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AVAILABILITY OF GROUND WATER FOR LARGE-SCALE USE IN THE MALAD VALLEY-BEAR RIVER AREAS OF SOUTHEASTERN IDAHO--AN INITIAL ASSESSMENT

By

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ABSTRACT

Five areas within the Bear River drainage of southeastern Idaho offer potential for further development of ground water--the valley north of Bear Lake, north of Soda Springs, Gem Valley, Cache Valley in Idaho, and Malad Valley in Idaho. Saturated deposits north of Bear Lake are too fine-textured to yield large quantities to wells; the areas north of Soda Springs and in Gem Valley would provide large yields, but at the expense of current beneficial discharge. Northern Cache Valley has small areas of high yield in the northwestern part, but total annual yield would be only about 20,000 acre-feet and seasonal water-level fluctuation would be large.

Malad Valley contains a large aquifer system within valley fill underlying about 75 square miles. The aquifer system is several hundred feet thick, and contains about 1.8 million acre-feet of water in storage in the top 300 feet of saturated thickness. Average annual recharge to the valley-fill aquifer is about 64,000 acre-feet. Lowering of the water level 100 feet uniformly over the valley area would theoretically yield about 300,000 acre-feet from storage and salvage a present-day large nonbeneficial discharge. Sufficient water to irrigate all lands in a planned project near Samaria could be pumped with a maximum 200-foot pumping lift and then delivered by gravity flow. Such pumping would cause water-level lowering of a few feet to a few tens of feet in present artesian areas, and would cause many present-day artesian wells to cease flowing at land surface. Chemical-quality problems in Malad Valley seem not to be sufficient to prohibit development and use of the ground-water resource.

INTRODUCTION

Objective and Scope

The available surface-water supply for irrigation in Malad Valley and in the remainder of the Bear River drainage in Idaho has reached, or is rapidly reaching, full development. Still, thousands of acres of highly productive land are available to be irrigated and many people believe that irrigation of this land is necessary to the economic growth of the area. Potential industrial growth in parts of the Bear River drainage also hinges on water availability.

Recent studies by the U.S. Bureau of Reclamation and the Idaho Water Resource Board have included, among other items, consideration of the need for, and ways to accomplish, storage of Bear River water, and its distribution to the irrigable land. One result of the Bureau of Reclamation study is a proposal to transfer water by canal and pumping lift from the main stem of the Bear River to the western part of Malad Valley in Idaho. An alternative to such transfer is the development and use of the ground-water resource of Malad Valley if, in fact, one of sufficient quantity and suitable quality exists.

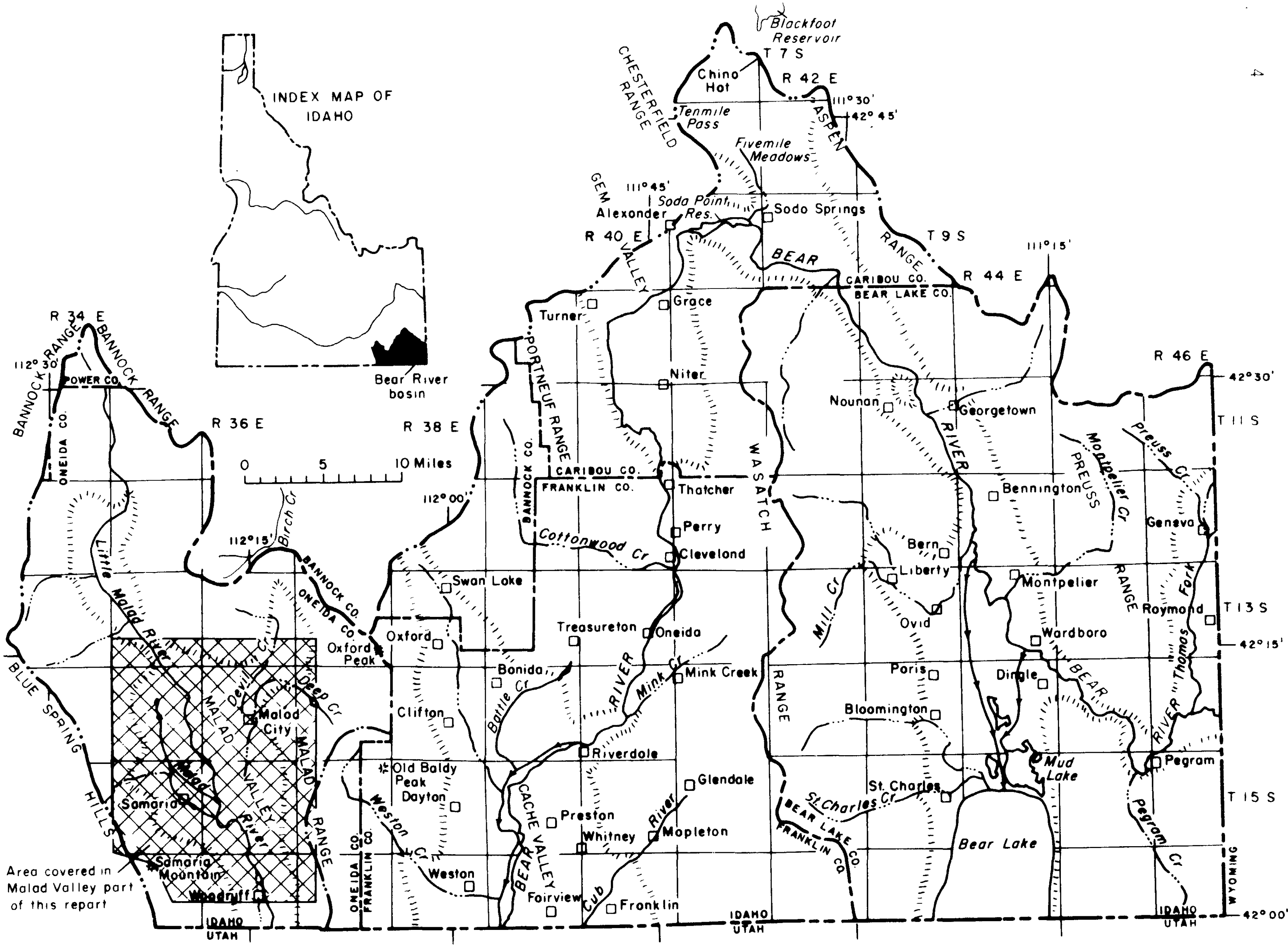
Ground water has long been developed in Malad Valley for domestic, municipal, and agricultural use, but the magnitude of the resource in terms of quantity, long-term availability, chemical quality, and capability for economic development has never been fully determined. To do so would require detailed study of a scope beyond the existing funding resources available. However, a generalized determination of the availability of ground water as an alternative to the transfer of surface water is needed as a basis for immediate administrative and engineering decision. Therefore, the principal objectives of this study and report are (1) to determine and describe the extent and character of the ground-water reservoir in Malad Valley; (2) to estimate the amount of ground water available, its recharge and discharge conditions, and its long-term yield potential for use in Malad Valley; (3) to attempt to define the chemical-quality problems in Malad Valley, identify the causes, and estimate long-term change with increased use; (4) to provide a foundation of information on which to base judgments as to future courses of development and needs for additional data; and (5) to identify areas within the Bear River drainage in Idaho wherein a potential for large-scale development of ground water may exist.

To accomplish these objectives, the work on which this report is based included: (1) assembly of published and unpublished geologic data on the Malad Valley area and additional field mapping to define the general framework of the ground-water basin; (2) gravity and seismic surveys of the Malad, Cache, and Gem Valley areas to gain data on subsurface distribution of water-bearing units; (3) drilling of 11 exploratory holes in Malad Valley to identify the character and extent of the upper confining clayey sediments; (4) drilling of one deep test well in Malad Valley to confirm geophysical data and drillers' logs; (5) analysis and synthesis of all existing hydrologic data from well logs, water-level records, chemical analyses, and user reports; and (6) preparation of a preliminary appraisal, based on available data, of ground-water occurrence, availability, and potential for development in Malad Valley and the Bear River drainage in Idaho. The report is necessarily brief and generalized, owing to shortage of time and funds. It is intended primarily as an interim information report, with the expectation that additional detailed work will be possible in the near future which will allow more precise determination of pertinent hydrologic factors.

Location and General Features

The Idaho parts of the Bear River basin, which includes the Malad Valley, are in Bear Lake, Caribou, Franklin, and Oneida Counties in the southeastern part of the State (fig. 1). Malad Valley, the principal area of study, is entirely within Oneida County. The Soda Springs-China Hat and Gem Valley areas are in Caribou County, and Cache Valley is in Franklin County. The valley areas of interest overlie structural depressions filled to varying degrees with alluvial and volcanic deposits. These areas are bounded by mountain ranges of consolidated-sedimentary, metamorphic, and igneous rocks of many types. The physiography is of the basin-and-range type, with each basin being virtually a distinct hydrologic unit.

Malad Valley, the basin of primary concern, occupies a a structural depression and is bounded by major faults with probable displacements of at least 10,000 feet along the northern and eastern margins of the valley. The down-faulted block is tilted to the northeast, so that lesser displacement occurs along the southern and western margins. Little Malad River enters the valley from the northwest and drains the bounding areas of the Blue Spring Hills on the



Base from U S. Geological Survey, Idaho 1968

FIGURE 1.-- Map of Bear River basin including the Malad Valley, Idaho.

west and the Bannock Range on the north. Devil Creek and Deep Creek combine to drain the mountainous area northeast of the valley, between the Bannock Range and the Malad Range along the eastern valley margin. These are the principal streams, which combine within the valley with large spring flows and smaller peripheral tributaries to form Malad River. Malad River leaves the valley at the south between the Malad Range and the eastern end of Samaria Mountain. The mountains surrounding the basin average about 7,000 to 8,000 feet in elevation, while the lowest elevation on the valley floor is about 4,400 feet. The total drainage area of the valley is about 485 square miles, about 90 of which compose the valley lowlands. The lowland part of the valley contains the ground-water basin.

