BRIGHAM YOUNG UNIVERSITY RESEARCH STUDIES

Geology Series Vol. 1 No. 2 May, 1954

GEOLOGY AND GROUNDWATER OF NORTHERN DAVIS COUNTY, UTAH

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CONTENTS

ILLUSTRATIONS

ACKNOWLEDGEMENTS

The writer gratefully acknowledges the assistance given by the personnel of the Ground Water Division of the United States Geological Survey in supplying well data, maps, aerial photos, and published and unpublished data from several previous investigations. Ben Lofgren was especially helpful in giving suggestions, constructive criticisms, and actual help in the field.

The Bureau of Reclamation and the State Engineer's Office have also aided much in supplying various forms of information, and the writer is most grateful to them.

Acknowledgement is also extended to Dr. George H. Hansen and Dr. Harold J. Bissell, special committee members, for their counsel, advice, and able supervision of the study.

The writer is also indebted to his wife, Sally, for her assistance in the field, help in copying well logs, preliminary typing of the thesis and constant encouragement during the period of the investigation.

INTRODUCTION

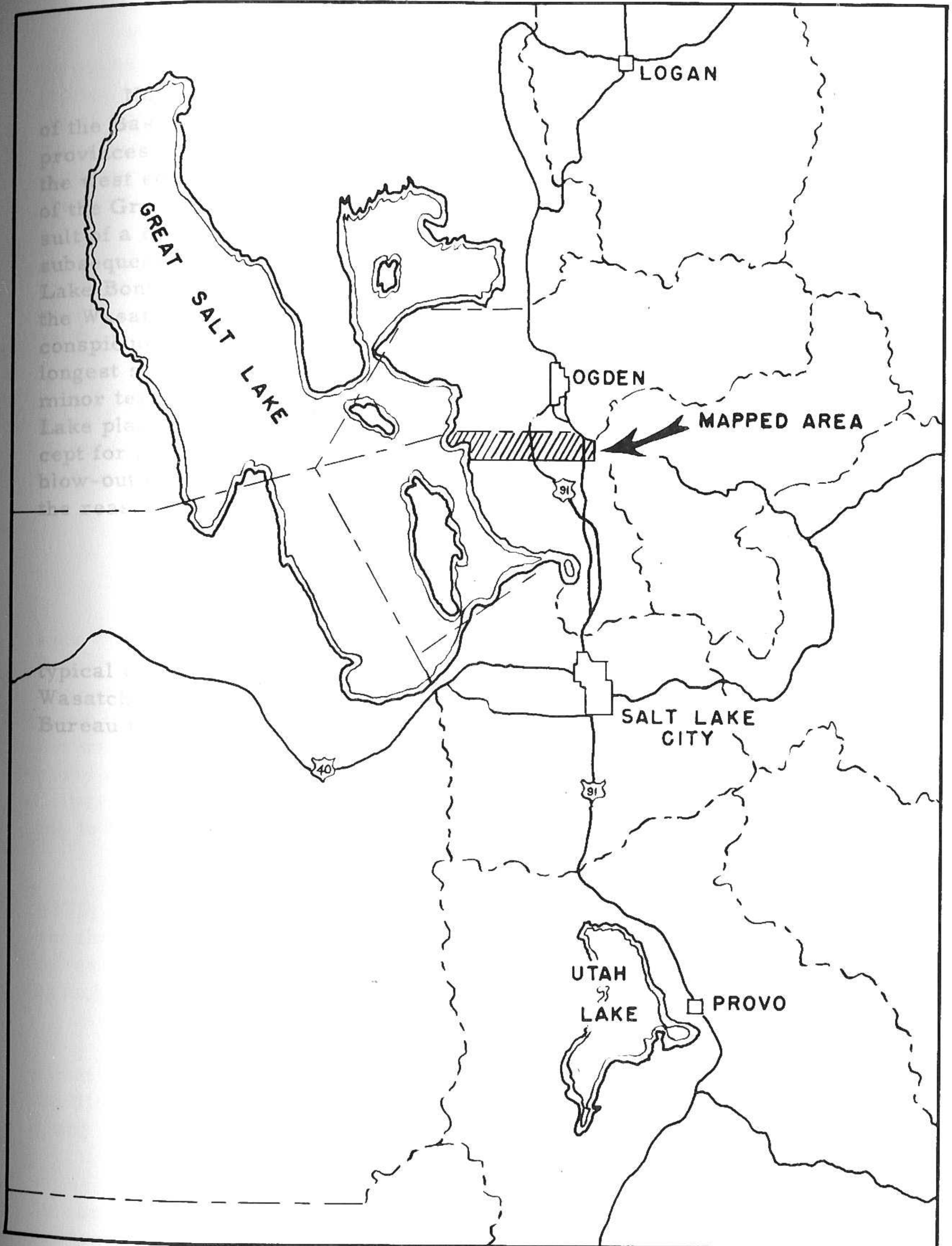
Purpose and Scope of Investigation

A well defined ground water unit exists along the eastern shores of Great Salt Lake from the Lower Bear River Valley to Salt Lake City. Thomas (1948, p. 63) refers to this area as "The East Shore Area", which he conveniently divides into three districts: the Bountiful district in Davis County, the Weber delta district in Weber and Davis Counties, and the Brigham district in Box Elder County. This area is one of the most highly populated as well as agriculturally and industrially productive regions in the State of Utah. During the past decade its importance and value have been increased greatly by the developments of new industries and the establishment of several military installations. These developments coupled with an increased population have brought about a corresponding increase in the demand for water which necessitated a greater exploitation of the ground water resources. This increased demand motivated the long range study of the ground water conditions in the East Shore Area. As the first part of this project H. E. Thomas and W. B. Nelson of the U. S. Geological Survey conducted ground water studies of the Bountiful district, the results of which are published in the Twenty-sixth Biennial Report of the State Engineer to the Governor of Utah. Current studies are being made of the Weber delta and Brigham districts (Feth, 1954).

The purpose of this report is to contribute to the East Shore area study by compiling and correlating all available well data, mapping the surficial geology, and studying the general ground water hydrology of northern Davis County, which is the southern portion of the Weber delta district.

Location

The area considered in this report is located in the northern extremity of Davis County. It consists of a strip of land four and one-half miles wide extending from the Wasatch Mountains on the east to the shores of the Great Salt Lake on the west and is bounded on the north by the Weber-Davis County line. In respect to the Salt Lake base and meridian it includes the northern parts of Township 4 North, Ranges 1, 2, and 3 West, and the southern parts of Township 5 North, Ranges 1, 2, and 3 West. Hill Air Force Base, Ogden Arsenal, U. S. Naval Supply Depot, Clearfield, Syracuse, West Point, and Clinton are all located within its boundaries. U. S. Highways 89 and 91 extend north and south through the area, and Highway 31 joins them from the east at the mouth of Weber Canyon. Numerous county roads, most of them section roads, form a grid pattern over the entire area, making all points readily accessible by automobile (see index map).



INDEX MAP

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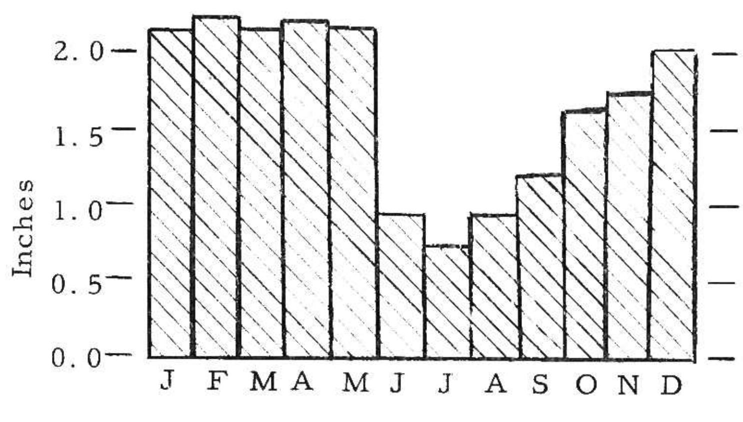
SCALE

Physical Features

Northern Davis County lies along the boundary of the eastern edge of the Basin and Range and the Middle Rocky Mountain physiographic provinces (Fenneman, 1949). That is, this area includes a small part of the west edge of the north-central Wasatch Mountains and an eastern part of the Great Basin. The present physical features of the area are the result of a combination of various diastrophic movements with attendant and subsequent erosion. The last modifying agent was largely that of ancient Lake Bonneville, which once occupied most of western Utah. Except for the Wasatch Mountains the most prominent physical feature is a large, conspicuous, gentle west-sloping delta built by Weber River during the longest still-stand of the ancient lake. Westward from the delta, fifteen minor terraces descending in successive steps to the shore of Great Salt Lake plainly indicate the levels that the receding lake once occupied. Except for a small area of reworked spits which have produced a series of blow-out dunes, the terraces provide excellent farm land, which is one of the reasons for the productiveness of this area.

Climate

The climate of northern Davis County is temperate and semi-arid, typical of the eastern part of the Great Basin near its boundary with the Wasatch Range. Interpretation of data obtained at the U. S. Weather Bureau for Morgan and Riverdale stations is summarized in Figure 1.



Average monthly precipitation.

Figure 1

Temperature, as well as precipitation, is irregularly distributed throughout the year, producing four distinct seasons. Actually, the precipitation in Morgan and Summit Counties has more effect on the ground-water conditions in the Weber delta area than does that in Davis County. The reason for this condition is that the headwaters which control the volume of flow in the Weber River are located principally in the former counties.

The higher precipitation recorded at the Morgan station results from an average increase along the Wasatch slopes of about one inch for each 160 feet rise in elevation and an average decrease in temperature of 1° F. for each 482 feet.

The prevailing wind direction is southwest during the entire summer, but it varies from northwest to southwest during the winter. Throughout the year an almost constant wind issues forth from the mouth of Weber Canyon and at times attains near-gale velocity.

Previous Studies

From 1776 to 1875 a number of exploratory and trapping expeditions were conducted in the Great Basin. Padre Escalante (1776), B. L. E. Bonneville (1833), H. Stansbury (1852), E. G. Beckwith (1855), F. V. Hayden (1872), F. H. Bradley (1873), and J. D. Simpson (1876) were among those to note various geologic and geographic features of this area. To the writer's knowledge, however, the first person to publish a systematic study of the sediments and shore features of Lake Bonneville was G. K. Gilbert (1875), who wrote the first of a series of briefer publications leading to his comprehensive monographic study (Gilbert, 1890, p. 438).

King, Hague, and Emmons, geologists of the 40th Parallel Survey (1875), published the first map of the former outline of the ancient lake, but their pioneer studies were confined wholly to a belt one hundred miles wide and should be considered as a general reconnaissance. The actual mapping of the lake features, however, was done by G. K. Gilbert.

Gilbert (1890) in his monograph on Lake Bonneville describes in great detail the shore features, types of sedimentation, volcanic activity, faulting, and a general history of the lake. He discusses in great length many areas, but tells little of the Weber delta area.

Since Gilbert, various geologists have studied a number of areas in connection with Lake Bonneville sedimentation, but most of them are located south of Salt Lake City.

Davis (1903) described the Wasatch fault in some detail and postulates as to the physiographic conditions before faulting and vertical displacement. Blackwelder (1909) observed various overthrusts in the Ogden area and mapped a number of transverse faults. A more recent publication on the structure of the North Central Wasatch Mountains is that of Eardley (1939). He describes the structural trends and evolution of the entire area and mapped a number of overthrusts adding to the work of Blackwelder.

Eardley (1944, pp. 821-842) published a report on the general stratigraphy, structure, and geomorphology of an area of more than 1,000 square miles located in the North Central Rockies. He briefly described the physical features of the Weber delta, but studied it only from aerial photographs.

H. E. Thomas and W. B. Nelson (1948, pp. 60-206) published the first part of "Ground Water in the East Shore Area" in their report on the Bountiful district. Their work consisted of geologic mapping, extensive well tests, geochemistry, and generalized ground-water hydrologic studies. Their report has been extremely useful in this study and has served as a general guide for this investigation, since many of the problems in the two areas are very similar.

Investigations of the ground-water and geology in the vicinity of Ogden, Utah, were conducted by P. E. Dennis and H. R. McDonald (1950 and 1951) as a continuation of the East Shore area study. During the summer of 1951, P. E. Dennis started mapping the geology along the foothills in the Weber delta area, but his work was discontinued August 25, 1951. His notes and work sheets have been checked by the writer and have been utilized in this report whenever possible.

G. L. Bell (1952, pp. 38-51) made a rather detailed study of the pre-Cambrian rocks of the north-central Wasatch Mountains near Farmington. His geologic map (Plate V) on the north includes part of the present area, and on it are shown the Bonneville and Provo shorelines.

Abstracts by H. J. Bissell, G. M. Richmond, R. B. Morrison, H. E. Thomas, G. H. Hansen, B. E. Lofgren, and J. S. Williams published by the Geological Society of America (1952, pp. 1358-1375) revise some of the stratigraphic nomenclature of Lake Bonneville and correlate it with Lake Lahonton and Quaternary deposits of the LaSal Mountains.

C. B. Hunt (1953) studied the stratigraphy and paleontology of alluvial, cave, and lake deposits of late Quaternary age in an effort to better establish the Pleistocine-Recent boundary in the Rocky Mountain region.

Field Work and Methods

The field work which provided the data for this study was essentially completed during the summer of 1952 while the writer was working on a ground-water project for the U. S. Geological Survey. Adequate topographic maps and aerial photographs were available providing complete coverage of the area.

In mapping the unconsolidated material the basic principles similar to those used in mapping bedrock geology were used; special attention, however, was given to the delineation of shore lines and similar topographic features.

An integral and important part of this investigation includes a detailed study of all the well logs in the area. From the data provided by these logs, the writer prepared and drafted an isometric fence diagram showing the subsurface geology. Numerous well logs were made available by the State Engineer's office and the U. S. Geological Survey, but only the deeper and strategically located ones were plotted on the diagram. A general difficulty encountered was that well drilling in this area was done by several different drillers, each using his own method of recording data. Obviously all have not recorded data in the same degree of completeness; thus the writer has attempted to interview each driller and study the various methods of logging in order to better evaluate each log.

Discharge and temperature measurements were made of all the flowing wells in the area. This information, together with data on recharge experiments made available by the Bureau of Reclamation, provided a basis for estimating the ground-water reservoir capacity.

