likely picked up from contact with the shale. Since the flow of this spring is very small (at least for most of the year) the salt contribution is very small — less than one-tenth of a ton per day.

North Salt Creek Spring near Nephi has a much higher salt content than the South Salt Creek Spring, but a much smaller flow also limits the total salt to Salt Creek in terms of tons per day. This spring also issues as a contact spring from the contact of an upper sandstone and conglomerate and a lower shale formation. Salt Creek undoubtedly received its name from the two springs where the early pioneers used to go to make salt for domestic use. There is no present use of either of the two springs and they have no measurable effect on the water quality of Salt Creek.

Utah Lake Hot Springs consist of several hot springs in and around Utah Lake, including hot springs at Saratoga, Lincoln Point, and Bird Island. Utah Lake is a fresh water lake normally about 20 miles long and 10 miles wide, with about 150 square miles of surface area in the central northern part of Utah, and is connected by the Jordan River to Great Salt Lake. It covers from 20 to 25 percent of the floor of Utah Valley which formerly was a bay in historic Lake Bonneville. The drainage basin into Utah Lake includes parts of Juab, Summit, Utah, and Wasatch counties, and totals over 2,600 square miles. Utah Lake discharge is used principally in Salt Lake County to the north in irrigation and industrial uses.

The geologic structure that controls the location of the hot springs is probably a fault zone concealed by valley alluvium and the lake. A recent gravity survey (Cook and Berg, 1961) shows a remarkably continuous set of steep gravity gradients that extend along the west side of Utah Lake from Santaquin, on the south, to Saratoga Springs, on the north, for a horizontal distance of 27 miles. The series of hot springs in and around Utah Lake coincides with this postulated Utah Lake Fault Zone.

Mineralized spring inflows into Utah Lake are mainly concentrated in the Goshen Bay and Saratoga areas. A Bureau of Reclamation unpublished report on the chemical quality on the waters of Utah Lake indicates that there are numerous mineralized springs in the Goshen Bay area as well as along the west side of West Mountain and on the Lincoln Point. Additional contributions of mineralized spring waters come by way of White Lake — a small lake on the northern tip of Utah Lake's Goshen Bay. The outflows from White Lake are the waters accumulated from the winter flows of the Goshen Warm Springs and other springs plus any return flows from irrigation, all collected in White Lake, then released to Goshen Bay and exchanged for pumping rights from the lake to irrigate lands on the west side of Goshen Bay. U.S. Bureau of Reclamation measurements of the outflow to Utah Lake from White Lake show about 1,000 acre-feet per year.

The U.S. Bureau of Reclamation estimates of other mineralized spring inflows to Utah Lake are based on data of earlier investigations and on measurements and estimates obtained during 1960 and 1961 when the lake was at a low level. At this low level, additional springs were revealed from which samples could be collected as they were no longer submerged beneath the surface of the lake. During the late fall and winter of 1960 the springs on Lincoln Point were measured by current meter. The combined measured flows from these springs was reported to be about 2.8 cfs or 2,000 acre-feet per year. The flows and temperatures of the Lincoln Point Springs are shown in the following table.

Table 3. Flows and Temperatures of Lincoln Point Springs.

Spring No.	Average Flow (cfs)	Temperature (°F)
1	1.0	80
2	0.5	90
3		90
4	0.6	90
5		85
6	0.7	100
Total	2.8	

Outflows of 2 and 3 were channeled together for measurement. These flows are an average of measurements made on 10 different dates from October 1960 to April 1961 by the Bureau of Reclamation. Some of the Lincoln Point Springs are shown in the photographs, Fig. 24.

In the Saratoga area some of the springs emerge as sand boils 6 to 10 feet across into which a 6-foot pole could be thrust without touching bottom. The sands of some springs in the area are gray in color while others are reddish. Some of these sand-boil springs gush violently — at times rolling the sand about a foot into the air. Some big pools appear to be quite deep and crater-like and are a light blue-green in color with no suspended sediments. The total flow of water from mineralized springs and seeps in the Saratoga area is estimated at 4 to 5 cfs or 3,000 to 3,600 acre-feet per year.

Springs in the Bird Island vicinity are also assumed to be controlled and fed from the inferred Utah Lake Fault Zone. The north bay of Bird Island has at least one large thermal and mineralized spring on the right bank that keeps a considerable portion of the bay clear of the usual suspended sediments in the lake water. Water in the area of this spring has been sampled by the U.S. Bureau of Reclamation and found to have a temperature of 86° F and EC of 14,800 micromhos.

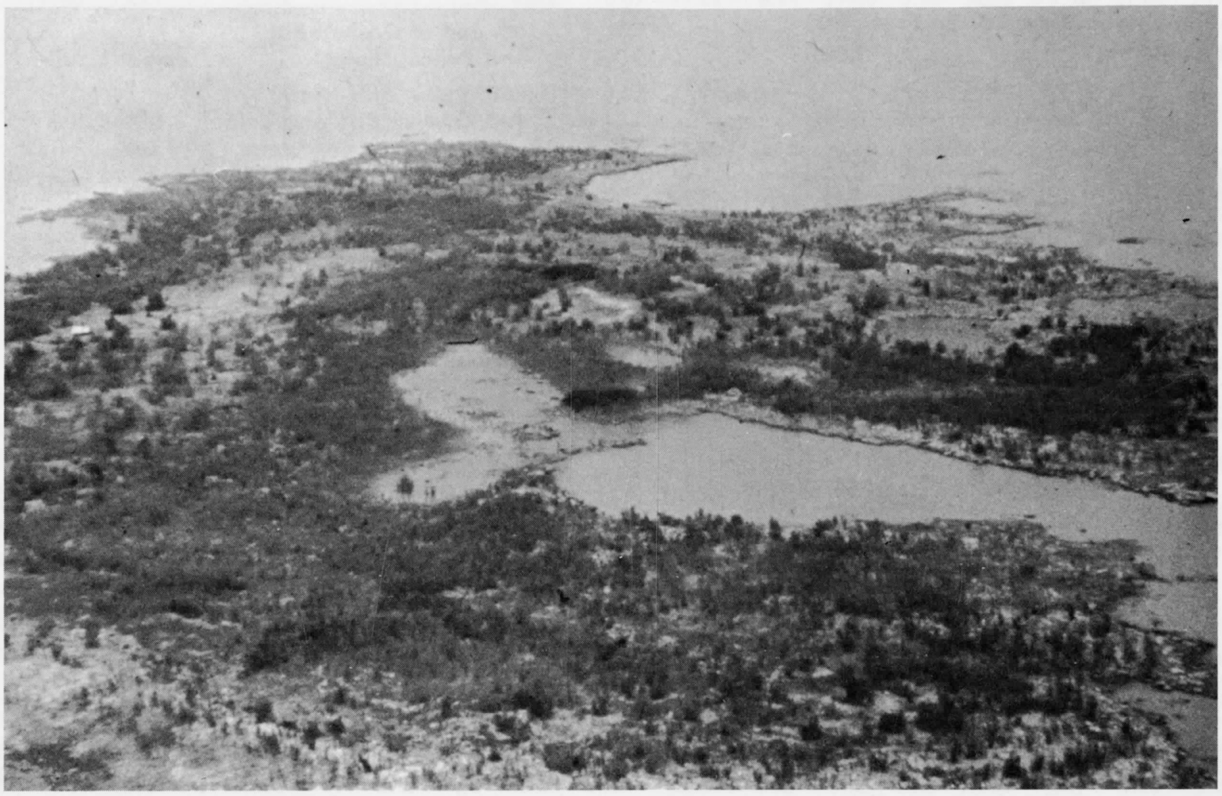

Fig. 24. Lincoln Point mineral springs in south end of Utah Lake.

No springs were located in the west bay but the measured temperature in this vicinity was 75° and EC was 5,900 micromhos. This temperature is 5 to 7 degrees warmer than the general lake temperature, and the conductivity is about twice as high as normal conductivity of the lake. There are several other small spring areas on the island, but there seems to be very little flow from these springs to the lake. Some have inferred that the entire island is composed of minerals precipitating from the springs which rise from the fault.