The Bear River enters Idaho from Wyoming and flows northward from Bear Lake toward Soda Springs through a valley between the Wasatch Range on the west and the Preuss and Aspen Ranges on the east. The valley north of Soda Springs to the vicinity of China Hat and the Blackfoot Reservoir, between the Chesterfield Range on the west and the Aspen Range to the east, contains highly permeable volcanic rocks and alluvial deposits. This valley, between about 5,800 and 6,500 feet in elevation, contains a minimal amount of undeveloped land suitable for cultivation, but it has a large ground-water supply.

Bear River flows westward from Soda Springs between the Wasatch and Chesterfield Ranges into Gem Valley, thence southward between the Portneuf and Wasatch Ranges into Cache Valley before entering Utah. The floor of Gem Valley is at about 5,500 feet elevation and is underlain largely by basaltic volcanic rocks. The northern end of the valley, in the Portneuf River basin, is drained by the Portneuf River which receives some underflow from the Bear River basin. The rest of the valley is drained southward by the Bear River, which cuts deeply through the basaltic rocks and drops several hundred feet before leaving the southern end of the valley.

Only the northern end of Cache Valley lies in Idaho, and this part forms a wedge narrowing northward between the Malad Range and the southern end of the Portneuf Range. The valley floor is underlain by a deep alluvial fill, only the western part of which is significant as a ground-water reservoir. The valley floor is about 4,700 to 5,000 feet in elevation and is drained southward by Battle Creek and other minor tributaries. Oxford and Old Baldy Peaks rise abruptly some 3,000 feet along the western margin of the valley and provide a large recharge from winter snowmelt to the alluvial fill.

MALAD VALLEY AREA

Generalized Geology

The mountains that surround the valley-fill deposits of Malad Valley are composed of diverse crystalline, metamorphic, and consolidated-sedimentary rocks ranging in age from possibly Precambrian to early Tertiary. Most, however, are carbonate sedimentary and meta-sedimentary rocks of Paleozoic age that are broken or fractured and contain solution openings through which ground water may move. A thick section of fine-textured, moderately consolidated deposits of Tertiary age, mapped as Salt Lake ? Formation (fig. 2), occurs in the northern part of the Malad Range in the drainages of Deep and Devil Creeks, and probably occurs at depth beneath the valley floor.

The valley floor overlies a deeply depressed structural block, covered by a great thickness of sediments. The upper several hundred feet of these sediments represent the late Tertiary, Pleistocene and Holocene (Recent) Epochs when alluvium and lake sediments were washed into the valley from the surrounding mountain areas by essentially the present-day drainage system.

Morrison and Frye (1965) stated that the Great Salt Lake basin and its tributary valleys have been occupied by lakes several times during the last 75,000 years, with long periods of desiccation between. The shoreline scars from the latest of these lakes, Lake Bonneville, are clearly visible throughout Malad Valley. The present-day water-bearing units within the valley fill probably represent sheets of alluvium that were deposited during periods when there was no lake in the valley, and during the early period of the latest lake filling of the valley. Clay, silt, and other fine-textured units probably represent deposits of sediments brought into and distributed in the lakes. Some units may represent fossil soil horizons that were developed during periods of desiccation. Subsurface data are not sufficient to identify specifically the glacial or lacustrine stages of the Pleistocene Epoch. It is quite clear, however, that during the latest and highest level of Lake Bonneville, a blanket of fine-grained sediments was deposited over nearly all of Malad Valley south of about the latitude of Malad City. Large deltaic deposits associated with this high lake level, and particularly with the slightly lower level at about 4,800 feet elevation, during Provo time, form an extensive bench around the northern end of the valley west of Malad City.

Physiography

Land forms in and around Malad Valley are typically those of the basin-and-range topography of the Great Basin. Physiographically, the valley area may be divided into four major parts: the mountains, the alluvial apron, the deltaic benchland lake features, and the nearly flat valley floor.

Mountains.--The mountains that border the southern and western parts of the valley contain principally carbonate rocks (limestone and dolomite), calcareous sandstone and siltstone, and quartzite. Those mountains along the eastern margin contain massive units of carbonate rocks, quartzite, siliceous metamorphic rocks, and large thicknesses of moderately consolidated alluvial and colluvial deposits (Salt Lake ? Formation). At the northern end of the valley, the Bannock Range contains carbonate and siliceous metamorphic rocks, and great thicknesses of Tertiary volcanic rocks of many types. The overall size and shape of the mountains have been determined largely by uplift and warping associated with large-scale faulting. Subsequent weathering and erosion have produced characteristic topographic features for each of the many rock types. Of particular interest is the subdued, rolling topography having only moderate drainage development on the soluble carbonate rocks that predominate in the Blue Spring Hills. The siliceous and metamorphic rock units form bold ridges and valleys, whereas the softer sediments of the Salt Lake ? Formation erode readily into broad valleys of low relief.

The rocks of Paleozoic age in the mountain areas were mapped (fig. 2) as undifferentiated pre-Tertiary bedrock.

Alluvial apron.--The alluvial apron is the area of intermediate slope between the mountains and the flat valley floor or the deltaic benchland. It is composed principally of coalescing alluvial fans deposited by the many small streams. The apron is poorly formed or absent along much of the southern and western parts of the valley, owing to the erosional characteristics of the Blue Spring Hills. At the northern end of the valley, and along the flanks of the Malad Range south of about Malad City, the apron is well developed and extensive. The deposits are mapped (fig. 2) as Quaternary gravels and represent exposed parts of the extensive alluvial sheets that were deposited throughout the valley during periods of low lake level and around the lake margin during other periods.

Slopes on the alluvial apron decrease from more than 500 feet per mile near the mountain front to a few tens of feet per mile near the valley floor. The lower part of the apron merges with or is overlapped by, similar deposits that poured into the edge of Lake Bonneville during its highest level and during its recession to the Provo level. The deposits of the different stages are virtually indistinguishable, as the younger were largely derived from reworking of the older. Local relief on the apron gravels is commonly as much as 100 feet, but averages less than 50, and results from stream and rill entrenchment.

Lake features.--The northern end of the valley, between approximately the 4,700-foot topographic contour and the Provo shoreline (fig. 2), is a benchland underlain by moderately coarse but heterogeneous alluvium. The surface slope of the benchland is only about 50 feet per mile. This alluvium was transported by the Little Malad River and by Deep and Devil Creeks and was deposited as coalescing deltas built into Lake Bonneville during Provo time. The valleyward toe of the deltaic deposits extends to about the 4,600-foot contour, where the valley-floor slope breaks sharply to only a few feet per mile. The canyons of Malad River, Little Malad River, Devil Creek, and Deep Creek are cut deeply into the deltas, exposing alternating beds of dirty gravel, sand, and clayey silt.

During the last major filling of Lake Bonneville in late Pleistocene time when the water rose to an elevation of about 5,250 feet, a long arm of the lake was formed in Malad Valley. Although many of the resulting shoreline features and deposits characterizing this level have been eroded away or buried by stream deposits, beach-line scars and cut benches are still prominent around the valley at about the 5,200-foot level. The Provo stage designates a long period of time when the lake was at a level of virtual stability at about 4,800 feet elevation. During this stage, the rivers and streams entering the northern end of the lake built the extensive deltaic benchland. Hydrologically perhaps the most important feature formed during the period of Lake Bonneville is a blanket of silt, silty fine sand, or clayey silt that represents the deep-water, lake-bottom sediments spread over the entire valley floor south of the toe of the deltaic deposits. These sediments are from about 70 to 100 feet thick at the northern end of the valley, thin to about 50 feet near the valley center, and then thicken to more than 100 feet in the narrow outlet at the valley mouth. All these deposits were mapped as alluvium.

Valley floor.--The valley floor is flat, sloping from north to south only about 20-30 feet per mile. The flatness extends without break nearly to the mountain flanks to the east and west and covers an area of about 28,000 acres. The principal streams are entrenched a few feet into the clayey sediments, and the peripheral drainages built minor alluvial cones or fans onto the floor as Lake Bonneville receded and abandoned the valley. Throughout the period of Lake Bonneville and since, large springs discharged on and at the fringes of the valley bottom. Some of the spring water was mineralized, and some was warm. Consequently, the valley bottom contains areas of travertine or of well-cemented sediments that reflect a long period of spring discharge. Evaporation of ground water that has been forced upward to the land surface by artesian pressure, created by the clayey blanket of the valley floor, has produced extensive areas of saline soils in the central and southern part of the valley.

Principal Lithologic Units

In this report, the rocks occurring in Malad Valley divided into two major groups on the basis of their hydrologic properties. The unconsolidated deposits that form the valley fill and the flanking alluvial apron are highly porous and the coarser of them commonly transmit and yield water readily. The consolidated rocks, which occur in the mountains and at depth beneath the valley fill, commonly have low porosity and permeability and, except where highly fractured or altered by secondary features such as solution cavities, do not readily transmit or yield large quantities of water.