All the laboratory work was conducted at Brigham Young University and consisted of size grade analysis, in which standard sieves were used, and petrographic analysis of the sediments.

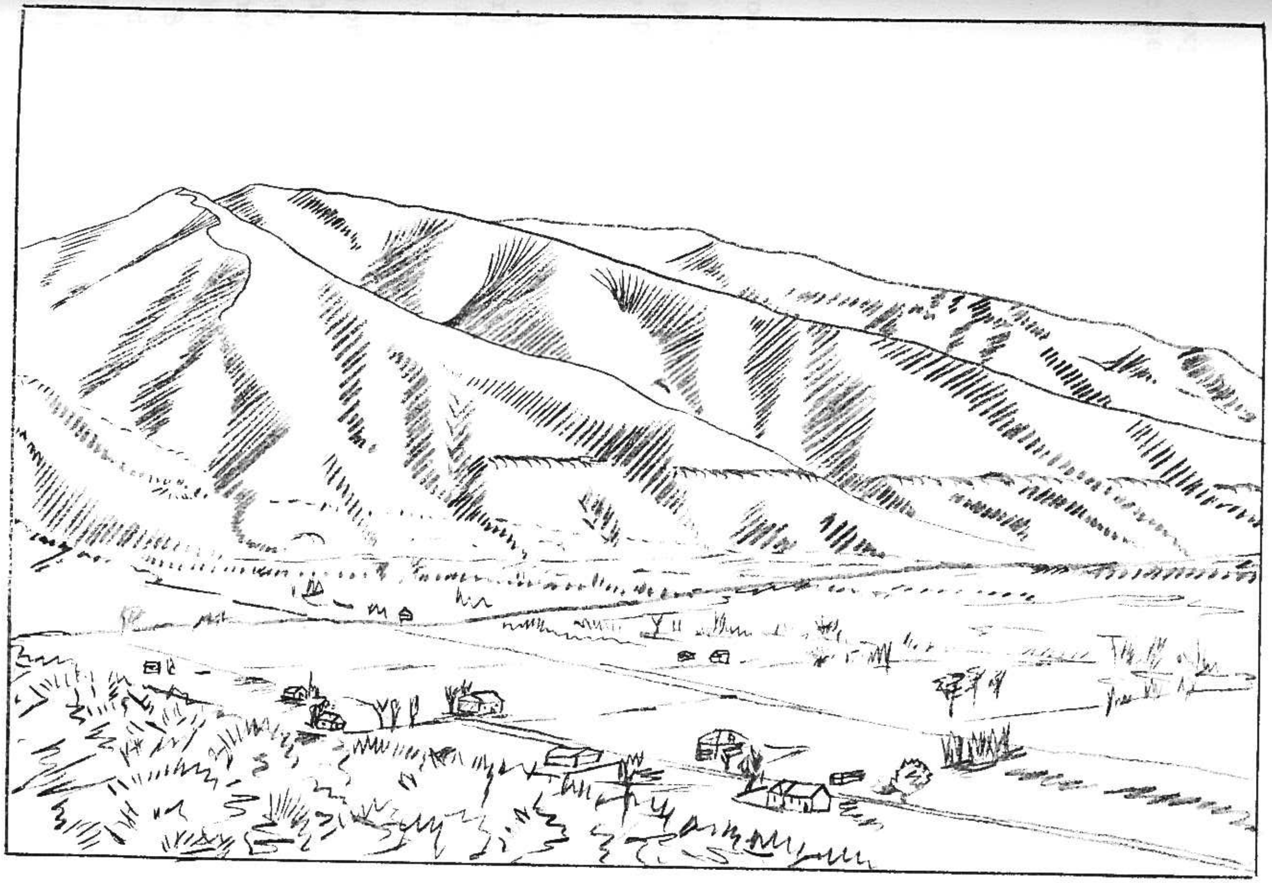


Figure 2. Wasatch front just South of Weber Canyon

GEOLOGY

General Relations

Only pre-Cambrian rocks and Quaternary unconsolidated sediments are exposed in Northern Davis County. The absence of Paleozoic and Mesozoic sediments is explained by Eardley (1939, pp. 1285-1286).

> "A feature of the structural pattern equally as prominent as the Uinta axis is the buttress of pre-Cambrian crystalline rocks north and northwest of Salt Lake City. It stood out as a highland through parts of the late pre-Cambrian, Paleozoic, and Mesozoic time, and during the Laramide revolution it acted as a small semi-rigid shield midst an area of failing sedimentary rocks."

Basin and Range faulting which began early in Cenozoic time had a profound effect on the present land forms in this area. Since that time an arid climate has prevailed, with great thicknesses of torrential stream and playa lake deposits accumulating in the depressions (H. E. Thomas, 1946, p. 77).

Volcanic activity was widespread throughout most of the state of Utah during the Tertiary, and it is likely that much of Davis County is underlain by volcanic debris, although no well has encountered such material.

Cold and humid climatic conditions interrupted the arid cycle of erosion at least once and probably several times during the Pleistocene epoch. Immediately after the peak of the last of these glacial stages, that is, the Iowan substage of the Wisconsin stage (Bissell, 1952, p. 1358; Richmond, Morrison, and Bissell, 1952, p. 1369), great quantities of water accumulated in the basin forming closed lakes. The largest of these, Lake Bonneville, attained a maximum area of about 20,000 square miles and a depth of at least 1,000 feet. The shore lines and embankment deposits built by this lake constitute some of the major topographic features in northern Davis County and the lake bottom sediments cover the entire Salt Lake Valley.

Stratigraphy

Pre-Cambrian Rocks

A crystalline complex of meta-sedimentary rocks, meta-igneous rocks, and igneous rocks, named the Farmington Canyon Complex (Eardley, 1940, pp. 58-72), outcrops at various places along the Wasatch front, locally below the elevation of 5,100 feet. According to Eardley (1944, p. 823), the foliation is north and northwest and generally parallels the bedding. Although the area has been mapped, the structure is very complex and has not been satisfactorily solved. Eardley (1944, p. 823) states:

> "The sedimentary rocks of the ancient complex are now metaquartzites, quartz schists, arkosites, conglomerate schists, and metamorphosed graywacke. After sediments whose thickness exceeded 10,000 feet were deposited, they were thoroughly injected by sills and dikes during a prolonged orogeny which resulted in widespread development of foliation and cataclastic structures."

Bell (1953, pp. 38-40) classified these rocks according to "mineral facies" and found zones of arteritic migmatite widespread in the Weber Canyon area.

Examination of various outcrops, road cuts, and exposures in the Weber Valley project tunnel reveals highly fractured and brecciated rocks, probably due to overthrusting and folding.

Tertiary (?) and Quaternary Systems

Pliocene (?) and Pleistocene Series

Pre-Lake Bonneville Beds

Underlying the fine silts, sands, and clays of the Lake Bonneville group is a series of coarser sands and gravels believed by the writer to be in part Pliocene and in part Pleistocene in age. Virtually every well in the area penetrates these beds, but none have drilled through them into the Salt Lake formation of late Pliocene age (Yen, 1947, pp. 268-277); so it is possible that the lowermost part of these pre-Bonneville sediments may be very late Pliocene. The bottom of the deepest well in the area is 675 feet below the Lake Bonneville group, indicating the thickness of the late Tertiary (?) and early Quaternary beds to be at least 675 feet and possibly more.

Well log data gives evidence of both lacustrine and fluviatile deposits interbedded throughout the section. For the most part, the individual gravel beds do not continue over large areas, but interfinger with sand and clay. These fluvial deposits were probably spread over the valley during semi-arid periods which preceded and interrupted at least two pre-Bonneville lake cycles. Deposits of these pre-Bonneville lakes are recorded in all of the deeper wells as alternating beds of sand and clay and constitute the majority of pre-Bonneville sediments. They are concentrated westward away from the mountain front which would indicate that the pre-Bonneville lakes had smaller areal extent than Lake Bonneville itself. A number of the wells bottom in a coarse gravel which can be traced with a reasonable amount of accuracy throughout the entire area. It thins to the west and in places grades into sand, but it is still by far the most extensive fluvial deposit of pre-Bonneville time.

None of the well logs examined contain evidence of volcanic debris, although the writer did not have the opportunity to examine any of the cuttings.

Quaternary System

Pleistocene Series

Lake Bonneville Group

The history of Lake Bonneville is recorded in northern Davis County by various shore lines and embankment deposits concentrated along the base of the Wasatch Mountains and in the wells themselves. These deposits have been divided into three formations each of which represents a different stage in the level of the ancient lake (Bissell, 1948, p. 155). They are, from oldest to youngest, the Alpine, the Bonneville, and the Provo, which correspond to Gilbert's Intermediate, Bonneville, and Provo shore lines (Gilbert, 1890, pp. 90-152). In addition to these formations, the writer has mapped recessional shore deposits and lake bottom sediments as separate features because of their particular relationship to the present study.

The outstanding study of the various aspects of Lake Bonneville and its related shore features is that of Gilbert (1890). As recognized by Gilbert, the waters of the Quaternary lake fluctuated through several cycles of high stages with intervening periods of nearly complete desiccation. At the highest stage, the Bonneville Stage, Lake Bonneville remained at an altitude of 5, 135 feet while wave-cut and wave-built terraces, as well as delta structures, were built around the shore lines and within the basin (Bissell, 1952, p. 1358). Prior to this maximum stage, and separated by an interval of desiccation, the history is one of an oscillating water surface, characterized by extensive embankments built to an altitude of 5, 050 to 5, 100 feet.

The Bonneville stage of the lake ended by an overflow through Red Rock Pass near Oxford, Idaho, and drainage northward into the Snake River (Williams, 1952, p. 1375). After a rapid drop of about 325 feet, the level of the lake stabilized at an altitude of 4, 800 feet (Provo Stage of Gilbert, 1890, p. 126). Subsequent desiccation, with numerous brief intervals of stabilization, has lowered the surface of this early lake to the present level of Great Salt Lake.

Shore Deposits of Alpine Stage

The Alpine formation contains the oldest shore deposits of Lake Bonneville. Gilbert (1890, p. 135) refers to the temporary stillstands of the Lake between the Bonneville and Provo levels as "Intermediate shorelines", but as far as stratigraphic position and age are concerned "Intermediate" is a misnomer and describes only its relative position between the Bonneville and Provo levels. Hunt (1948) introduced the name "Alpine formation" for these sediments because of the excellent development of outcrop and exposures near the town of Alpine in Northern Utah Valley. The U. S. Geological Survey has sub-divided this formation into four members. In ascending order these are as follows: one largely of gravel, one largely of sand, one largely of silt, and another of clay (Bissell, 1948, p. 164). In the Weber delta area the coarse textured sediments are not abundant and where present are only a lateral facies within the formation. Gravel and coarse sand are found near the mouths of the larger streams, but by far the largest proportion of Alpine sediments consists of silt, fine sand, and clay. For this reason the writer has not sub-divided the lithotopes of the Alpine formation, but has mapped this lithofacies as Alpine shore deposits.

Excellent sections are exposed along road cuts immediately north of Kay's Creek and north of Weber River where Highway 89 traverses the delta in a dugway. The following section measured in the vicinity of the junction of Highways 89 and 30 is typical of the Alpine formation:

Section of the Alpine formation exposed at the intersection of the Hill Field road and highway 89 (center of Sec. 1 - T4N - R1W).

Alpine formation	Feet
Sand, medium to fine grained, light brown to buff; composed of sub - angular to moderately well rounded fragments of predominantly quartz, Well-sorted.	5.0
Gravel, granules range to three inches in diameter, moderately well-rounded to sub - angular; poorly sorted, composed mostly of fragments of gnessic rocks.	1.0
Sand, fine grained, light brown to buff, moderately well-rounded quartz grains predominate; composed mostly of fragments of gnessic rock.	2.5
Clay, light yellow to brown, hard and compact	0.5
Sand, fine grained, light brown to buff, well-rounded quartz grains; well sorted	2.0

Clay, light brown, highly calcareous, hard and compact.	0.6
Sand, medium to fine grained, light brown to buff, composed of sub - angular to sub - rounded grains of quartz; well sorted.	4.0
Clay, light yellow to brown, hard and compact, weathers lighter and in blocky fragments.	3.0
Sand, medium to fine grained, light brownish yellow, sub - rounded, quartz grains predominate, laminated with iron stains about one-fourth of an inch thick	3.0
Sand, medium grained, light yellowish brown, quartz grains moderately well rounded predominate, very loose	12.0
Clay, light brown to buff, hard and compact	1.0
Sand, medium grained, light yellowish brown, silt lenses containing iron laminations interbedded throughout.	3.5
Sand, medium to fine grained, light brown to buff, quartz predominates, moderately well rounded, well sorted and loose.	6.0
	46.1

The Alpine shore features were deposited unconformably and in onlap fashion upon pre-Cambrian rocks and pre Bonneville alluvium. Due to a long narrow estuary that extended about fifteen miles up Weber Canyon the depositional environment during the Alpine stage in the Weber delta area differed greatly from most of the other major deltas of Lake Bonneville. The estuary extended into Morgan Valley, where it flared out and formed a depositional basin in which most of the coarse material carried by Weber River was deposited. Thus only the fine sediments were carried out past the mouth of Weber Canyon to form the delta. Because most of the other major rivers were occupied only by short estuaries which soon filled up, the deltas built by them contain considerable amounts of coarse gravel.

Although approximately three-fourths of the Weber delta is at the same elevation as the Provo shore level, considerable evidence was found indicating that the bulk of the sediments comprising the delta is Alpine in age. This evidence is as follows:

1. The remaining one-fourth of the delta above the Provo shore line is lacustrine capped by eolian sand.

2. A strong pedalfer soil is present in various localities separating the Alpine and Provo facies.

3. Well logs, road cuts, and excavations indicate that the distinctive lithology of the Alpine constitutes the bulk of the sediments of the delta. If the delta were of Provo age, there would be a different lithofacies due to a different environment of deposition.

4. The only change in lithology is a gravel bed approximately thirty feet thick which caps the delta.

The exposed thickness of the Alpine formation near the mouth of Weber Canyon is approximately 450 feet. Well logs show that the same type of sediments continue westward to an altitude of 4,403 feet, which would make the total thickness of the Alpine formation approximately 647 feet. Throughout the entire section, the Alpine formation is characterized by excellent sorting and very distinctive bedding. In some places the individual beds are only a fraction of an inch thick. Size grade analysis of several different outcrops were made, the results of which are shown in Figure 3.