The Bureau of Reclamation has estimated the total inflows to Utah Lake from White Lake and from springs in and around the lake, and these are shown in Table 4.

Table 4. Estimated inflow to Utah Lake from White Lake and Mineralized Springs.

Source		Average Annual Water Inflow (acre-feet)
White Lake		1,000
Lake Springs		17,900
Saratoga and northwest area	5,800	
North Shore area	2,900	
Northeast and East Shore	4,400	
Lincoln Point Springs	2,100	
West Mountain, West Side Springs	700	
Bird Island	2,000	
Total		18,900

Not all of the sources listed in the table are mineralized, however. This inflow of about 19,000 acre-feet per year is about 3 percent of the average computed lake inflow. It is believed that this estimate of spring inflow is conservative, particularly in view of the unmeasurable thermal springs in the Saratoga, Bird Island, and Lincoln Point areas. While contributing only 3 to 5 percent of the total inflow to Utah Lake, if these sources have a weighted average of 2,000 to 2,500 ppm dissolved solids, they are bringing 20 to 25 percent of the dissolved mineral into the lake. Thus, three springs, along with the high evaporation rate from the lake, cause considerable deterioration of quality in water flowing out of Utah Lake.

Representative samples of salt concentrations in the Utah Lake are very difficult to obtain since samples taken in the lake are influenced by adjacent springs and by lake currents. Samples taken at the lake outlet are also influenced by local inflows and adjacent springs. Some widely separated samples collected by the U.S. Bureau of Reclamation at nearly simultaneous sampling dates show a wide variation in salt concentrations. Salt concentrations in the lake range from 900 ppm to 2,000 ppm of total dissolved solids, whereas inflows from White Lake reaching the lake have been measured with total dissolved solids concentrations as high as 28,000 ppm and inflows from springs within the lake up to 8,000 ppm.

The salt concentrations in the lake generally reach a peak during the later summer months as a result of increased evapotranspiration and diminished diluting inflow. This peak is gradually reduced during the winter months when there is less evapotranspiration and increased inflows.

The chemical analyses of samples from springs within or flowing into Utah Lake are shown in Table 6. Most of these analyses were performed by the Bureau of Reclamation. The approximate ranges of dissolved solids and sodium percentage of chemical analysis of springs grouped by areas of the lake are tabulated as follows:

Table 5. Concentration of dissolved solids and percent sodium of mineral springs discharging into Utah Lake.

	Dissolved Solids (ppm)	Sodium (%)
South end of Goshen Bay and Pelican Point	about 1,500	50-65
Lincoln Point, Bird Island, and Goshen Bay east side	3,000-8,000	65-85
East and northeast lake area	400-1,000	20-30
North end of lake	300-1,100	10-40
Northwest area of lake (Saratoga)	1,200-1,600	30-40

The chemical analyses of these springs should be viewed as an exact analysis of what was in solution at the time of analysis but not an exact representation of the chemicals in solution at the time of sampling. There was some known precipitation of chemical constituents in part of the samples. The samples collected from springs in the lake could be (and in some cases definitely are) a mixture of the spring source and the lake water.

The springs on Lincoln Point were numbered from 1 through 6, starting on the east side and progressing to the west. The concentration of chloride increases from 38 epm in spring No. 1 to about 76 epm in spring No. 6. The temperature of the water increases also

Table 6. Chemical analyses of springs in and around Utah Lake.

Sampling Date	EC @25°C (mmhos)	pH	Total Dissolved Salts (ppm)	Boron (ppm)	Sodium (%)	Sodium Adsorption Ratio	Residual Carbonates (me/1)	Temp. °F and/or Flow (cfs)	Equivalents per Million or Milliequivalents per Liter: Cations: Ca	Mg	Na	K	Anions: CO_3	HCO_3	Cl	SO_4
Lincoln Point Spring 100 yards west of swimming pool (No. 4)																
								90°								
7/ 7/60	9,960	7.1	6,500	2.22	64.9	17.0	none	2.00	22.47	10.20	68.76	4.56	none	12.00	71.39	22.60
10/19/60	9,847	7.4	6,514		65.3	17.2	none	0.73	21.78	10.05	68.50	4.60	none	11.81	71.86	21.26
11/30/60	9,522	7.7	6,200					0.32					none	6.96	71.58	
1/17/61	9,847	7.6	6,488		65.6	17.4	none		19.80	11.73	69.00	4.70	none	11.06	71.53	22.64
2/ 2/61	9,735	7.3	6,354	2.40	66.8	18.2	none	0.75	20.47	10.15	71.00	4.70	none	9.82	71.79	24.71
4/10/61	9,522	7.6	6,282		68.2	18.8	none	0.75	18.36	9.90	70.50	4.60	0.17	9.44	71.27	22.48
7/14/61	9,522	7.4	6,554		64.5	17.1	none	0.60	22.98	10.29	69.50	4.90	none	12.37	72.51	22.79
8/ 4/61	9,623	7.5	6,528		64.7	12.1	none	0.75	22.74	10.26	69.00	4.60	none	11.44	73.01	22.15
11/ 2/61	9,630	7.6	6,220		67.1	18.1	none	0.50	14.88	14.62	69.50	4.56	0.24	7.11	73.04	23.17
12/ 6/61	9,630	7.5	6,292		67.0	18.0	none	0.50	19.21	10.50	69.50	4.52	none	8.99	73.04	21.70
Mixture of springs No. 2 and 3 on Lincoln Point																
10/19/60	7,601	7.6	4,906		66.0	15.3	none	0.61	15.01	8.52	52.50	3.50	none	8.64	54.44	16.45
								41°								
11/30/60	7,343	7.7	4,698		68.7	16.4	none	0.63	12.19	8.11	52.25	3.48	0.48	4.84	53.40	17.31
1/17/61	7,535	7.5	4,802										none	7.94	54.32	
								41°								
2/ 2/61	7,161	8.1	4,478		71.4	17.8	none	0.50	9.76	7.91	52.75	3.50	none	1.96	53.56	18.40
7/14/61	7,282	7.8	4,772		67.7	16.0	none	1.00	13.51	8.06	52.50	3.50	none	7.38	54.74	15.45
8/ 4/61	7,282	7.6	4,524	1.60	67.5	12.9	none	1.00	12.73	8.44	50.50	3.20	none	6.75	52.87	15.25
11/ 2/61	7,223	7.6	4,536		68.6	16.1	none	0.75	12.14	7.91	51.00	3.28	0.13	5.66	53.12	15.42
12/ 6/61	6,879	7.6	4,434		68.1	15.6	none	0.75	12.10	7.76	49.00	3.12	none	7.75	50.09	14.14
Lincoln Point Spring No. 1																
								70°								
1/21/60	5,633	7.9	3,464	1.20	67.2	13.4	none	2.00	9.79	6.17	37.75	2.48	0.59	7.33	37.63	10.64
								88°								
7/ 7/60	5,777	7.4	3,622	1.49	65.8	13.2	none	1.00	11.85	6.28	39.60	2.48	0.24	8.77	38.32	12.88
10/19/60	5,855	7.7	3,664		65.2	12.9	none	0.67	11.62	6.94	39.40	2.50	none	9.54	38.99	11.93
								74°								
11/30/60	5,554	7.9	3,478		66.6	13.5	none	0.95	9.63	7.70	39.80	2.60	0.51	5.49	38.62	15.11
								72°								
2/ 2/61	5,519	8.0	3,434		69.6	14.5	none	0.75	8.41	6.33	39.40	2.50	0.49	5.06	38.31	12.78
4/10/61	5,554	7.8	3,484	1.30	66.8	13.5	none	75°	10.62	6.46	39.40	2.50	0.16	7.39	38.36	13.07
								76°								
7/14/61	5,554	7.5	3,588		64.5	12.7	none	0.75	13.88	4.79	38.80	2.64	none	9.55	38.51	12.05
8/ 4/61	5,701	7.4	3,544		63.8	12.1	none	0.75	12.40	6.33	37.07	2.30	none	9.53	37.75	10.82
11/ 2/61	5,350	8.0	3,328		67.1	13.0	none	0.75	9.05	6.17	36.00	2.40	0.52	6.57	36.92	9.61
12/ 6/61	5,383	7.5	3,446		63.6	11.0	none	0.75	11.70	6.55	36.00	2.38	none	9.21	36.82	10.60
South Bird Island Spring																
1/27/60	10,452	7.8	6,644	2.30	74.6	23.5	none		13.75	9.36	80.00	4.08	0.49	9.99	82.12	14.59
9/ 6/61	10,442	7.7	6,552	2.25	74.7	23.9	none	70°	13.87	9.90	82.50	4.20	none	9.13	84.02	17.32
North Bird Island Spring																
9/ 6/61	12,381	7.2	7,932	2.55	72.3	24.1	none	86°	20.80	10.82	95.50	4.90	none	13.48	10.81	7.73
1/27/60	12,393	7.4	7,768	2.47	73.2	24.6	none	0.02	19.59	11.02	96.00	4.56	0.45	12.41	98.74	19.57
Crater Spring (in Saratoga area)																
8/29/61	2,299	7.5	1,556	0.56	39.7	3.6	none	92°	9.94	4.49	9.60	0.58	none	5.65	9.84	8.67
9/ 6/61	2,317	8.0	1,588	0.54	41.2	3.8	none	109°	8.94	4.39	9.80	0.66	0.15	5.52	10.18	7.94
Hot Springs near Saratoga																
5/27/57	2,140	7.3	1,390		44.0			107°	9.00	4.03	10.09			5.25	8.97	8.84
5/ 4/58	2,230	7.3	1,440		43.0	3.9		110°	9.55	4.27	10.22			5.25	10.10	9.17
1/31/61	2,251	8.0	1,500		39.1	3.5	none	104°	9.33	4.68	9.40	0.65	0.40	4.66	9.70	9.30
1/24/61	2,257	7.8	1,488	0.50	41.3	3.8	none	106°	9.07	4.03	9.68	0.68	0.43	4.84	9.78	8.41
4/11/61	2,222	7.9	1,486		41.1	3.8	none	101°	9.11	4.05	9.64	0.66	none	4.51	9.63	9.32
5/ 5/61	2,251	8.0	1,514		41.3	3.8	none	108°	8.84	4.17	9.68	0.67	none	4.56	9.69	9.16
5/31/61	2,058	8.1	1,371		46.1	4.2	none		6.34	4.29	9.68	0.69	none	2.17	9.63	9.20
7/14/61	2,280	7.5	1,522		38.7	3.6	none		10.95	3.55	9.60	0.68	none	5.15	9.57	10.06
8/11/61	2,281	7.2	1,508		39.3	3.6	none	110°	9.47	4.50	9.48	0.65	none	5.15	9.84	9.11
9/ 1/61	2,273	7.5	1,530	0.45	41.1	3.8	none	110°	9.40	3.88	9.70	0.64	none	5.18	9.94	8.50
9/ 8/61	2,273	7.3	1,520	0.55	30.3	2.4	none	111°	9.12	4.44	6.16	0.64	none	5.11	9.66	5.59
10/ 6/61	2,257	7.6	1,530		39.7	3.6	none	110°	9.78	4.12	9.60	0.66	none	5.05	9.70	9.41