The five principal lithologic units used in this report are presented in table 1. These units are: The Cambrian and Ordovician sedimentary and metamorphic rocks of the Bannock and Malad Ranges, the Pennsylvanian sedimentary and metamorphic rocks of the Blue Spring Hills and Samaria Mountain, the Tertiary sediments (Salt Lake ? Formation), the Quaternary gravels, and the younger alluvium. Distribution of the units is shown in figure 2.

Table 1.--Principal lithologic units

Age	Unit designation	Estimated thickness (feet)	Lithology	Occurrence	General hydrologic properties
Quaternary: Pleistocene and Holocene	Valley fill: Alluvium (Qal)	0-200	Unconsolidated alluvial and colluvial deposits of interbedded sand, gravel, silt, and clay. Materials generally moderately to well sorted and form lenticular bodies. Top 50-200 feet is dominantly clayey silt or silty fine sand in southern part of valley. Coarser, with more gravel in northern one-fourth of valley.	Occurs primarily as Lake Bonneville and associated deposits over most of the valley and as slope wash, flood-plain, channel, or reworked lake deposits along the valley margin and in tributary canyons.	Sand and gravel deposits are highly permeable and act mainly to transmit surface recharge to the deeper aquifer units. Generally above the water table. Silt and clay deposits are nearly impermeable and act as a confining blanket over most of valley.
Quaternary: Pleistocene	Valley fill: Gravel (Qgr)	0-2,500	Alluvial and colluvial deposits and sand, gravel, silt, and clay. Dominantly coarse, with lenses and sheets of gravel. Coarsest toward the north, becoming more silty at depth and toward the south. Deeper lithology inferred from geophysical data.	Occurs primarily as alluvial-fan deposits and sheet outwash related to periods of high precipitation. Includes talus near the mountains, high-level shoreline deposits, and extensive sheets of gravel or sand that form the main aquifer of the valley. May be locally faulted and uplifted.	Permeability ranges from low to very high. Upper 250-300 feet mainly gravel of high permeability, overlying about 300 feet of alternating permeable sand and tight clay. Basal part of section probably poorly permeable.

Tertiary	Consolidated rocks	(Salt Lake ? Formation) (Tsl)	0-5,000	Moderately consolidated sand, silt, and clay with some scattered gravel. Unit generally massive and silty. Principally an alluvium and colluvium of great areal extent and thickness. May contain some volcanic material.	Occurs widely over the northern end of the Malad Range and in the drainages of Deep and Devil Creeks. Also, is probably the basalt deposit beneath the valley fill. Easily eroded, and reworked material makes up much of the volume of younger deposits.	Generally poorly permeable. A few gravelly zones moderately permeable, but bulk of deposit outside valley area. Accepts seasonal precipitation and yields slowly to provide sustained base flow. Probably poorly permeable and water saline beneath valley.
Pennsylvanian		Sedimentary and metamorphic rocks of the Blue Spring Hills and Samaria Mountain (pTu)	---	Largely dolomite and calcareous sandstone of the Wells Formation. May contain some units of the Mississippian Brazer Dolomite or Madison Limestone south of Woodruff fault. Contains some massive beds of quartzite south of Samaria.	Occurs as the mountain-forming rocks of the Blue Spring Hills and Samaria Mountain. Probably forms the basement of the valley. Highly faulted, folded, and tilted. Beds are tilted generally southwest at low angle.	Generally poorly permeable except along joints, fracture, and bedding planes where solutioning has opened large passageways. Malad Spring, Pleasantview Springs, and Woodruff Spring all derive part of their large flows from this unit. May transmit large volumes directly to the valley-fill aquifers, and probably serves as part of the subsurface-outflow section.

Table 1.--Principal lithologic units--Continued

Age		Unit designation	Estimated thickness (feet)	Lithology	Occurrence	General hydrologic properties
Cambrian and Ordovician	Consolidated rocks	Sedimentary and metamorphic rocks of the Malad and Bannock Ranges. (pTu)	---	Limestone, quartzite sandstone, and conglomerate, highly cemented and, in part, re-crystallized.	Occurs as the central masses of the Malad and Bannock Ranges. Highly faulted and tilted. Dips are highly variable in short distances. Deeply jointed and fractured.	Generally poorly permeable, but may transmit large volumes through openings in calcareous units. Probably permits deep circulation to supply warm springs on valley margin.

Structural Features

Major faulting was the primary process in formation of Malad Valley. Geophysical studies suggest that the deepest part of the valley fill is beneath the western edge of Malad City near the northeastern corner of the valley. Those studies and regional geologic relationships indicate that large normal faults with many thousands of feet of displacement bound the valley along its northern and eastern margins.

The southern end of the valley is bounded by the northern flank of the Samaria Mountain which is an expression of the east-west trending Woodruff Fault. Although it apparently does not displace the alluvium in the outlet from the valley, displacement of the basement rocks by the fault clearly controls the narrow, subsurface-outflow section of alluvial deposits across the southern end of the valley.

Faulting is not as clearly evident near the western margin of the valley as elsewhere. However, geophysical data indicate the existence of a normal fault that displaced basement rocks downward at least 500 feet on the valley side. Hydrologic data suggest that this faulting produced in the valley fill material a barrier to the flow of water moving toward the valley from the Blue Spring Hills. This suggests that the latest fault movements occurred recently enough to affect the aquifer systems.

Although much detailed field work is needed to determine the exact locations and characteristics of the various faults, the regional geologic relationships require large displacements and thus dictate the relative direction of movement. Detailed gravity and seismic data indicate, however, that the greatest displacements by faults are along the eastern and northern sides of the valley. Possibly, 7,000 feet of sediments fill the valley depression over the down-faulted Paleozoic rocks that are tilted northeastward. This suggests perhaps 10,000 feet of vertical displacement near Malad City since Pennsylvanian time, and as much as 3,000 feet since late Pliocene time.

Valley-fill Reservoir

The valley-fill reservoir is composed of Quarternary gravel and younger alluvium that partly fills the structural depression underlying Malad Valley. These deposits overlap the bedrock along the valley margins and extend both up the principal tributary valleys and southward through the outlet valley. The upper few hundred feet of the deposits contain the only known aquifers in the valley from which large-scale ground-water supplies may be obtained. Consequently, the elements of the hydrologic system are discussed in the following pages in terms of their relation to the valley-fill reservoir.

Extent and Boundaries

The valley-fill reservoir is about 12 miles long, 7 miles wide, and has a surface area of about 75 square miles. Bedrock surfaces of the adjacent mountains and their subsurface extensions form the lateral boundaries of the reservoir, except in the northwestern corner where alluvium and older sediments provide conduits for subsurface inflow to the reservoir, and at the southern end of the reservoir where alluvium provides a conduit for subsurface outflow to Utah. The boundary bedrock is largely calcareous, with solution channels that probably transmit water directly to the aquifers from the mountains. Nevertheless, the overall permeability of these rocks is so much less than that of the aquifers of the reservoir that the mountain rocks are considered to be the reservoir boundaries.

The configuration of the lower surface of the valley fill has not been determined, but several deductions can be made from geophysical data and geologic principles. Detailed gravity measurements made by the Geological Survey suggest that the thickness of sediments in the valley ranges from about 600 feet near the southwestern margin to as much as 7,000 feet beneath the western edge of Malad City. Figure 3 shows gravity anomalies and their distribution in the valley. The anomaly lines reflect the approximate configuration of the base of low-density sediments. To further define the character of these sediments, the Geological Survey made a seismic survey across the valley from the northern end of Malad airport to the western valley margin. This survey provided data which indicate that the base of valley fill rests on either basement rock or semi-consolidated older sediments (Salt Lake ? Formation) at depths ranging from about 600 feet on the west to about 2,500 feet on the east (geophysical section A-A, fig. 2). From these data it seems that the valley fill has a wedge shape, thickest at the northeast adjacent to the major faults along the northern and eastern valley margins, and thinning toward the west and southwest. The geophysical data suggest that throughout most of its thickness the valley fill abuts faults on all but the southern side of the valley. The upper part of the valley fill overlaps the fault along the western margin of the valley and extends into tributary drainages.

The thickness of alluvium in the Little Malad River valley is unknown, but wells about 170 to 210 feet deep reportedly hit bedrock within about 1 mile of the flank of the Bannock Range. Farther west, in sections 27 and 34, T. 13 S., R. 35 E., wells 385 to 415 feet deep failed to reach bedrock. Therefore, it is inferred that the Little Malad River valley has permeable fill to depths of at least 415 feet capable of transmitting underflow to the main aquifers of the valley fill.

All data indicate that the alluvium in the Deep and Devil Creeks embayment is probably little more than 100 feet thick. Fine-grained, semi-consolidated sediments, or consolidated bedrock is encountered in wells at shallow depth. Also, re-working of fine-textured Salt Lake ? Formation and Quaternary gravels has caused the alluvium there to be less permeable than that in Little Malad River valley.

The geophysical data for the valley indicate that the alluvial valley fill in the outlet valley of Malad River at the southern end of the valley is quite thin and narrow. This is further indicated by the distribution of the consolidated-rock outcrops and the faulting pattern. There are no records of wells having reached bedrock in the center of this valley, but well 16S-36E-10adl (fig. 5) reportedly was drilled 360 feet in search of flowing water. There is no record of materials drilled, and it is assumed that drilling stopped when bedrock was struck. This well, in the center of the outflow valley, provides the only direct indication of depth of fill, and the data relate closely to the geophysical data. Consequently, it is assumed that the alluvium is about 350-400 feet thick in the outflow section. The upper 100 feet of this section was tested during the study by augering six test holes and was found to be uniformly silty to clayey, with only minor amounts of fine sand.

