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GROUND WATER-SURFACE WATER RELATIONS
IN THE SILVER CREEK AREA,
BLAINE COUNTY, IDAHO

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Idaho Department of Water Resources
Water Information Bulletin No.

GROUND WATER-SURFACE WATER RELATIONS
IN THE SILVER CREEK AREA,
BLAINE COUNTY, IDAHO

By

Joe A. Moreland, 1943-

Prepared by the U.S. Geological Survey
in cooperation with
the Idaho Department of Water Resources

Statehouse
Boise, Idaho

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FACTORS FOR CONVERTING ENGLISH UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

The International System of Units is being adopted for use in reports prepared by the U.S. Geological Survey. To assist readers of this report in understanding and adapting to the new system, many of the measurements reported herein are given in both units.

Multiply English units	By	To obtain SI units
	Length	
inches (in)	25.40	millimeters (mm)
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
	Area	
acres	0.4047	hectares (ha)
square miles (mi^2)	2.590	square kilometers (km^2)
	Flow	
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)
	Volume	
acre-feet (acre-ft)	1233	cubic meters (m^3)
cubic feet (ft^3)	0.02832	cubic meters (m^3)
	Transmissivity	
feet squared per day (ft^2/d)	0.0929	meters squared per day (m^2/d)

GROUND WATER-SURFACE WATER RELATIONS
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ABSTRACT

The relations between ground water and surface water were studied by the U.S. Geological Survey in the Silver Creek area, Blaine County, Idaho, as part of a comprehensive investigation of the area's water resources. Ground-water withdrawals calculated for 1975 totaled about 16,000 acre-feet (2.0×10^7 cubic meters) of pumped ground water and 12,000 acre-feet (1.5×10^7 cubic meters) of ground water extracted through flowing wells. The ground water is contained in alluvial and basalt aquifers comprised of gravel, sand, and basalt interbedded with fine-grained silt and clay. Nineteen shallow test holes were drilled and cased to define the extent and effectiveness of confining layers in the southern part of the valley. Water-level fluctuations monitored in about 75 wells showed seasonal variations of 40 feet (12 meters) in the northern part of the area and less than 5 feet (1.5 meters) in some wells in the southern part of the area. Numerous stream-discharge measurements were made to define areal and temporal distribution of ground-water discharge. Most of the flow in Silver Creek rises

from springs discharging from the shallow aquifer near the edge of the confining beds. Only a small amount of discharge to the creek is attributable to upward movement of water through the confining beds. Discharge from the artesian aquifer near Stanton Crossing may contribute a significant portion of the spring flow which feeds the Big Wood River. Seasonal fluctuations in spring discharges are directly related to fluctuations in ground-water levels. Although losses from Silver Creek downstream from the confining beds were documented during various times of the year, losses were relatively small. A deposit of fine-grained sediments near Picabo effectively perches Silver Creek above the deep basalt aquifer.

INTRODUCTION

A number of socioeconomic factors related to impending land- and water-use changes combined in the early 1970's to cause concern to local residents of the Silver Creek area of Blaine County, Idaho (fig. 1). They feared that these changes might alter the complex balance between surface- and ground-water systems in the area. The Silver Creek area also includes the area of ground-water discharge to Big Wood River. Many of the changes would result in a reduction in recharge to the aquifer or a change in the quality of the recharging water. The changes might cause ground-water levels and artesian pressure heads to decline, streamflow in Silver Creek and the Big Wood River to be reduced, and water quality of the ground-water system and the creek and river to deteriorate. Some of the specific proposed and actual changes that were the cause of concern included: (1) changing irrigation practices from flood irrigation to sprinkler irrigation which requires application of less water and consequently less recharge to the aquifer; (2) changing land use from undeveloped or agricultural use to urban or suburban tract-type development; (3) agricultural expansion on the valley floor itself and on the adjacent foothills and terraces; and (4) proposals for alternative methods of collection, treatment, and disposal of urban sewage wastes from the upstream Sun Valley-Ketchum area.

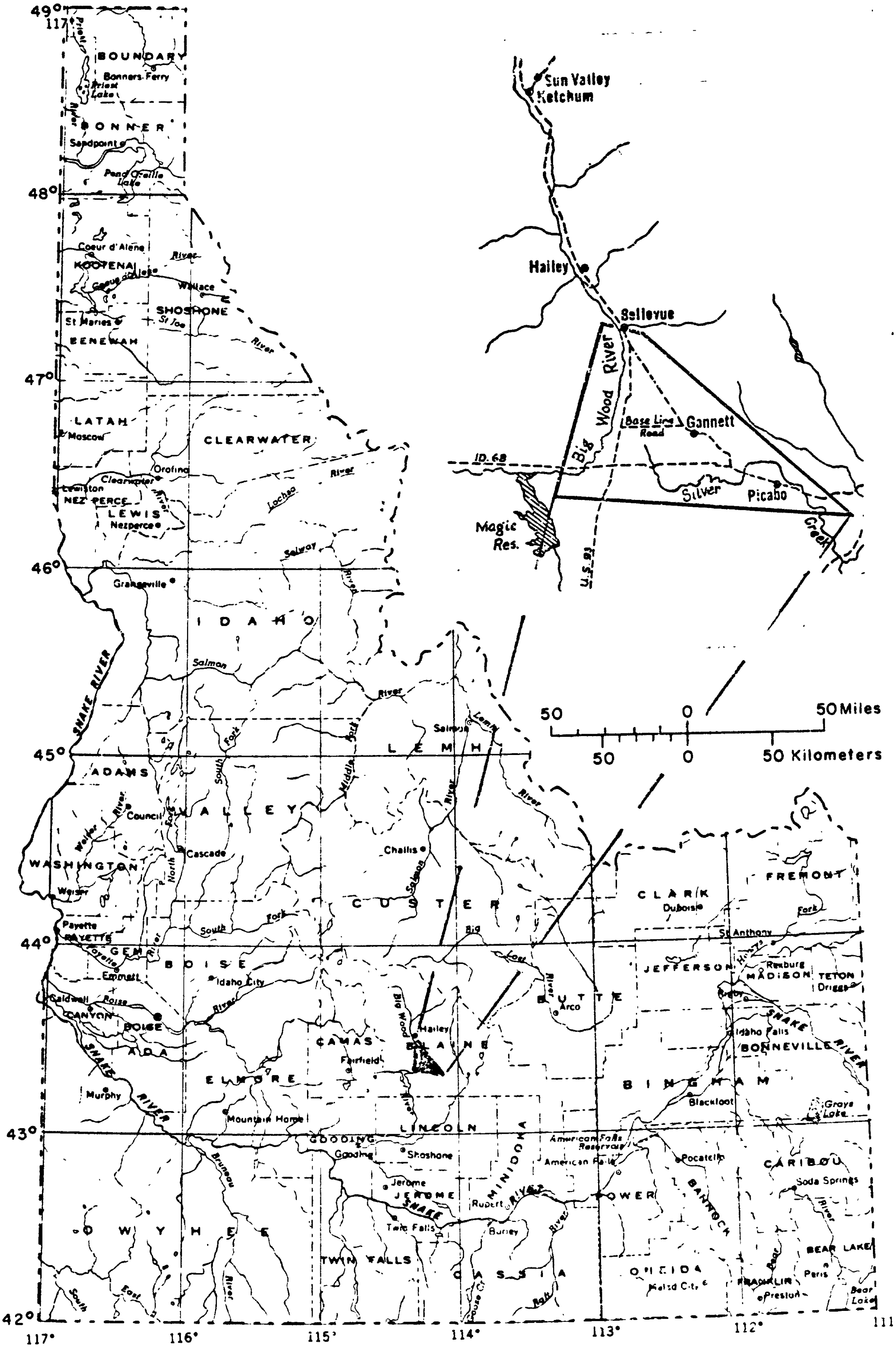

FIGURE 1. -- THE SILVER CREEK AREA

To assist local agencies in formulating alternative plans for development, and predicting potential effects of the alternative developments on the water resources, the Idaho Department of Water Resources (IDWR) began a three-phase investigation of the Silver Creek area. The initial phase was a comprehensive data-collection effort to define the complex relations involved and to provide data needed to construct a model of the system. Phase two would use the findings of the first phase to construct and calibrate a hydrologic model of the system. The second phase would also include definition of alternative actions which could be evaluated on the completed model. Phase three would be an evaluation of the various proposed alternatives utilizing the calibrated model.

Realizing the wide range of data needed to complete this task, IDWR invited several local, State, and Federal agencies to participate in the first phase of the study. By using the expertise available in the participating agencies, IDWR felt that a more complete and accurate collection of information would result. For example, the Idaho Department of Health and Welfare (IDHW) provided data on water quality in Silver Creek; the Agricultural Research Service (ARS), U.S. Department of Agriculture, measured meteorological conditions; Idaho Water Resources Research Institute (IWRRI) measured surface-water diversions; Soil Conservation Service

(SCS), U.S. Department of Agriculture, mapped crop distribution; Idaho Department of Fish and Game (IDFG) conducted fish surveys; and IDWR collected ground-water-quality data. The U.S. Geological Survey (USGS) measured streamflow in Silver Creek, estimated ground-water extractions for agricultural use, and defined the relations between ground water and surface water.

The Study Area

The study area (fig. 1) is a roughly triangular valley bounded by mountains and low hills. Bellevue is at the northern apex and is the largest community within the project area. Two small communities, Gannett and Picabo, are in the southern part of the area.

The Big Wood River enters the triangle at the northern apex, flows along the western edge, and exits the study area at the southwestern apex. Silver Creek rises from numerous springs and seeps south of Gannett and exits to the southeast.

The economy of the valley is based primarily on agriculture, although tourism, prompted by proximity to the Sun Valley ski area and excellent trout fishing in Silver Creek, is becoming increasingly important. Developers, realizing the recreational appeal of Silver Creek and the Sun Valley area, have proposed condominium and tract-type developments within the study area.

Scope of Investigation

Information collected during an earlier study indicated that Silver Creek lost flow before reaching the vicinity of Picabo (P. M. Castelin, oral commun., 1974). A stream-gaging station about 3 mi (5 km) southeast of Picabo was discontinued in 1962, so quantitative discharge data were lacking to define the ground water-surface water relations. Therefore, as a part of this investigation, the USGS reestablished a gaging station on Silver Creek. A new site was selected at Sportsman Access (see fig. 7) near the area of assumed maximum flow, and about 7 mi (11 km) upstream from the discontinued station. Continuous river stage is recorded, and periodic discharge measurements are made at this new site.

To define ground-water-level fluctuations, about 75 wells were measured monthly from July 1975 to June 1976. Five automatic water-level recorders also were installed on water-table and artesian wells to monitor continuous water-level and potentiometric head changes.

Discharge measurements were made on numerous pumped irrigation wells and flowing wells to provide data needed to compute irrigation pumpage and flows from artesian wells.

To obtain information needed to define the extent and effectiveness of shallow, fine-grained confining layers, 19 test holes were drilled by machine auger at 10 sites. The test holes were cased with plastic pipe to facilitate collection of water levels and potentiometric heads at various depths in the area of confined water.

To define the source and seasonal variations of inflow, three series of discharge measurements were made throughout the system of springs that feed Silver Creek. Measurements also were made along Silver Creek to document any gains or losses in the creek itself. The measurements were made in May, June, and October 1975 to define the temporal changes that occur in the system. In October 1975, discharge measurements were made on springs flowing to the Big Wood River.

Purpose of Report

The results of investigations by the various agencies participating in the overall project are being made available in different formats. No attempt has been made at this time to assimilate all the collected data into a comprehensive report. IDWR is planning to release a final report on the overall project after a hydrologic model has been constructed and calibrated.

This report only summarizes the findings of the USGS work. As such, it cannot and does not address many important aspects of the hydrology of the study area. A conceptual model of the ground-water-flow system and stream-aquifer interaction is presented to provide a starting point for construction of a mathematical model. Because the conceptual model has not been tested with data collected by other agencies, some refinement is expected during construction of the mathematical model.

Acknowledgments

The agencies which participated in this study were very cooperative in supplying preliminary data. Their information was helpful in analyzing the hydrologic system and substantiating hypotheses. For example, precipitation and snowmelt data supplied by ARS were useful in reconstructing part of the Silver Creek discharge record lost when the gage malfunctioned. Blaine County Soil Conservation District assisted by planning and hosting several local information meetings.

Landowners and local residents were helpful in supplying important information about ground-water extraction, well discharges, and historic water-level fluctuations. Several residents permitted use of their wells for periodic water-level measurements or installation of continuous water-level recorders. Special thanks are extended to Harvey Bickett, a local resident, who supplied equipment, storage space, and considerable hydrologic information about wells in the area. His support and generous loan of snowmobiles, tractors, and miscellaneous supplies are gratefully acknowledged.

Well-Numbering System

The well-numbering system used by the USGS in Idaho indicates the locations of wells within the official rectangular land subdivision, with reference to the Boise base line and meridian. The first two segments of the number designate the township and range. The third segment gives the section number, followed by three letters and a numeral, which indicate the quarter section, the 40-acre (16.2-ha) tract, the 10-acre (4.0-ha) tract, and the serial number of the well within the tract, respectively. Quarter sections are lettered a, b, c, and d in counterclockwise order from the northeast quarter of each section (fig. 2). Within the quarter sections, 40-acre (16.2-ha) and 10-acre (4.0-ha) tracts are lettered in the same manner. Well 1S-19E-3ccb2 is in the NW¼SW¼SW¼ sec. 3, T. 1 S., R. 19 E., and was the second well inventoried in that tract.