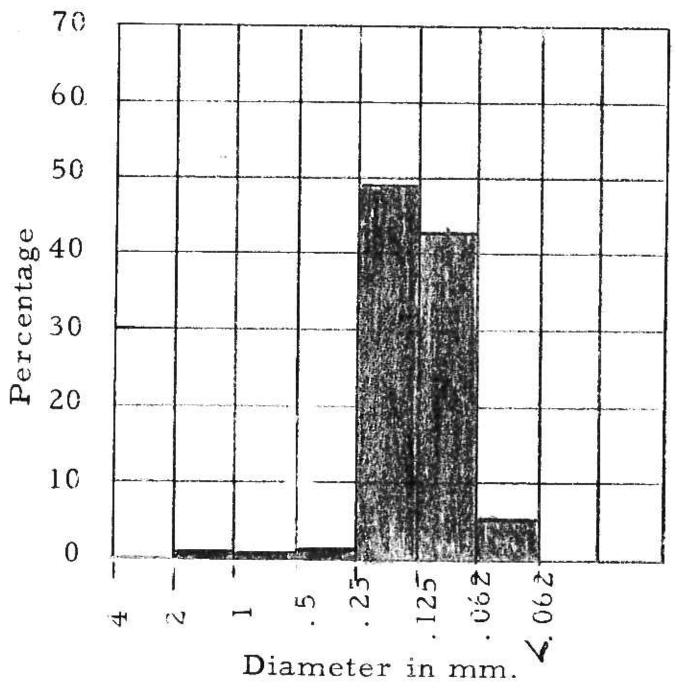


Figure 3. Bar-graph of Mechanical Analysis of the Alpine Formation

Shore Deposits of Bonneville Stage

The Bonneville shore line (Gilbert, 1890, p. 94) represents the highest level that Lake Bonneville attained. During this stage of the lake extensive hillslope embankment deposits accumulated at an elevation of approximately 5,100 to 5,135 feet. These embankments contrast sharply with the steep slopes of the Wasatch Mountains against which they were deposited. This shore line marks the boundary between two different kinds of land forms which makes it one of the more conspicuous topographic features of the area. Above it is a stream-sculptured fault with steep-sided canyons and narrow ridges, whereas below it there are wave-cut and wave-built terraces, bars, and deltas.

The sediments deposited during this stage of the lake consist chiefly of gravel ranging in size from very fine gravel to large boulders (Lane, et al, 1947, p. 937). Road cuts and gravel pits show a concentration of the granule-size clastics near the top of the section. The pebbles are highly angular and only moderately sorted. Individual beds range from one to four feet thick and are separated by thin lenses of coarse sand, commonly containing clay layers a fraction of an inch thick. Results of grade-size analysis are shown in Figure 4

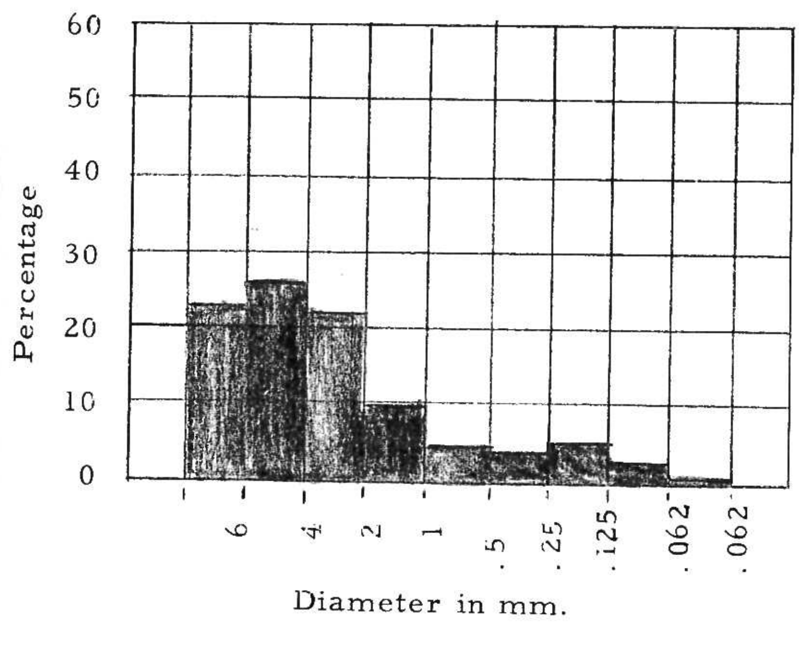


Figure 4. Bar-graph of Mechanical Analysis of the Bonneville Formation.

The coarse gravel and boulders are also poorly sorted, but have a much greater degree of rounding than does the granule-size material. Locally sand and clay lenses, mostly as intercalations, are found within the formation, but everywhere the materials are concentrated as beach deposits in a belt as much as 530 feet wide and resting unconformably upon the earlier deposited Alpine silty lithofacies. It is likely that meltwaters from mountain glaciers carried large quantities of gravel and finer sediments into the lake. The coarse material was concentrated as a beach deposit at the base of the mountains and the finer textured sediments were transported into the deeper part of the basin during the wave-washing action.

As is shown on the accompanying geologic map (Plate I), stream action has somewhat modified these embankment deposits since the lake receded from its highest stillstand. Several of the intermittent streams have dissected it into segments, whereas others have covered it with small alluvial fans. Streams issuing from the three forks of Kay's Creek have been most active in this fluviation.

Due to an overflow which developed at Red Rock Pass (Gilbert, 1890, p. 71; Williams, 1952, p. 1375) the still stand of Lake Bonneville at the Bonneville level was short lived. Evidently the down-cutting of the overflow lip was rapid and the lake waters receded rather quickly until temporary stabilization was acquired on firm bedrock. A long stillstand resulted at an altitude of 4, 800 feet, and the Provo stage of the lake began.

Shore Deposits of Provo Stage

Extensive shore features named the Provo shore line by Gilbert (1890, p. 126) represent probably the longest stillstand of the ancient lake. During this stage the waters dropped to an elevation of 4, 800 feet, which was too low for an estuary to extend up into Weber Canyon. This condition changed the environment of deposition somewhat from the earlier Alpine and Bonneville stages. Previously the coarse material was deposited in the estuary leaving only the fine sediments to be transported past the mouth of the Weber Canyon. Now the entire load of Weber River reached the delta area, where wave action reworked large sements of the Alpine shore deposits and cut them down to the Provo level.

Gravel deposited during the Provo stage constitutes a central facies which caps the delta in the area of Hill Field and then grades southward and westward into fine sand and silt (see geologic map, Plate I). The thickest section of Provo gravel lies just east of Hill Field, where more than thirty feet of this lithotope was measured in an exposure which displays offlap relations to the fine Alpine silt. The discrete pebbles are as much as six inches in diameter, and the deposit is moderately well sorted. The entire section in this area is relatively free from sand and is very compact. Several gravel pits in the area have been worked by the Air Force for construction purposes.

A number of exposures in Hill Field Base and Ogden Arsenal indicate a general thinning to the west accompanied by a facies change into sand and clay. As one might deduce, in this area the individual pebbles are smaller, the section is not nearly so compact, and there is an abundance of sand matrix. The south and west portions of the benchland contain fine sand which grades into clay on the flanks. House excavations and pipeline cuts on the southern border of the delta indicate that the Provo clay is at least seven feet thick. It is extremely hard and weathers into "blocky" fragments. The clay, as is typical of all the finer sediments in the delta area, is red to yellowish brown in color.

In northern Davis County a well developed soil profile constructed upon the Provo gravel and covered by lacustrine sediments testifies to the existence of two separate cycles of sedimentation when the lake was at an elevation of approximately 4800 feet. The first was apparently the longest during which the above mentioned gravel facies was deposited. Desiccation of the lake permitted the soil to be formed on this gravel which in places is over four feet thick. The lake rose once again to approximately the same elevation depositing gravel sand and silt upon the soil profile and gravel of the previous Provo stage. Sediments of the second Provo stage range from a little over a foot to six feet thick. Sand constitutes the major part of this lithotope but in places it grades into gravel and silt.

Post-Lake Bonneville Torrential Deposits

Small alluvial fans are found overlying the stratified beds of Lake Bonneville opposite the mouths of all the larger streams. This debris is very poorly sorted although the larger boulders, which range in size up to five feet in diameter, are concentrated near the apices at the mouth of the canyons. A few of the larger boulders display moderate to good rounding, but for the most part the material found in these fans consists of angular fragments of crystalline rocks derived mostly from the pre-Cambrian Farmington Canyon Complex. Channels cut by the three forks of Kay's Creek contain considerable amounts of the finer debris which extends over a mile out from the mountain front. The fans that were not confined to the stream channels but were spread over the lake sediments are much smaller in area, nevertheless they contain a greater volume of material. Although the fans are numerous in this region, none are extremely thick. No wells have been drilled through them, so the full thickness and stratigraphy of each fan is not known. Of those that were measured, however, none exceeded twenty feet.

Recent Series

By means of interstadial soils the different stages of Lake Bonneville have been correlated with the standard sequence of substages of the

Wisconsin glacial stage (Richmond, Morrison, and Bissell, 1952, p. 1369). This together with paleomtologic evidence discussed by Hunt (1953, pp. 14-15) places the time boundary between the Pleistocene and Recent after the last Provo stage. In this report the sediments deposited in post-Provo time include the recessional shore deposits, eolian deposits, Weber River terrace materials, and deposits made by Recent Great Salt Lake. As the lake waters subsided from the Provo level, Recent fan gravels, colluvium, fluvial alluvium, and soils accumulated. Eolian activity reworked the Alpine sediments of the delta that were exposed above the elevation of 4,800 feet. Fluvial action of the Weber River cut into the delta and deposited gravel on the different terraces it formed as well as in an apron in front of the delta. The formation of lacustrine deposits on the bottom of the receding lake and the construction of shore features at temporary stillstands continued until the lake reached approximately its present elevation. In many places the stratigraphic relations of the Recent deposits one to another are not clearly defined. The following discussion concerns the separate stratigraphic units.

Recessional Shore Deposits

Since the Provo stage the history of Lake Bonneville has been one of gradual, discontinuous recession during which minor, but locally conspicuous terraces were built. The most prominent of these is the Stansbury shore line (Gilbert, 1890, p. 134) at an elevation of about 4,538 feet above sea level. Due to the relatively short duration of the lake at this elevation the feature was not sufficiently impressed to be everywhere identifiable. In the Weber delta area there is virtually no indication of any shore line at this elevation as the delta has an almost uniform grade from its top to more than 100 feet below the elevation of the Stansbury shore. Below the elevation of 4,450 feet, however, at least thirteen minor terraces indicate temporary halts of the regressing lake. These terraces stand out very prominently on aerial photographs, being spaced approximately one-eighth of a mile apart. This equal spacing suggests rhythmic cessations in the desiccation of the ancient lake, likely indicating a close relationship to climatic cycles. The average height of these terraces ranges from ten to twenty feet except for the largest, which is thirty-five feet high. All are composed principally of fine reddish-brown to buff sand and silt interfingering with and grading laterally into clay. Both wave-cutting and wave-building activity were very important in the construction of these terraces. The fine unindurated lake bottom sediments deposited during Provo time were easily reworked to produce the new shore features. The writer made a series of hand auger holes across several of the larger terraces in an effort to determine their exact composition and to see if any facies changing from top to bottom are in evidence. In every case it was found that the terrace proper is composed of medium to fine-textured sand and that there is a concentration of clay at the base. This basal clay in turn grades into sand, but does not extend to the next lower terrace. A possible explanation for this facies change is the sorting action which took place as the terrace was being built. (See Figure 5).

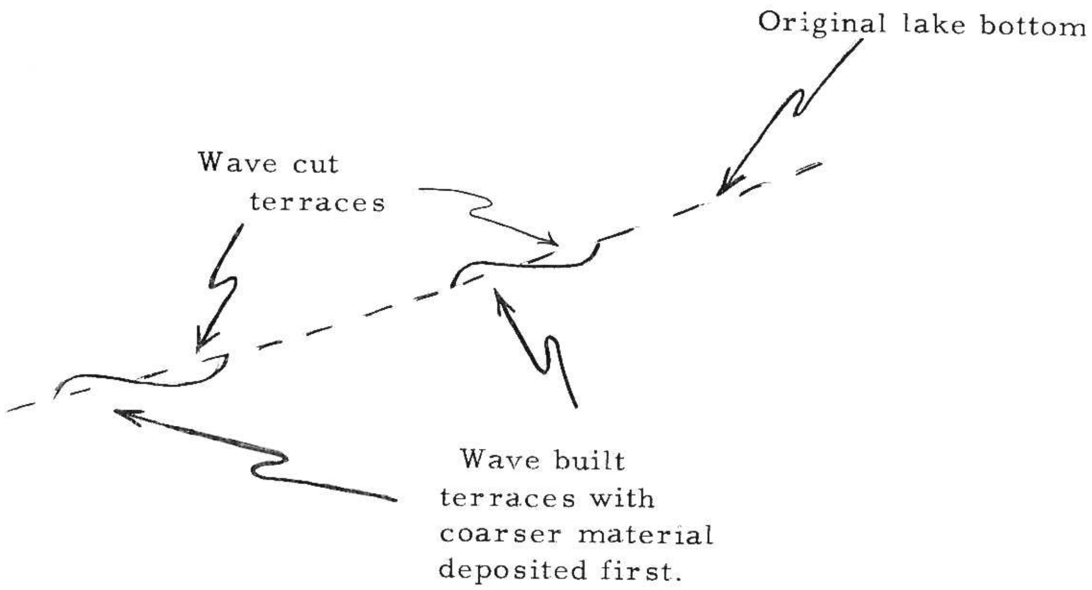


Figure 5

Within the area are topographic suggestions of several spits, but the material has been reworked by both wind and water to such a degree that they can not be mapped with any certainty.