Well records and reports from local residents also confirm that the upper 100 feet or more of the alluvium is too fine textured to transmit large amounts of water under existing ground-water gradients.

Distribution of Water-bearing Units

There are several hundred wells drilled, dug, or driven varying distances into the subsurface materials of Malad Valley. These have been constructed during more than 70 years, by many people with a wide variety of experience and purpose, and almost always without accurate record or description of what was found in the subsurface. A few professional well drillers, however, did keep records of their drilling and these form the basis for interpreting the occurrence and distribution of the water-bearing units of the valley fill. One driller, Mr. Charles B. Gardner, has lived and worked in the valley since about 1934, has drilled wells over most of the valley, and has kept the most detailed and most descriptive logs available. To test and confirm these logs, to gain direct data on subsurface lithology, and to confirm interpretations drawn from the geophysical data, a test hole was drilled as a part of this study in sec. 35, T. 14 S., R. 35 E.

The test hole was located near an irrigation well, 14S-35E-35db1, drilled by Mr. Gardner for which a log was available. Also, at this location the geophysical data indicated the valley fill to be at least 1,000-1,200 feet thick. Although planned to be drilled to the base of the valley fill, the well was terminated at 915 feet because of costs and limitation of funds. Figure 4 presents the logs of the test hole. Because these logs verified the driller's log of well 14S-35E-35db1, it was assumed that most of the other well logs in the valley are reasonably accurate. With these confirming data, the distribution of the water-bearing units over the valley could be interpreted using drillers' logs. The distribution of the wells used for interpretation is shown in figure 5, and the continuity and variabilities of the units are suggested by generalized cross sections in figure 2. Locations of the cross sections also are shown in figure 2.

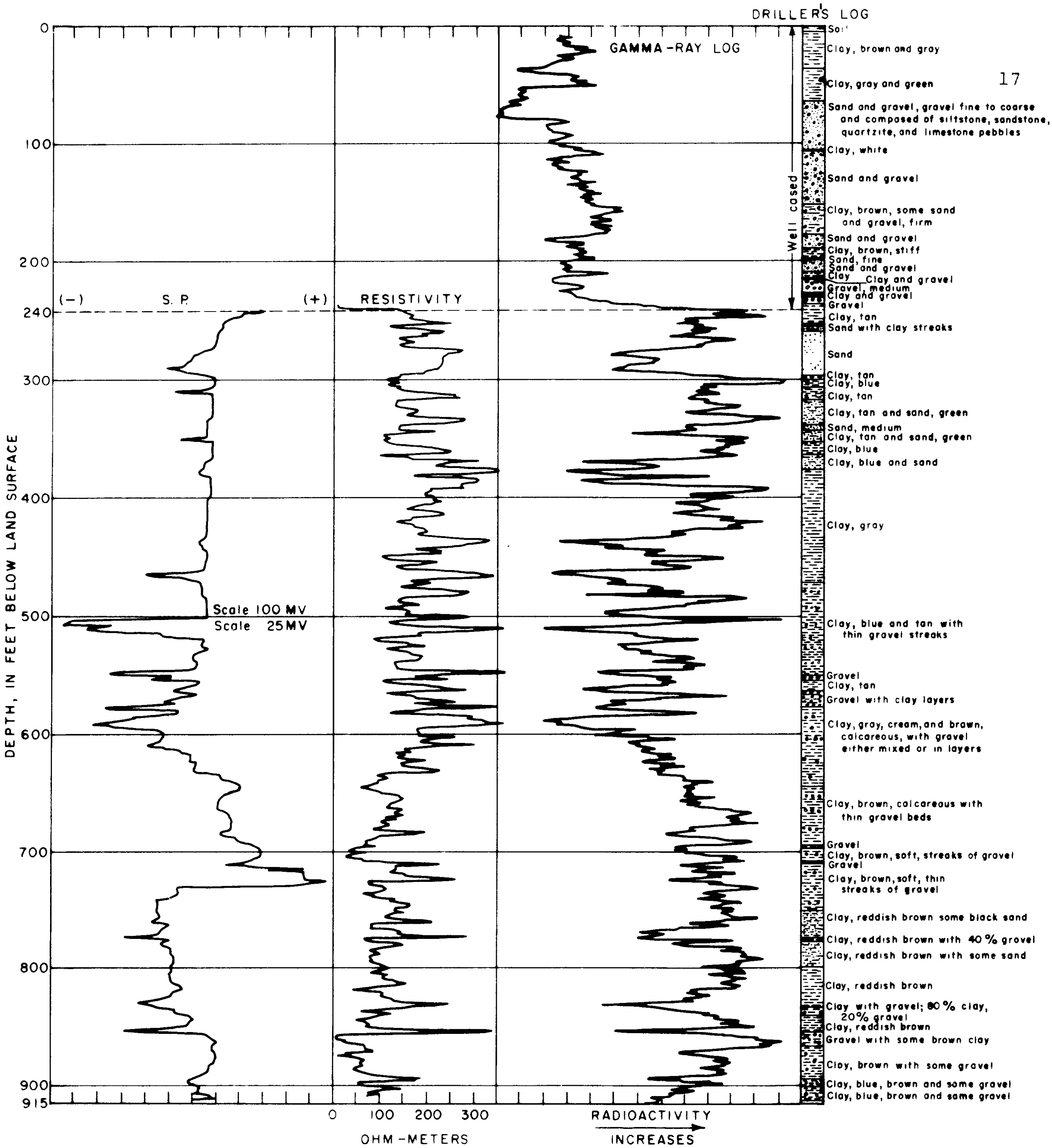


FIGURE 4.-- Graph showing the electric, gamma-ray, and driller's logs for test hole 14S-35E-35ac1 in Malad Valley, Idaho.

From the well data it can be seen that from about the toe of the deltaic benchland southward, a blanket of silty to clayey sediments covers nearly all the valley floor. Beneath this blanket, which serves as the principal confining unit, is a thick section of gravel and sandy gravel with interbedded lenses and thin beds of clay. The gravel is about 170 to 200 feet thick, is highly permeable, and is the principal aquifer of the valley. Although it becomes silty or finer textured locally, the gravel unit is present over most of the valley, and is continuous with the alluvium in the recharge areas at the northern end of the valley.

Beneath the gravel-aquifer unit is approximately 350 feet of alternating beds of sand or gravel and clay. The sand or gravel beds range from about 5 to 15 feet in thickness and compose about 40 percent of the unit. The clays are about 10 to 30 feet thick, are very tight, and form extensive confining layers. Only a few wells in the valley are drilled into this unit, but those wells indicate that the unit is also widespread over the valley.

Beneath the alternating sand-gravel and clay unit, the valley fill at the test-well site is principally clay or clayey silt with only minor beds of sand down to 915 feet. There are no other data in the valley to indicate the extent of this unit, but the geologic history of the basin during the Pleistocene lake sequences when the unit was deposited suggests that it, too, is widespread. Consequently, in this report, it is considered that (1) the thick gravel unit is the principal aquifer; (2) it is widespread and nearly everywhere confined south of about Malad City; (3) it contains clay layers that cause variations in confined water-level heads in the unit; (4) it is continuous with coarse alluvium in the northern part of the valley; (5) it is underlain by about 350 feet of gravel or sand alternating with thick clay beds; (6) this lower unit is only a moderately good aquifer but of widespread distribution; and, (7) the remainder of the valley fill is probably not water yielding.

Source and Occurrence of Ground Water

Virtually all ground water in the valley-fill reservoir is derived from the infiltration of precipitation that falls within the drainage basin. An estimated 4,000 acre-feet of surface flow is imported annually for irrigation use, a part of which contributes to the ground-water body. Most deep infiltration is from runoff and occurs on the upper slopes of the alluvial apron and in the valley of Little Malad River. However, some deep infiltration also occurs on the mountain areas, particularly the Blue Spring Hills. This percolating water moves through bedrock fractures and solution openings to discharge either in springs or directly to the valley-fill aquifers through subsurface contacts. During wet years, significant amounts of water may infiltrate directly from precipitation on the upper parts of the alluvial apron and on the northern part of the valley floor.

Runoff from Little Malad River, the flanks of the Bannock Range, and the drainages of Deep and Devil Creeks provides by far the majority of the ground-water recharge to the valley-fill reservoir.

Within the valley fill, ground water occurs under both water-table and artesian conditions. Artesian conditions occur where the saturated permeable deposits are overlain by less permeable strata and where the water is under greater than atmospheric pressure.

Artesian conditions occur under a large part of central and southern Malad Valley. Figure 5 shows the approximate area of artesian pressure in the spring of 1969, and the approximate area of flowing wells. North of these areas, ground water generally occurs under water-table conditions, although locally it may be semi-confined by discontinuous clayey deposits. There are several pressure zones within the artesian area, so that wells that are open to the aquifer at differing depths may have different water levels. Nevertheless, the ground water within the upper few hundred feet of saturation may be considered as one water body so that pumping stresses in any part of the valley fill could cause water-level changes in the rest of the aquifer system.

Contrary to the concept of one water body within the valley fill, there are a few springs within, or on the fringe of the valley proper that do not respond to pumping stresses as predicted. These springs, Malad Spring, some of the springs at Pleasantview, and small springs in and just south of Malad City, have their source in the adjacent bedrock and respond to seasonal and long-term climatic variation.