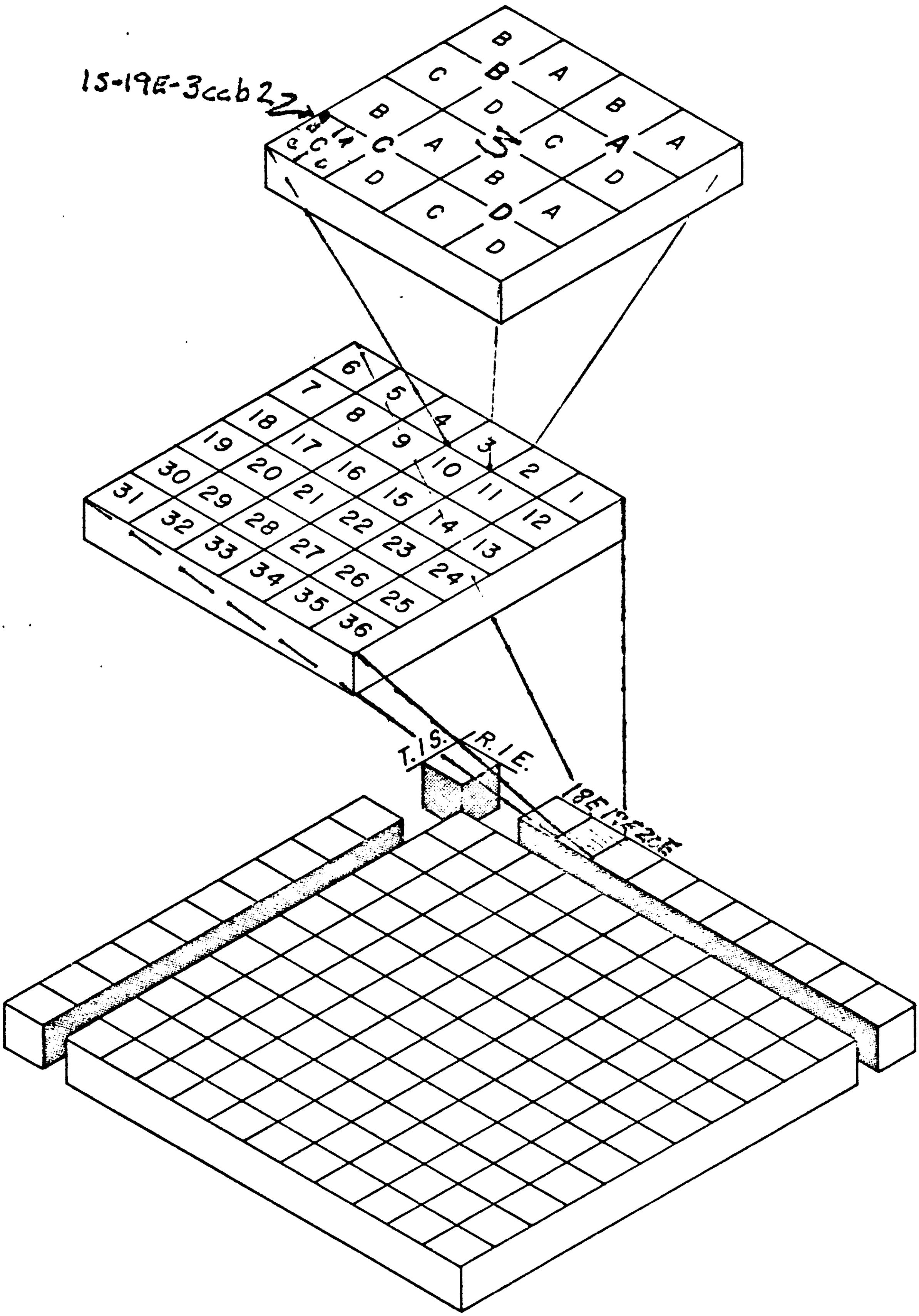

FIGURE 2.-- WELL-NUMBERING SYSTEM

GEOHYDROLOGIC FRAMEWORK

Geologic Units

Bordering and underlying the valley are consolidated sedimentary, volcanic, and intrusive rocks of Tertiary and older age. The various rocks have been described in detail by Schmidt (1961). Because these rocks are virtually impermeable compared to the valley fill material and the basalts of the Quaternary Snake River Group, they are considered as a single unit referred to as basement complex. The basement complex completely surrounds the valley, except where the Big Wood River enters and exits the valley and where Silver Creek exits to the southeast. A number of remnant hills (fig. 3) composed of basement complex crop out in the valley (T. 1 N., R. 18 E., sec. 12; T. 1 S., R. 19 E., sec. 13; and T. 1 S., R. 20 E., sec. 17).

The valley is filled to depths of as much as 500 ft (150 m) with a sequence of interbedded clay, silt, sand, and gravel of Pleistocene and Holocene age. This valley fill is the primary source of ground water in the area. The unit has been subdivided by Schmidt (1961) into several individual units based on age and method of deposition. In this report, the sedimentary valley fill is considered a single geohydrologic unit referred to as fluvioglacial sediments.

In the southern part of the valley, Pleistocene basalt flows considered to be part of the Snake River Group have been identified (Schmidt, 1961). Flows are fractured and jointed and contain numerous contact zones between individual flows. Several high-yield wells have been completed in the basalt. The basalt underlies the valley fill and is a part of the aquifer system in the southern part of the valley.

History of Valley-Fill Deposition

To understand the character of the fluvioglacial sediments, an understanding of the sequence of geologic events that caused their deposition is essential. During Pliocene time, the Big Wood River flowed from the deep, narrow canyon upstream from Bellevue onto a partly erosional and partly structural depression, which is the present-day valley. At that time, the Big Wood River flowed southeastward and exited the valley through the gap now occupied by Silver Creek.

In the early part of the Pleistocene Epoch, a basalt flow occurred in the vicinity of the southeastern outflow gap. The flow blocked the river causing a lake to form. Sediments were deposited in the lake with coarse-grained material being dropped from the river at the upper end of the valley and fine-grained sediments being deposited over the floor of the lake at the southern end of the valley. The regraded valley floor received finer grained sediments as the floor flattened. The lake eventually filled to an elevation sufficient to overflow through the western gap, resulting in the diversion of the Big Wood River to its present-day channel.

Sometime later, a second basalt flow occurred near the southwest gap, which dammed the new channel of the Big Wood River and caused a second lake to form. The second basalt flow resulted in the Big Wood River being rediverted to the former southeast outflow gap.

Several more lava flows occurred alternately at the southeast and southwest outflow gaps. Each successive flow dammed the river, which resulted in additional deposition across the valley floor. Although not all the flows caused the river to change course from one gap to the other, the river did alternate between the two gaps several times.

Concurrent with the repeated damming and diversion of the river, at least two periods of glaciation occurred. Glaciers formed in the upstream part of the Big Wood River drainage basin and provided large quantities of glacier-melt runoff and high loads of detritus to the river. This glacial outwash spread over the valley floor, resulting in extensive deposits of poorly sorted coarse-grained material.

The last glacial period spread a layer of coarse sand and gravel over the entire valley. Some windblown sand and silt has since been deposited over the most recent glacial outwash. The sediments have been reworked by the Big Wood River and Silver Creek, and organic matter has accumulated in swampy areas to form the present-day valley floor.

Schmidt (1961) described this series of events in some detail and discussed the individual sedimentary deposits resulting from the various events. For this study, the brief explanation given should suffice to illustrate how alternating layers of coarse- and fine-grained deposits were emplaced.

Lithology of Valley Fill

The lithology of the valley fill is a controlling factor in the movement of ground water through the study area. Ground water is transmitted easily through coarse sand and gravel but moves slowly through fine-grained silt and clay. Some thick, extensive layers of fine-grained material serve as barriers to ground-water flow and effectively retard movement. Thus, to understand ground-water-flow patterns in the valley, an understanding of the spatial and vertical distribution of sand, gravel, silt, and clay is important.

To define the lithology of the fluvioglacial sediments, drillers' logs of wells within the study area were collected and analyzed. Test holes were machine augered at 10 sites (fig. 3) in the southern part of the area to supplement the available information. The geologic data were used to construct generalized lithologic sections across the valley (figs. 3 and 4).

The heterogeneous nature of the valley fill makes correlation of specific lithologic units difficult. Also, drillers often use different terminology to describe the same material--clay in one well log might have been reported as silt or even silty sand by another driller. These factors, combined with the mechanical difficulty of obtaining truly representative samples of material penetrated by the drill, complicates the construction of lithologic sections across the valley.

Despite the difficulty of correlating individual lithologic units, some success was obtained in correlating more generalized units comprising predominant lithologic types. For example, a thick sequence of predominantly fine-grained material could be traced across the valley, even though individual clay or silt zones within the unit could not be traced more than 1 mi (1.6 km). This was the technique used to construct the cross sections shown in figure 4. No attempt was made to correlate individual lithologic units unless an extensive layer was observed in several wells over a large area.

Four basic units are shown in the cross sections: basement complex, basalt of the Snake River Group, sand and gravel, and fine-grained deposits of silt and clay. The probable distributions of gravel within the sand and gravel also are shown because gravel is a fairly reliable correlation unit. No attempt was made to differentiate between silt and clay.

Although not completely accurate, the cross sections indicate the general position, thickness, and extent of permeable aquifer materials and possible confining layers.

In general, the northern part of the valley is underlain by predominantly coarse sand and gravel; however, a few thin and discontinuous deposits of fine-grained material are present. Because of the limited areal extent of the fine-grained material, confinement of ground water is limited or nonexistent.

In the central part of the basin, more fine-grained sediments are evident, but again, sand and gravel predominate. The fine-grained sediments appear to be extensive enough to provide some degree of confinement, although water-level data indicate no occurrence of artesian conditions. No wells exist which are perforated only in the bottom part of the section. Without such wells, no conclusions about artesian conditions are possible.

From approximately Baseline Road south, significant amounts of fine-grained sediments occur. Continuous layers were found below depths of about 150 ft (45 m). The amount of fine-grained material increases to the south, and confinement of water is indicated clearly over all the southern part of the valley from Hayspur Fish Hatchery to Stanton Crossing. South of Highway 68, sand and gravel compose less than 25 percent of the total thickness of the valley fill.

The lithologic cross sections clearly illustrate the northernmost advance of the basalts which dammed the Big Wood River in earlier times. Basalt occurs as far north as T. 1 S., R. 19 E., sec. 15, as shown on section D-D'. In the southeastern part of the study area, basalt is the predominant unit. Section B-B' illustrates the dominance of the basalt aquifer across the gap through which Silver Creek leaves the study area.

Extent of Effective Separation of Aquifer

To define more accurately the character of the underlying shallow sediments which contribute flow to Silver Creek, test holes were machine augered to depths of as much as 129 ft (39 m) below land surface. Ten holes were drilled along Highway 68 and on north-south roads intersecting the highway. At locations where a suspected confining bed was penetrated, additional holes were drilled and cased with 1.5-in (38-mm) diameter plastic pipe to obtain hydraulic heads above and below the confining layers. Short sections of perforated pipe were installed at the bottoms of wells to obtain point-value hydraulic heads.

Figure 3 shows the locations of the test holes completed as piezometer tubes. Geologic and hydrologic data collected at each site are summarized in figure 5.

In the northernmost test holes (1S-19E-3ddd, 8aad, and 17aaa), virtually no fine-grained material was found in the upper 100 ft (30 m) of valley fill. However, data from nearby deep wells indicate that deeper confining beds are present, but no shallow confinement exists.

Test holes in the western part of the area drilled (1S-19E-17ddd and 18ddd) penetrated some fine-grained sediments at depths less than 90 ft (27 m) below land surface, but head differences in piezometers perforated above and below the suspected confining beds were small (less than 1 ft or

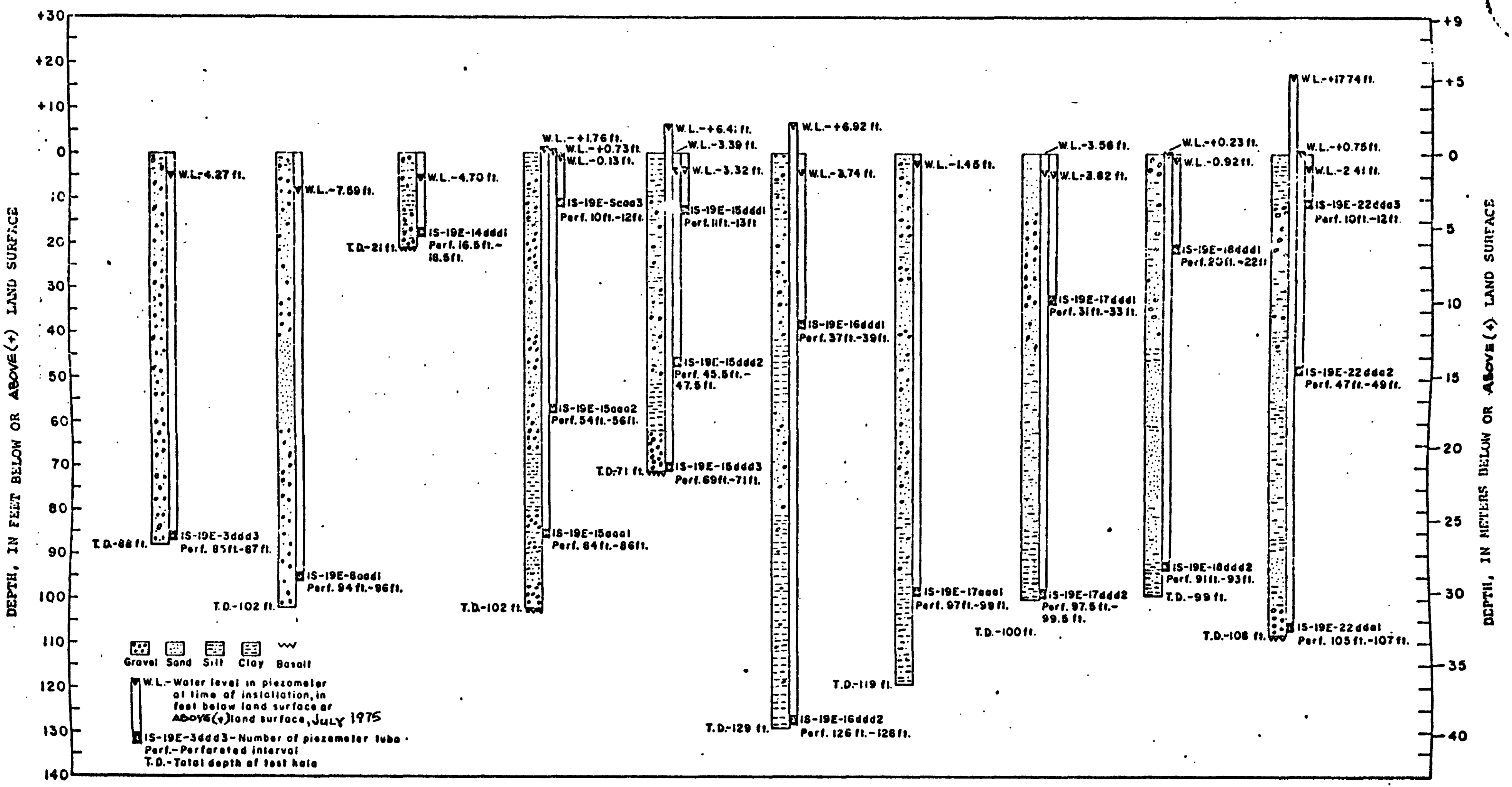

FIGURE 5.-- GEOHYDROLOGIC DATA FROM AUGERED TEST HOLES

0.3 m). However, both test holes bottomed in fine-grained material that appears to be an effective confining bed.