Lake Bottom Deposits

Sediments deposited on the bottom of Lake Bonneville during probably all four of the previously described stages are found between elevations of 4, 245 and 4, 212 feet. The boundary between lake bottom deposits and Recent lake sediments was taken arbitrarily by Thomas (1946, p. 105) at the highest historic shore line of Great Salt Lake, 4, 212 feet above sea level. At the base of the last recessional terrace a hardpan layer extends as a band about one-third of a mile wide across the entire area. It is dark grayish brown and contains considerable amounts of $CaCO_3$ as a cementing material. Its exact thickness is unknown as the writer was unable to penetrate it with a hand auger and pick, but exposures indicate that it is over three feet thick.

Fine sand and silt are exposed on the surface from the hardpan to the historic shore line of Great Salt Lake. Shallow streams cut across the area exposing the materials of the upper beds of the lake-bottom sediments.

A typical section is summarized below:

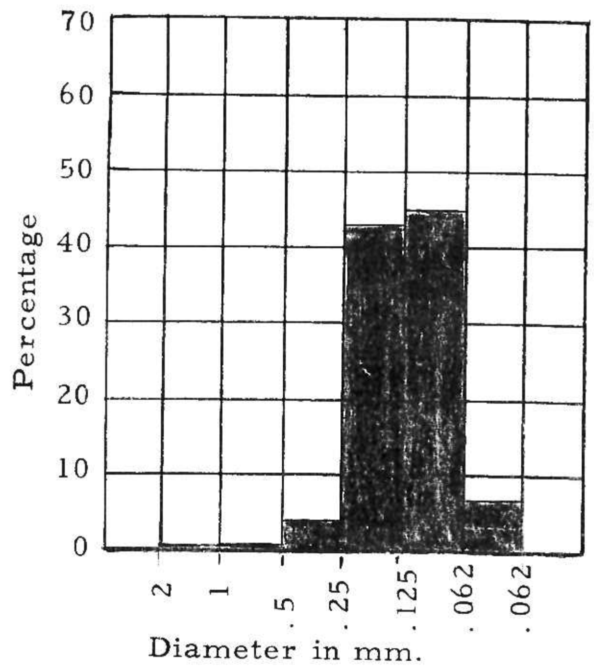
	Thickness (feet)	Depth (feet)
Silty soil-dark brown	1	1
Hard compact sandy silt	3	4
Light tan fine sand with alternating light and dark beds about 1/2" thick	3	7
Blue clay, light and brownish at first becoming dark blue with depth	4+	11+

No attempt was made to correlate the sediments deposited during the individual stages of the lake. As a group the fine lake-bottom sediments deposited by Lake Bonneville has an average thickness of seventy-five feet which overlies the coarse pre-Bonneville alluvium.

Eolian Deposits

Wind action has played an important role in post-Lake Bonneville time as an agent of erosion and transportation of the sand previously deposited by Lake Bonneville. Much of the Alpine formation of the delta that is above an elevation of 4, 800 feet has been extensively reworked by the wind into a series of southwest trending longitudinal dunes. Road and pipeline cuts reveal that these dunes were not formed entirely by deposition, but they are in part erosional remnants produced by a furrowing blow-out action of the wind. The eolian material that caps these furrows and ridges is mostly tied down by vegetation and in some areas it is under cultivation. Only in the southwest end of the dune area is the sand found in the process of migration. The majority of the dunes range between 100 and 200 feet high, although a few exceed 270 feet. Results of mechanical analyses are shown in Figure 6. Most of the grains are quartz which show a fair degree of rounding and frosting. Compared to the typical dune sand the material comprising the longitudinal dunes is very dirty, probably due to the large quantity of small silt size particles present.

Eolian activity has also modified portions of the recessional terrace sediments, obliterating some of the lake shore features. In the central part of section 33, Township 4 North, Range 2 West, a concentration of eolian sand has produced a hummocky topography, without actually constructing dunes. The prevailing winds in this area are not as strong and constant as those blowing out of Weber Canyon, but vary from east to west.



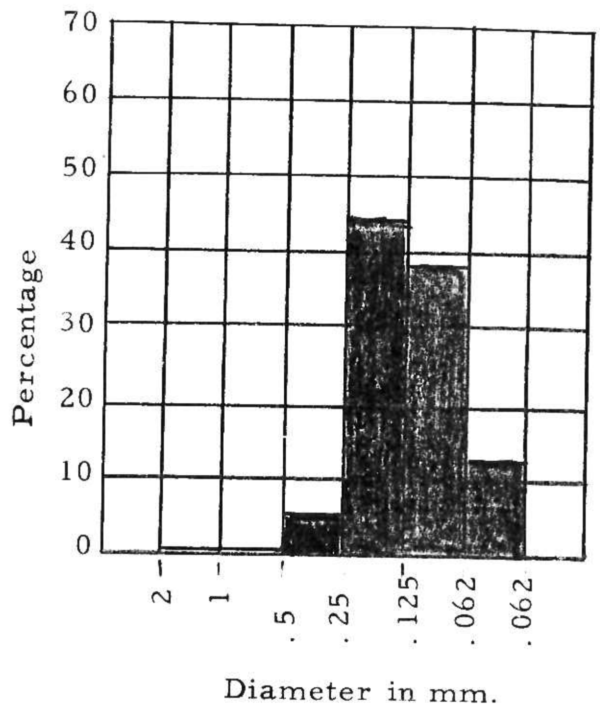


Figure 6. Bar-graphs of Mechanical Analysis of Longitudinal Dunes.

Poorly developed blow-out dunes and small longitudinal dunes were observed although the longitudinal dunes may be reworked spits. They range in height from ten to twenty feet and seem to be migrating at a slow rate. The sand is loose and supports little or no vegetation. Size grade analyses are shown in Figure 7. Over eighty percent of the grains are quartz which are well rounded and frosted.

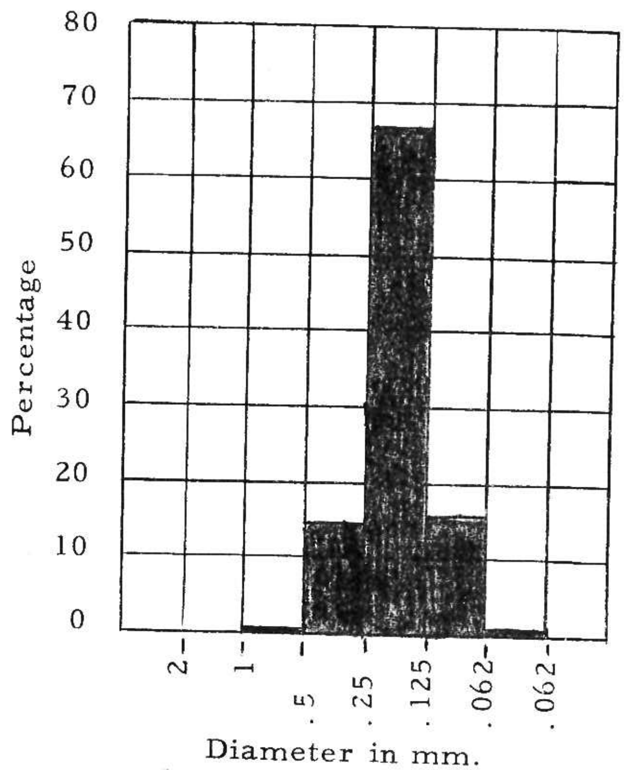


Figure 7. Bar-graph of Mechanical Analysis of the Blow-out Dunes.

Weber River Terraces

The most conspicuous effect of post-Bonneville erosion is the wide valley cut in the delta by Weber River. This valley in places is slightly more than two miles wide and 300 feet deep. It extends essentially due west from the mouth of Weber Canyon for a distance of about five miles, where it turns abruptly north and then widens and merges with Salt Lake Valley. The sides are extremely steep and are composed of the fine alpine sediments, except for four well-developed, mappable river terraces along the southern flank. The upper terraces contain considerable amounts of loose gravel mixed in a fine reddish sand matrix. Scars of recent mudflows reveal that this gravel is not very thick and varies from place to place. In the lowest terrace (elevation 4,575 feet) over twenty feet of well sorted gravel was measured. The individual pebbles and cobbles range in size up to six inches in diameter and are more tightly packed than the gravel in the higher terraces.

The present river bed and floodplain are characterized by large amounts of gravel interbedded with sand and in places covered with clay and soil.

Deposits of Great Salt Lake

The sediments deposited by Great Salt Lake are exposed between the present shores of the lake and its highest historic shore line, approximately 4,212 feet above sea level. The sediments which are accumulating in Great Salt Lake have been described in detail by Eardley (1938, pp. 1305-1411). They consist of clay, oolites, calcareous algae deposits, and faecal pellets of the brine shrimp, *Artemia gracilis*, and chemical precipitation.

Structure

Since the pioneer work by geologists of the 40th Parallel Survey (King, 1878), the northern Wasatch Mountains have received a considerable amount of detailed geologic study (Davis, 1903, pp. 127-175; Blackwelder, 1909, pp. 517-542; Eardley, 1944, pp. 880-881; Bell, 1952, pp. 38-50). Of these, Eardley and Bell have provided numerous details concerning the structure of the bedrock geology, and the interested reader is referred to their publication for details.

The Wasatch Fault

The great frontal fault which follows the west base of the Wasatch Range from Nephi on the south to Collinston on the north is well known from the writings of several eminent geologists. Gilbert (1890, pp. 340-387) discusses the fault scarps in the lake sediments in which he found considerable displacement of both the Bonneville and Provo shore features. He attributes the deformation to epeirogenic movements along the major faults of the Basin and Range, more particularly the Wasatch fault. From his observations he concludes that the recent uplift of the Wasatch Range is greater than that of any other range in the basin (Gilbert, 1890, p. 60).

Davis (1903) described the Wasatch fault and visualized a vertical displacement of approximately 10,000 feet. He concludes that before faulting there was extensive peneplanation and that the present drainage was developed afterwards. Eardley (1944, pp. 180-181) in a more recent publication concluded that prior to faulting the Wasatch Range was a maturely dissected mountainous area with extensive pediments extending valleyward (his Weber Valley surface). He also noted that the maximum displacement of the Wasatch fault at the mouth of Weber Canyon is approximately 3,000 feet.

The writer has traced the Wasatch fault along the foothills and has noted that lake sediments not only have been deposited against the footwall block of this large fault, but also contain numerous fresh scarps. The faceted spurs above the Bonneville shore line have a westerly slope ranging from 30° to 40° and clearly indicate that the major displacement occurred prior to the inception of the ancient lake. Recent movement in some localities likely along or near the Wasatch fault, however, has displaced the lake sediments and has produced a scarp which follows the base of the mountain through the entire area. The major displacement of the lake sediments ranges from 25 to 75 feet with downdrop to the valley, but numerous small minor faults that essentially parallel the Wasatch fault are present along the mountain front with a displacement of approximately ten feet. A few springs rise along the fault just south of Weber River where the scarp forms a topographic low near the beginning of a small indentation at the mouth of Weber Canyon. The origin of this indentation is explained in Figure 8. Eardley (1944, p. 883) concludes that the aspect of such a re-entrant depends on: "(1) the position of the fault in relation to the mountains and flanking pediments; (2) the throw of the fault; (3) the elevation to which alluvium accumulates, and (4) the extent of dissection." Weber Canyon, according to this concept, was a major transverse valley during the Weber Valley surface stage similar to that shown in Figure 8.

Deformation of the Delta

As far as three miles westward from the mountain front deformation of the Weber delta is evidenced by displacement ranging up to approximately 100 feet. In the area considered by this report the actual displacement was not determined, but in segments of the delta immediately to the north and south, fault scarps are traceable for a considerable distance. These faults also trend essentially north and south and most likely they join the Wasatch fault before leaving the delta area. A possible explanation why the Weber River swings abruptly north after extending five miles due west from the mouth of the canyon is that it is controlled by a major fault. No direct evidence for the existence of a fault in that area was observed; however, the deltaic sediments are very fine and the scarp would soon be obliterated by erosion.

Gilbert (1890, pp. 365-370) describes the effects of broad epeirogenic undulations which have raised the Bonneville shore line in places and lowered it in others. No topographic control of the Bonneville shore line was available to the writer and no attempt was made to establish the exact elevation of that feature. It is, therefore, impossible to state whether the shore line has been raised or lowered in the Weber delta area.

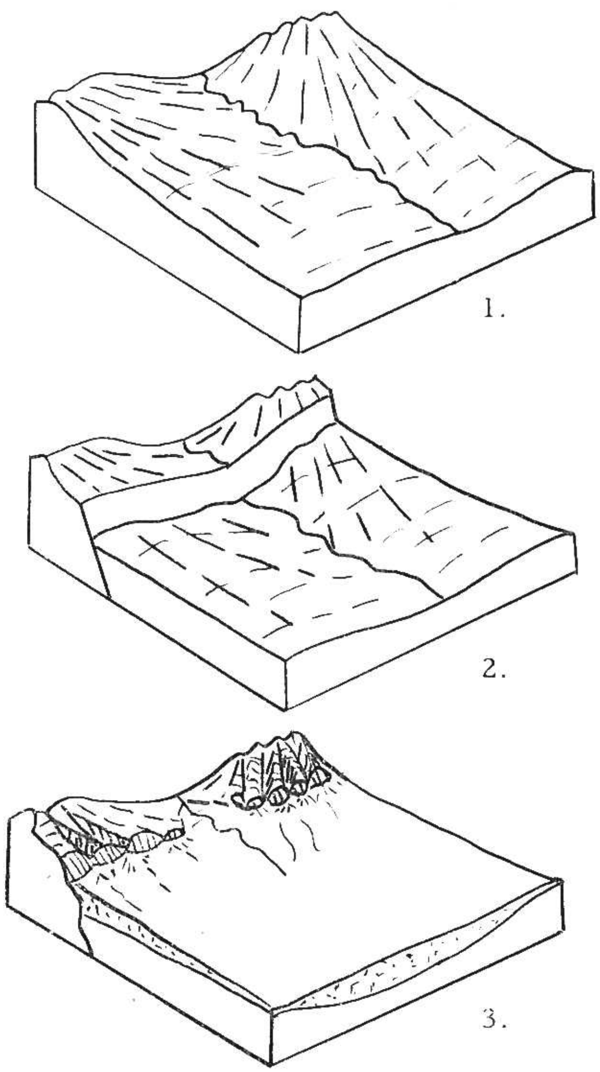


Figure 8. Development of re-entrant and fault scarp after Eardley

1. Extensive pedimentation. 2. Normal faulting. 3. The scarp is buried and in part disected. Alluvium has accumulated up the valley somewhat even over the upthrown block.