Hydrologic Features of the Valley-fill Reservoir

Pluhowski (1968) estimated that more than 100,000 acre-feet of water moves into, through, and out of Malad Valley annually. There are too few data now available to determine precisely the true water yield of the basin, but the general manner by which the water available for use enters the basin, is utilized, and leaves the basin can be described.

Areas of Recharge

Recharge to the ground-water body within the valley fill is derived from precipitation on the Malad Valley and the drainage areas tributary to the valley, plus a minor amount from about 4,000 acre-feet of irrigation water imported annually from Birch Creek (in Bannock County) by diversion to the Devil Creek drainage. Neither the exact amount nor the precise areas and avenues of recharge can be determined from existing data, but the general magnitude of recharge may be estimated from data on storage change within, and discharge from, the ground-water reservoir. Recharge, over the long term, must equal discharge plus or minus changes in storage. Because there has been no significant long-term net change in storage, recharge is approximately equal to discharge.

As has been noted, probably the largest segment of recharge is from the Little Malad River drainage and its adjoining area. Fractured and cavernous calcareous rocks underlying the Blue Spring Hills and much of the Little Malad River drainage absorb water and transmit it to the valley. Some of the water reappears in Malad and Pleasantview Springs but much undoubtedly recharges the aquifers directly through subsurface contacts. The channel of Little Malad River is underlain by permeable deposits that transmit seepage directly to the valley fill, and the flanks of the Bannock Range are underlain by gravels that also serve as intake areas and conduits for recharge.

Much of the lower parts of the drainages of Devil and Deep Creeks overlie the rather impermeable deposits of the Salt Lake ? Formation. Consequently, only the narrow, shallow, alluvial-stream channels provide recharge opportunity, which is minor compared to the conditions in the Little Malad River drainage. Most of the water yield of the area plus the importation from Birch Creek, is stored and delivered for irrigation. Some becomes recharge by way of irrigation application.

Precipitation on the Malad Range largely drains to the valley through short, steep canyons that discharge onto the coarse, gravelly, apron along the mountain flank. Diversion of the sustained flow of these drainages for irrigation of this flank aids percolation and recharge, but flashy stormflow often crosses the apron and moves on through the valley as streamflow. Calcareous-rock units in the Malad Range probably also transmit recharge to the valley through subsurface channels, but the amount is probably small.

Precipitation directly on the valley floor contributes only a small amount of recharge. The approximately 25 square miles of the southern part of the valley floor underlain by water under artesian pressure has no storage space available and cannot accept recharge. The remainder of the valley floor may receive some recharge to shallow zones, but only on the flanking alluvial aprons and the upper part of the deltaic benchland is there significant recharge capability.

Ground-Water Movement

Ground-water movement through the valley-fill aquifers is principally from north to south. The lines of equal elevation on the potentiometric surface (fig. 5) show that some water also moves laterally from east and west into the basin.

Most of the ground water moves through the principal gravel aquifer in the upper few hundred feet of valley fill. The outlet for the deeper aquifers is greatly restricted at the southern end of the valley, and water movement is slow.

Areas of Discharge

Discharge from the principal aquifers of the valley fill occurs by evapotranspiration, seeps and springs, pumping, and subsurface outflow. The general locations and character of these discharges are discussed in the following sections.

Evapotranspiration.--Within virtually all the area southeast of the 4,450-foot water-level contour (fig. 5) ground water is being discharged by evaporation and transpiration. Mower and Nace (1957, p. 29, 30) computed the net ground-water evapotranspiration from this 16,000-acre area to average 28,500 acre-feet annually. They also noted that an additional 8,500 acre-feet of direct precipitation and runoff was evaporated and transpired annually in the area. In addition there is a small amount of evapotranspiration along the major stream channels and around the principal springs, but the quantity is too small to be of significance here.

Water levels and artesian pressures in 1969 are about the same as, or slightly higher than, in 1957, thus it is estimated that about 28,500 acre-feet of water is lost from the aquifers by evapotranspiration at the present time.

Seeps and springs.--Over much of the area of evapotranspiration, ground water flows from the land surface as seepage. In some areas this seepage is great enough to more than sustain the evapotranspiration demand, and water flows off as streamflow. The seepage is too diffusely distributed to measure, and is estimated to average perhaps 3,000 acre-feet per year. It discharges into the normal drainage channels and is included in the amount measured at the Woodruff gage.

Two major spring areas also discharge ground water from the valley-fill aquifers. These are Samaria Springs and Woodruff Spring. Samaria Springs may discharge a small amount from recharge immediately west of Samaria, but nearly all their discharge is from the ground water of the valley fill. The exact discharge today (1969) from these springs is not known, but conditions in the lower end of the valley have not changed significantly since the discharge of these springs was measured by earlier workers. Livingston and McDonald (1943) reported the annual flow as approximately 3,000 acre-feet, and it is estimated for the present study that 2,900 acre-feet of this is from the ground-water of the valley fill.

Woodruff Spring discharges an average of about 13,000 acre-feet per year, but its flow varies somewhat seasonally. This variation, and the combined high temperature (89°F) and dissolved solids content, 5,130 mg/l (milligrams per liter), indicate that not all the discharge of this spring comes directly from the ground water of the valley fill. There are no data to allow precise differentiation of the quantities from all sources, but assumptions can be made that indicate the order of magnitude of contributions from the valley-fill reservoir. By use of the relationship:

$$Q_1C_1+Q_2C_2 = Q_{mix}\ C_{mix};$$

where

$$Q_1 + Q_2 = Q_{mix},$$

and

Q_1 = Quantity of water from valley-fill reservoir, acre-feet.

C_1 = Concentration of dissolved solids in Q_1, mg/l.

Q_2 = Quantity of water from saline water source, acre-feet.

C_2 = Concentration of dissolved solids in Q_2, mg/l.

Q_{mix} = Quantity of flow from Woodruff Spring, acre-feet.

C_{mix} = Concentration of dissolved solids in flow of Woodruff Spring, mg/l.

the relative volume from each source may be estimated, if a reasonable assumption for the concentration of the saline water can be made.

For purposes of estimating relative flow volumes for this study, a concentration of 15,000 mg/l is assumed for the saline water source. The concentration in water from the valley-fill aquifer averages about 500 mg/l. If values of 500 mg/l and 15,000 mg/l are used, then:

$$(5 \times 10^2)\ Q_1 + (1.5 \times 10^4)\ Q_2 = (5.130 \times 10^3)(1.3 \times 10^4)$$
$$= 6.7 \times 10^7$$

and since:

$Q_2 = Q_{mix} - Q_1$, then:

Q_1 = 9,000 acre-feet, approximately.

Consequently, the proportion from the valley fill is estimated as approximately 9,000 acre-feet per year.

The combined ground-water discharge from seeps and springs is thus estimated as 14,900 acre-feet annually.

Pumping.--As of 1966, approximately 10,600 acres were irrigated in Malad Valley, wholly, or in part, from ground water pumped from the valley-fill aquifers. There has been only minor change in this total since 1966. The number of acres that may have received only partial irrigation from ground water was not determined, it is assumed that all received full irrigation from pumps. The duty of water in the valley, considering the crops and growing season conditions is estimated to be 1.5 acre-feet per acre per year. Consequently, the net consumptive use of ground water from pumping averages an estimated 15,900 acre-feet each year.

Subsurface outflow.--Earlier workers estimated a large quantity of subsurface outflow from the basin toward the south. Data from the current study, both from drill holes and geophysical surveys, suggest that subsurface outflow through the alluvial fill is quite small.

The outflow cross section at the southern end of the valley is probably no more than 1 mile wide. Within this gap, the top 100 to 200 feet of fill is silty or clayey and very low in permeability. The geophysical data suggest that the total fill may be only about 400 feet thick. Consequently, the remaining permeable section may have an average transmissivity of about 300,000 gpd (gallons per day) per foot, (assumed permeability = 1,500 gpd per square foot; estimated thickness = 200 ft.). It is difficult to imagine that these values could be greater and they probably are considerably less. The gradient in the outflow area is less than 10 feet per mile, so by multiplying transmissivity by the gradient and by the width, the quantity of subsurface outflow is estimated to be:

$$Q = TIL$$

$$= 300{,}000 \text{ gpd/ft} \times 10 \text{ ft/mile} \times 1 \text{ mile}$$

$$= 3{,}000{,}000 \text{ gpd, or approximately } 3{,}400 \text{ acre-feet per year}$$

The total estimated average annual discharge from the ground-water aquifers of the valley fill is, therefore:

Evapotranspiration -----	28,500
Seeps and springs ------	14,900
Pumping ----------------	15,900
Subsurface outflow -----	3,400
Total (rounded)	63,000 acre-feet

This is believed to be certainly a maximum. Lowered water levels during the pumping season have reduced the evapotranspiration and seepage outflow during the period of highest transpiration demand. The estimated subsurface outflow may be twice the actual, but data are insufficient to define it correctly.

Of this total, several thousand acre-feet annually is derived from peripheral inflow from flanking mountains south of the northern edge of T. 15 S. The remainder must move southward from recharge in the area to the north. The absolute values of these two increments of ground-water inflow to the central part of the valley cannot be derived with existing information, but reasonable estimates can be made. The gradient across the northern edge of T. 15 S. is about 20 feet per mile (fig. 5) and the aquifer width at that location is about 6 miles. The aquifer section averages about 550 feet in thickness and the overall average transmissivity of the aquifer section is estimated to be 400,000 gpd per foot (average coefficient of permeability about 750 gpd per square foot). Consequently, it is estimated that at least 50,000 acre-feet of average annual recharge moves from the north southward to areas of discharge, and that a maximum of 13,000 acre-feet is derived from peripheral inflow.