The southern- and easternmost test holes (1S-19E-15aaa, 15ddd, 16ddd, and 22dda) all penetrated several fine-grained zones which serve as effective confining beds. Flowing artesian piezometers were completed in the deepest holes at all four sites. Piezometer 1S-19E-22dda1 had the highest hydraulic pressure head at the time of installation--17.74 ft (5.41 m) above land surface.

Four of the test holes apparently reached the underlying basalt. Drilling was halted in 1S-19E-14ddd, 15aaa, 15ddd, and 22dda at depths of 21 ft (6.4 m), 102 ft (31 m), 71 ft (22 m), and 108 ft (33 m), respectively, when the drill was unable to penetrate further. Basalt is thought to be the impenetrable material encountered.

The data from the test holes and piezometer tubes provide valuable proof that confining beds exist at shallow depth in the southern part of the study area. More importantly, the hydraulic head data for discrete depths in the aquifer clearly indicate that heads vary with depth. Deeper zones have significantly higher head values than shallower zones, provided sufficient fine-grained material is present between the zones. Where only small amounts of fine-grained material exist in a vertical section, head differences are slight, which suggests that confinement is minimal.

As indicated in several of the test holes, not all the fine-grained sediments serve as effective barriers to ground-water flow. Insufficient thickness and limited areal extent of many of the identified fine-grained sediments make them ineffective confining beds. Therefore, the effectiveness of fine-grained sediments to retard or prevent ground-water flow cannot be assessed solely on the basis of lithology. Water-level differences in permeable zones separated by the layers, however, would appear to indicate effective separation.

Using the criterion of water-level difference between shallow and deep zones, the extent of effective confinement was mapped. Figure 3 shows the approximate extent of areas underlain by effective confining beds.

Although data from the test holes identified more than one confining bed, no attempt has been made to map the individual layers. Development of a mathematical hydrologic model requires generalizations to simplify the aquifer system. Generally, simulating more than two layers of flow is too costly and time consuming to be practical unless a need exists for more detail. Therefore, only the maximum extent of confinement is shown in figure 3 by compositing individual confining beds.

Effective confinement extends to about 1 mi (1.6 km) north of Baseline Road on the west side of the valley. On the east side of the valley, confinement apparently extends only 1 mi (1.6 km) north of Highway 68. The entire west side of the valley is underlain by an effective confining bed, except for a small area near the outflow gap of the Big Wood River. On the east side of the valley, the confining bed extends only to the vicinity of Hayspur Fish Hatchery.

In addition to the artesian area in the southern part of the valley, water-level differences between shallow and deep zones were noted in the vicinity of Picabo. In this area, the fine-grained material overlying the basalt aquifer acts as a perching layer, rather than a confining bed. Water levels in the shallow water body are near land surface, while water levels in the deeper aquifer are as much as 130 ft (40 m) below land surface as the deeper aquifer merges with the Snake Plain aquifer to the south.

Aquifer Transmissivity

An integral part of a hydrologic model is the spatial distribution of the aquifer characteristics. Although the physical parameters of the aquifer model are adjusted during construction and calibration of the model, a starting point is needed. Therefore, to provide assistance to the investigators who will build the hydrologic model, a preliminary estimate of aquifer transmissivity was made as part of this study.

During a previous study, Smith (1959) made aquifer tests at five sites in the study area. Although the data were inconclusive, estimates of aquifer transmissivities were obtained. Smith's tests indicate transmissivities that ranged from about 100,000 ft^2/d (9,000 m^2/d) to 430,000 ft^2/d (40,000 m^2/d).

To supplement these data, well-performance tests reported by drillers were used to estimate aquifer transmissivities throughout the study area. Thomasson and others (1960) described a rough approximation that relates specific capacity of a well (ratio of yield in gallons per minute to drawdown in feet) to aquifer transmissivity:

$$T \cong 267 x SC,$$ where

T = transmissivity in feet squared per day, and

SC = specific capacity in gallons per minute per foot of drawdown.

The transmissivities calculated from specific-capacity data are illustrated in figure 3. This map shows the distribution of transmissivities based on performance of wells drilled into the deep aquifer. Data were insufficient to map transmissivities of the shallow, unconfined aquifer.

Generally, in the northern part of the study area in the vicinity of Bellevue, the aquifer transmissivities range from 30,000 to 70,000 ft^2/d (2,000 to 7,000 m^2/d). The highest aquifer transmissivity of 300,000 ft^2/d (30,000 m^2/d) occurs northwest of Gannett (fig. 3), reflecting the presence of coarse sand and gravel. South of Baseline Road, in the artesian area with confining beds of low hydraulic conductivity, transmissivities generally are less than 30,000 ft^2/d (3,000 m^2/d). West of Baseline Road and Highway 93, within the artesian area, is an anomalous area where the transmissivity is 70,000 ft^2/d (7,000 m^2/d).

Data are sparse for the basalt aquifer in the southeastern part of the study area. Basalt aquifers tend to be highly variable in degree of jointing and occurrence of permeable contact zones. Therefore, transmissivities in this area are probably quite variable from location to location. The values shown in figure 3 range from 7,000 ft^2/d (700 m^2/d) to 30,000 ft^2/d (3,000 m^2/d), but locally, transmissivities could be much higher or lower.

Adjustments to these preliminary estimates are expected as information contributed by other agencies is applied to the hydrologic model. However, significant changes from the values shown in figure 3 might indicate a need for a re-evaluation of some concepts or interpretations of the hydrologic conditions.

GROUND WATER

Ground water occurs throughout the valley in the fluvioglacial sediments and basalt. Unconfined or water-table conditions exist over the entire study area, and confined or artesian conditions exist in the southern part of the valley. Extensive use is made of the ground water for domestic supplies, irrigation, and stock water. Ground water discharging from the aquifer in springs and seeps maintains flow in the southern part of the Big Wood River and is the primary source of water in Silver Creek.

Recharge to the aquifer is derived from percolation of snowmelt and precipitation, percolation of excess irrigation water applied to crops, leakage from canals and ditches, and seepage in the northern part of the Big Wood River channel and tributary streams. Underflow through the alluvial fill in the Big Wood River canyon upstream from Bellevue is another primary source of ground water to the valley. Data which quantify the recharge to the system were collected by other agencies. Therefore, no attempt was made in this phase of the investigation to compute inflow to the aquifer.

Discharge from the aquifer occurs as withdrawal by wells, discharge in springs and seeps, evapotranspiration, and underflow through the southeastern and southwestern gaps. This investigation quantifies the major ground-water withdrawals by wells. Evapotranspiration was studied by another agency and was not considered in this study. Underflow to the southwest is considered to be negligible because of the occurrence of basement complex at shallow depth in the gap through which the Big Wood River flows. The southeastern gap transmits a significant amount of underflow in the basalt aquifer. Because of the difficulty of defining transmissivity of the basalt aquifer, this item of outflow can best be computed as the difference between all inflow quantities and other items of outflow. Ground-water discharge through springs and seeps as it relates to inflow to the Big Wood River and Silver Creek will be discussed in detail in a later section of this report.

Ground-Water Withdrawals

Ground water is withdrawn for municipal, rural domestic, stock, and irrigation use. Although municipal, rural domestic, and stock uses were not computed as part of this study, the total quantity withdrawn is negligible compared to other items of ground-water discharge. Municipal use by the city of Bellevue averages only about 50 acre-ft (60,000 m^3) per year. Rural domestic use can be estimated by assuming an average rate of withdrawal per household of 1 acre-ft (1,000 m^3) per year. Total domestic use is probably much less than 200 acre-ft (250,000 m^3) per year. Stock water is obtained mostly from artesian wells or diverted surface water. The small amount pumped can probably be included with the estimate for rural domestic use.

About 60 wells are pumped to irrigate croplands. Nearly all the pumped wells are powered by electric motors. To calculate pumped irrigation water, power records were obtained from the Idaho Power Company. Discharge measurements were made at most of the irrigation wells during August and September. Knowing the rate of discharge, the total power consumed, and the rate of power consumption for the wells, total withdrawals were computed from:

$$Q_t = Q_r x \frac{kWh}{D}, \qquad \text{where}$$

Q_t = total monthly withdrawal in acre-feet,

Q_r = discharge rate, in acre-feet per hour,

kWh = total monthly power consumed, in kilowatthours,

D = hourly power demand of the pumping plant, in kilowatts.

Withdrawals from wells for which discharge measurements could not be obtained required an alternate method of computation. The average amount of power consumed to lift 1 acre-ft (1,000 m³) of water 1 ft (0.3 m) in this area is 1.8 kWh. By measuring depth to water while the well is pumping and either measuring or estimating the dynamic pressure head at the well, total lift can be calculated. Total monthly extraction can be computed from:

$$Q_t = \frac{kWh}{1.8} x (H+P), \qquad \text{where}$$

Q_t = total monthly withdrawal, in acre-feet,

kWh = total monthly power consumed, in kilowatthours,

H = Depth to pumping water level, in feet,

P = pressure head at the well, in feet of water, and

1.8 = average efficiency of pumping plants, in kilowatt-hours per acre-foot per foot of lift.

Because of customer confidentiality, Idaho Power prefers that total pumpage not be identified by individual well or owner. Therefore, computed withdrawals were composited by quarter section. Table 1 lists the monthly ground-water withdrawals by quarter section for the 1974 and 1975 irrigation seasons. Total withdrawal was 19,300 acre-ft (2.4×10^7 m^3) in 1974 and 16,000 acre-ft (2.0×10^7 m^3) in 1975.

The values shown in table 1 have not been adjusted to account for seasonal variations in discharge. Discharge rates from pumped wells are dependent on depth to water. Water levels fluctuate significantly over the irrigation season, and some variation in discharge rates would be expected as water levels change. However, in wells discharging into sprinkler systems, a relatively constant discharge is required for the system to operate satisfactorily. Discharges in these systems are controlled by valves at the well head. As water levels rise, the valves are closed, thereby limiting discharge and increasing dynamic head at the well. As water levels decline, the valves are opened to increase discharge and decrease dynamic head. Thus, the seasonal variation in discharge because of changing lift is compensated somewhat. For wells discharging to ditches, the discharge rate probably is not controlled. However, most wells in this area produce high yields, and pump capacity is the limiting factor, rather than lift. The wells that discharge to ditches are mostly in the lower part of the valley where annual fluctuations generally are less than 10 ft (3 m). This small variation in lift probably doesn't affect discharge by more than 10 percent, which is well within the probable error of pumpage calculations.

Water levels in the valley are generally lower than average in the early part of the irrigation season (May), reach a maximum in June and July, and decline through August, September, and October. During late August and September, when discharge rates were measured, water levels were near the average for the irrigation season. Thus, the reported monthly values for pumped water were probably higher than actual in May and October and lower than actual in June and July. Even though the monthly totals reported in table 1 are somewhat in error because variations in water levels were not taken into account, the totals for the irrigation season are considered reasonably accurate.

In addition to pumped wells, about 50 flowing artesian wells were used for irrigation in the southern part of the valley. Two flowing wells supplied water to the Hayspur Fish Hatchery. Unlike the pumped wells, no documentation is available for flowing wells which can be used to calculate withdrawals. In most cases, discharge measurements could be made to determine rates of flow, but the period and length of use were not readily available. To obtain this information, well owners were personally interviewed to establish when individual wells were allowed to flow, how long they were used, and what the approximate rate of flow was. Recollection was not always precise, but reasonable estimates were made. Based on measured flow rates and well owners' estimates of periods of use, total monthly flows were calculated. These values were also composited by quarter sections and are listed in table 2. Only 1975 values were calculated because most well owners could not recall periods of use for the previous irrigation season. Total flow from artesian wells for 1975 was estimated to be 12,000 acre-ft (1.5×10^7 m^3).

Discharges from flowing wells are directly related to potentiometric head and thus vary significantly through the year. In fact, some wells only flow part of the year. For this reason, potentiometric head fluctuations could not be ignored in computing flows from artesian wells. In most cases, only one or two measurements of discharge were available for flowing wells. Therefore, a straight-line relation between potentiometric head and discharges was assumed. Using this assumption, estimates of flow rates for each month were made. Thus, the values reported in table 2 reflect not only reported periods of flow but also variations in flow because of potentiometric head fluctuations.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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TABLE 2.—FLOWS FROM ARTESIAN WELLS, 1975 — MONTHLY TOTALS, IN ACRE-FEET

1/4	SECTION		JAN.	FEB.	MAR.	APR.	MAY.	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	1975 TOTAL
1N-18E -	35	SW					50	106	123	123	106	46			554
1S-18E -	1	SW					1	7	12	11	8	6	4	3	52
	1	SE					1	3	4	4	3	3			18
	2	SE					93	105	198	220	99	93			808
	11	NE					178	186	99	206	93	86			848
	11	SE					123	133	73	151	66	60			606
	12	NE					1	7	12	11	8	6	4	3	52
	12	NW					68	80	96	119					363
	12	SW						12	48	2					62
	13	NE					129	294	321	321	56	46			1167
	13	NW					53	88	100	100	98	53			492
	13	SW					68	122	124	122	94	7			537
	13	SE	27	25	27	26	35	48	57	56	37	40	26	27	431
	14	NE					164	172	99	206	43	80			814
	14	NW	11	10	11	11	11	12	14	14	12	11	11	11	139
	14	SE					2	2	2	2	2	1			11
	15	SE					148	176	204	204	177	148			1057
	23	NE						30	28	25	9				92
	24	NW						42	28	26	14	7			117
1S-19E -	13	NW	123	105	116	106	116	126	144	144	126	130	119	123	1478
	16	NW							75						75
	16	SW							127						127
	17	SW	27	19	14	14	27	40	41	41	26	27	26	27	329
	17	SE							214						214
	18	NE							62						62
	18	SW					42	93	103	103	46				387
	21	NE						9	183	28					220
	22	NE							80						80
	22	NW							148						148
	22	SW						239	350						589
TOTAL (ROUNDED)															12,000

TO CONVERT ACRE-FEET TO CUBIC METRES, MULTIPLY BY 1233

Ground-Water Movement

Ground water under unconfined or water-table conditions moves in response to gravity from areas of higher altitude to areas of lower altitude. The rate of movement depends upon the transmissivity of the material through which the ground water moves and the steepness of the water-table surface. In confined or artesian aquifers, ground-water moves in response to potentiometric head from areas of higher head to areas of lower head. Again, rate of movement depends upon aquifer transmissivity and steepness of the potentiometric gradient.