Slumping

Large scale slumping and landsliding along the margins of the valley cut by Weber River through the delta have produced a number of sag ponds and a general hummocky topography. Gilbert (1928, p. 34) suggests that superficial movement of the unconsolidated material may be responsible for setting off these slides and that it is not necessarily due to movement in the bedrock. In mapping the sediments of the delta it was found that the sediments are for the most part very fine grained, ranging from clay to silt and fine sand. This is covered in part by a veneer of gravel capable of absorbing large quantities of water. Movement of the water in the gravel is downward until the fine sediments are encountered and then the majority of the movement is down the dip of the beds until it outcrops at the margin. The fine sediments are thus extensively lubricated, which together with the existing steep slopes is ideal for the occurrence of slumping and landsliding.

The hummocky topography along the Alpine shore line also strongly suggests that slumping was prominent in that area. Road cuts reveal minor faults showing the slump type displacement. To the writer's knowledge no great amount of slumping of the Alpine shore features along the foothills has occurred in historic time, but it was undoubtedly very active during recent movement along the fault.

SURFACE WATER

The only perennial stream that flows through the area considered in this report is the Weber River which drains an area of approximately 1,584 square miles. Most of the head waters are located in Morgan and Summit Counties and receive water from a number of small glacial lakes that lie among the lofty peaks on the northwest slopes of the Uinta Range. From its source the Weber River flows through a steep, rugged canyon, at first northward, then gradually swinging due west. It enters the Salt Lake Valley through Weber Canyon, turns abruptly north, joins Ogden River, and meanders on to Great Salt Lake.

According to Utah Water and Power Board (1948, p. 115) Weber River discharges annually about 450,000 acre - feet of water into the Great Salt Lake. Woolley (1924, pp. 213-216) states that the discharge of Weber River at Devil's Slide, Utah is as follows:

Year	Discharge in Sec. Feet			Run-off in
	Max.	Min.	Mean	acre feet
1905-1906	3,150	73	529	383,000
1906-1907	4,620	166	945	685,000
1907-1908	2,110	175	426	309,000
1908-1909	5,120	217	1,027	744,000
1909-1910	2,550	106	594	429,000
1910-1911	2,270	80	444	321,000
1911-1912	3,910	---	510	370,000
1912-1913	2,460	105	417	302,000
1913-1914	3,420	88	640	463,000
1914-1915	1,430	48	302	219,000
1915-1916	1,940	---	276	201,000
1916-1917	4,102	---	---	549,000
1917-1918	2,28-	69	379	274,000
1918-1919	1,630	31	289	209,000
1919-1920	5,500	105	596	433,000

Weber County Canal receives water from the Weber River and transports it out to the farm land to be used for irrigation. It is constructed of concrete so little water escapes in seepage. The only other canal in the area is the Hooper Canal located at the western end of the area. It also has little or no effect on the groundwater conditions.

Minor intermittent streams drain the west face of the Wasatch Range and have cut through the Bonneville gravels and in places have constructed fans upon the lower Alpine terraces. The largest of these streams, the North, South, and Middle Forks of Kay's Creek have succeeded in excavating deep channels through the fine Alpine silt of the Weber delta, forming a dendritic pattern along its south edge. Hobb's Resevoir has been constructed in one of the northern branches of these channels and a relatively large quantity of melt water is caught and stored each spring for irrigation use during the summer.

Westward near the lake a separate drainage system has resulted from seepage. Irrigation water, after being spread over the bench land, perculates downward until it encounters an impermeable layer of clay. Movement is then essentially westward down the dip. At the margin of the major recessional terrace efluent seepage occurs and has begun to erode the fine sediments. Numerous tributaries form an accentuated dendritic pattern which collect into one stream that flows southwestward into the lake.

A number of small, intermittent, dendritic-patterned streams have been developed all along the shore of the Great Salt Lake between its historic and present level. These separate patterns are roughly parallel and have without a doubt been developed from seepage similar to that described above.

Springs

A few springs worthy of mention exist in the area and presumably flow most of the year. Several thermal springs known as the Hooper Hot Springs are located near the shore of Great Salt Lake in the extreme northwest corner of the area. The largest of these flows approximately sixty gallons per minute and has built a mound about twelve feet high and approximately one quarter of a mile in diameter. An east trending channal about twelve feet wide and three feet deep has been cut in the mound and serves as a conduite for most of the discharge. Most of this water is spread over an extremely flat area east of the lake producing general swamp conditions. The temperature of the water is 139° F and is said to be highly charged with minerals, although no chemical analysis was made for this study.

Surrounding the large spring are more than a dozen minor springs and spring mounds. All do not produce water and there seems to be no apparent alignment indicated on aerial photographs. The temperature of these smaller springs is lower than the large one, probably due to their slower rate of flow. According to Stoddard (1952, personal communication), who has drilled most of the wells in the area, the water from the wells which tap the intermittent aquifer is approximately six degrees higher in the vicinity of the Hooper Hot Springs than that of the Syracuse wells which tap the same aquifer elsewhere. This indicates a fairly large influence of the thermal springs upon the ground water of the surrounding area.

Springs from the Wasatch fault near the mouth of Weber Canyon discharge approximately fifteen to twenty gallons per minute. This water has

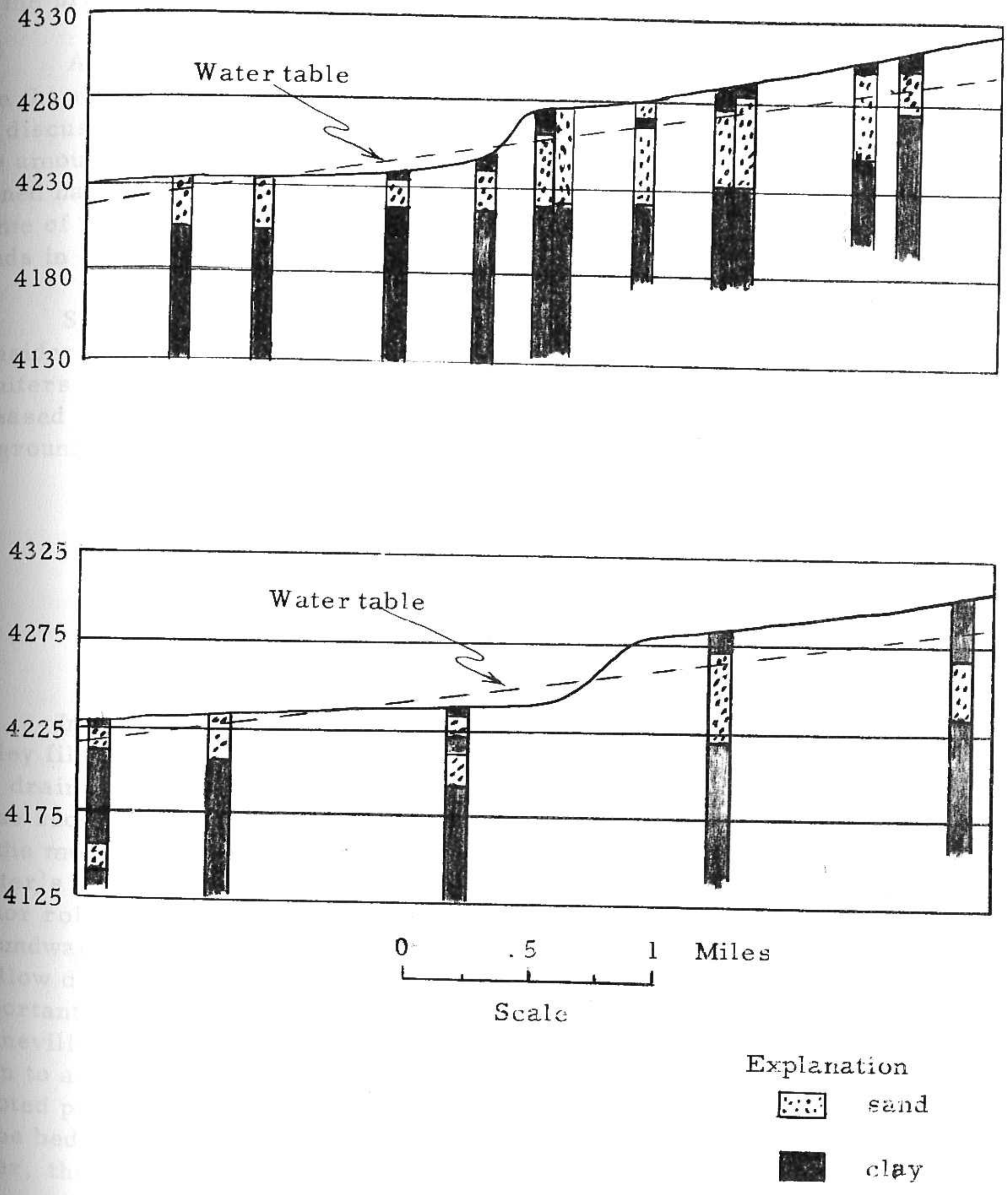


Figure 9. Profile of Largest Recessional Terrace Showing Clay Beds Which Cause Effluent Seepage.

been utilized for domestic purposes by the nearby farms in the past, but at the present time most of it is wasted.

A number of springs occur along the margins of the benchland which are the result of seepage primarily from perched water tables. These will be discussed subsequently. The flow of these springs is directly related to the amount of water poured out upon the benchland and as previously mentioned has a considerable influence upon the slumping problem of the area. Some of the water from these springs is utilized for irrigation of the farmlands in Uinta Valley and eventually finds its way into Weber River.

Several fresh water springs are located in Great Salt Lake and are considered to be one of the main natural discharge outlets for the principle aquifers of the region. According to local farmers, these springs have decreased in number and volume of discharge since the large scale utilization of ground water in the area has taken place.

GROUND WATER

General Relations

In northern Davis County the uncolsolidated sediments that form the valley fill yield by far the most important supply of groundwater. All wells and drains constructed for water supply within the area obtain water from these sediments. Water does occur, however, in the bedrock that makes up the mountain range and underlies the unconsolidated sediments. To the writer's knowledge, this water has never been utilized, but it does play a minor role in recharge. Unconfined water in the valley fill was the first groundwater to be used by the early settlers. They obtained this water from shallow dug wells, a few of which are still functioning. By far the most important supply of groundwater comes from the artesian aquifers of pre-Bonneville sediments. These aquifers are encountered at various depths down to an elevation of 3500 feet. The following discussion is therefore devoted primarily to confined water, but because the occurrence of water in the bedrock and unconfined water differs in many ways from confined water, they will be briefly considered first.

Water in the Bedrock

The bedrock formations that make up the mountains in the area are chiefly gneiss and schist (see Stratigraphy, pre-Cambrain rocks). The permeability of these rocks is generally much less than that of the valley fill; however, groundwater does occur in them in fractures and joints. This water is derived chiefly from downward penetration of precipitation upon the area of outcrop and from perculation from residual soil mantle that covers the bedrock (Thomas, 1946, p. 144). Croft (1946, p. 378) observed that "(1) practically all water from rains or melt snow passes through the soil mantle (Regolith) before it becomes available to stream flow; and (2) the mantle has a high capacity to retain water that otherwise would be available for stream flow." "The major loss of water from the Farmington water shed is that which enters the mantle each year only to be retained there by capillarity and later lost by evaporation and transportation." When the mantle reaches its field capacity, gravity water enters the bedrock, but may later appear as springs or seeps, especially in the beds of streams. Thus it becomes an important source for those streams. The ability of the regolith to retain large quantities of water decreases the surface runoff which in turn decreases the recharge of the principle artesian aquifers.

Unconfined Water

A number of shallow wells have been dug in the Lake Bonneville sediments ranging in depth from ten to thirty feet. These wells penetrate the zone of saturation and obtain water from sands and gravels under water table conditions. No measurements of the water table fluctuations were available, but during the summer of 1952, the writer found the water table to be approximately six feet below the surface in several places in the bottom land. The movement of the unconfined water is generally westward away from the mountain front although certain movements with a southern component most likely exist off the face of the delta.

Well logs indicate that clay beds, although not continuous over extensive areas, are wide spread and obstruct the downward movement of the unconfined water. In several places these clay beds are near the surface and efluent seepage occurs, producing general swampy conditions. This condition prevails below the last recessional terrace due to extensive irrigation in the valley. Stoddard (1952, personal communication) states that before the bottom lands were irrigated the swamp condition did not exist. (see Figure 9)

Perched Water Tables

As was previously explained, the Weber delta is composed mostly of clay, silt, and fine sand, capped by a thin veneer of gravel which grades laterally into sand. This lithologic relationship has produced a perched water table upon the delta from which a few dug wells obtain water. In places the perched water table is close enough to the surface to form a semi-swamp condition characterized by growth of cat-tails, willows, and tall grass. Movement of the perched water is (1) north to the margins of Uinta Valley where springs and seeps are produced, (2) west off the distal portion of the delta, and (3) south off the deltas flank. In some areas the south and westward movement of the water reaches the surface and has eroded small channels. The grain size of the material above the confining clay is important in relationship to the movement of the perched water body. The coarse Provo gravel to the north permits greater movement than the finer sands to the south; therefore the movement in a northern direction is somewhat accentuated. This has caused some of the slumping and land-slides that are discussed in the section on structure.

Recharge experiments conducted by the Bureau of Reclamation (1953) indicate another perched water table along the flood plain of the Weber River. It is encountered in the Kindell, Bryan, and Dye wells about two miles west of the mouth of Weber Canyon. This water table is from twenty-five to fifty feet below the surface and fluctuates with the flow of Weber River, indicating that the river loses water in this section. It appears one hundred feet higher than the projected water table of Observation Well No. 1 and the Hill Field Wells. Contrary to the general slope of the ground surface, the slope of this water table is toward the east where it "spills over the lip" and contributes to the lower water table.