Water-level Changes

Water-level data are available for the valley-fill area from a large number of wells measured infrequently for specific study purposes, and from about 47 wells measured for various periods for water-level change information. Of these, 30 wells have modern water-level measurements from which hydrographs may be constructed to show water-level changes within the significant aquifer units of the valley. Hydrographs of five wells (fig. 6) were selected to represent the character of water-level change from north to south in the

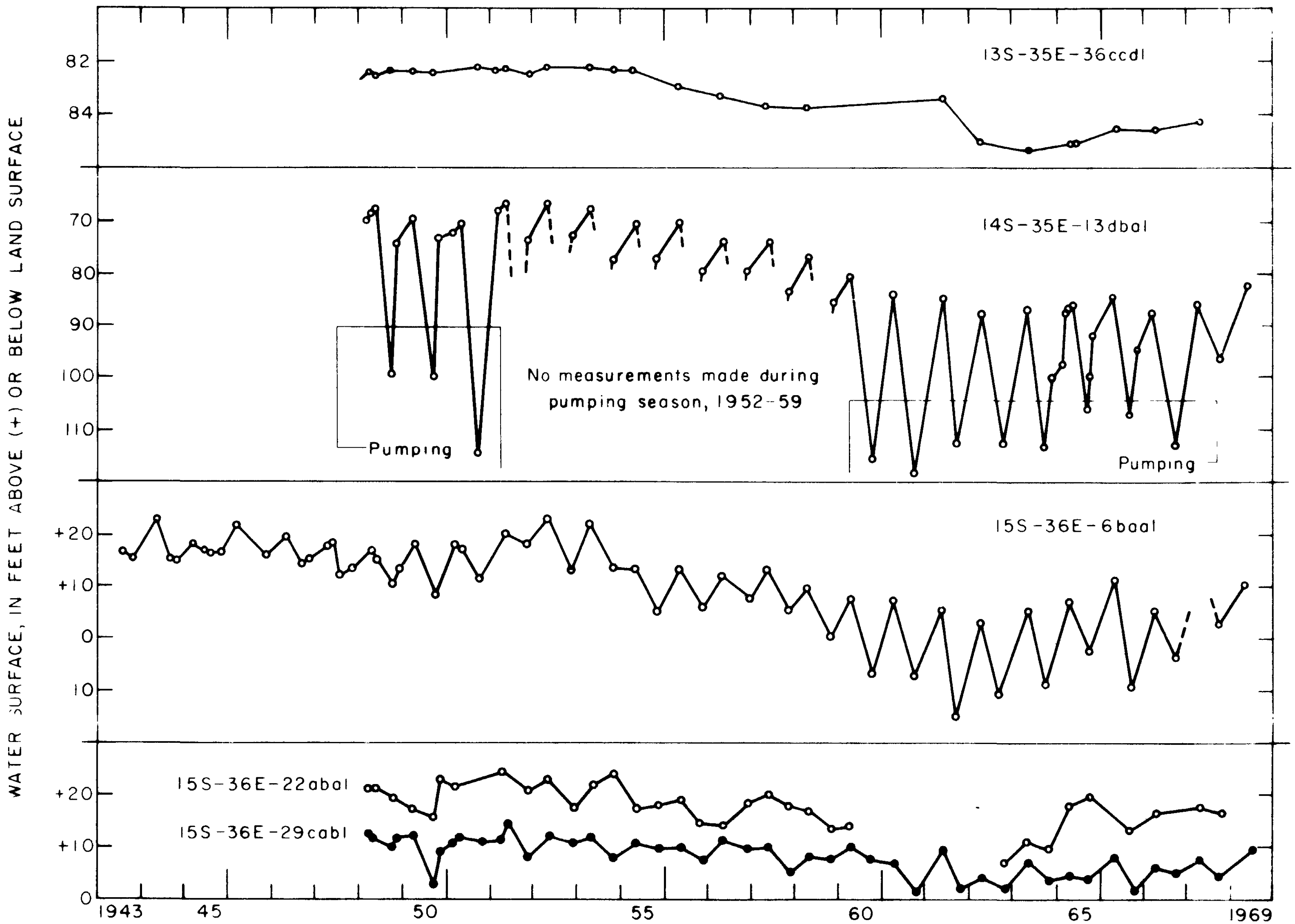


FIGURE 6.-- Hydrographs of selected wells in Malad Valley.

main aquifer of the valley. These hydrographs show that during the late 1940's and early 1950's there was little influence from the increasing amount of pumping being developed in the basin. Water levels were high because of several years of above-average recharge. Some wells have records going back to at least 1931, and these records show that until about 1953 the ground-water reservoir was as full as it had ever been. In about 1953 or 1954 water levels began to decline in response to increased pumping and a prolonged period of below-normal precipitation. The greatest decline occurred in the water-table area at the northern end of the basin, but the character and timing of the decline was uniform throughout. The least change occurred near the outlet at the southern end of the basin.

By 1964, non-pumping water levels near the center of T. 14 S. had declined as much as 20 feet, and pumping-level declines were much greater. At the northern edge of the artesian-pressure zone (well 15S-36E-6baa1), piezometric levels fell accordingly, and many small wells ceased to flow. The wet winter and spring of 1965 required less pumping for irrigation that year, and increased the quantity of recharge. Consequently water levels began to recover. The recovery peaked in 1966, fell off slightly in 1967, then has continued upward to 1969. As of the spring of 1969, water levels throughout the basin have recovered about 5 feet over the 1964 low, or have returned almost to the natural full level of the basin. In general, the hydrographs show that the total demand on the ground-water resource exceeded recharge during the dry years prior to 1965; but, over a long period, when recharge is normal, the water levels will recover despite increased pumping at 1960-69 rates.

The hydrographs also show that the effect of pumping the existing wells, which are distributed largely along the northern edge of the artesian area, is spread fairly uniformly over the basin. This supports data from logs that the aquifer units are widely distributed and interconnected. It particularly emphasizes the condition, however, that in order to pump water levels down in the artesian area with the existing pump distribution, very large declines will be effected in the water-table area. To lower water levels sufficiently to stop the present nonbeneficial phreatophyte and seepage losses in the lower valley would possibly cause about 100 feet of decline in the water-table area. Such a decline could be accepted where the present water table is near the land surface, but, elsewhere, it might make some water-table wells uneconomical to operate.

Estimated Storage in Principal Water-Bearing Units

The principal water-bearing units of the valley-fill reservoir underlie nearly all the approximately 75 square miles of the valley floor, aggregate several hundred feet in thickness, and contain several million acre-feet of water in storage. Not all of this stored water is economically recoverable, nor is it all of suitable quality for present-day use. Nevertheless, it has been shown that the principal aquifers occur as widespread sand or gravel units beneath at least 30,000 acres of the valley bottom. By assigning a conservative estimate of 20 percent average porosity to these materials and their interbedded clayey or silty members, and another conservative estimate of 300 feet for average aquifer thickness, a minimum estimate of 1.8 million acre-feet of water in storage within the top 300 feet of saturated thickness beneath the valley bottom is indicated.

The Available Ground-Water Supply

Although at least 1.8 million acre-feet of ground water is in storage, planned development of the ground-water resource can recover only a part of that amount. Of the approximately 30,000 acres of valley-floor area, about 4,000 acres is underlain by ground water occurring under water-table conditions in 1969. The remainder is underlain by ground water under varying amounts of artesian pressure. As water levels are lowered, the artesian-pressure area will be progressively reduced, until eventually the ground water in the principal gravel aquifer would occur everywhere under water-table conditions. To accomplish this, water levels would need to be lowered an average of about 60 feet uniformly over the valley. During this lowering, water would be released from storage only in the progressively enlarging water-table area in accord with the specific yield of the materials being drained.

Specific yield.--The specific yield of a deposit with respect to water is the ratio of (1) the volume of water which, after being saturated, the deposit will yield to gravity to (2) its own volume, usually expressed as a percentage (Meinzer, 1923, p. 28). Estimates of the specific yield of the upper 100 feet of saturated deposits below the 1969 water levels were made from descriptions in drillers' logs. The deposits were grouped into seven lithologic categories as listed in table 2. Values were assigned to

Table 2.--Estimated specific yield of materials described in drillers' logs

Lithologic category (based on drillers' description)	Assigned Specific-yield value[1] (percent)
Coarse to medium sand	30
Gravel, sand and gravel	24
Sand, gravelly sand	18
Sand, gravel, and clay or gravel and sand, dirty gravel	15
Fine sand, sand and clay, sandy clay, cemented gravel	8
Silt, silty fine sand, silt and clay	3
Clay, mud, muck	0-1

1 Assigned specific-yield values based on Morris and Johnson (1966), modified slightly downward to meet indicated conditions elsewhere in Idaho and the Great Basin.

each category based on experience in other areas and on values determined by Morris and Johnson (1966) for similar deposits. Some interpretation is needed when working with drillers' logs; however, comparable results are usually obtainable in adjacent wells. Observations made while drilling the test well (fig. 4) were used to supplement data from the drillers' logs.

The estimated specific-yield distribution for the 100 feet of aquifer below the 1969 water level is shown in figure 7. The highest values are generally along the western side, and in the Malad City part of the valley. This suggests that these places are probably the best areas for ground-water development.