from east to west from about 75° F to about 100° F.

The springs with the highest concentrations of dissolved solids are on Bird Island, but the discharges from these springs are comparatively small.

The samples from springs in the lake and from shore springs in the northwest area all have about the same concentrations of chlorides and other chemical constituents.

Investigations of the Bureau of Reclamation showed that the suspended solids in the outflow of the lake have a high percentage of calcium and magnesium carbonates from May through September. These sediments, kept in suspension in the shallow lake by wave action, give the lake and its outflow water a gray, chalky appearance. Utah Lake water, when used for irrigation, leaves a gray residue of these suspended sediments on the irrigated lands. In the winter, when the temperature is lower, there is little suspended sediment in the lake. This would seem to be further evidence that these sediments are chemical precipitates, since the solubility of the carbonates would increase as the temperature decreases.

In addition to the suspended solids load of calcium and magnesium carbonates, there are large areas of tufa and travertine deposits especially on the shore of Lincoln Point, the west side of West Mountain, and on Bird Island. These appear to be mainly spring depositions.

The Bureau of Reclamation report on the chemical quality of Utah Lake waters has shown that there is a definite relationship between the concentration of salts in the lake and the hydrologic data – the inflow, content, evaporation, and outflow of the lake. From these studies it has been concluded that: (1) the concentration of salts in the lake is not increasing, (2) irrigation in Utah Valley is not the main source of mineral load to Utah Lake as has been stated by others, and (3) that it is in error to use a single sample collected at an unknown location in order to document the chemical quality of the lake.

Proper management of the contributions of mineralized spring waters to Utah Lake should be an important consideration in the Central Utah Project.

Midway Hot Springs, or Hot Pots, consist of a scattered group of thermal springs called collectively the "Hot Pots" which include Schneitter's Hot Pots and the Ken Johnson Hot Springs. These occur just north of the town of Midway in Heber Valley, at the eastern base of the Wasatch Range. Some of these springs have built conical, beehive-shaped mounds of tufa that form conspicuous hills on the valley floor. These springs are all located in a roughly square-shaped area one and one-half miles wide and lie in portions of sections 26, 27, 34, and 35 in T3S, R4E. Memorial Hill, near the center of section 35, is a large tufa mound of circular form at the base and 177 feet high. Another huge tufa mound is located at a resort called the Homestead. This cone is about 75 feet high.

Evidently, these unique tufa mounds began as crust-like deposits around the edge of a circular hot spring pool and as the water overflowed the rim the lime deposit grew in height, with a thicker layer at the immediate rim than farther down the sides of the growing mound. Thus the beehive shape of the deposit was formed.

The controlling geologic structure of the Midway group of hot springs is not known for certain, for the springs issue in all cases from the alluvium of the valley floor. Three major spring areas form a western group that line up in a general northwest direction. A similar northwest trend is displayed by an eastern group, beginning at the south in section 35. At best, these patterns might suggest buried northwest trending faults.

The waters of the Midway Hot Springs differ markedly in composition from those already described in Jordan River drainage and other parts of the Great Basin farther west. For example, analyses in connection with this report as well as others show much lower total dissolved solids. Further, the water is very high in calcium and sulfates and relatively low in chloride. The temperatures of these springs range from 100° F to 114° F.

Most of the hot springs in this area have a relatively small flow and in fact many of the hot pots have no apparent surface flow at all. There is little visible effect on surface-water supplies. There is one spring called the Ken Johnson Hot Spring (Mahogany Spring on U.S. Geological Survey map) which has a very large flow in comparison with the other springs in the area. This spring had a total measured flow of 2.5 cfs on July 23, 1964, which makes the total salt contribution quite large (12.3 tons per day). The water from this spring flows about 1,000 yards before it is mixed with a large surface water flow diverted from Snake Creek to a group of fish ponds which dilutes the salty water considerably. This comingled water was of fairly good chemical quality with specific electrical conductance of less than 500 micromhos in Snake Creek. The water is diverted downstream and used for irrigation.

The Sevier Unit

Earlier reports on thermal springs in this area indicated that there must be a tremendous inflow of mineralized thermal water to the Sevier River – a situation which would be important to define and understand because of existing water-quality problems on the lower Sevier River (Stearns, Stearns, and Waring, 1937). It

Fig. 25. Monroe Hot Springs area showing build-up of travertine terrace.

seems, however, that many of the springs mentioned in these very early reports have ceased to flow or are not mineralized. In connection with this study only one mineralized spring of consequence was found which flows into the Sevier River. Other mineralized springs in the Sevier unit are either out in the desert where the flows are evapotranspired or the flows are of such small consequence that they do not reach the river or have any discernable effect on other surface-water supplies. The main mineralized spring areas studied in connection with this report are Monroe Hot Springs, Red Hill Hot Springs, Joseph Hot Springs, Redmond Lake, and Abraham Hot Springs.