By contouring the potentiometric surface, the direction of flow can be determined. In general, the direction of flow is at right angles to the contour lines. Thus, to determine patterns of ground-water flow, potentiometric contour maps are indispensable.

Numerous water-level and pressure-head measurements have been collected throughout the valley by previous investigators. Measurements collected during this study indicate that water levels have not changed substantially since the early 1950's, when a comprehensive well inventory was made as part of a USGS investigation (Smith, 1959). Annual water-level changes which have occurred have, in general, been smaller than seasonal fluctuations (see section on ground-water fluctuations). Therefore, measurements from previous investigations were adjusted from known seasonal fluctuations to fall 1975 conditions and used to supplement data collected in October 1975 from about 75 wells.

The complex aquifer system underlying the valley presents some problems in defining and illustrating ground-water-flow patterns. In the area of confined ground water, potentiometric head is related to the depth of wells. Deeper zones are confined by more extensive confining layers and therefore are pressurized farther upgradient than shallower zones. Thus, potentiometric differences between wells could represent potentiometric gradients and flow patterns between the wells or could indicate that the wells tap separate zones with different potentiometric heads, or both. In addition to this problem, several areas suspected to be underlain by confined aquifers have never been drilled. Potentiometric heads had to be projected into these areas of sparse data.

An important consideration in contouring water levels and potentiometric heads is the seasonal variations in recharge and discharge. The October period selected for illustration of water-table and artesian conditions is a period of declining water levels when recharge has nearly ceased and the aquifer is draining toward points of discharge. This period probably best represents average annual flow conditions for the present conditions of development, although average annual water levels and pressure heads for specific areas may not be represented.

Figure 6 illustrates the water-table and potentiometric contours for October 1975. In areas where two separate aquifers can be identified, head conditions in each are shown.

In the northern part of the valley, only one aquifer is identifiable. In this area, ground water flows in a southerly direction radiating outward from the canyon of the Big Wood River at Bellevue. A steepening of the gradient in T. 1 N., R. 18 E., secs. 12 and 13 probably reflects lower transmissivity or reduced cross-sectional area of the aquifer because of the bedrock hill in section 12.

As ground water moves southward into the area underlain by deposits with higher percentages of fine-grained confining material, artesian conditions become evident in deeper wells. In T. 1 N., R. 18 E., secs. 35 and 36, head differences become evident between the deep and shallow zones. In this area, the directions of ground-water flow in the deep and shallow systems diverge.

In the shallow system, ground-water movement generally follows the surface drainage moving southwestward toward Stanton Crossing or southeastward toward Picabo.

As the water in the shallow system moves southward, it overrides the fine-grained confining beds. Higher percentages of fine-grained material in the southern part of the valley cause a rapid decrease in transmissivity of the shallow sediments and ground water is forced to the surface. This is the spring discharge which feeds Silver Creek and the tributaries to the Big Wood River.

Because of the higher percentage of fine-grained material south of Highway 68, probably only a small amount of water in the shallow sediments passes the areas of spring discharge. On the Silver Creek side of the valley, most of the discharge occurs in T. 1 S., R. 19 E., secs. 8, 9, 10, 11, 14, 15, and 16. On the Big Wood River side, springs occur mostly in T. 1 S., R. 18 E., secs. 11 and 13.

The ground water that moves beneath the confining beds flows mostly toward the Silver Creek side of the valley. The portion that moves southwestward toward Stanton Crossing flows parallel to the shallow water body but under a much steeper gradient. This water travels beneath the confining beds and apparently escapes vertically through a gap in the fine-grained sediments near Stanton Crossing. Substantial spring discharge is noted in Willow Creek in T. 1 S., R. 18 E., secs. 21 and 22 that probably represents upward movement of water from the confined aquifer.

The deep ground water which moves toward the Silver Creek side of the valley moves eastward through the confined aquifer toward the basalt aquifer underlying the southeastern part of the valley.

The potentiometric contours shown in figure 6 in the vicinity of T. 1 S., R. 19 E., sec. 17, show a peculiar flow pattern in the deep system that is difficult to explain. If the contours are correct, water apparently moves along a corridor of high transmissivity, perhaps a buried ancestral channel of the Big Wood River which was entrenched in the fine-grained deposits. Figure 3 indicates a zone of high transmissivity in this general area that lends support to this hypothesis. A more likely hypothesis is that wells in sections 17 and 18 tap a deeper system under higher head than do surrounding wells. If this more plausible explanation is true, perhaps a third set of contour lines is needed to illustrate flow patterns in two confined aquifers instead of one.

Beneath Silver Creek, the confined ground water enters the basalt aquifer (fig. 4, section C-C'). The fluvioglacial deposits which overlie the basalt become thinner and the fine-grained sediments disappear. With no confining beds present, the deep and shallow aquifers merge into a single system near the line separating T. 19 S. and T. 20 S.

Ground water in the basalt aquifer flows southward and eastward toward Picabo and out of the study area. The gradient steepens rapidly southeast of Picabo as the ground water descends to levels in the Snake Plain aquifer.

In the vicinity of Picabo, a layer of fine-grained sediments, apparently deposited by Silver Creek, overlies the basalt aquifer. Water from irrigated crops and seepage from Silver Creek are perched by the fine-grained layer. Several shallow wells obtain small amounts of domestic water from this local perched water body.

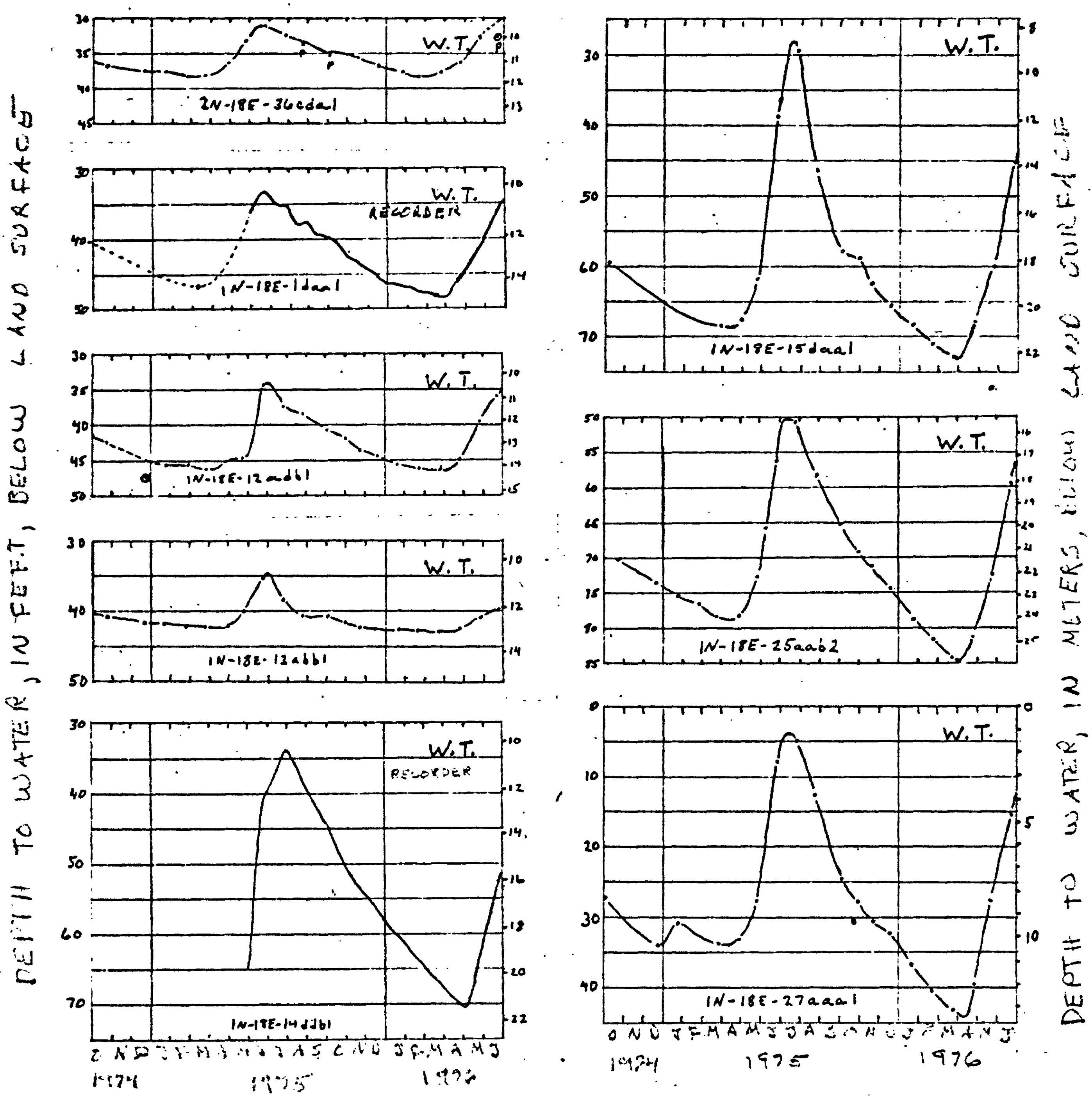
Ground-Water Fluctuations

Ground-water levels rise and fall in response to recharge to and discharge from the aquifer. To document the amount and timing of fluctuations, about 75 wells were measured monthly from January 1975 to June 1976. Data collected in October and December 1974 by IDWR were helpful in extending the period of record. Five continuous water-level recorders were installed to monitor short-term changes in both the artesian and water-table aquifers (fig. 7).

Hydrographs of the wells are shown in figure 8. In addition, selected hydrographs are shown in figure 6 to illustrate fluctuations in different parts of the aquifer.

In the Big Wood River canyon near Bellevue, water levels fluctuate nearly 10 ft (3 m) per year, as illustrated by well 2N-18E-36cdal. Water levels rise in late spring in response to recharge from snowmelt and flood flows in the Big Wood River and continue to rise through early summer as irrigation-return water recharges the aquifer. From about July on, water levels decline as ground water flows to the south into the aquifer underlying the valley.

Ground-water levels in Poverty Flats west of the Big Wood River are represented by well 1N-18E-15daa1. Annual fluctuations in excess of 40 ft (12 m) occur in this area. A dramatic rise in water levels occurs in May and June, corresponding to the spring runoff period in the Big Wood



A. - ARTESIAN WELL
S.A. - SHALLOW ARTESIAN WELL
W.T. - WATER TABLE WELL
• - MEASURED DEPTH TO WATER
⊙ - QUESTIONABLE MEASUREMENT

P - PUMPING
R - RECENTLY PUMPING
F - FLOWING
E - RECENTLY FLOWING
N.R - NO RECORD
∅ - OBSTRUCTION

FIGURE 8.-- HYDROGRAPHS OF OBSERVATION WELLS

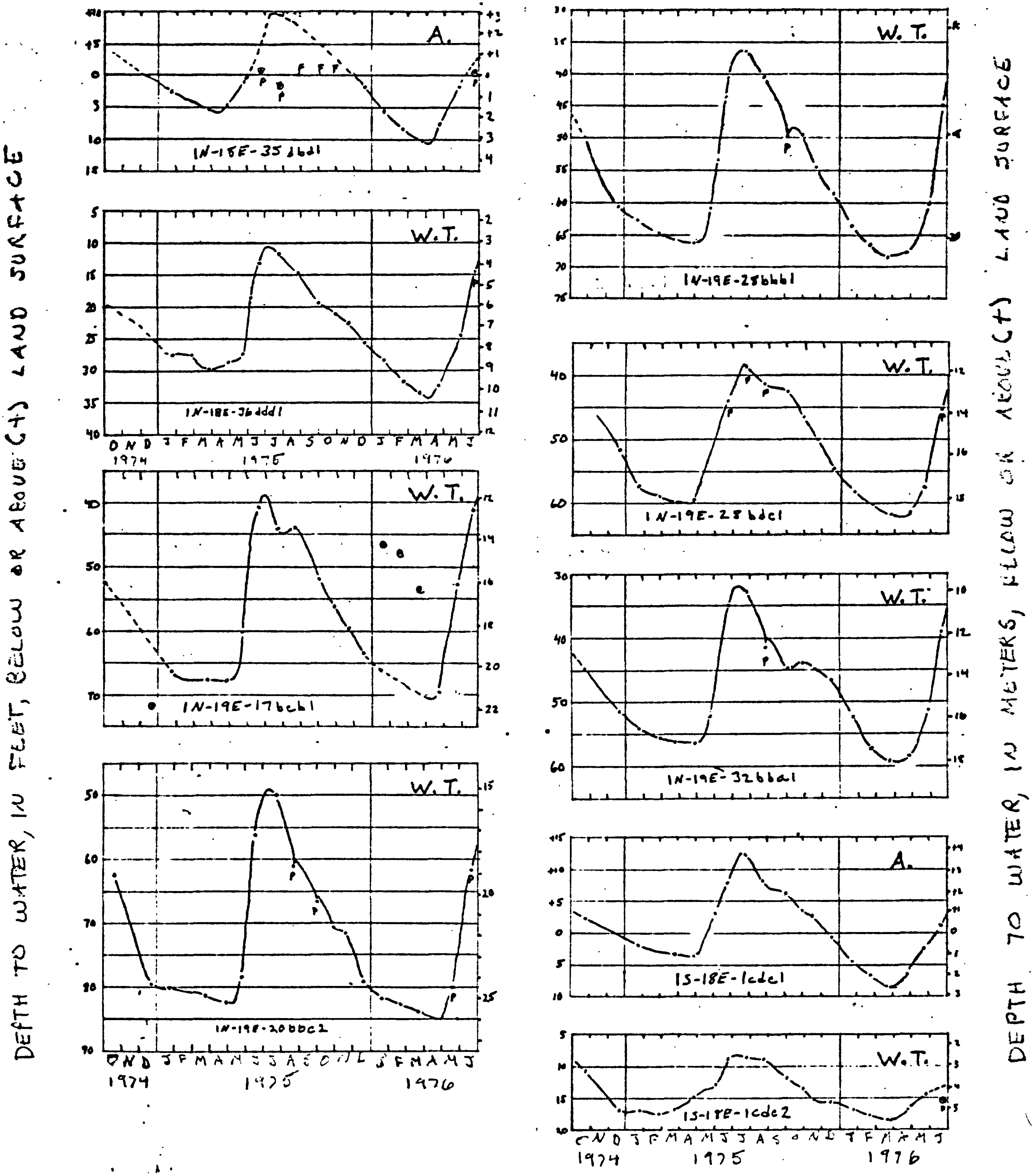


FIGURE 8 ... (CONT)