Storage depletions caused by water-level declines under water-table conditions may be estimated as the product of an area, a depth of lowering, and the average specific yield as shown on figure 7, assuming the average specific-yield value remains constant through the zone of lowered water level. It must be emphasized that in the areas of artesian pressure, specific-yield estimates apply only after sufficient reduction of head has taken place so that the lowering of water level occurs under water-table conditions. This could be accomplished in Malad Valley only by careful placement and control of pumping points, and at the expense of lowering of water levels in the present water-table area, possibly beyond economic lifts.

<u>Ground water from storage</u>.--From the foregoing and figure 7, it can be shown that the average specific yield of the aquifer that would yield water from storage as water levels are lowered is about 15 percent. Beginning with the 1969 water level, the amount coming from storage would increase as lowering progressed because the area of water-table condition would progressively increase. The initial 10 feet of lowering would yield about 1.5 acre-feet per acre from the present approximately 4,000-acre area underlain by water-table conditions, plus half again that amount from another approximately 4,000 acres under which water-table conditions would progressively develop. If water levels could be lowered uniformly 60 feet beneath the whole valley floor, nearly all the artesian head would be removed, and at least 120,000 acre-feet of water would be removed from storage. Uniform lowering of an additional 40 feet for a total of 100 feet would remove an additional approximately 180,000 acre-feet of water.

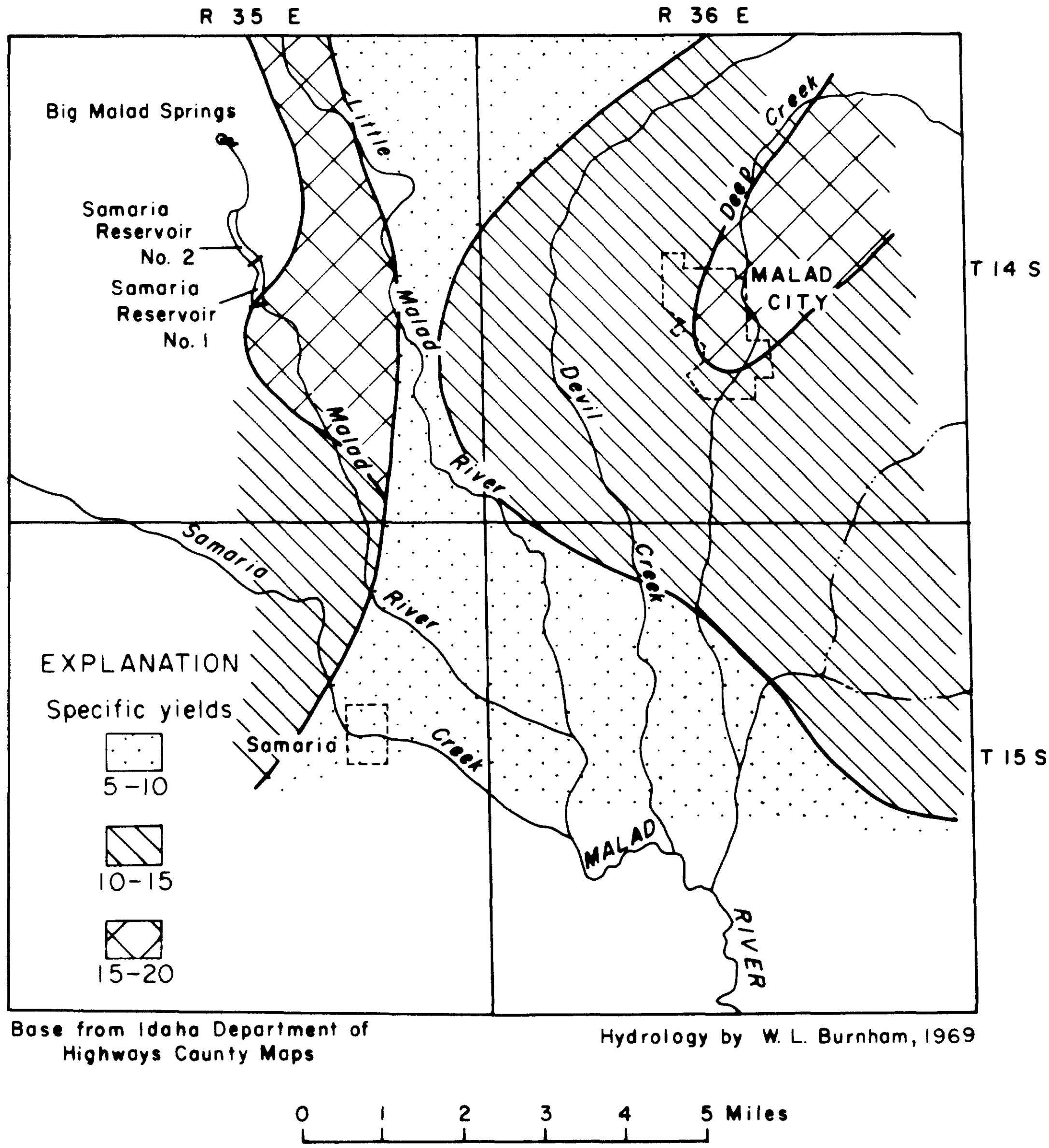


FIGURE 7.-- Distribution of average specific-yield values for upper 100 feet of saturated deposits below 1969 water levels, Malad Valley, Idaho.

It must be emphasized that these figures for quantity of water available from storage are tentative and subject to large errors of estimation. They are presented primarily to provide a basis of comparison between relative volumes of water available, and volumes required for further agricultural development and use within the valley area.

It is obvious that it would require a very carefully planned and controlled distribution of pumping to effect a uniform lowering of water level throughout the valley. It is equally obvious that any lowering will increase the gradient outward toward the valley perimeter, and hence increase the area of storage depletion. In general, it appears probable that if sufficient ground water were consumptively removed from the present-day system to cause 100 feet of water-level lowering beneath the 30,000 acres of valley bottom, about 300,000 acre-feet of the water pumped would come from storage.

Summary of availability.--It has been estimated (p. 25) that each year approximately 50,000 acre-feet of underflow moves from north to south, at about the latitude of Malad City, to discharge from the basin. Minimum beneficial use is made of this water within the valley. Concentration of pumping from wells spaced in a band across the valley at this latitude would intercept a part of the underflow. Because of variabilities within the aquifers, and because pumping could not be maintained continuously, it would be virtually impossible to intercept all the underflow or eliminate all the gradient between the pumping area and the outlet at the southern end of the valley. Nevertheless, a pumping depression at this location would greatly modify the existing ground-water flow system, and would intercept or salvage large quantities of water now lost to nonbeneficial discharge. Part of the north-to-south underflow would be intercepted, some peripheral inflow would be diverted toward the pumping area, and a large quantity of water would be recovered from storage as water levels declined. Consequently, it seems that a large ground-water supply is available for development in Malad Valley. Such development would, however, lower water levels over the valley bottom with attendant loss of flowing wells, but it also would salvage a large part of the existing non-beneficial evapotranspiration. It would, if water levels were sufficiently lowered, eliminate much water-logging of land that now exists, and would allow downward leaching on some land and thus return it to production. Such development probably would not effect Malad or Pleasantview Springs in significant amount, but it would reduce the flow of both the Samaria Springs and Woodruff Spring.

Water Quality Problems

It has long been known that there is highly saline water at some locations in Malad Valley and that some soil areas are also saline. Mower and Nace (1957, p. 21-28) describe these soils, the water, and some of the vegetation characteristic of the various saline conditions. Many residents of the valley, and others who have considered the water resources of the valley briefly, have concluded that saline ground water is widespread and that the ground-water resource is therefore not worthy of development. The evidence at hand does not support such conclusions. Admittedly, the evidence is incomplete and sketchy, but it does show that the highly saline water (1) is small in volume compared with the recharge and water in storage, (2) is associated directly with deep circulation along or on the bedrock side of the boundary faults of the valley, and (3) is localized in only three small areas. By far the largest area of saline ground water, and the most serious in terms of threat to the use of the fresh water resource, is the area along the eastern margin of the valley from Malad City south to Cherry Creek. The source of the high salinity is unknown but the principal eruption of salt water appears to occur within about a mile of the southern edge of Malad City. Some saline water discharges at the surface through springs and wells but some also moves southwestward within the aquifer. Additional eruptions may occur farther south also, but they seem to be of smaller volume. Large drawdown of the water level immediately west of these saline eruptive areas might divert saline water to the pumping centers, but the volume of non-saline waters that would also be moving to those centers would be much greater. Consequently, it is doubtful that the effect of the saline water would be sufficient to cause the water pumped to be unfit for use.

The second most important saline area is that of the Pleasantview Springs. These warm springs derive water mainly from the bedrock of the Blue Spring Hills, and the salinity is not derived from the ground water of the valley fill. The third area of saline water is at Woodruff Spring, but this area is at the outlet from the valley and will not influence the use of ground water within the valley. Again, the salinity seems to be derived from a small quantity of very saline water derived from the bedrock of Samaria Mountain or from the Woodruff fault zone.

During the many thousands of years since Lake Bonneville receded southward from the valley, ground water has moved southward through the aquifers to discharge at the southern end of the valley. Some of this water was saline as just described. Much of the discharge has always been by evaporation and transpiration, leaving behind in the soil whatever salts the ground water contained. Consequently, the soils are the most saline downgradient of the Pleasantview Springs and the eastern eruptive spring. It is not probable, however, that a majority of the ground-water resource of the valley fill or even a significantly large amount, is sufficiently saline to be a deterent to its agricultural use if properly managed.