Monroe Hot Springs, sometimes referred to as Cooper's Hot Springs, are a series of very small hot springs issuing at the base of the Sevier Plateau one-half mile east of the town of Monroe and behind an abandoned bathhouse and dance hall. The flow from these springs is very small and most of it is evapotranspired on the site by saltgrass, greasewood, tamarisk, and other salt-tolerant phreatophytes. At the present time only one spring has a sufficiently large flow to flow beyond the travertine terrace. This flow was measured at different times during the summer of 1964 and found to be fairly constant at an average of 0.06 cfs.

The Monroe Hot Springs are located in the SE ¼ of the SE ¼ of section 10, T25S, R3W, and in the NE ¼ of the NE ¼ of section 15. The springs are quite hot, with a temperature of 140° F at the orifice of one of the larger springs. The bedrock adjacent to this spring and to the nearby Johnson Hot Spring is porphyritic latite of Miocene age, and the Sevier Fault Zone appears to be the source of these springs. The Johnson Hot Spring is located somewhat to the south of the Monroe Hot Springs, but the flow from this spring is practically negligible. A very small patch of salt grass and greasewood manage to thrive on the water from this spring but the water is completely used at the site. A large travertine terrace has been built by these springs along the base of the plateau as evidence of large flows and many springs at one time. This is illustrated in the Fig. 25 photograph, which also shows an abandoned resort near the travertine terrace.

Red Hill Hot Spring is another hot and mineralized spring associated with the Sevier Fault Zone. The hot springs in the Sevier Valley (Monroe Hot Springs, Redmond Lake, Red Hill Hot Springs, and Joseph Hot Springs) occur on both sides of the lower Sevier Valley.

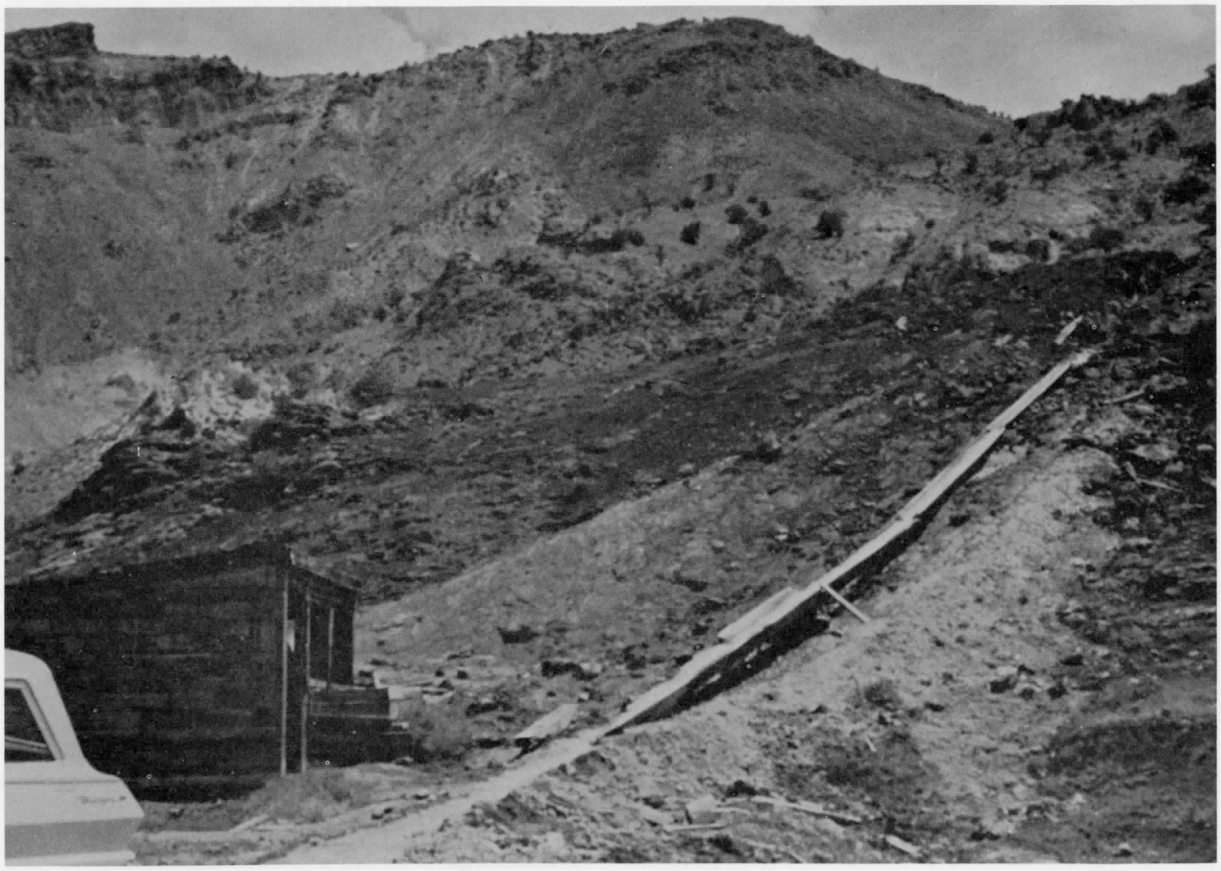

Fig. 26. Bathhouse and flume at Red Hill Hot Springs near Monroe, Utah.

(See Fig. 1.) The springs on the western border of the valley are associated with the Elsinore Fault Zone, while those on the east rise along the Sevier Fault Zone. Both faults trend north-south and control the structure of this portion of the Sevier Valley, which is a "graben" or a downthrown valley between two faults. The Elsinore fault lies at the eastern base of the Pavant Plateau, which is composed of Tertiary sedimentary rocks (Flagstaff formation) to the north. The Sevier fault marks the western base of the Sevier Plateau, composed of Mid-Tertiary tuffs and latitic lavas. These fault zones in this reach of the Sevier Valley have been the source of severe earthquakes since settlement by Mormon pioneers in the middle of the last century.

The Red Hill Hot Spring is one of the springs found along the Sevier fault in the vicinity of Monroe. The Red Hill Spring is located in the NE ¼ of the SW ¼ of section 11, T25S, R3W. An old bathhouse is located near a large beehive-shaped hill near the spring. The mound is composed of both travertine and tufa deposited by the spring (Callaghan and Thomas, 1939). A temperature of 168° F was obtained at the source of the hot water on July 15, 1964. Veinlets and small lenses of manganese dioxide are present in the mound. The old bathhouse and the flume carrying the water from the mound are shown in Fig. 26.

The water from this spring is collected and channeled across a small foothill area and across a canal to a holding pond. The water is diverted from this holding pond and used for irrigation as needed. The canal, across which the mineralized water is flumed, is not used except during periods of high spring runoff, when flood flows are diverted from Monroe Creek to the holding reservoir. Thus, during high runoff periods the waters from Monroe Creek and Red Hill Hot Springs are mixed and used for early summer irrigations. In this way the rather permeable soils, to which these waters are applied, can be leached of salts which accumulate during the late part of the irrigation season. Crops such as alfalfa and barley are raised.

Another factor which tends to improve the quality of the mineralized water is the long distance which the water is flumed from the spring to the holding pond. In this distance much of the mineral content is precipitated so that the specific conductance of the water is reduced from 6,000 micromhos at the source to 4,000 micromhos at the holding pond.

There is no apparent surface flow from this spring

Fig. 27. Tufa mounds and travertine terrace above canal at Joseph Hot Springs.

which affects surface supplies other than the one mentioned.

Joseph Hot Springs are located one mile southeast of Joseph on the east side of Sevier Valley. The thermal springs rise at the base of a steep scarp on the northern spur of the Antelope Range. The springs are located in the NE ¼ of section 23, T25S, R3W. The spring waters rise in a deposit of travertine and tufa, and some of the water drains into an irrigation canal immediately below. The setting is shown in Fig. 27. Temperatures of 140° F to 145° F were obtained from pools into which the water is running.

The northeastward-trending Dry Wash fault is the probable channelway for the thermal water. This fault, when extended northward, lines up with the Elsinore fault on the west side of Sevier Valley. The bedrock exposed above the springs is Dry Hollow gray, basaltic-andesite of probably Pliocene age.