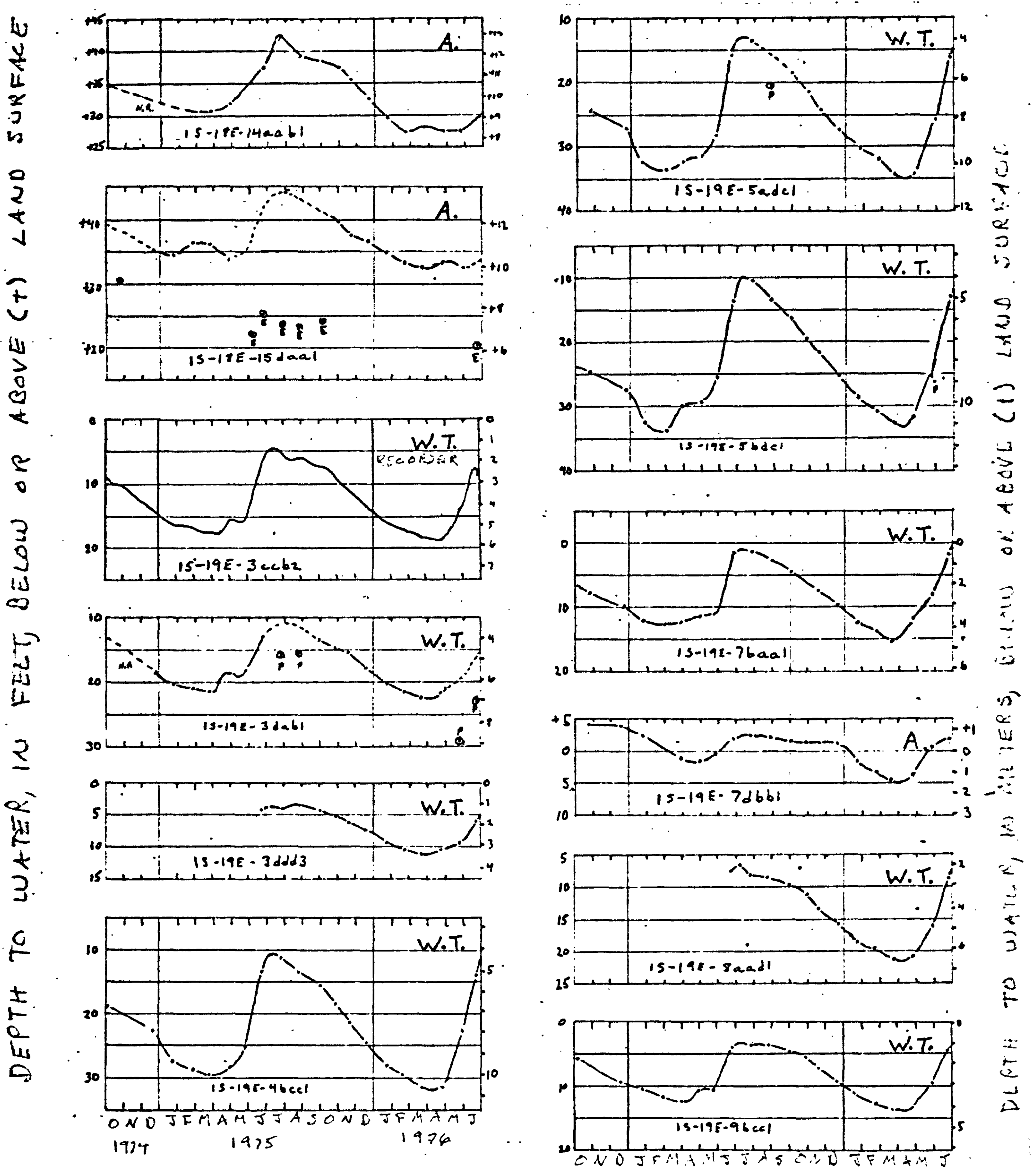


FIGURE 8.-- (CONT.)

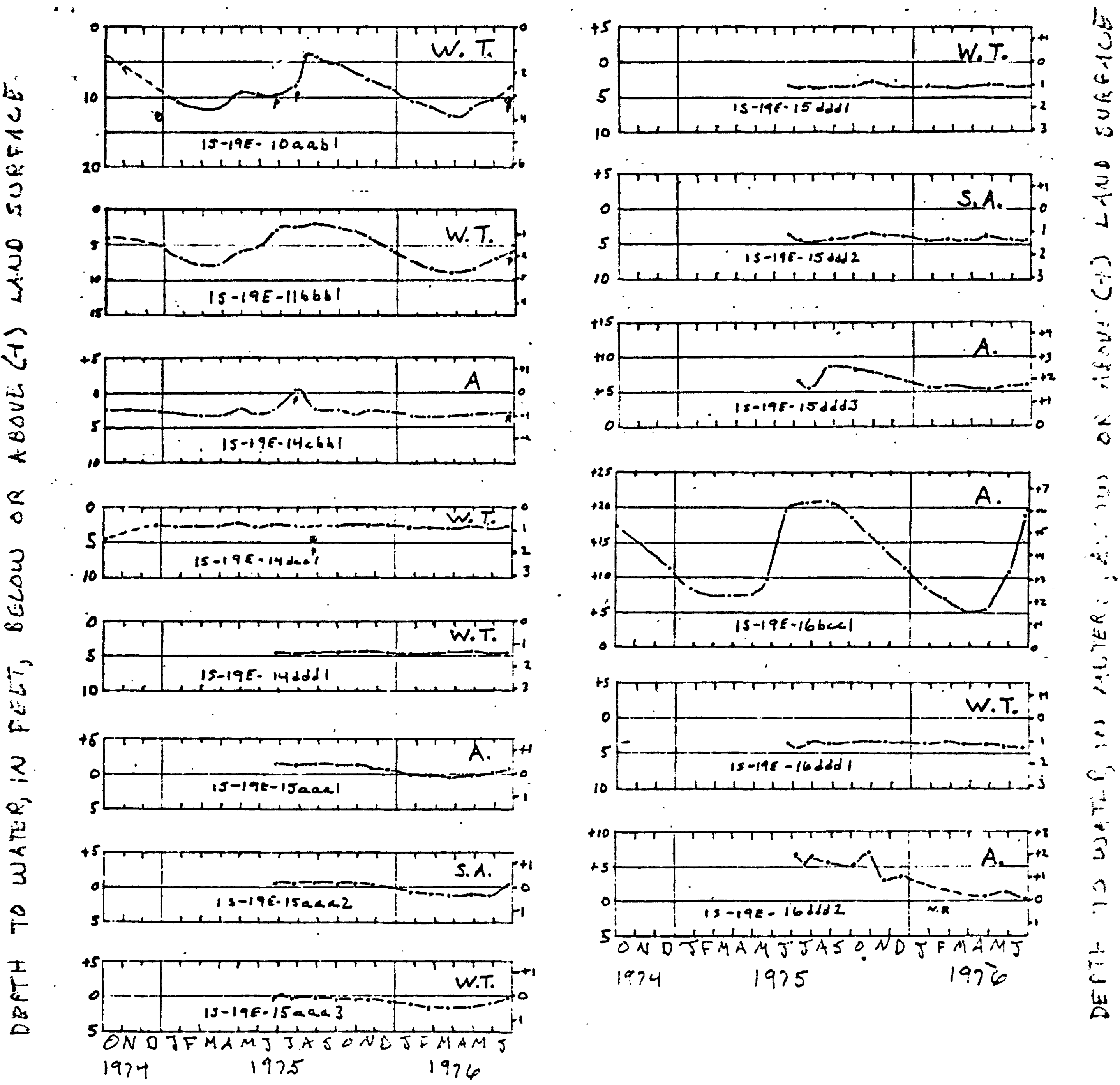


FIGURE 8.-- (CONT)

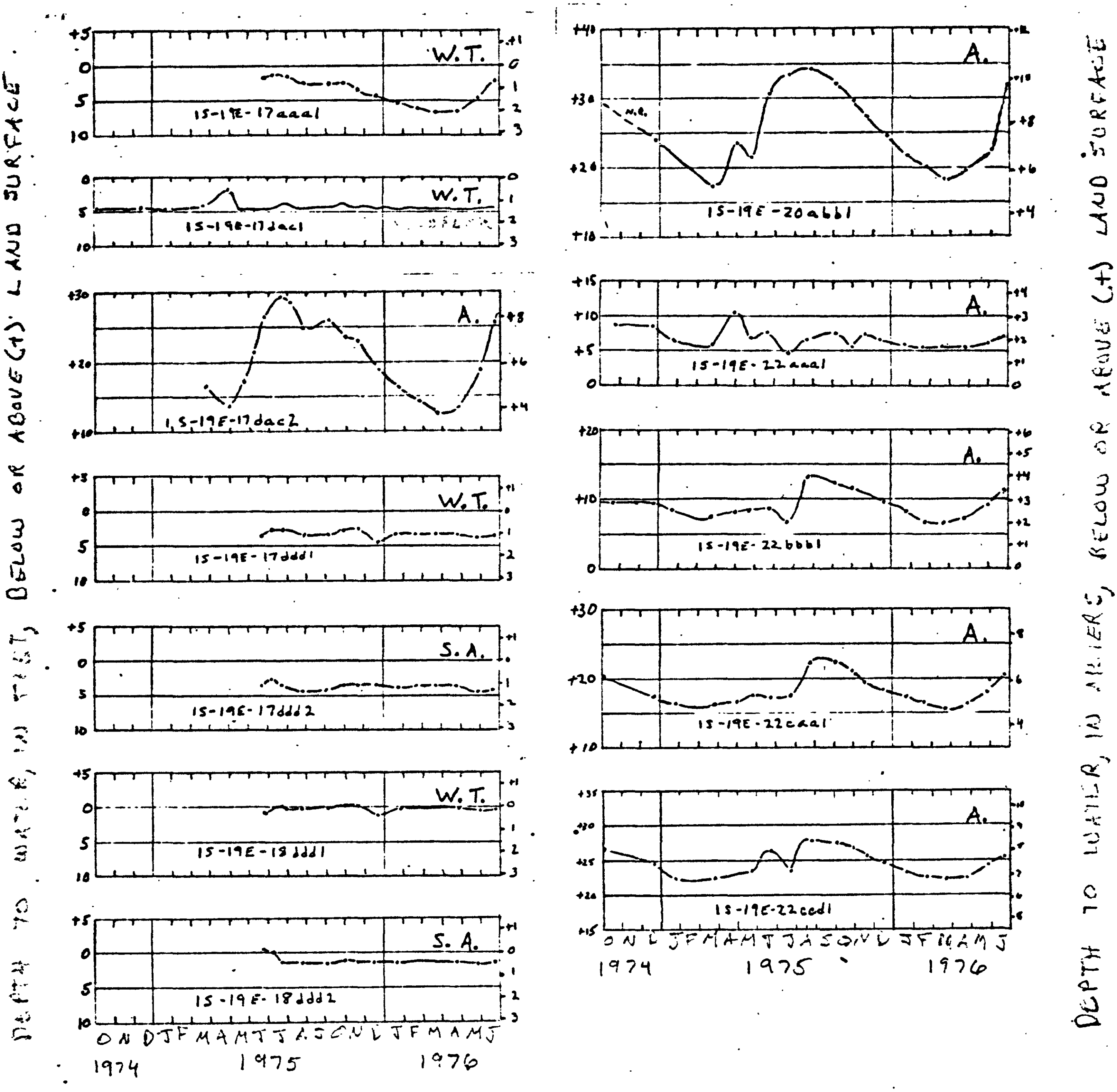


FIGURE 8, -- (CONT)

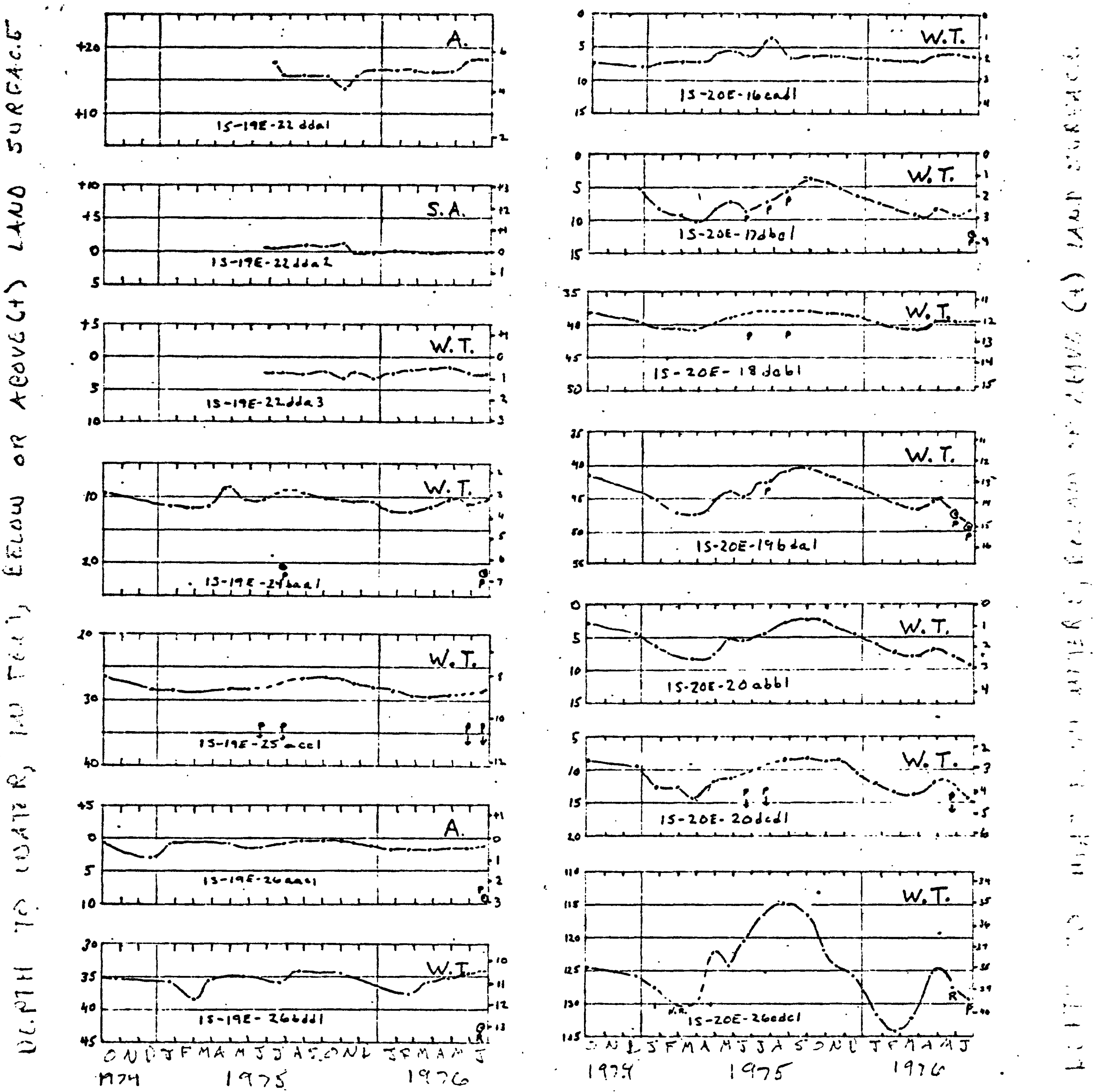


FIGURE 8.—(Contd)