This report noted earlier that the Malad Valley depression has been occupied several times by major lakes, with apparent complete drying and soil formation between some lake episodes. It is entirely possible that saline deposits occur, as a result of these earlier episodes, at localities within the valley other than the present-day areas of saline soils. If so, the modern ground-water circulation system may be re-dissolving some of these saline materials and moving them southward to the areas of present discharge. Also, this would account for small variations in salinity between different aquifer zones, and from place to place within the valley None of these variations are known to be of sufficient importance to influence the general ability to develop and use the ground water. However, there may be places where a planned program of mixing water from several wells will be necessary to reach a salinity level that is acceptable for the planned use of the water.

Conclusions

Growth of the agricultural economy of the Malad Valley of Oneida County, Idaho, depends upon bringing more and better land under full irrigation. Surface-water resources for irrigation are fully developed and ground water is being developed in some areas. Although importation of additional surface water from the Bear River is under consideration, practical consideration of alternatives requires full assessment of the availability of additional ground water to meet the needs. The following conclusions may be drawn as a result of a largely reconnaissance evaluation of the ground-water resources of the valley and their availability for development and use in lieu of additional importation.

1. The valley is underlain by an alluvial deposit that contains a wide-spread aquifer system averaging several hundred feet in thickness.

2. The aquifer contains interbedded clays that separate it into depth zones with varying hydraulic properties, and is overlain by a thick clayey blanket that causes artesian conditions over much of the southern half of the valley.

3. The valley-fill of the area is bounded by major fault structures that bring low-permeability consolidated rocks into lateral continuity with the main aquifer units in all except the northeastern and northwestern corners of the basin.

4. The valley fill contains essentially one water body underlying about 75 square miles, recharged mainly from the north. Movement of water within the valley fill is principally from north to south, and natural discharge is almost entirely by upward leakage to land surface and by subsurface outflow near the southern end of the valley.

5. Water supply to Malad Springs and the Pleasantview Springs is almost entirely independent of the ground water of the valley fill, and additional pumpage from the valley should not materially affect those springs. Samaria and Woodruff Springs are related to the valley-fill aquifers and spring flows will vary with aquifer use.

6. Average annual recharge to the valley-fill aquifers is about 64,000 acre-feet, of which at least 50,000 acre-feet moves from north to south through the aquifers.

7. At least 300 feet of the approximately 550 feet of aquifer unit beneath the valley-bottom area of the valley is saturated. Within that 300 feet there are at least 1.3 million acre-feet of water in storage, the major part of which is available for management and use.

8. Average specific yield of the valley-fill deposits is about 15 percent. A uniform 60-foot lowering of the water level beneath the 30,000 acres of valley bottom, if it could be attained, would eliminate nearly all artesian pressure, and would release about 120,000 acre-feet of water from storage. A uniform lowering of 100 feet would release an additional approximately 180,000 acre-feet, or a total of about 300,000 acre-feet.

9. Additional large-scale pumping anywhere in the valley-fill area will reduce artesian pressure and cause some wells to cease flowing.

10. Creation of a pumping depression across the valley from the southern edge of Malad City westward would intercept a part of the north-to-south movement of ground water, would cause a lowering of water level in the present marshy, water-logged lower valley area, and would salvage a part of the ground water now lost to nonbeneficial use by phreatophytes and surface outflow.

11. An additional 25,000 to 30,000 acre-feet of ground water can be pumped annually from the southern part of T. 14 S. across the valley without lowering water levels more than a few feet or a few tens of feet. Careful spacing of wells and control of discharge rates would allow pumping such quantities to altitude 4,600 feet with a maximum average lift of about 200 feet, from which it would serve virtually all irrigable land in the presently planned Samaria unit by gravity. Individual plots could be served from locally placed wells with lesser lifts.

12. Salinity in the ground water is a significant problem along the eastern margin of the valley south of Malad City and near Pleasantview Springs on the western edge. The salinity can be controlled by planned pumping locations and discharge rates and is not considered a significant deterent to ground-water development for agricultural use.

BEAR RIVER DRAINAGE WITHIN IDAHO

Objective and Scope

The objective in this section of the report is to identify and describe briefly those areas within the drainage of the Bear River in Idaho (fig. 1) wherein a ground-water resource of sufficient magnitude for irrigation or industrial use might be developed. The identification of these areas is based upon existing data and knowledge from past and current studies of the region by the Geological Survey and others, and the description is based on reconnaissance appraisal of published information, unpublished data in the files of the Geological Survey, current studies by Geological Survey personnel of the Idaho and Utah Districts, and geophysical exploration in

Gem and Cache Valley by personnel of the Geologic Division of the Geological Survey. The primary intent is to identify only those areas where a significant potential for ground-water development exists, and to describe the degree to which the resource is known. For each area, an attempt is made also to identify the character and scope of additional investigation needed to determine the availability of the ground water for use.

Areas of Ground-Water Potential

The area in Idaho drained by the Bear River and its tributaries is one that has undergone great geologic activity. Fault-block mountains of consolidated rock surround structural depressions filled with sediments and eruptive volcanic rocks. Only the depression areas provide potential for storage or transmission of significant ground-water supplies and there are but four of these.

Bear Lake Valley

The valley north of Bear Lake is a broad sediment-filled basin with apparent potential for ground-water development. However, although the valley sediments are apparently saturated, all available evidence shows the deposits to be too fine textured to yield readily significant quantities of water to wells. In general, therefore, the Bear Lake valley and the trough extending northward toward Soda Springs offer no real potential for ground-water development in terms of modern economy and needs. There may be large volumes in storage, but they are not economically recoverable.

Valley Area from Soda Springs to China Hat

Northward from Soda Springs, the valley broadens and rises toward the lava fields of the Blackfoot River drainage. High mountains along the eastern flank of the valley shed abundant calcareous-rock debris into the valley and provide a large volume of recharge water annually. Along the western flank of the valley, the Chesterfield Range separates the valley from the much lower Gem Valley. Tenmile Pass cuts through the Chesterfield Range and once served to drain a part of the valley area. The pass is now partly filled with lava and no longer provides surface drainage. It may provide some subsurface drainage.

China Hat is a prominent landmark peak in the lava field at the southeastern edge of the Blackfoot Reservoir and may be considered the northern end of the valley. Blackfoot River and the reservoir lose water into the lava field, and much of that water moves southward to discharge into the Bear River near Soda Springs. The lava and sediments of the valley are permeable and yield large volumes of water to wells. So long as the Blackfoot River and reservoir exist to provide recharge, there appears little doubt that large volumes of ground water could be pumped from this valley area. Doing so would presumably reduce the underflow, if one exists, through Tenmile Pass and toward Soda Springs. However, there are now insufficient data to allow quantitative estimates of the magnitudes of effects. The valley and its outflow areas should be investigated by intensive geophysical surveys, then test drilling should be done to investigate specific locations and gain quantitative data.

It is worthy of note that heavy pumping in this valley probably would not create sufficient steepening of gradient to the north to induce any significant increase in leakage out of the Blackfoot system. Such pumping might salvage a small amount of nonbeneficial discharge in Fivemile Meadows and near Soda Springs, but virtually all would be at the expense of present beneficial outflow to Bear River and the Gem Valley after a small change in storage and after the system adjusted to a new equilibrium.

Gem-Portneuf Valley

Bear River flows westward from Soda Springs into an elongate northwest-southeast valley now largely filled with basaltic lava. The underflow of the river and part of what is lost from the river to the lava is divided--part moving northwestward to the Portneuf River, and part moving southward and on down the Bear River. There is evidence that the Bear River once flowed northwestward as a tributary of the Portneuf River, but the lava changed the river course southward. Ground water now occurs in the basal part of the lava and in the underlying sediments. Some of the sediments are coarse stream deposits, others are fine grained.

The valley area of saturated lava and sediments is large and at some localities within the valley large yields can be obtained from wells. It must be noted, however, that any ground water that is developed must come from storage or from present surface discharge from the valley because there is no known significant subsurface discharge, and ground-water development cannot induce additional recharge. Any storage depletion would also eventually reduce surface discharge from the valley, as stream base flows are now sustained by drainage from water stored in the valley fill. Extensive subsurface investigation, with drilling and surface geophysical studies, is needed before the ground-water conditions can be further defined.

Cache Valley

Cache Valley occupies a long, slender trench along the western flank of the Wasatch Range, mostly in Utah. The part of the valley in Idaho narrows sharply toward the northwest, is flanked on the west by the high peaks of the Malad Range, and contains a wide variety of sediments. Hydrologic conditions beneath the valley floor vary widely.

Data from wells and from gravity and seismic surveys show that the eastern and central parts of the valley fill are poorly permeable so that wells of large yield are rare. High yields may be obtained from coarse deposits along the northwestern margin of the valley, but the available data show these deposits to be thin, with only about 200 feet of saturated section. The coarse deposits are only a few square miles in area and, although recharge from the west is large, the total storage volume is moderate and seasonal recharge and discharge cause large water-level fluctuations. Specific-yield estimates from drilling and geophysical-study data suggest that only about 20,000 acre-feet would be yielded from each 10 feet of water-table decline in the upper 100 feet of saturated section. Recharge is believed sufficient to replace all existing annual withdrawals.

Geophysical data also suggest that bedrock, or at least high-density material, underlies much of the western side of the valley at shallow depth and south of the area of coarse sediments. Much additional study will be necessary to define details of the hydrology of the valley, but present data do not suggest availability of a large ground-water supply.

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