Since the combined surface flow of the Joseph Hot Springs is extremely small, there is no measurable change in the water quality of the canal waters above and below the springs. At one time the thermal waters were used for bathing purposes, but there is no present use of these mineralized spring waters.

Redmond Lake is a pond which submerges a group of warm springs in sections 11 and 12, T21S, R1W, near the town of Redmond, Utah. These springs have a specific conductance of only 1,910 micromhos, but their large flow of 18 cfs makes them quite large salt producers — 67.5 tons per day. As may be expected from nearby industries, these waters are high in chlorides and sulfates. Rock salt is mined from open mines near the town of Redmond. Gypsum is mined commercially a short distance up the valley near Sigurd, Utah.

Abraham Hot Springs are located in an isolated desert region about 25 miles northwest of Delta, Utah. Consequently they flow out over the Sevier Desert and are dissipated before reaching any live water course. The springs are also known by the names "Crater Springs" and "Baker Hot Springs." By whatever name they are known, they represent a large hot spring area extending over two to three square miles in T14S, R8W. The springs are scattered over such a large area that the discharge is extremely difficult even to measure or estimate. The discharge of one of the largest groups of springs was estimated at 3.0 cfs, while a flow of 0.2 cfs was measured near one of the bathhouses. Others have estimated the total flow at about 10 to 12 cfs which would seem reasonable. The waters are generally quite hot, with measured temperatures ranging from 154° F to 175° F.

These springs are associated with a relatively young (geologically speaking) volcanic field of basalt flows, similar in aspect to the Fillmore craters in eastern Millard County. This is a hot spring area where the heat may be derived from slowly cooling igneous rocks. However, it is also admitted that basalt flows are highly fluid, spread widely in thin sheets, and cool rapidly. A buried vent may still transfer heated vapors to the surface. Some manganese oxides, resembling the deposits in the Jordan Narrows, also are found here.

In the Sevier unit there are miscellaneous other warm spring areas which either have ceased to flow or are not mineralized. For example, the Hatton Warm Springs about two miles southwest of Meadow is a thermal spring area that formerly was much more active than now, for a series of elongate tufa mounds of great size mark the site of hot springs no longer active. It seems reasonable to assume that the fault zone along which relatively geologically recent basaltic cinder cones and lava flows occur (the Fillmore Craters) is responsible for the associated hot spring activity.

Another thermal spring in this unit is the Sterling Warm Spring or Ninemile Warm Spring. This small thermal spring, which is not highly mineralized (specific conductance 600 micromhos) occurs about one-half mile south-southeast of Sterling with a flow of only 19 gpm and a temperature of 72° F. This spring is probably associated with a north-south trending fault which intersects an east-west fault south of the spring area. The water emerges from the Funk Valley Sandstone of Upper Cretaceous age. A strong odor of hydrogen sulfide gas escapes from the water and free sulfur is precipitating from the spring water. The spring water is comingled with water from the overflow of the Gunnison City supply and flows into Ninemile Reservoir. The small flow becomes highly diluted and of no consequential detriment.

The Cedar Unit

In the Cedar hydrological unit in southern Utah only Thermo Hot Springs is of any consequence. Its isolated location precludes any effect on other surface-water supplies. Other thermal springs within the Cedar unit have been mentioned and described in early reports, but were found to be dry when visited during this study. Springs which fall in this category are Sulphurdale Hot Springs, McKean's Hot Spring, and Minersville Hot Spring. All of these areas show evidence that at one time there were hot, mineralized springs at these locations, but in 1964 they were dry. Information regarding these locations and the water which once flowed from these springs is reported in U.S. Geological Survey Water Supply Paper 217, "Water Resources of Beaver Valley, Utah."

Thermo Hot Springs consist of two large thermal spring areas which occur on the flat valley floor of the Escalante Desert about 15 miles west of Minersville and about three and one-half miles southwest of Thermo, a siding on the Union Pacific Railroad. The northernmost springs issue at the top of an elongated mound 15 to 20 feet high, 500 feet wide, and nearly 5,000 feet long, in the east half of section 21, T30S, R12W. The largest group of springs is associated with the southernmost mound which is about 10 feet high, 160 feet wide, and 3,000 feet long, in the center of section 28, T30S, R12W, at an elevation of approximately 5,037 feet.

The thermal water issues at many places on these mounds, but no single spring discharges any great quantity of water. Discharges from some of the larger orifices were measured at 0.05 cfs and 0.01 cfs. The highest temperature observed in 1964 was 164° F. Hydrogen sulfide gas (H_2S) evidently escapes from the hot waters.

The source of the hot waters is not positively known, since the springs issue from the alluvium of the valley floor. Their north-south trend suggests a concealed fault typical of the Basin and Range structure in the Great Basin. Later Tertiary lava flows outcrop a few miles away, both to the east and to the west.

Since the flows are small and the water is all evapotranspired in the very near vicinity of the mounds, there is no effect of the mineralized water on other surface supplies. There have been filings in the State Engineer's Office to develop and use the spring for its thermal energy potential. The present use is for occasional wintertime stock watering. Since the mineral content is not too high, livestock seem to do well on the warm water during the winter.

The Uinta Unit

Other than the mineralized seeps and contact springs mentioned earlier, there are only two mineralized springs considered in this report for the Uinta unit. These are Split Mountain Warm Springs and Strawberry Springs. Of the two, Strawberry Springs is much more highly mineralized, but the large flow of the Split Mountain Warm Springs makes it the larger producer of salt.

Split Mountain Warm Springs flow into the Green River from both sides of the channel and from within the channel at a point about two miles above the lower end of Split Mountain Canyon (319.4 miles above the mouth of Green River). Both the entrance and exit to Split Mountain Canyon are spectacular because of the highly inclined strata of sandstone. The canyon is more than 2,800 feet deep, and its walls rise to the summits of Split Mountain and the Yampa Plateau more than 7,000 feet above sea level. The average gradient through the canyon is 20 feet per mile, which is steeper than that of any other canyon along the Green or Colorado Rivers in Utah. The warm springs rise from cavernous beds near the top of the Madison limestone, or possibly at the base of the Morgan formation. Although some of the spring openings are above the high-water level of the river, most of the flow comes to the surface only one or two feet above the river level in the late summer part of the season. These openings would most certainly be covered during the earlier part of the year. Movement of spring water into the main channel below the level of the river surface was observed in several of the shallows along the edge of the river. It is certain, therefore, that the flow of water into the river is large but practically impossible to measure. The amount of flow estimated by the U.S. Geological Survey in 1948 was 20 cfs (USGS Circular 129, p. 31), and this estimate seems reasonable based on observations in August 1964.

The temperature of the water from the various spring openings varies from about 84° F to 88° F, indicating that the water rises from considerable depth. The waters from Split Mountain Warm Springs are more highly mineralized than other springs upstream which likewise rise near the base of the Morgan formation.

The limestones from which the warm springs issue are buried under at least 6,000 feet of younger sedimentary rocks in the Island Park syncline north of Split Mountain. These limestones, however, appear at the surface again along the south flank of the main Uinta Range, in the headwaters of Pot Creek about 15 miles north of Split Mountain Canyon. This is shown by Forrester (1939). It is believed that the outcrop area along Pot Creek generally exceeds 8,000 feet in elevation.

The warm springs are, therefore, considered to be artesian springs which depend on this high outcrop area for recharge. The water, as it moves southward, must go down to considerable depths under the younger sedimentary rocks in the Island Park syncline where the temperature is increased considerably. As the water moves up the flank of the Split Mountain anticline under artesian pressure, there is undoubtedly some loss of heat to the limestone, and the temperature of the water at the spring openings is only moderately higher than the average annual temperature of the region.

In spite of the large salt contribution to the Green River by the Split Mountain Warm Springs, there is no observable change in water quality of the river above and below the spring area.