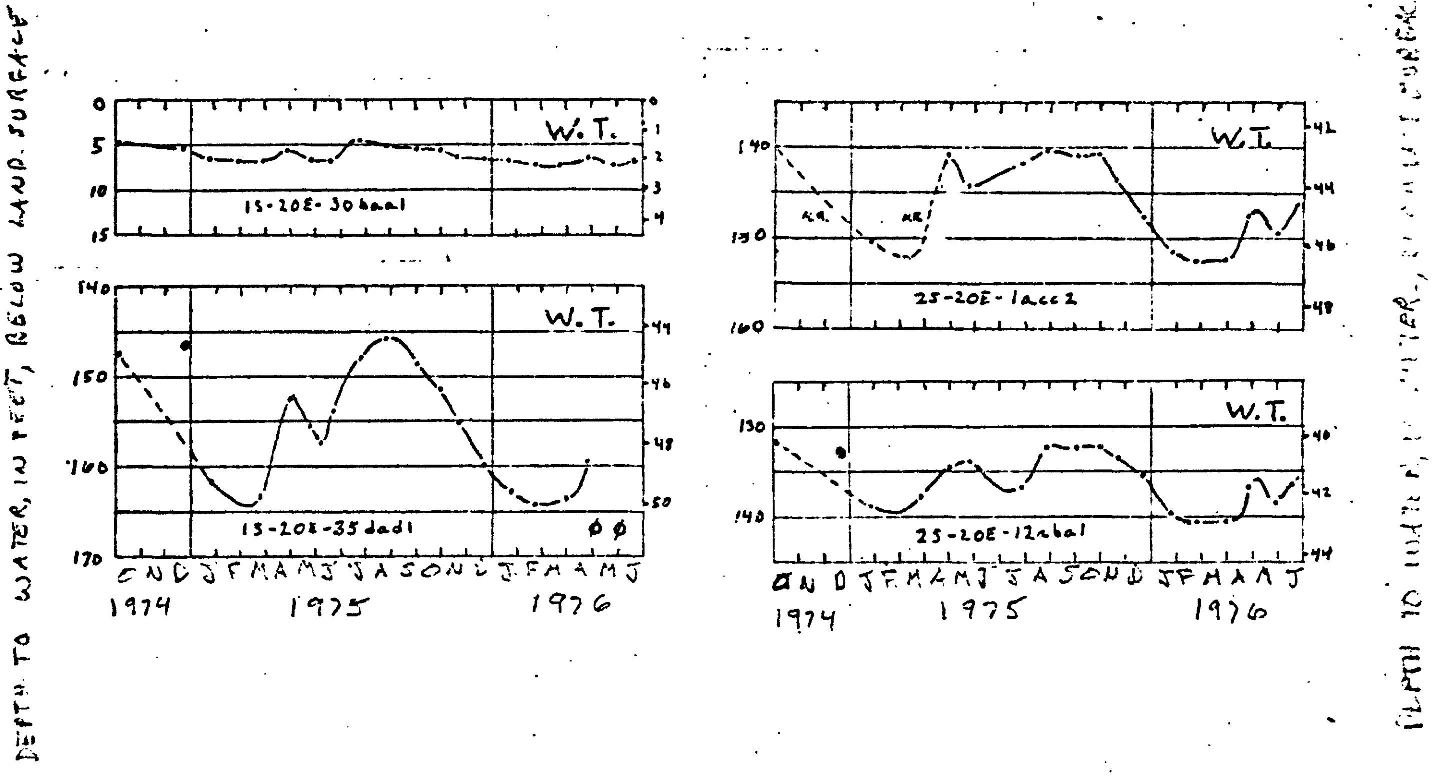


FIGURE 8 .-- (CONT.)

River and beginning of diversions to irrigation canals. Early season losses from irrigation canals and deep percolation of excess irrigation water applied to immature crops result in a rapid rise in water levels in this area. During much of the year, the river is dry or flows only a small amount in the 3-mi (5-km) reach downstream from the diversions to Bypass Canal and Glendale Canal. However, during the late spring runoff, high flows pass this intermittent reach and considerable water percolates to the aquifer. The rapid water-level rise in the aquifer is partly due to this recharge. Most of the water in the Big Wood River is diverted to irrigation canals during the irrigation season, and the reach becomes dry in late July or August. Ground-water levels quickly decline after cessation of recharge from the river.

Ground-water levels east of the river in the northern part of the valley are represented by well 1N-19E-20bbc2. The hydrograph of this well also shows a marked rise in water levels during the spring runoff period. In this area, the rapid rise is probably also due to diversion of surface water to croplands. Diversions usually begin in April and continue through October. During the early part of the irrigation season, significant losses occur from the canals and ditches. In addition, crops utilize only a fraction of the applied irrigation water during the early part of the season, thus providing much excess irrigation water to the aquifer. Later in the season, canals become partly sealed with silt and organic deposits and crops utilize more of the applied water as plants reach maturity. Therefore, recharge declines significantly from the spring high as the irrigation season progresses. The reduction in recharge is reflected in the hydrographs as water levels begin to decline in July. Compared to the Poverty Flats area, declines occur at a moderate rate on the east side of the valley, probably because recharge continues at a reduced rate until late October.

Concurrent with recharge, ground-water withdrawals for irrigation use occur throughout this area (see table 1). The withdrawals probably lessen the rises in water levels and hasten the declines. Withdrawals usually cease in October at the end of the irrigation season, which could account for the fact that water levels do not decline at a more rapid rate after cessation of irrigation application.

Toward the southeastern end of the unconfined area, water-level fluctuations become smaller because of the proximity to spring discharge areas. The water level in well 1S-19E-11bbb1, for example, fluctuates only about 5 ft (1.5 m) per year. This characteristic occurs throughout the southern part of the unconfined aquifer near the springs. The springs effectively hold water levels near a constant level--increasing in discharge as water levels rise and decreasing in discharge as water levels fall.

Pressure fluctuations in the artesian aquifer are represented by wells 1S-18E-1cdc1, 1S-19E-16bbc1, and 22caa1. Well 1S-18E-1cdc1 is near the edge of the confining beds; therefore, the fluctuations are similar to those in the northern unconfined area. Farther into the artesian system, the fluctuations are delayed as the pressure waves move through the system. For example, well 1S-19E-16bbc1 peaks in late July and August, whereas wells in the unconfined area and artesian wells near the edge of the confining beds peak in early and mid-July. Still farther into the artesian system, well 1S-19E-22caa1 peaks in late August and September.

A second phenomenon is apparent in the artesian system. Water levels in wells near the northern edge of the confining beds fluctuate nearly as much as water levels in wells in the unconfined area, but fluctuations become smaller farther into the confined system. Artesian wells near the lower end of the confined area display very small annual fluctuations. Well 1S-19E-22caa1 exemplifies the reduced amount of fluctuation. This may be partly because springs dampen the fluctuations near the point of confinement.

In the southeastern part of the study area where the confined aquifer merges with the unconfined aquifer, water-level fluctuations are minimal because of hydraulic connection with Silver Creek. Water levels are held relatively stable with fluctuations of less than 10 ft (3 m) occurring in well 1S-20E-20abbl. The fluctuations that do occur apparently are related to recharge from snowmelt and irrigation return and changing amounts of underflow from the upstream part of the system.

Near Picabo where the water-level gradient in the basalt aquifer steepens, water-level fluctuations increase to about 20 ft (6 m), as illustrated by well 1S-20E-35dadl. In this area, water levels commonly rise twice during the year. In April when snowmelt recharges the aquifer, a brief rise occurs. After the snow has melted, water levels recede to almost the level reached before snowmelt occurred. Late in May or early in June, the water levels again rise. This second rise probably represents irrigation return but also reflects the recharge wave, which is passing through the aquifer from the upstream area. This second rise continues until late August or early September. After September, the water levels fall rapidly as ground water drains to the southwest.

SURFACE WATER AND ITS RELATION TO GROUND WATER

Two principal streams drain the study area. The Big Wood River enters the valley through a deep, narrow canyon upstream from Bellevue and exits through a gap to the southwest. Silver Creek rises in numerous springs and seeps in the southern part of the valley and exits through a gap to the southeast.

A stream-gaging station on the Big Wood River at Hailey about 4 mi (6 km) upstream from Bellevue provides a record of daily flows entering the study area. A second gage on the Big Wood River near Bellevue (just downstream from Stanton Crossing) gages surface flow leaving the valley. Although a gaging station had been operated on Silver Creek near Picabo for many years, it was discontinued in 1962. To provide data needed in this study, a second gaging station was installed in October 1974 on Silver Creek at Sportsman Access near Picabo about 7 mi (10 km) upstream from the old gaging station.

Most of the flow in the Big Wood River is runoff from the 640-mi^2 (1,660-km^2) drainage area above the Hailey gage, which occurs mostly in May, June, and July (fig. 9). Total flow passing the gage near Stanton Crossing is less than flow past the Hailey gage because of diversions to irrigation canals and seepage losses between the gages. The effects of irrigation diversions are apparent in the hydro-

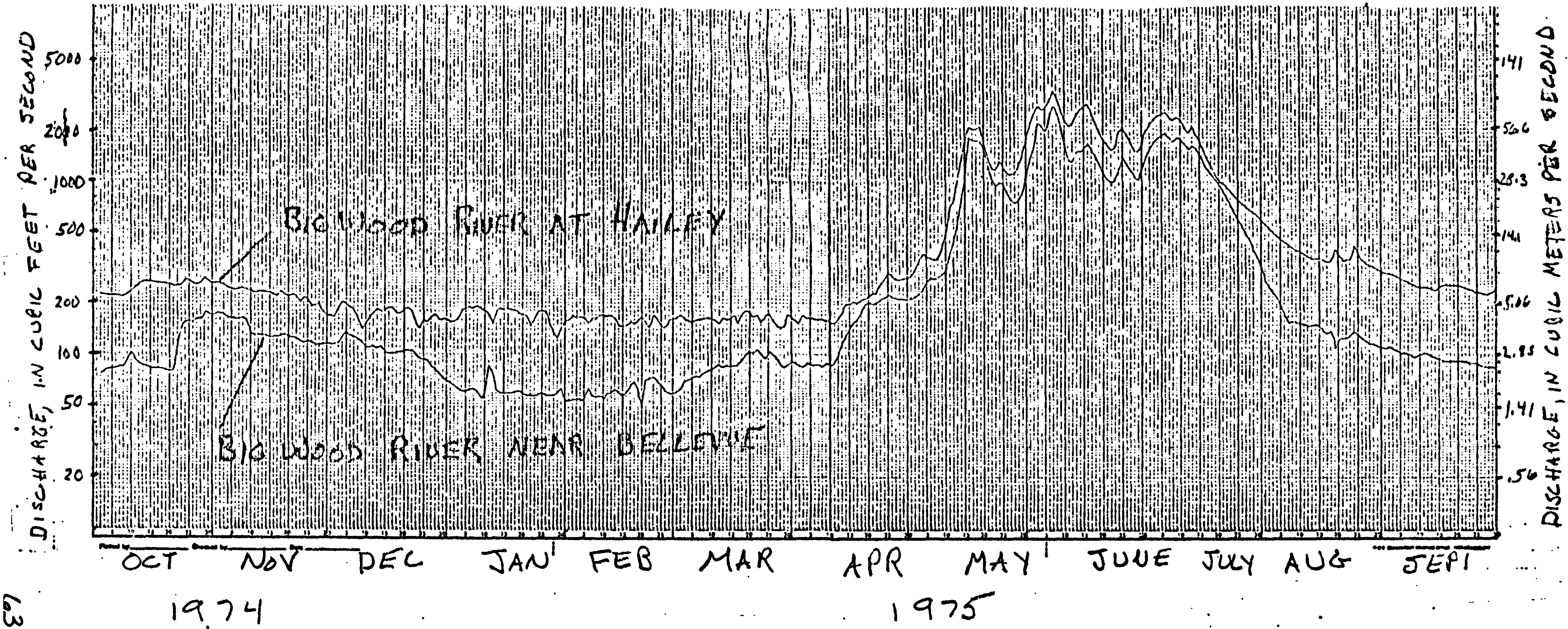


FIGURE 9.--FLOW IN BIG WOOD RIVER, 1975 WATER YEAR.

graphs (fig. 9) in August when flow past the Hailey gage recedes from the peak spring runoff. While the flow past Hailey averages about 400 ft^3/s (10 m^3/s) in August, flow at Stanton Crossing declines to less than 150 ft^3/s (4 m^3/s). An even more dramatic effect can be seen in late October when irrigation ceases. A sharp rise in flow past the gage near Stanton Crossing occurs while flow at the Hailey gage remains relatively stable through October.

These hydrographs unfortunately do not illustrate an important aspect of the flow in the Big Wood River. All the flow passing the gage near Stanton Crossing in the late summer and early fall is ground-water discharge from the aquifer. After spring runoff has receded, irrigation diversions completely drain the river just south of Bellevue. From the point of diversion of the Bypass and Glendale Canals, the river is dry from about August through late October. Ground-water discharge feeds the lower part of the river beginning about 1 mi (2 km) north of Baseline Road, and the river gains from seeps and tributary spring flow all the way to Stanton Crossing.