CONFINED WATER

General Relations

Water under artesian pressure is encountered at various horizons as deep as the deepest wells have penetrated. A study of the wells logs reveals that the individual sand and gravel aquifers do not continue over wide areas, but lens out and interfinger with each other. Because of this, in discussing the confined ground water conditions, it is convenient to group the individual aquifers possessing common hydrologic characteristics into aquifer zones. These zones are separated by aquicludes which act as a confining layer although within them there are a few permeable sands that supply water to several wells. Lake Bonneville sediments cover the floor of the valley to a depth ranging up to approximately 150 feet. Generally these sediments are very fine grained and act as a confining layer for the aquifer below. A few small sands are found within the Lake Bonneville sediments which act as aquifers and supply water to a small number of shallow wells. The principle aquifers, however, are all located in pre-Bonneville sediments and have been grouped into (1) the shallow aquifer zone, (2) the intermediate aquifer zone, and (3) the deep aquifer zone (see Plate II). The confining layers separating these zones are predominately clay, but some alternating sand beds are present in certain localities.

The deepest wells within the area are located near the distal portion of the delta and supply water for the various communities and military establishments. The more shallow wells are scattered out in the valley floor and provide the water to the small farms within the area.

Aquifers in Lake Bonneville Beds

A few small wells obtain water under slight artesian pressure from beds of sand within the Bonneville sediments. Some of the oldest wells in the area obtain water from these quifers. A few of these are still flowing. Generally the pressure head in these wells is not over three feet above the land surface and the discharge is small. The water from these aquifers is, however, the coldest ground water obtained in northern Davis County and is ideal for light culinary purposes.

Shallow Aquifer Zone

Aquifers grouped in the shallow aquifer zone are generally located from 80 to 250 feet below the surface. They immediately underlie Lake Bonneville beds and represent alluvial fan and stream channel deposits of pre-Bonneville time. The accurate prediction as to the depth of this zone is sometimes difficult in areas removed from wells because the contact with the Bonneville clay is an uneven erosional surface. The uppermost aquifers in this zone are located immediately below the Bonneville sediments and usually produce more water than any other horizon within the shallow aquifer zone. The material at the contact with the Bonneville beds is predominately sand and gravel in strong contrast to the fine clay above. The lower producing horizons within the shallow zone are characterized by alternating sand and clay, each being about ten feet thick. They probably represent glacial and interglacial epochs of pre-Bonneville time. The shallow aquifer zone is not traceable under the delta area for it looses its identity as it interfingers with coarse gravel and clay in that area. The entire zone is much more productive in the northern part of the area where 102 wells currently produce from it as compared to 21 wells in the southern part. This is probably due to the fact that the sediments in this area were deposited in the flood plain of the ancient Weber River and are more directly connected with the recharge area than the fan sediments to the south. The average discharge of the wells from this zone is three gallons per minute. The temperature of the water is approximately 55° to 60° F. A serious problem of "sanding up" makes it very hazardous to attach a valve or pump to the wells so most of them flow continually.

The clay beds separating the shallow and intermediate aquifers ranges from 75 to 150 feet thick. This confining layer is not homogenous, but contains several sand beds and lenses which act as small isolated aquifers. Generally very little seepage passes through this confining layer as the temperature, pressure head, and chemical composition differ below and above it.

Intermediate Artesian Aquifer Zone

The intermediate aquifer zone is commonly encountered approximately

300 feet below the surface. The water in this zone usually is under a considerably greater head than the shallow aquifer zone and supplies water to the majority of the wells in northern Davis County. Numerous beds of alternating sand and clay, each being approximately ten feet thick, characterizes the unit. Often it is impossible to make exact correlation between the logs of wells only a short distance apart. Available evidence tends to indicate that the individual aquifers in this zone are more or less interconnected in a horizontal direction as the water is under approximately the same head. The most productive horizon, however, is a thick sand encountered approximately 400 feet below the land surface. The alternating sands and clays grade into gravel approximately 100 feet thick beneath the delta. Well logs describe this gravel unit as being composed of alternating tight and loose beds with individual pebbles ranging up to six inches in diameter. Many of the deep industrial wells have their casing perforated and obtain water from this gravel although their major supply comes from the deep aquifers.

The clay separating the intermediate and deep aquifer zones is more continuous than the upper clay unit although it does thin somewhat towards the west. (See Plate II) This unit is usually encountered at an approximate elevation of 3, 800 feet and lithologically becomes more heterogeneous with depth. Beneath the delta, this clay is described as hard and blue in most of the well logs.

Deep Artesian Aquifer Zone

Gravel underlying the hard blue clay constitutes the most productive aquifer of the area. All deeper wells encounter these sediments, indicating they are continuous and more or less blanket the area. Individual beds are much thicker beneath the delta, but show the same facies change to the west as do most other units. Logs of wells drilled out in the valley indicate a general westward thinning with an increase in the number of small tongues of sand and clay within the gravel unit. All of the large industrial wells obtain water from this zone, but those located on the delta have to lift the water from 400 to 500 feet. The deep aquifer zone is the largest underground resevoir and constitutes the most reliable zone in the area. There is no problem of the wells "silting" and consequently a greater discharge is made available.

Fluctuations of Water Level and Artesian Pressure

Changes in barometric pressure, compression of the aquifer, tidal changes and earthquakes all cause fluctuation of the water level in artesian wells in northern Davis County. The most important fluctuations, however, are due to the rate at which water is taken into or discharged from the underground resevoir. Seasonal fluctuations and extensive discharging of wells are probably the most important factors governing the quantity of water stored underground. Extensive pumping of the larger industrial wells together with a greater water consumption by the farmers in the summer results in a general drop of artesian pressure in all the wells during the summer months. Hydrograms from the various wells were not available to the writer, but generally, pressure heads drop from a maximum in April, commonly reaching a minimum in late July or August and then rising to its maximum again.

Ground Water Discharge and Use

Before any wells were drilled in the area, the only ground water discharge was through springs, seeps, evaporation, and transpiration. A number of springs are located out in Great Salt Lake and consequently their water can never be utilized. Springs along the Wasatch fault and in the valley, however, serve as a source of water for vegetation and sometimes are recoverable for domestic use. Since the drilling of wells in the area, these natural modes of discharge have undoubtedly decreased, but have not disappeared.

No data is available on the quantity of water transmitted through the less permeable material that separates the aquifers. Loss of water in this manner would take place only through the Bonneville bed as it would be lost through evaporation and transpiration after entering the free water zone.

The movement of ground water, in the area considered, is generally from its source near the mountain front, westward, and southwestward toward Great Salt Lake. The average rate of movement of water in the artesian aquifers in the Bountiful district is estimated by Thomas (1948, p. 140) to be slightly more than one foot per day. This estimation could also be applied to the Weber delta area since the two districts are very similar. The writer measured the discharge of the majority of artesian wells used for agricultural purposes in the area during the summer of 1952. This was in conjunction with a general well inventory being conducted along the East Shore Area at the time. Several previous inventories have been made--the results of which are presented in the appendix, Table 1. From these measurements it is evident that the discharge has fluctuated appreciably from year to year. In 1940, 65 wells were measured with a total discharge of 1, 019 gal/min. In 1946, 114 wells were measured with a total discharge of 1, 320 gal/min. In 1952, 67 wells were measured with a total discharge of 609/min. These figures do not tell the complete story because the wells were not measured the same time each year. A maximum discharge occurs in April and gradually decreases during the entire summer.

A record of the discharge from the industrial and military wells has been kept since they were drilled. Records made available to the writer reveal the following:

Clearfield depot is supplied by two wells, one capable of pumping 1,400 gal/min. and the other 1,050 gal/min. When they are pumped simultaneously, there is considerable interference with each other, but combined they are capable of pumping 2,400 gal/min. The drawdown is approximately 12 feet after pumping 1,360 gal/min. for four hours. Since the wells were drilled in 1942, there has been no change in the water level, indicating that the ground water resevoir is not over developed in the general area.

Hill Field is supplied by four wells, which combined, are capable of pumping more than 4 m.g.d. In 1950 the use of water was less than 1.2 m.g.d. on an average, but reached 2.1 m.g.d. in July. Hill Field and Ogden Arsenal wells are reported to yield 100-600 gal/min. per foot of drawdown. Annual pumpage in million gallons:

Hill Field	Ogden Arsenal	Year
185.0		1942
367.6	63.7	1943
480.3	143.7	1944
457.4	132.4	1945
275.7	112.2	1946
268.1	89.5	1947
327.0	65.1	1948
401.8	93.1	1949
427.2		1950

Recharge

The ground water resevoir in northern Davis County is recharged from two principle sources: (1) penetration of precipitation and irrigation water; and (2) seepage from streams. Because the area considered by this report is not a complete groundwater unit in itself, there is undoubtedly underground movement of water into the area from adjacent regions. This fact, however, will not be considered as part of the recharge. Upward movement of water along the Wasatch fault may also contribute to the recharge, but the writer believes that if any it is small and may be neglected since only one minor spring exists along the fault zone.

The surface material throughout most of the area is relatively permeable and is very favorable for the rapid penetration of rain, melting snow, and irrigation water. This could be considered as the principle recharge for the free groundwater resevoir as no influent seepage from streams exists in the area. Penetration of precipitation and irrigation water contributes very little to the principle aquifers, however, because the area of recharge for these aquifers is rather restricted. It does contribute a large portion of recharge, however, to the shallow aquifers within the Lake Bonneville beds.

One of the chief reasons for mapping the geology of the area was to determine the area of recharge for the principle aquifers. Dennis (1951) devoted much of his time to this problem.

Dennis recognized that several geologic conditions restrict the area of recharge to certain portions of the mountain front. The presence of springs along the margins of the bench lands together with the existing perched water tables encountered by wells and test holes indicate that very little, if any recharge reaches the aquifers from the delta.

According to Dennis, lakeward beyond the 300 foot contour, the hydraulic pressure is upward, preventing any downward movement of the water in that area. With these two areas eliminated as recharge areas, the only other possibility is a narrow belt along the mountain front and portions of the Weber River flood plain. Much of the Alpine and Bonneville terraces along the foothills are well above the present level of the streams. This would restrict the recharge in that area to penetration of percipitation. It would, therefore, appear that recharge areas along the mountain front are restricted to the beds of the streams. No discharge measurements have been made on the three forks of Kay's Creek; so the quantity of water coming from these minor streams is not known.

The flood plain of the Weber River is by far the most important area of recharge. The perched water table encountered in the Kendell, Bryan, and Dye wells further indicates that most of the recharge in the Weber River flood plain occurs within two miles from the mouth of Weber Canyon.

Recharge experiments conducted by the Bureau of Reclamation during February and March, 1953, reveal much concerning the problem. The area selected for these experiments is located near the junction of Highways 89 and 30. The materials in this area consist of boulders, gravel, and sand, which extend down to an unknown depth. A conical pit thirty feet deep and having a surface area of three and one-fourth acres was used in both experiments. Current meter measurements to determine the inflow and outflow of Weber River in a reach of one to one and one-half miles show a 4 to 15 percent loss of total flow.

Figure 10 is a hydrogram of Observation Well No. 1 showing the variation from January to June. Figure 11 and 12 respectively show loss of water in cubic ft/sec. in experiments 1 and 2 respectively.

It was concluded (Recharge Exp. 1 and 2, p. 8) from these experiments that appreciable quantities of water (probably from 20,000 to 40,000 acre feet annually) can be stored in the groundwater aquifers. This, of course, is the groundwater resevoir of the entire Weber delta area and not just northern Davis County.

> "Water thus stored in the ground is not subject to evaporation losses. Since there is now a tremendous

quantity of water in the aquifers, a quantity equal to that stored can be drawn out without depleting the groundwater basins. In years of drought such as the 1930's several times as much water could be drawn out of the ground than goes in; and then in years of high precipitation such as the 1940's these depletions could be returned to the groundwater basin by natural and artificial recharge. Thus long-time, holdover storage could be accomplished with only a fraction of the cost that would be required by the use of surface resevoirs."