The Strawberry Springs are a group of small mineralized springs which rise on the right bank of the Strawberry River about 11 miles up the river from the highway near Duchesne. The spring area is located in T4S, R7E, Uinta Base survey. The measured temperature of 50° F is about what would be expected for ground water in the area, especially since the springs are so close to the river. Strawberry Springs occur in the narrow floodplain of the Strawberry River and flow into a pond created by a road fill which parallels the river. There is no visible flow of surface water from the pond to the river, except in times of high runoff when the brines remaining in the pond after evapotranspiration are flushed into the river. This occurs during occasional summer storms and probably during spring runoff periods.

A flow of 50 gpm was measured at one of the main spring orifices and more was coming from a group of springs, but because of the ponding and lack of surface runoff, the total production of the springs is impossible to measure. The water is consumed by greasewood and saltgrass or is evaporated.

Even though there is no direct surface runoff entering the Strawberry River, the springs still have an effect on the chemical quality of the river. In August 1964 the effect of the springs was to increase the specific conductance of the river from 600 micromhos upstream from the springs to 800 micromhos immediately downstream. During periods of high runoff the effect is not discernable and the specific conductance of the river is then about 550 micromhos.

The Strawberry Springs have the highest boron concentration of any mineralized springs sampled for this study. Their boron concentration of 12.0 ppm is decidedly unusual for natural waters and would only be expected in brines. These springs, together with waters from nearby Indian Creek, undoubtedly contribute a great deal to the boron problem on the Duchesne River. During low flow periods the Duchesne River contains enough boron to injure plants which are sensitive to boron (Thorne and Thorne, 1951). Toxic contents of boron in Duchesne River waters may be the cause of some instances of low crop yields. These problems may be somewhat alleviated if the contributions of boron from Strawberry Springs could be kept from the Strawberry River.

The West Colorado Unit

No mineralized springs are discussed in this report for the West Colorado hydrologic unit. There are many

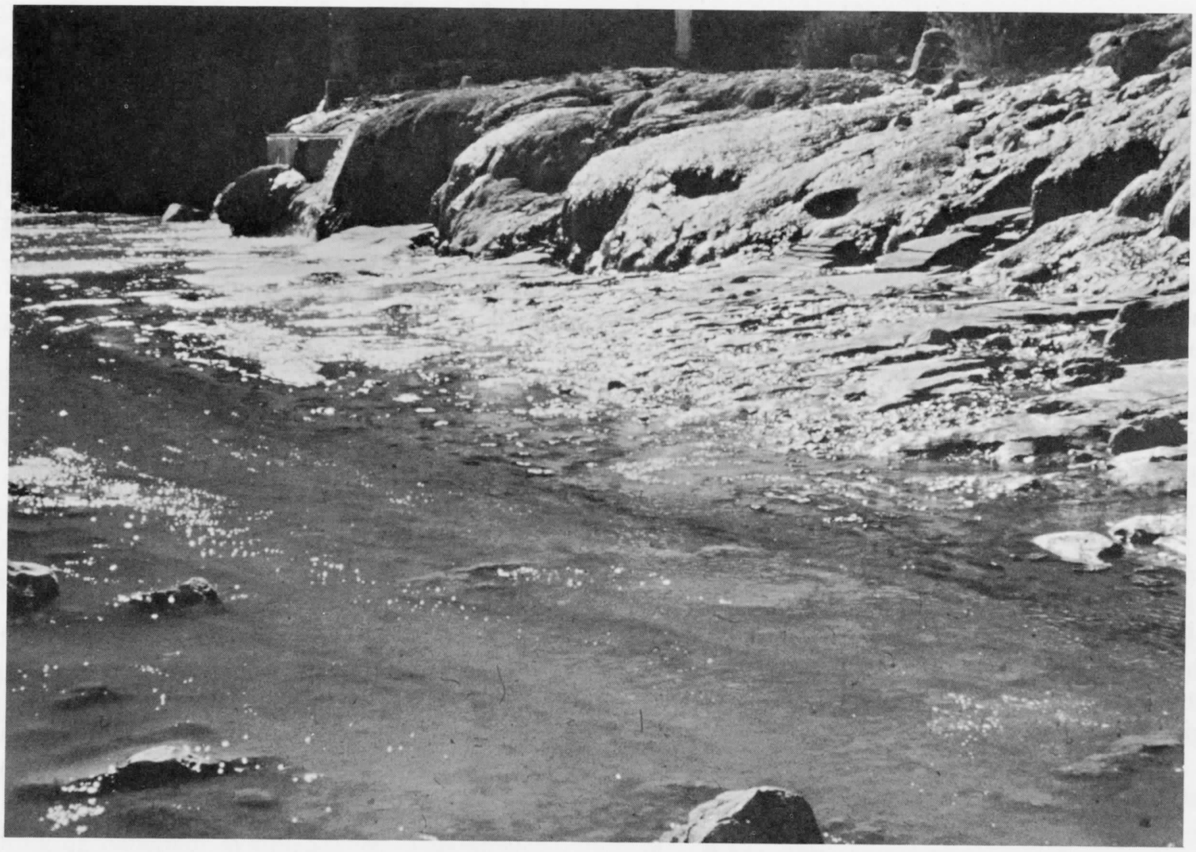

Fig. 28. LaVerkin Hot Springs issuing directly into the Virgin River during low flow season.

mineralized seeps and undoubtedly some mineralized contact springs in the area as mentioned earlier in this report. Further information regarding these types of mineralized waters can be found in U.S. Geological Survey Professional Paper 442, by Iorns and others, entitled "Water Resources of the Upper Colorado River Basin."

The South and East Colorado Unit

Like the West Colorado unit and the Uinta unit described earlier in the report, the South and East Colorado hydrologic unit probably has many mineralized seeps which may contribute salts to surface water supplies. However, very few mineral springs of major consequence are known. Of the warm springs in this unit investigated, only the LaVerkin Hot Springs was found to be of sufficiently high flow and mineral content to deserve consideration.

LaVerkin Hot Springs, sometimes called Dixie Hot Springs, are a series of fairly large hot springs issuing from the bottom and both banks of the Virgin River in the lower reach of Virgin River Canyon, about a mile south-southeast of the town of LaVerkin, and 2,500 feet due east of State Highway 17. The springs rise at intervals throughout a horizontal distance of about 1,600 feet in the SW ¼ of section 25, T41S, R13W. During low flow periods (July, August, and September) most of the hot water emerges from fissures and joints on the south bank and in the river bed as well as from a tunnel in the Kaibab limestones of Permian age. Strong fissuring in the footwall of the nearby Hurricane fault provides channelways for the water. The springs can be seen issuing directly into the Virgin River in Fig. 28. The reach of the Virgin River where LaVerkin Hot Springs issue is shown in Fig. 29. Practically the entire flow at the time of the photo was from the springs. It is interesting to note that the Hurricane Canal, shown in the upper part of the Fig. 29 photographs, was carved out of the mountainside by hand tools by the early settlers of the Hurricane area.

Discharges of about 12 cfs were measured. This approximate discharge also has been reported by the Bureau of Reclamation. The temperatures of the water range from 108° F to 132° F. A strong odor of hydrogen sulfide gas is present in the vicinity of the springs. Total dissolved solids have been reported as 9,600 ppm by the Bureau of Reclamation and were measured as

Fig. 29. The reach of the Virgin River where LaVerkin Hot Springs issue.

9,930 ppm in this study. Sodium is by far the most abundant cation, while chloride and sulfate ions are the most abundant anions.

From a water quality standpoint, the Virgin River and it tributaries are probably the most critical of all the major streams in the state. In this area the water is extensively used and reused as it flows through important irrigated areas in Utah, Arizona, and Nevada, and since the flow from upstream diversions is always more highly mineralized when it returns to the main stem after being used for irrigation and other purposes, these return flows contribute significantly to the dissolved mineral content of the downstream flows. The largest increase in downstream mineral content, however, has its source in the LaVerkin Hot Springs. During periods of low river flows, this source contributes a large percentage of the total flow downstream. The salt content of the downstream flows is increased to the point that the use of these springs together with return flows is questionable even for irrigation.

MANAGEMENT AND CONTROL POSSIBILITIES

Of the several springs sampled and measured in connection with this study, only a few have a noticeably harmful effect on the important surface water supplies. This is not to infer that there may not be an effect on ground water supplies through intermixing as flows rise toward the ground surface.