Because flow in the Big Wood River at Stanton Crossing is greatly affected by upstream runoff and diversions, it is extremely difficult to analyze the ground-water component of flow based only on the two hydrographs. The flow at Stanton Crossing is derived solely from ground-water discharge for only about 2½ months. For the remainder of the year, a significant portion of the flow originates from upstream runoff. Available data preclude determination of the ground-water component based on data from the two stations because of lack of information on losses from the river between Hailey and Stanton Crossing and because the high flows which occur in late spring completely mask the ground-water discharge.

Silver Creek, being fed almost entirely by ground-water discharge, has a very different hydrograph. Figure 10 shows daily discharges for the 1975 water year. Although a peak runoff occurs when the snowpack on the valley floor melts (the 1975 melt occurred in April), the sustained high flows observed in the Big Wood River in May, June, and July are absent. Diversions are made from Silver Creek but in much smaller quantities. Therefore, separation of the ground-water discharge component of flow is possible.

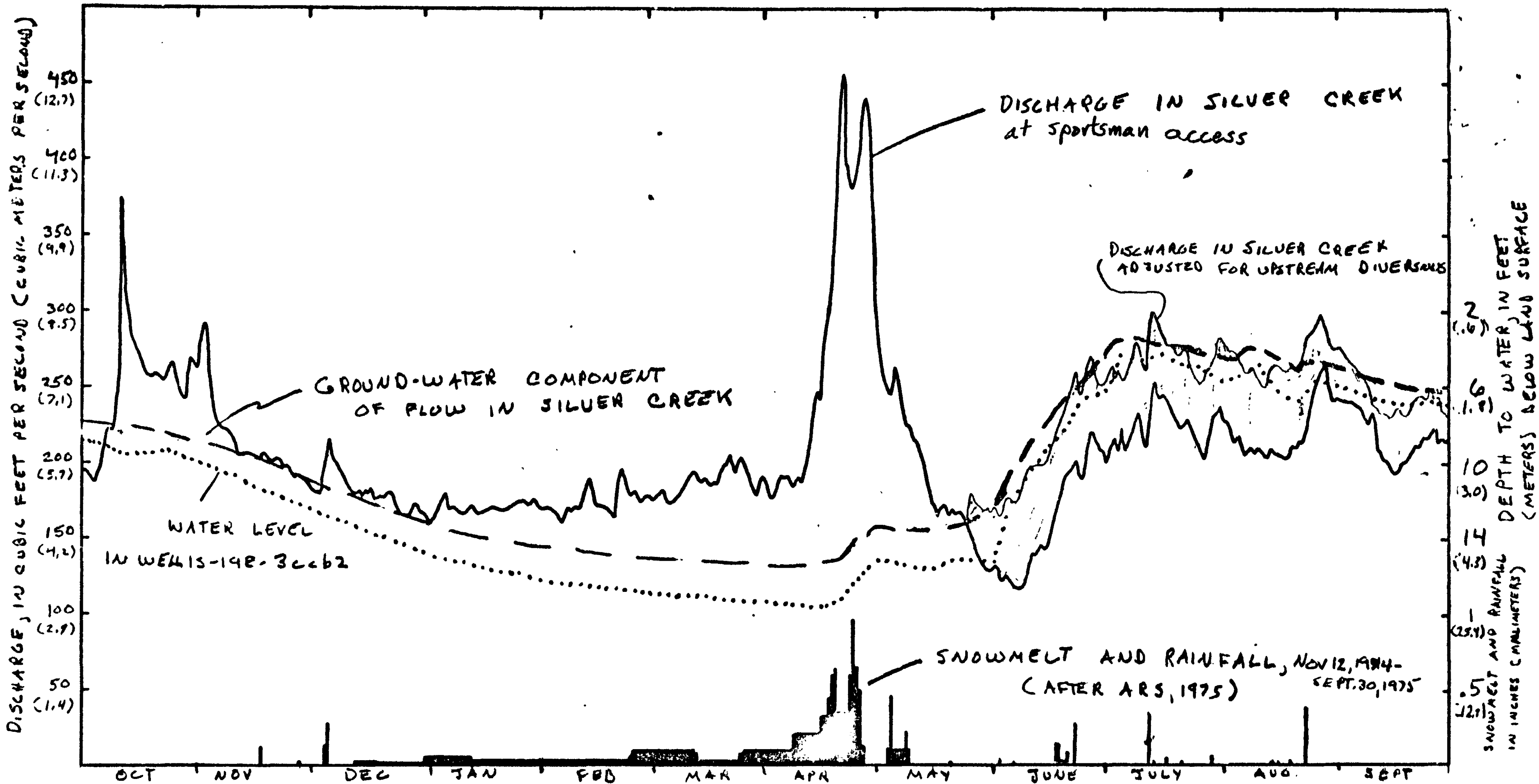


FIGURE 10.-- FLOW IN SILVER CREEK, WATER LEVEL IN OBSERVATION WELL, AND DAILY SNOWMELT AND PRECIPITATION FOR 1975 WATER YEAR

Separation of Flow in Silver Creek

The flow in Silver Creek which passes the gaging station at Sportsman Access is derived from two basic sources: overland runoff and ground-water discharge. Conversely, Silver Creek loses water by three different methods: diversion, evapotranspiration, and seepage. Several of these factors are interrelated to complicate the system. For example, overland runoff contributes water to the aquifer and consequently causes water-level rises which result in increased ground-water discharge. Evapotranspiration from areas underlain by shallow ground water removes water from the aquifer and therefore reduces ground-water discharge to the creek. Increased diversions may result in higher rates of irrigation return to the aquifer, thereby causing water levels to rise and increase ground-water discharge. Thus, the various items cannot be separated completely from each other. However, substantial separation of the components of flow is possible.

The effects of overland runoff are quite apparent on the hydrograph of flow in Silver Creek (fig. 10). Overland runoff results from intense rainfall and snowmelt. Excess irrigation water applied to crops also may enter the stream system as overland flow from fields. However, this item is difficult to measure and is probably small.

Not all rainfall or snowmelt becomes overland runoff to the stream. Because of the high soil permeability, much of the rainfall or snowmelt north of Baseline Road percolates to the aquifer. Some water evaporates from the soil or is transpired by plants. Only on rare occasions does runoff from this area reach the creek. South of Baseline Road, soils are generally less permeable because of the higher percentage of fine-grained material and organic matter. In this area, much of the rainfall and snowmelt does enter the stream system. The amount of runoff is dependent on a number of factors, including intensity of rainfall, rate of snowmelt, antecedent soil moisture content, rate of evaporation, amount of vegetation, and soil permeability.

Data collected by ARS (written commun., 1975) on rainfall and snowmelt at several locations were averaged and plotted on figure 10 to illustrate the amount of water available for overland runoff. Data are available for November 12, 1974, through November 17, 1975.

Although ARS did not begin data collection until mid-November, the peak flows in Silver Creek recorded in October 1974 are undoubtedly related to rainfall events. The first significant rainfall event recorded (December 4 and 5, 1974) caused a small but noticeable rise in discharge in the creek. During the winter months, ARS data indicate that snowmelt apparently resulted in a relatively stable amount of overland flow which sustained streamflow during January and February. As temperatures increased in March, daily rates of snowmelt increased, causing a slight rise in flow. When rapid snowmelt occurred in late April, the effects on streamflow are readily apparent. Rainfall in early May sustained the above-average flows until mid-May. Summer rainfall recorded in June, July, and August apparently caused small increases in streamflow.

The effects of diversions are illustrated in figure 10. Diversions upstream from the gage at Sportsman Access were added to the gaged flow to illustrate the total ground-water discharge.

Measurement of evapotranspiration rates was beyond the scope of this study. However, one may assume that the rate is relatively high during late spring, remains high and fairly constant during the summer, and is minimal during the winter. The almost constant flow rate in January and February probably is partly because of minimal evapotranspiration during that period. Evaporation from the tributary creeks and swampy areas in spring and summer probably reduces the flow in Silver Creek so the recorded flow at Sportsman Access is probably less than total discharge from the contributing springs.

By adjusting the flow in Silver Creek to remove the effects of overland runoff, diversions, seepage, and evapotranspiration, the resulting hydrograph should represent ground-water discharge. Most of these items were not quantified as part of this study; therefore, only a graphical separation is possible with available information. An approximate hydrograph of the ground-water component of flow is shown in figure 10, based on visual adjustment of the recorded flow to account for the various inflow and outflow items. Also plotted in figure 10 are water-level fluctuations in well 1S-19E-3ccb2 (located near the headwaters of the major tributary to Silver Creek).

The illustrated relation, based on 1 year of record, suggests that a reasonable approximation of base flow in Silver Creek could be obtained from ground-water-level measurements (assuming adjustments were made for the other factors which affect the flow). However, records from one well would be insufficient to accurately compute flow because of the variations in water-level fluctuations and timing of peaks in various parts of the aquifer.

Discharge in Silver Creek at Sportsman Access, adjusted for upstream diversions, was plotted against depth to water in well 1S-19E-3ccb2 in figure 11 for periods unaffected by overland runoff. The resulting curve illustrates the relation between flow in Silver Creek and depth to water (or stage) in the unconfined aquifer. Because of the numerous factors discussed previously, a precise relation cannot be

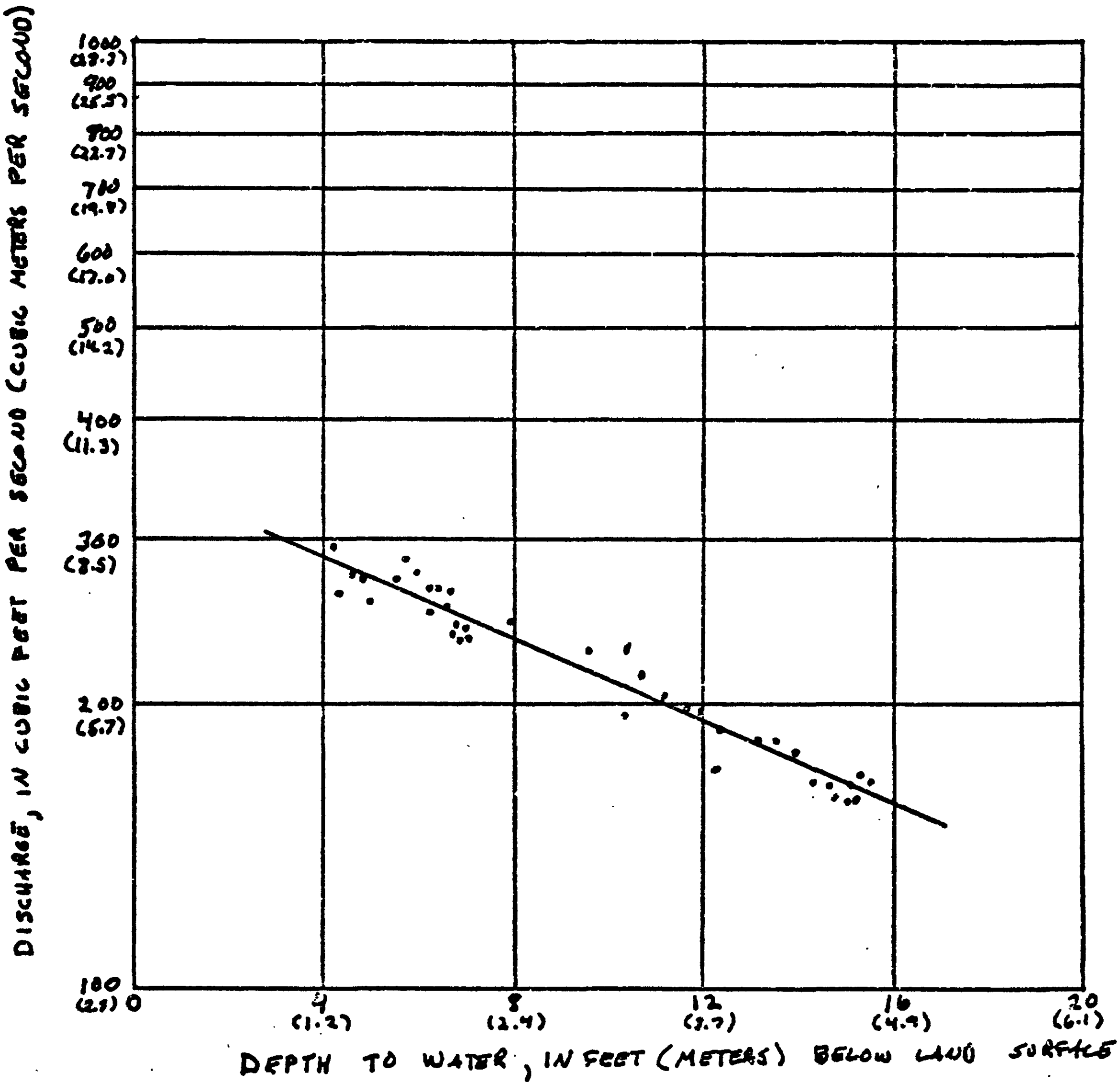


FIGURE 11.-- STAGE-DISCHARGE RELATIONSHIP BETWEEN DEPTH TO WATER IN WELL 1S-19E-3ccb2 AND ADJUSTED BASE FLOW IN SILVER CREEK

FOLD

defined from a single well, but the data clearly indicate the relation between flow and depth to water.

The curve illustrating the approximate ground-water component of flow in Silver Creek (fig. 10) is similar to the hydrograph that a hydrologic model of the ground-water system could generate if properly calibrated. Simulation of diversions and evapotranspiration could be easily incorporated in the mathematical hydrologic model to generate a more accurate hydrograph; simulation of the overland-runoff component of flow would be much more difficult. However, this study was limited primarily to a general evaluation of the relation between the ground-water system and flow in Silver Creek.

Areal Distribution of Ground-Water Discharge

In May, June, and October 1975, a series of discharge measurements were made throughout the system of tributaries which feed Silver Creek. In October 1975, measurements were also obtained at several sites on tributaries to the Big Wood River. Data obtained during these runs are tabulated in table 3, and locations of measuring sites are shown in figure 7.

These data define the areal distribution of ground-water discharge in springs and seeps. To illustrate the findings, a graphical flow pattern of tributaries to the Big Wood River and Silver Creek was constructed (fig. 12). The width of the flow pattern indicates the total measured flow at each site in October. Because this type of presentation does not clearly illustrate small variations, the computed gains or losses between measuring sites are shown on the map. The differences between the three series of measurements on the Silver Creek tributaries were too small to diagram meaningfully by this method, but gains and losses for the June and July runs also are listed for comparison.