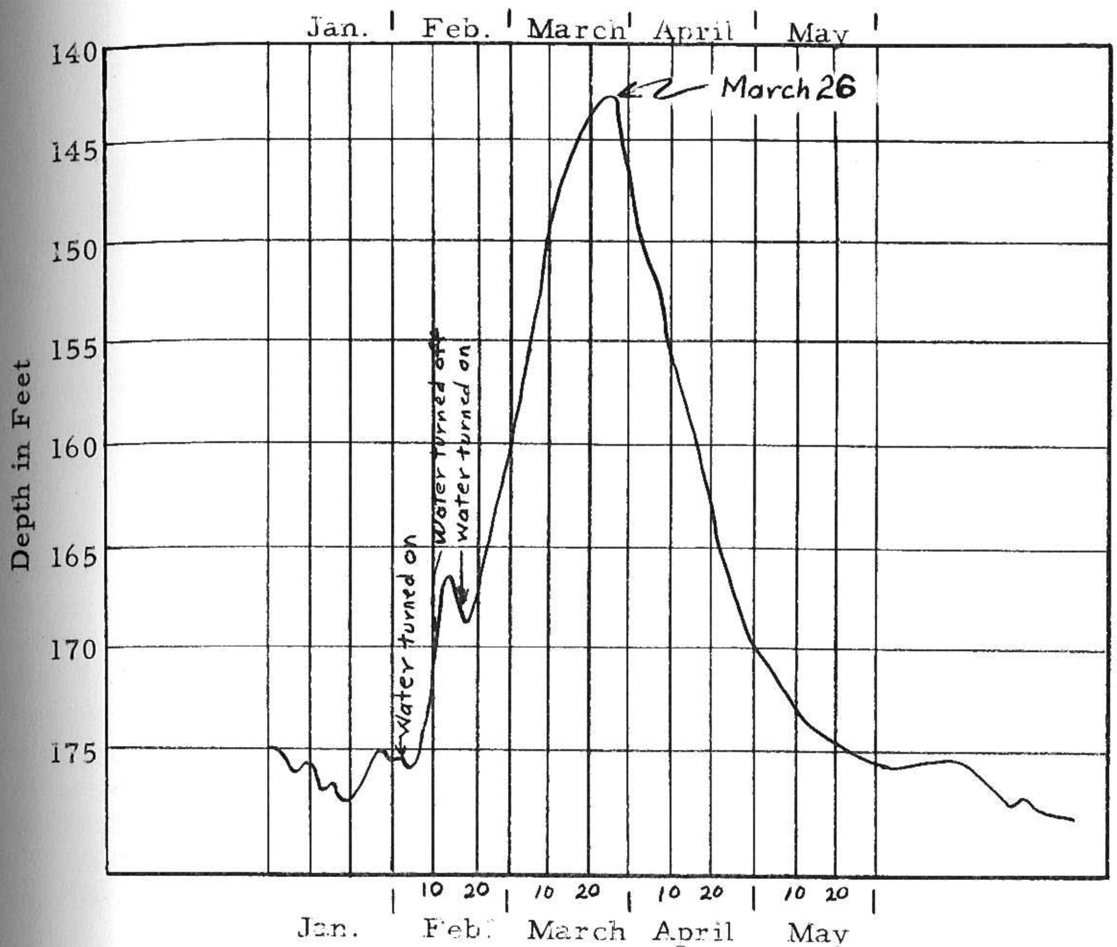


Figure 10. Hydrogram for Observation Well No. 1

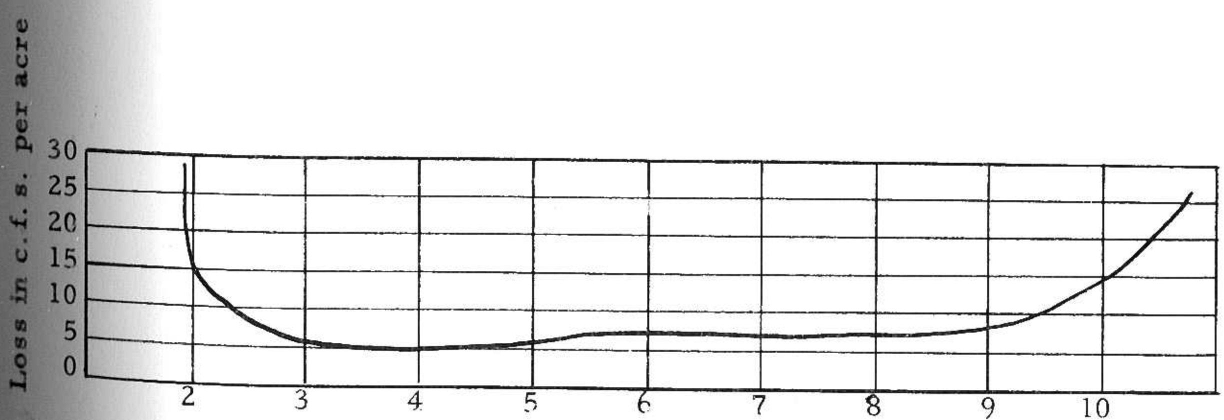


Figure 11. Loss of Water in Experiment No. 1

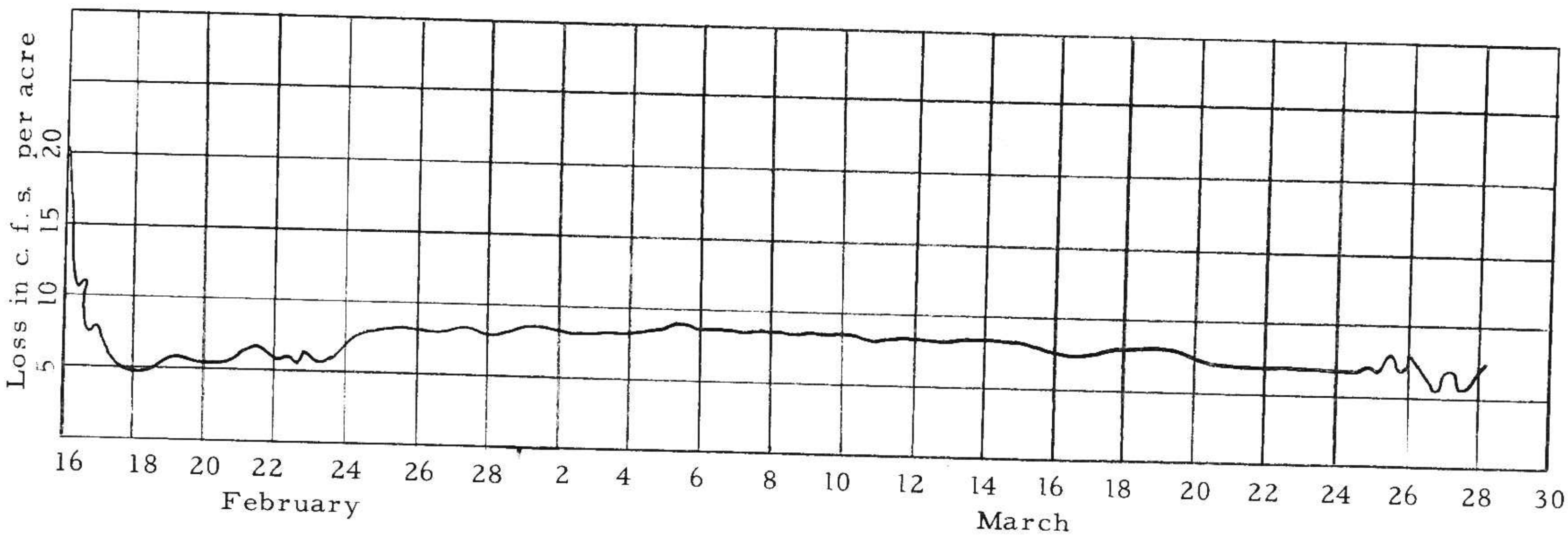
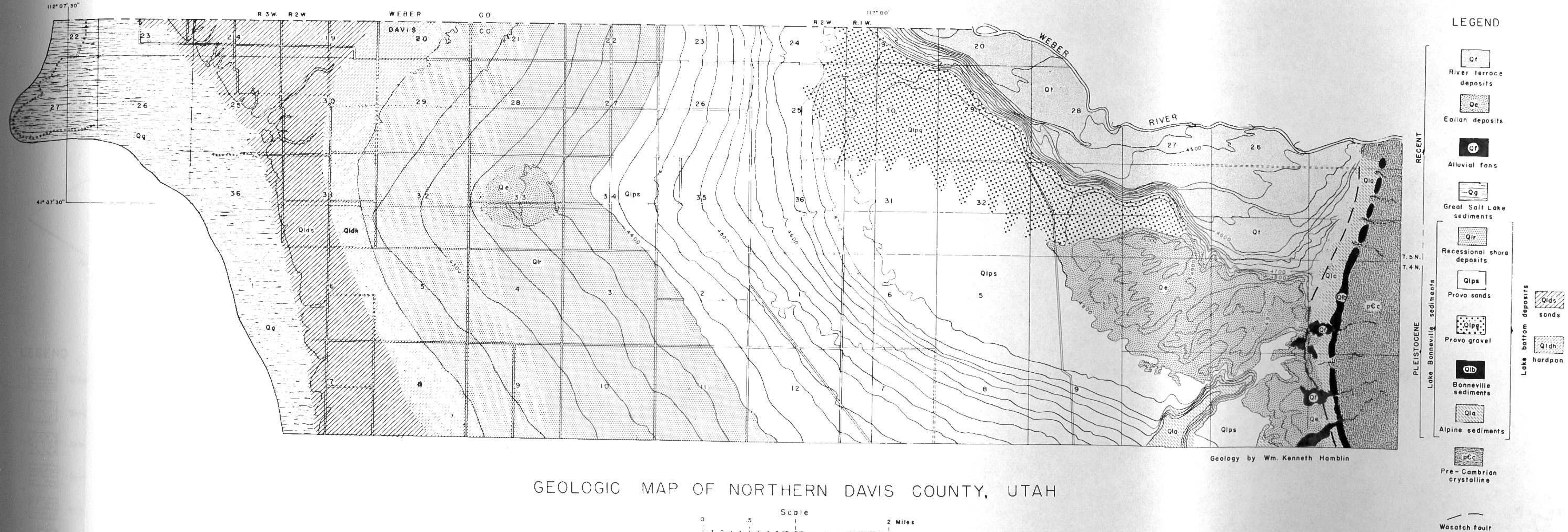


Figure 12. Loss of Water in Experiment # 2.

DEVELOPMENT POSSIBILITIES

Throughout Utah the Bonneville formation has been worked with considerable success for its sand and gravel deposits. In the area considered in this report, however, the Bonneville formation is not productive. This is due to the relative scanty development of the Bonneville and the numerous outcrops of pre-Cambrian bedrock. The gravel deposited during the Provo stage on the delta and recent deposition on the flood plain of Weber River have been worked for sand and gravel, but are by no means exhausted. Together they constitute one of the major sand and gravel resources in the area.

Groundwater has been extensively developed in northern Davis County, but it is by no means completely exploited. Discharge records indicate that there has been little if any depletion of the groundwater resources since the first wells were drilled, due to the effective recharge from Weber River. Proper control of discharge, pumping, and drilling is necessary, however, to insure the continuation of this plentiful ground water supply. Recent recharge experiments conducted by the Bureau of Reclamation reveal that if necessary, artificial recharge by water flooding could be instigated to build up any depletion. The most productive horizon comes from the sands and gravel of the deep aquifer zone (see Plate II) which should be kept in mind for any future drilling.



GEOLOGIC MAP OF NORTHERN DAVIS COUNTY, UTAH

Scale

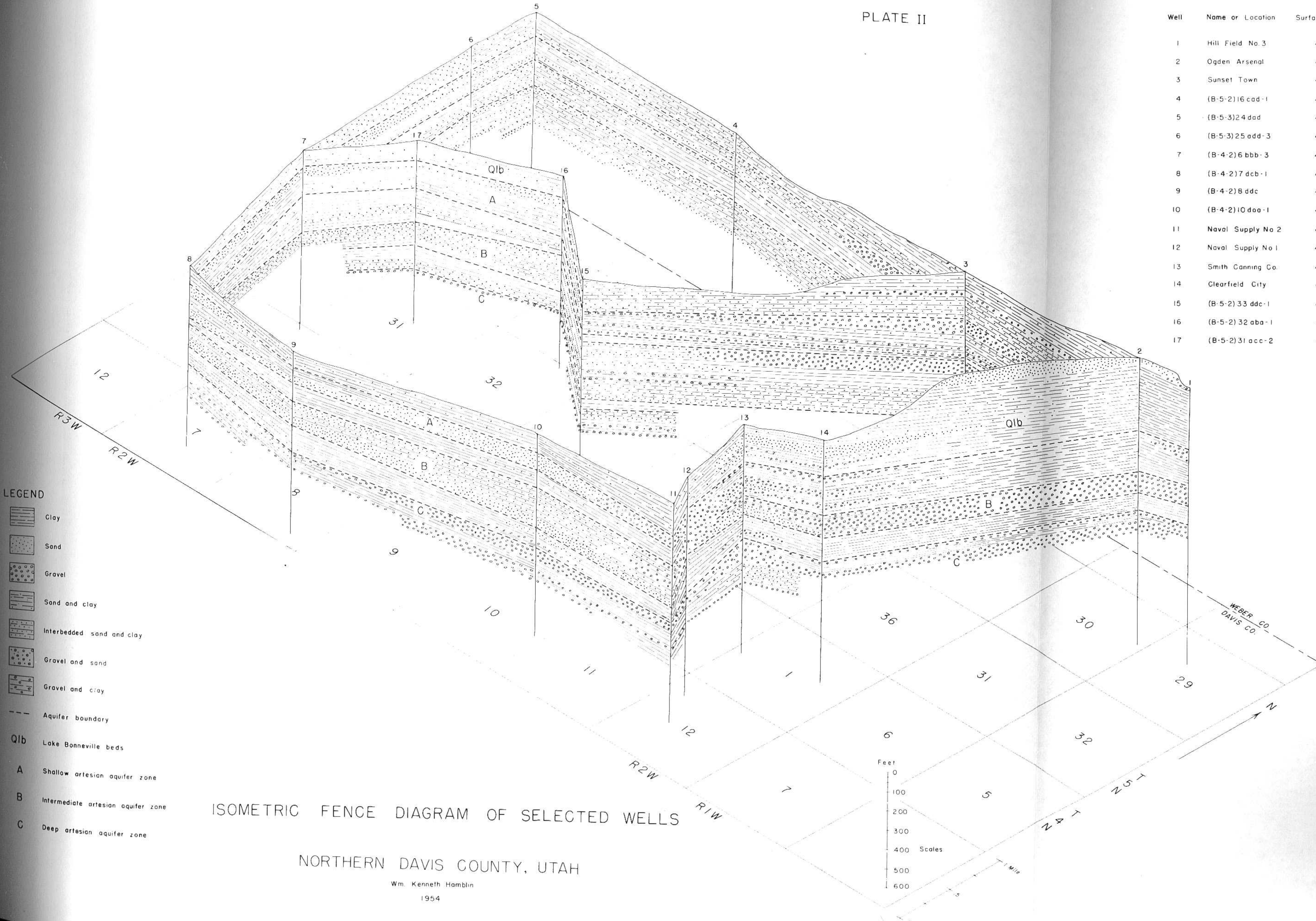
0 .5 1 2 Miles

Contour intervals

4212 - 4700 25 feet

4700 - 5000 50 feet

PLATE II



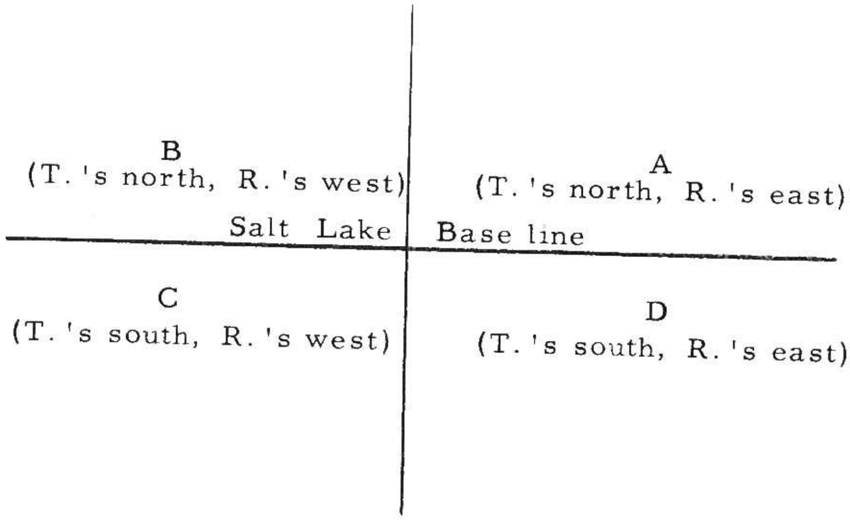
Well	Name or Location	Surface Elevation
1	Hill Field No. 3	4730'
2	Ogden Arsenal	4778'
3	Sunset Town	4575'
4	(B-5-2)16cad-1	4225'
5	(B-5-3)24dad	4230'
6	(B-5-3)25add-3	4229'
7	(B-4-2)6bbb-3	4220'
8	(B-4-2)7dcb-1	4227'
9	(B-4-2)8ddc	4238'
10	(B-4-2)10daa-1	4342'
11	Naval Supply No. 2	4435'
12	Naval Supply No. 1	4431'
13	Smith Canning Co.	4448'
14	Clearfield City	4560'
15	(B-5-2)33ddc-1	4353'
16	(B-5-2)32aba-1	4297'
17	(B-5-2)31acc-2	4240'

ISOMETRIC FENCE DIAGRAM OF SELECTED WELLS

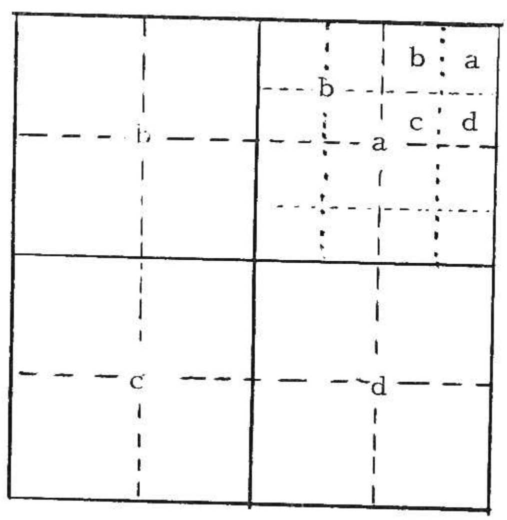
NORTHERN DAVIS COUNTY, UTAH

Wm. Kenneth Hamblin

1954



Divisions of the State of Utah into Quarters.