Those springs sampled and studied which warrant some considerations in management and control of their waters are discussed by hydrologic unit in the following paragraphs.

Great Salt Lake Desert Unit

The mineralized springs in this unit which affect surface water supplies are Deseret Springs near Iosepa and Blue Spring near Howell.

The water from Deseret Springs is used for stock watering and for irrigating saltgrass meadows. These waters drain eventually into Great Salt Lake mud flats without joining any major stream. Both the salinity hazard and the alkali hazard of this water are very high. Production is limited to plants with high salt tolerance. Proper management in order to make better use of this water may include drainage of the land along with treatment to improve the sodium exchange. The ground water in this area is also of poor quality, so that ground water could not be used for dilution. The general quality of ground water in Skull Valley has been described by Everett (1958). According to Everett, the ground water in Skull Valley is generally saline from the northern end of the valley at Timpie Springs to as far south as the Deseret Ranch at Iosepa. This fact is supported by the quality of water in the springs just to the north of Deseret Ranch known as Deseret Springs, as well as that of the wells just south of Deseret Ranch. Deseret Springs have salty water (TDS = 6,563 ppm), while the wells just south of Deseret Ranch have good-quality water (TDS = 300 ppm). The ground water yield in the area south of Deseret Ranch would not be sufficient to support irrigation in the northern part of Skull Valley since this ground water is already being used rather extensively in the south end of the valley.

Water from Blue Spring near Howell is impounded in Howell Reservoir from which the water is diverted and used for irrigation. Water having about 2,000 ppm of TDS might be of questionable quality for irrigation except that most of the water used for irrigation during the early part of the season is mixed and diluted by spring runoff waters of Blue Creek. This allows leaching of the soil with better quality water during the early part of the irrigation season when plants are particularly susceptible to salt damage. During the latter part of the irrigation season, the salt concentration of the reservoir water is increased slightly, since the only source of supply to the reservoir during this time of the year is the mineralized spring. This water has been used effectively for many years, and farmers in the area using this water indicate that there seem to be no deleterious effects on crops from the Howell Reservoir water. Proper management practices have been the key to the beneficial use of this water for irrigation.

Bear River Unit

Nearly all of the mineralized springs in this unit have some effect on downstream surface supplies, since most of the springs are located on the stream banks or in the channel of the Bear River or its tributaries. As the Bear River approaches the Utah state line from Idaho, it receives salt contributions from two major spring groups. These are Battle Creek Hot Springs and Vincent Hot Springs. Other springs on the Bear River itself, which cause an increase in the salt concentration of the Bear River, are the Cutler Springs and the mineralized springs at Crystal Springs near Honeyville.

If management and control of the waters from Battle Creek Hot Springs and Vincent Hot Springs should become necessary in the future, the best possibility for these appears to be diversion to holding ponds from which the water could be diverted to the Bear River during high flow stages in the spring of each year. In both cases nearby meadow land could be used for the purpose.

Since the present salt concentration of the Bear River above Cutler Narrows is not high, control and management of the springs is not critical. However, as upstream development of the Bear River proceeds, quantities entering Utah will be decreased and the mineral concentration increased. The relative detrimental effect of the springs at that time will be significantly increased. The location of the springs at Cutler Narrows in the river channel makes removal and treatment possibilities extremely difficult. To be aware of the water quality problem in the downstream waters and to adopt irrigation practices suitable for the situation may be the only reasonable course of management action for these springs. During high flows in the river, the quality of water below the spring area is not a problem.

The deleterious effect of Crystal Springs near Honeyville is noticeable on the quality of Bear River water, and consideration of management and control schemes for these springs is warranted now. The water from the cold springs is comingled with the water from the hot springs to form Salt Creek, which eventually flows into the Bear River several miles to the south. Management possibilities would suggest a number of alternatives. The most apparent possibility may be to channel the water from the hot spring directly to Great Salt Lake without comingling or storing. Or it may prove more efficient to divert the hot spring discharge to a storage pond for complete evaporation. Other alternatives may be to convey Salt Creek water to an offstream storage site where the water could be partly evaporated and stored for timed releases to Great Salt Lake via the Bear River. The storage requirement for nine months would be 4,000 to 5,000 acre-feet. The three-month release period would have to be timed so as not to interfere with other users who may be using Bear River waters for leaching or flushing, such as in the bird refuge.

The Malad River, arising in Idaho and joining the Bear River at a point below Cutler Dam, has three major spring areas which issue directly into the river. These are at Pleasant View, Idaho (near Malad), at Woodruff, Idaho (Price's Hot Springs), and near Plymouth, Utah (Udy's Hot Springs). The total dissolved solids content of the Malad River is high to begin with, as the headwaters of the Malad are fed by mineralized springs. However, the total dissolved solids of the Malad River on July 11, 1964, was increased from 3,900 ppm to 4,900 ppm with the contribution of Price's Hot Springs near the Utah border. The concentration remained fairly steady but decreased slightly to 4,500 ppm by the time it reached Udy's Hot Springs. The total dissolved solids concentration of the Malad River was increased again to 5,500 ppm with the contribution of Udy's Hot Springs.

Two management possibilities for springs along the Malad River are suggested. First, the discharge from the springs along the Malad River is small enough that off-channel evaporation ponds could be successfully used in reducing salt input to the river. A storage capacity of about 2,200 acre-feet with a surface area of over 700 acres would be necessary to implement this scheme just to take care of Udy's Hot Springs alone. Even with the three groups of mineralized springs removed in this manner, however, the quality of the Malad River water still would not be "good." A second possibility would be to provide for dilution of all Malad River waters before their confluence with the Bear River. There is a damsite on the Malad River below most of the damaging springs which could store Malad River water and receive Bear River water through a feeder canal. The purpose of the Bear River water would be to sweeten by dilution the water stored from the Malad River. By such mixing and storing, the reservoir releases would be of good quality – the degree of quality depending on the amount of imported water. It is understood that the U.S. Bureau of Reclamation is examining the feasibility of a storage reservoir on Malad River. There are water management advantages in addition to those of water quality, of course, which make such a proposal desirable.

Another spring in the Bear River unit that has some potential for better management is the Bothwell Salt Creek Spring with a flow of about 16 cfs to 32 cfs, depending on the time of year. This spring has a salt load of about 90 tons per day. The major present use of this water is for wildlife ponds in the marshes and mud flats at the north end of Great Salt Lake. The vegetation thus supplied is of a relatively salt tolerant variety. However, the quality of Bothwell Salt Creek water is such that if it could be mixed with other fresh water supplies it could be safely used for irrigation or other uses.

Jordan Unit

Those mineralized springs of the Jordan River unit which may significantly affect the utility of manageable supplies are Jordan Narrows Warm Springs, Goshen

Warm Springs, Castilla Hot Springs, Midway Hot Springs, and the springs in and around Utah Lake, including those at Saratoga, Lincoln Point, and Bird Island.

The Jordan Narrows Warm Springs are being used as a supply for Camp Williams. These springs are not really highly mineralized as far as many uses would be concerned, but as a public water supply even this mineral content (TDS = 350 ppm) is somewhat undesirable. Again, mixing with a better quality supply would afford a satisfactory solution to this problem.

The water from Goshen Warm Springs is used for irrigation of the meadow grasses found in the bottomlands of Goshen Valley. Both the sodium hazard and the salinity hazard of this water are very high, but the grasses are salt tolerant and there is probably considerable springtime leaching. For better management of these springs, every possible source of good-quality water should be used for mixing. Since ground water in the vicinity is generally of poor quality, this means turning to whatever surface supplies are available for dilution and spring leaching of salts. Efforts should be made to maintain proper drainage and proper soil structure where the mineral springs water is used for irrigation. This would help to maintain a salt balance such that higher-quality crops could be grown. The water may not be at all objectionable for certain industrial uses. In fact, the water has been previously used in ore reduction.

Recent highway construction near Castilla Springs has effectively dammed off the surface flow from the springs so that on September 2, 1964, a surface flow of only 0.01 cfs was measured at a culvert crossing under the highway. A larger stream of 0.08 cfs was measured near the old bathhouse, but evidently most of this is used by salt-tolerant phreatophytes growing in the ponded area as well as by evaporation from the pond. There is also a likelihood that a large part of the original 1 cfs is moving through the alluvium and the road fill to the river. However, on the sampling dates both in August and in September of 1964 there was no noticeable change in the electrical conductivity of the river above and below the springs. If the water is moving through the alluvium, it may take some time to saturate the media with salts so that an appreciable amount of salts would begin to reach the river. There is very little, if any, measurable effect from the springs on the quality of the river water.

As long as the flows remain high in Snake Creek, which collects most of the surface flows of the hot springs near Midway, there should be no serious problem in using the water for irrigation. However, if there is much variation in the flows of Snake Creek there may be times when the water in Snake Creek could reach 1,000 to 1,500 ppm of dissolved salts. Downstream users should at least be aware of this problem so that appropriate irrigation management practices such as spring-time leaching and planting of salt-tolerant crops could be employed. This water would likely be highly undesirable for use as drinking water because of the high concentrations of calcium and magnesium sulfates.

Improvement of water quality on Snake Creek during low runoff periods would require reservoir storage for low flow augmentation when the comingled spring water becomes a high proportion of total flow. In this way more dilution could be accomplished in the latter part of the irrigation season.

Since a large fraction of the mineral contribution to Utah Lake enters the south end of the lake by way of Goshen Bay and Lincoln Point, it has been estimated that from 13,000 to 21,000 tons of chloride, or from 17 to 27 percent of the computed inflow chloride load to Utah Lake could be withheld from the Lake by constructing the Goshen Bay Dike, as proposed in the Central Utah Project plan report of the Bureau of Reclamation. This dike would effect an improvement in the chemical quality of Utah Lake and the Jordan River, not only from the withholding of salts from the lake, but also by the reduction in evaporation due to the reduced water surface area of Utah Lake.

Sevier Unit

Much of the mineralized waters occurring in the Sevier River Basin, and originally thought to result from thermal springs, is likely meteoric water which has had contact with near-surface salt beds. Either by nature of location or quantity of discharge the mineralized springs in this hydrologic unit do not cause major problems with other supplies. Flow from springs in the Redmond Lake area probably obtains its mineral content from salt beds in the Redmond Hills anticline. These springs are not exceptionally high in salt content but flow about 18 cfs so that total salt introduced by these waters is relatively high.

The warm waters from Redmond Lake are used for irrigation, and although the salinity hazard is high the alkali hazard is not. By comingling better-quality water diverted from Sevier River with the more saline water from Redmond Lake, good crops can be raised. Since the Redmond Lake waters are not excessively saline, they can be used beneficially with proper management.

Uinta Unit

The estimated 58 tons per day salt contribution of Split Mountain Warm Springs is relatively large but when diluted by the waters of the Green River, there is no observable change in the water quality of the river above and below the spring area. This fact makes the likelihood of control or management of the spring waters improbable. Even if the need were to arise, attempts to control or manage the spring waters separately would be practically impossible because of their location in the channel and the near-vertical canyon walls.

Strawberry Springs in the Uinta Unit, however, do present some management possibilities. Toxic contents of boron in the Strawberry and Duchesne rivers are undoubtedly due, in part, to the boron contributions from Strawberry Springs. Harmful concentrations of boron and other salts could possibly be kept from water supply sources by providing off-channel evaporation ponds near the springs. This may require building the adjacent road fill somewhat higher. Since most of the present contribution of salts appears to be reaching the Strawberry River through the alluvium, an underground cutoff by piling or by alluvial grouting would be the major management consideration. The economic justification of such measures would have to be studied in more detail, but prevention of crop damages due to boron contamination would seem to justify the management measures here.

South and East Colorado Unit

The possible increase in salt concentration with increased depletion under the proposed Dixie Project has come under considerable discussion and study in recent years. Of principal concern in this regard is the effect of LaVerkin Springs on downstream flows. The U.S. Bureau of Reclamation has made operational studies of the project with and without the water from LaVerkin Springs to determine the effects on quality of water leaving Utah. Under a plan which contemplated a dam and reservoir near the town of Virgin, Utah, the effect of the LaVerkin Springs was estimated to cause an increase of approximately 600 ppm of total dissolved solids in Virgin River at Littlefield, Arizona. The annual weighted mean quality in terms of total dissovled solids would increase from 1,560 ppm before Dixie Project to 1,790 ppm with LaVerkin Springs removed, and up to 2,370 ppm without removal of LaVerkin Springs water. Further detail on a monthly basis is given in Table 7.

The physical accomplishment of the collection and removal of LaVerkin Springs water would not be simple. The springs emerge in a narrow, steep canyon. There are one or two draws at the mouth of the canyon which might offer some possibility for temporary storage if it were not for the porous lava formations existing. Any removal scheme would likely involve pumping the mineral water out of the river channel during low flow periods. It might be possible to convey the water to the Bench Lake area and there provide evaporation opportunity. Whether or not the minerals precipitated would have some commercial value which would add to the economic feasibility of removing the spring waters would have to be investigated. Over 100,000 tons of dissolved solids are carried in the waters of LaVerkin Springs each year. Investigations still underway indicate that the development of a storage reservoir on the Virgin River under the Dixie Project will likely have to be below rather than above LaVerkin Springs.

Table 7. Estimated average discharge and quality of water, Virgin River at Littlefield, Arizona; present conditions and conditions after development of Dixie Project, Utah.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
						Average discharge of Virgin River at Littlefield (discharges in 1,000 acre-feet)							
Present conditions[1]	14.0	18.4	21.9	25.6	25.9	6.8	7.5	14.6	9.3	9.7	11.4	13.3	178.4
After development of Dixie Project:[2]													
LaVerkin Springs removed	9.7	11.9	10.5	9.1	9.8	5.2	7.1	13.1	6.9	6.7	9.1	9.0	108.1
LaVerkin Springs not removed	10.4	12.5	11.2	9.3	10.6	5.9	7.8	13.9	7.6	7.5	9.8	9.8	116.8
						Average quality of the flow of Virgin River at Littlefield (total dissolved solids in parts per million)							
Present conditions[1]													
Average daily quality	1,850	1,760	1,630	1,520	1,640	2,280	2,440	2,430	2,440	2,450	2,100	1,930	2,040
Weighted mean quality	1,800	1,530	1,160	1,020	935	1,870	2,280	2,050	2,130	2,320	1,950	1,870	1,560
After development of Dixie Project:													
Weighted mean quality:													
LaVerkin Springs removed	1,900	1,740	1,320	1,550	1,410	1,370	1,570	1,850	2,150	2,600	2,120	2,050	1,790
LaVerkin Springs not removed	2,450	2,160	1,870	2,140	1,970	2,370	2,340	2,260	2,840	3,270	2,670	2,600	2,370

[1] Average for October 1929-September 1955 period.

[2] Based on the average annual flow of 178,400 acre-feet for the October 1929-September 1955 period at Littlefield for present conditions. The apparent stream depletion would be only approximately that which would result from project operation plus transbasin exports of 8,000 acre-feet a year to the Cedar City area.

SUMMARY

Water demands and consumption are continually increasing in Utah through expanding population, agriculture, industry, and recreational uses. Water quality problems will become acute as our available water supplies are used more completely. One source of these quality problems, as discussed in this report, is that of mineralized spring waters which limit and sometimes destroy beneficial uses of water in some areas of the State.

For this study an inventory of the mineralized springs in the State was taken which included the location, hydrologic and geologic setting, and the quantity and quality of water. Evaluation and interpretation of this information have permitted appraisal of the current and potential effects of these mineral spring waters upon important usable supplies. The investigation accomplished a sorting of mineralized spring waters as they affect major water supplies. Results indicate that many of the springs described as thermal springs are not mineralized and, therefore, have no deleterious effect on the mineral quality of our water supplies. Also, many of the mineral springs are of no current consequence since they are either so small in salt production or the water merely flows out onto the desert and is evaporated. In the case of those springs which do affect our water supplies adversely, possibilities for control and management to extend the usefulness of these water supplies are suggested.

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