A Representative Section Showing Divisions into Quadrants of 160, 40 and 10 acre tracts.

Figure 13.

APPENDIX

Well Numbering System

The system of well numbering adopted by the State of Utah is presented in the Twentieth Bunnial Report, p. 87, 1936.

The state is divided into four quadrents by the Salt Lake base and meridian. The northeast quadrent is designated by the letter A, which includes Township north and Ranges east, the northwest quadrent containing Township north and Ranges west is designated by B; and the southwest and southeast are designated as C and D respectively (see Figure 13). Parentheses are used to enclose the township designation, which includes quadrent, township and range. The number after the parentheses indicates the section, and the small case letters a, b, c, and d represent, respectively, the northeast, northwest, southwest, and southeast quarters. Succeeding letters show location within the quarters down to the ten acre tract. If there are more than one well within the ten acre tract, they are numbered according to when they were drilled.

Table 1

Inventory of Flowing Wells Considered in This Report Study

Well Coordinate Number	Depth	Date Measured in Gal/Min. 1940	1946	1952
(B-4-2) 4 ccd - 1	675	4.0	---	7.3
" 4 cdd - 2	714	---	---	---
" 5 bbb - 1	620	14.0	---	---
" 5 bca - 1	680	3.7	---	---
" 6 abb - 1	150	2.0	---	---
" 6 acc - 1	363	12.0	---	---
! 6 caa - 3	250	13.0	---	---
" 6 cba - 1	350	12.0	---	---
" 6 cdd - 1	365	31.0	---	---
" 6 dda - 1	610	31.0	---	---
" 6 dad - 1	372	17.0	---	---
" 7 aaa - 1	?	1.3	---	---
" 7 aad - 1	?	---	---	2.3
" 7 abc - 3	618	8.0	---	---
" 7 acd - 1	608	33.0	---	10.0
" 7 acd - 2	360	6.0	6.4	12.0
" 7 bab - 1	365	23.0	---	2.2
" 7 bac - 1	?	21	---	---
" 7 bad - 1	?	---	---	3.3
" 7 bad - 2	?	5.0	---	9.5
" 7 bdc - 1	577	---	36.0	75.0

Well Coordinate Number		Depth	Date Measured in Gal/Min. 1940	1946	1952
(B-4-2)	7 bdc - 2	300	---	1.8	1.0
"	7 ccc - 1	190	---	3.6	---
"	7 cda - 1	723	60.0	60.0	62.0
"	7 cdd - 1	150	---	---	3.0
"	7 cdd - 3	175	9.0	---	12.5
"	7 daa - 1	65	---	1.0	---
"	7 dad - 1	600	---	6.0	8.7
"	7 dcc - 1	400	10.0	16.4	---
"	7 dcc - 2	?	---	2.0	---
"	7 dcc - 1	?	---	---	---
"	8 ada - 2	700	---	---	2.2
"	8 abb - 1	700	---	---	4.5
"	8 bbb - 1	165	---	---	2.2
"	8 bbc - 2	360	---	2.0	---
"	8 bbd - 1	625	6.0	---	---
"	8 bca - 1	?	40.0	---	---
"	8 bca - 2	?	5	---	1.4
"	8 cab - 1	600	26	---	3.1
"	8 cac - 1	300	8.0	8.2	11.9
"	8 ccb - 1	?	---	1.0	0.3
"	8 ccb - 2	?	---	1.7	---
"	8 cdd - 1	600	21.0	36.0	32.7
"	8 cdd - 2	?	47.0	---	---
"	8 dcb - 1	600	---	6.2	---
"	9 caa - 1	700	22.0	---	25.0
"	9 cdd - 1	450	21.7	---	---
"	9 ccd - 2	585	4.0	---	---
"	10 cbc - 1	556	1.0	---	---
			0.3	---	---
(B-5-3)	23 dca - 1	371	---	15.0	8.1
"	23 cad - 1	?	---	0.5	1.0
"	23 ddb - 1	490	41.0	37.9	---
"	23 ddb - 2	?	---	0.5	---
"	23 ddd - 1	600	46	50	---
"	24 daa - 1	475	4.2	---	36.0
"	24 dad - 1	200	---	---	22.5
"	24 dca - 1	115	---	6.0	---
"	24 dcc - 1	555	17.0	24.4	18.0
"	24 dda - 1	420	27.0	---	---
"	24 dad - 2	593	---	---	2.0
"	24 dda - 3	630	27.3	---	---
"	24 ddd - 1	600	---	10.7	---
"	24 ddd - 2	?	---	3.8	3.0
"	24 ddd - 3	?	---	2.0	7.5
"	24 ddd - 4	430	---	3.0	3.0
"	25 aaa - 1	150	---	5.8	3.1

Well Coordinate Number		Depth	Date Measured in Gal/Min. 1940	1946	1952
(B-5-3)	25 acd - 1	511	---	50.0	---
"	25 acd - 3	530	---	10.0	---
"	25 add - 1	480	7.0	6.6	4.5
"	25 add - 2	150	---	10.0	---
"	25 add - 3	532	---	10.2	8.2
"	25 bac - 1	36	---	1.0	---
"	25 bda - 1	345	---	22.5	---
"	25 bdc - 1	552	---	12.5	---
"	25 daa - 1	208	3.0	2.5	---
"	25 dad - 1	150	7.0	---	---
"	25 dbd - 1	525	28.0	30	---
"	25 dda - 1	127	23	30	---
"	26 aaa - 1	575	---	13.6	---
"	36 aad - 1	370	---	13.6	---
"	36 ada - 1	460	---	5.8	---
"	36 add - 1	630	---	6.2	---
"	36 add - 2	320	---	24.4	---
"	36 add - 6	600	---	2.4	---
"	36 daa - 1	320	---	37.5	47.4
"	36 daa - 3	490	---	50.0	---
"	36 daa - 2	601	44.0	50.0	56.2
"	36 dac - 1	?	46.0	---	---
"	36 ddd - 1	?	---	15.0	---
(B-5-2)	19 caa - 1	?	---	1.0	3.0
"	19 cbb - 2	?	---	---	6.0
"	19 dbb - 1	?	---	1.3	---
"	19 cbc - 1	?	5.0	---	---
"	19 cdc - 1	175	---	7.0	4.4
"	19 dcd - 1	80	7.0	---	---
"	21 daa - 1	80	---	0.0	2.0
"	21 daa - 2	80	---	---	2.5
"	21 daa - 3	60	---	2.4	---
"	21 dad - 1	?	6.0	5.3	11.7
"	21 dcd - 1	72	13.3	---	3.0
"	21 dda - 1	?	---	1.6	---
"	21 ddd - 1	110	---	8.2	---
"	21 ddd - 2	100	---	3.5	---
"	22 ccc - 1	50	---	1.2	---
"	22 cbb - 1	40	---	3.5	---
"	27 bbb - 1	80	---	0.2	---
"	27 bbb - 2	75	---	1.0	.3
"	28 aaa - 1	85	6.0	1.0	5.8
"	28 aaa - 2	85	---	1.0	---
"	28 aad - 1	80	---	4.4	3.9
	28 acc - 1	?	---	1.6	---

Well Coordinate Number		Depth	Date Measured in Gal/Min. 1940	1946	1952
(B-5-2)	28 acd - 1	?	---	3.0	3.9
"	28 acd - 2	?	---	4.0	4.0
"	28 ada - 1	?	---	0.5	---
"	28 ada - 2	?	---	1.0	1.0
"	28 add - 1	?	---	1.0	---
"	28 baa - 1	70	5.0	4.3	2.6
"	28 baa - 2	70	---	7.2	3.6
"	28 baa - 5	70	---	0.0	3.6
"	28 baa - 6	70	---	0.0	3.5
"	28 baa - 7	70	---	10.0	4.0
"	28 baa - 8	70	13.0	12.0	---
"	28 bcc - 2	?	---	1.0	---
"	28 bcd - 2	?	---	0.2	---
"	28 bdc - 1	?	---	2.5	---
"	28 caa - 1	70	---	1.0	1.0
"	28 cba - 1	?	---	0.8	---
"	28 cba - 2	?	---	0.2	---
"	28 cbb - 1	65	---	0.0	1.0
"	28 dba - 1	?	---	8.6	---
"	29 aab - 1	65	---	0.5	3.0
"	29 aab - 2	65	---	0.0	5.8
"	29 aba - 1	?	---	0.5	3.0
"	29 adc - 1	?	---	0.5	---
"	29 add - 1	600	---	1.9	---
"	29 add - 2	54	---	0.5	---
"	29 dda - 1	80	---	0.7	---
"	29 dcd - 2	65	---	---	2.0
"	30 bad - 1	165	---	3.3	---
"	30 bca - 1	?	37.0	---	---
"	30 bda - 2	645	---	40	---
"	30 caa - 1	70	---	1.5	---
"	30 cad - 3	394	---	33.6	---
"	30 cbb - 1	?	---	5.4	---
"	30 cdd - 1	324	---	30.0	---
"	30 dbc - 2	300	2.2	4.8	---
"	30 dcb - 1	80	7.0	7.9	---
"	31 abc - 1	387	25	---	---
"	31 acb - 1	200	---	10.7	---
"	31 acc - 2	730	---	33.4	---
"	31 acc - 1	140	---	0.5	---
"	31 ada - 1	672	14.0	0.0	---
"	31 adc - 1	603	9.0	2.0	---
"	31 add - 1	618	---	4.7	---
"	31 add - 3	672	---	3.9	---
"	31 add - 4	672	18.7	16.7	---
	31 baa - 1	70	---	2.2	---

Well Coordinate Number		Depth	Date Measured in Gal/Min. 1940	1946	1952
(B-5-2)	31 baa - 3	?	---	30.0	---
"	31 bcb - 1	400	---	2.5	---
"	31 bab - 1	627	100.0	100.0	---
"	31 bdc - 1	220	6.0	2.5	---
"	31 cbc - 1	327	---	4.7	---
"	31 cbc - 2	?	3.0	5.0	---
"	31 cbc - 3	503	---	7.1	---
"	31 ccd - 1	510	6.0	---	---
"	31 ccd - 2	440	6.0	2.9	---
"	31 cda - 1	275	---	0.5	3.0
"	31 cda - 3	327	---	---	12.0
"	31 dbb - 1	300	---	1.0	---
"	31 dcb - 1	75	---	0.5	---
"	31 dcb - 2	75	---	0.2	---
"	31 dcc - 1	380	---	2.5	3.0
"	31 dda - 1	?	---	1.0	---
"	31 dcc - 2	611	---	30.0	30.0
"	32 aba - 1	713	---	---	9.5
"	32 bbc - 1	620	---	0.0	---
"	32 bcb - 2	690	---	9.0	---
"	32 ccc - 1	672	---	---	10.6

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ABSTRACT

Northern Davis County lies along the boundary of the Basin and Range physiographic province and the North-Central Wasatch Mountains. It comprises the southern part of the Weber delta district of the East Shore groundwater unit and is one of the most productive regions in the State of Utah.

Subsurface studeis and geologic mapping have enabled the writer to make the following conclusions:

Several lake and inter-lake stages probably due to glacial cycles preceded the Lake Bonneville epoch during much of the Pleistocene and probably some of the Pliocene time. Sediments deposited during the lake cycle are predominantly alternating beds of sand and clay separated by fluvial gravel and sand deposited during the inter-lake stages.

Large quantities of silt and sand characterize the Alpine formation of the Lake Bonneville group. This is due, in part, to extensive erosion of thick mountain soils and in part to an estuary that existed up Weber Canyon which permitted only the finer material to be transported out into the valley. The greatest part of Weber delta is composed of Alpine silt and clay. The Bonneville stage is higher than the Alpine and is characterized by embankment deposits of gravel, but was short-lived due to an overflow which developed at Red Rock Pass. Stabilization was established at an elevation of 4800 feet producing the Provo level in which coarse sediments predominate.

Since the Provo stage sedimentation has been one of eolian activity in the delta area, fluvian action along the margin of Weber River and lacustine deposition in the receding lake.

The construction of an isometric fence diagram reveals three principle aquifer zones separated by impermeable silt and clay. Each zone contains many individual aquifer zone is the most productive.

The recharge of the principle aquifers is restricted to a portion of the Weber River flood plain immediately west of the mouth of Weber Canyon where large quantities of water are adsorbed by the permeable gravels.

The groundwater resevoir in the area is not over-developed and can be increased with proper supervision of drilling, pumping, and artificial recharges.