Figure 12 shows that much of the ground-water discharge to the Big Wood River occurs north of Highway 68. Springs in T. 1 S., R. 18 E., secs. 10, 11, and 13 contribute about 30 ft^3/s (0.8 m^3/s) of the 70 ft^3/s (2 m^3/s) of flow in the river at the Bellevue gaging station (Stanton Crossing) in

October 1975. These springs and others farther north are fed by the shallow water-table aquifer. A second major area of ground-water discharge to the river occurs in T. 1 S., R. 18 E., secs. 21 and 22. In October, discharge in this area was about 15 ft^3/s (0.4 m^3/s). Data from IWRRI indicate substantially higher discharges here in July and August. Springs in this area probably are discharge points for the deep, confined aquifer.

Virtually all the ground-water discharge feeding Silver Creek rises north of Highway 68. With the exception of one spring in T. 1 S., R. 19 E., sec. 25, which discharges less than 10 ft^3/s (0.3 m^3/s), and a short reach of Silver Creek between measuring sites 24 and 26 which gains a small amount, no significant ground-water discharges were observed in the area underlain by the confining beds south of Highway 68. These two discharge points may represent places of upward movement of water from the deep, confined aquifer where basalt is near the surface. Apparently, upward movement of water through the confining beds is limited elsewhere in the area.

Nearly half the flow in Silver Creek rises in springs which feed Grove Creek near the boundary of the confining beds. Much of the remaining flow in Silver Creek enters through Loving Creek, which also is fed by springs located near the boundary of the confining beds. These springs represent ground-water discharge from the shallow, unconfined aquifer and upwelling from the deep aquifer.

Several springs discharge north of Highway 68 but are 1 mi (1.6 km) or more south of the upstream edge of the confining member. These springs drain the shallow aquifer, but some upward movement of artesian water through the confining bed may contribute to the flow.

Gains and Losses in Silver Creek

The data collected during the May, June, and October ground-water discharge studies also included a series of measurements along Silver Creek. This information defines reach gains and losses along the main stem of the creek from the headwaters to the old gaging station near Picabo. Plotted in downstream order, together with measured inflows and diversions, these data define the ground water-surface water interactions along Silver Creek and also illustrate temporal changes in flow and reach gains and losses (fig. 13).

In analyzing the information contained in figure 13, accuracy of discharge measurements should be kept in mind. Under good measuring conditions, discharge measurements are accurate to within about 5 percent. Where the stream bottom is moss or mud covered, as is the case at many of the measuring sites, accuracy may be less than 7 percent. Thus, for a measured discharge of 200 ft^3/s (5.7 m^3/s), an error of ± 10 to 14 ft^3/s (0.3 to 0.4 m^3/s) is possible. Errors in gains or losses computed between adjacent measuring sites could actually be twice these amounts. At several sites, a gain or loss noted in one reach was offset by a loss or gain in the next reach. This suggests that the midpoint measurement was in error by the amount of gain or loss, and the stream did not actually gain or lose water through the section.

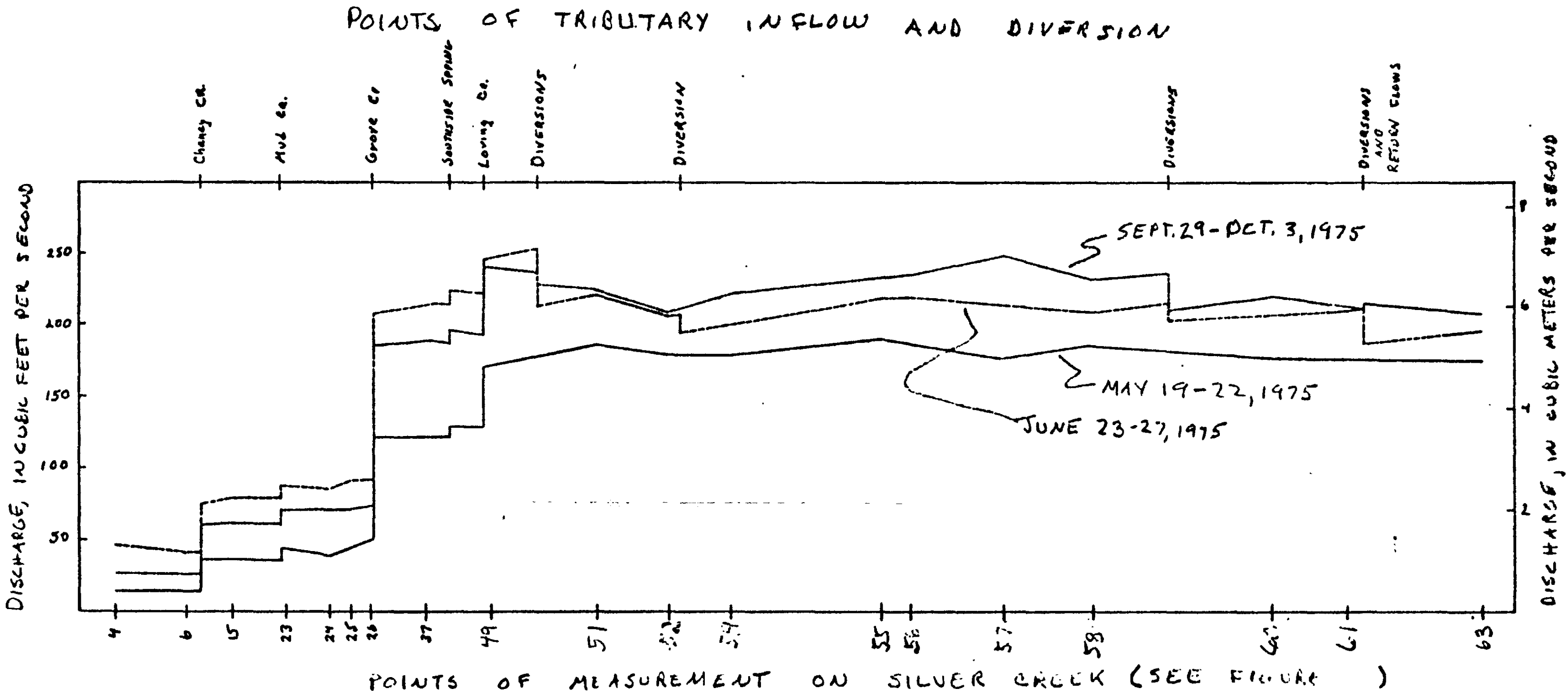


FIGURE 13.-- GAINS AND LOSSES IN FLOW OF SILVER CREEK

Silver Creek is underlain by the confining beds from its headwaters to about measuring site 51. In this reach, the creek increases in flow to about 200 ft^3/s (5.7 m^3/s), primarily from inflow from tributaries. Between stations 49 and 51 where Silver Creek leaves the area underlain by the confining member, significant gains were observed in May and June. In October, however, the creek apparently lost some water in this reach.

From station 51 to about station 57, Silver Creek is underlain by a shallow, unconfined water table. Losses from the creek were observed during all three series of measurements between sites 51 and 52. Evidently, the creek recharges the aquifer through this reach. In general, gains were noted from about station 52 to station 55, indicating that ground water feeds the creek along this northeast-flowing reach. Between stations 55 and 57, the stream lost water in May and June. In October, however, gains were noted as far east as station 57. This phenomenon suggests that the water table rises above the creek level in this area as a result of irrigation-return flows in late summer and early fall.

Downstream from station 57, water levels in the basalt aquifer drop steeply toward the Snake River Plain. From this point on, the creek is perched above the main aquifer. A shallow water body contained in the fine-grained deposits apparently interacts with the creek in this area. Water is gained or lost from the creek at various places in relatively small amounts, depending upon the water levels in the perched water body. In May, for example, the creek steadily loses water from station 58 to the site of the old gaging station (site 63). In June and October, the creek apparently gains water in this lower reach. However, the small gains and losses are less than measurement error, and numerous diversions and return flows partly mask the computed gains or losses.

SUMMARY AND CONCLUSIONS

Water enters the fluvioglacial valley fill in the Silver Creek area from seepage from the Big Wood River, irrigation return, leakage from canals, and precipitation. The recharge joins underflow from the Big Wood River canyon and moves generally southward through the valley. The various inflow sources cause significant seasonal fluctuations in ground-water levels.

The lithology of the valley fill partly controls the movement of ground water through the system. Extensive layers of fine-grained deposits in the southern part of the valley confine underlying coarse material and separate the aquifer into several essentially isolated zones. Numerous flowing wells tap the confined aquifers in the southern part of the valley, while wells tapping the shallow aquifer do not flow. Springs occur throughout the southern part of the valley where ground water overriding the fine-grained deposits is forced to the surface. Ground water in the confined system flows southwestward to discharge to the Big Wood River and southeastward to enter the basalt aquifer underlying the southeast outflow gap. Apparently, only small amounts of confined ground water on the east side of the valley move upward through the confining beds to discharge into Silver Creek.

Streamflow measurements made throughout the area of ground-water discharge show that most of the flow in Silver Creek is derived from springs issuing from the shallow, unconfined aquifer near the upstream edge of the confining beds. Over half the ground-water discharge which feeds the Big Wood River also rises from the shallow aquifer. However, a substantial part of the ground-water component of flow in the Big Wood River apparently is discharged from the downstream part of the confined aquifer near Stanton Crossing.

Seasonal fluctuations in the ground-water component of flow in Silver Creek are directly related to water-level fluctuations in the aquifer near the springs.

The complex interaction of ground and surface water is clearly demonstrated in seasonal variations of gains and losses along Silver Creek. In some downstream reaches near Picabo, the creek gains flow during periods of high ground-water levels and loses flow during periods of lower ground-water levels.

SELECTED REFERENCES

Castelin, Paul M., and Chapman, Sherl L., 1972, Water resources of the Big Wood River-Silver Creek area, Blaine County, Idaho: Idaho Dept. Water Adm. Water Inf. Bull. 28, 44 p.

Schmidt, Dwight L., 1961, Quaternary geology of the Bellevue area in Blaine and Camas Counties, Idaho: U.S. Geol. Survey Open-File Rept. 625, 135 p.

Smith, R. O., 1959, Ground-water resources of the middle Big Wood River-Silver Creek area, Blaine County, Idaho: U.S. Geol. Survey Water-Supply Paper 1478, 64 p.

Thomasson, H. G., Olmsted, F. H., and Le Roux, E. F., 1960, Geology, water resources, and ground-water storage capacity of part of Solano County, California: U.S. Geol. Survey Water-Supply Paper 1464, 693 p.

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(October 1957)
COMPUTATION FORM—DOUBLE

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77-456

TABLE 3. -- STREAM DISCHARGES AT SELECTED SITES

Station (no.)	Location	Late Spring Date	Late Spring Discharge (ft³/s)	Late Spring Specific conductance (µmhos)	Early Summer Date	Early Summer Discharge (ft³/s)	Early Summer Specific conductance (µmhos)	Fall Date	Fall Discharge (ft³/s)	Fall Specific conductance (µmhos)
1	1S-19E-19a - Unnamed Trib at Hwy 68	5-20-75	0	--	6-24-75	0	--	9-30-75	0.1	351
2	1S-19E-19a - Unnamed Trib at Hwy 68	5-20-75	5.11	357	6-24-75	19.9	391	9-30-75	5.2 est 8.18	353 355
3	1S-19E-20b - Patton Cr at Hwy 68	5-20-75	5.94	333	6-24-75	31.9	393	9-30-75	21.8	336
4	1S-19E-35a - Cow Cr below Marsh				6-24-75	46.2	352			
5	1S-19E-27b - Unnamed Trib to Patton Cr below Marsh	5-19-75	0	--	6-23-75	0	--	9-29-75	0	--
6	1S-19E-27b - Silver Cr above Cheney Cr	5-19-75	13.9	299	6-23-75	40.8	353	9-29-75	25.7	347
7	1S-19E-17a - West Trib to Cow Cr.	5-21-75	0.93	363	6-25-75	13.4	412	10-1-75	7.14	358
8	1S-19E-16b - East Trib to Cow Cr.	5-21-75	0.21	435	6-25-75	1.09	409	10-1-75	0.88	357
9	1S-19E-21b - Cow Cr. at Hwy 68	5-20-75	6.08	341	6-24-75	23.6	406	9-30-75	15.4	353
10	1S-19E-22c - Cow Cr above Cheney Cr.				6-23-75	16.5	335			
11	1S-19E-16a - Cheney Cr above Hwy 68	5-21-75	10.4	326	6-25-75	10.6	361	10-2-75	12.3	326
12	1S-19E-21a - Cheney Cr at Hwy 68	5-20-75	11.9	308	6-24-75	15.9	315	9-30-75	17.2	317
13	1S-19E-22c - Cheney Cr above Mouth	5-19-75	22.0	301	6-23-75	32.2	287	9-29-75	33.8	305
14	1S-19E-27a - Unnamed Trib to Silver Cr below Cheney Cr	5-19-75	0.45	310	6-23-75	0.43	--	9-29-75	0.5	323
15	1S-19E-27a - Silver Cr below Cheney Cr.	5-19-75	36.4	293	6-24-75	19.6	369	9-29-75	61.0	356
16	1S-19E-27a - Unnamed Trib to Silver Cr above Mud Cr.	5-19-75	0	--	6-23-75	0	--	9-29-75	0	--
17	1S-19E-16a - West Trib to Mud Cr.	5-21-75	0.09	383	6-25-75	1.33	411	10-1-75	0.37	400
18	1S-19E-16a - East Trib to Mud Cr	5-21-75	0.05	361	6-25-75	0.28	408	10-1-75	0.67	460
19	1S-19E-22a - Mud Cr at Hwy 68	5-20-75	6.00	318	6-24-75	7.83	368	9-30-75	9.21	355
20	1S-19E-23c - West Branch Mud Cr	5-19-75	8.65	--	6-23-75	7.60	354	9-29-75	10.1	329
21	1S-19E-23c - East Branch Mud Cr.	5-19-75	0.05	--	6-23-75	0	--	9-29-75	[illegible]	306
22	1S-19E-26b - Mud Cr at Mouth	5-19-75	7.66	271	6-24-75	8.24	335			
23	1S-19E-26b - Silver Cr below Mud Cr	5-19-75	43.9	305	6-24-75	86.1	355	9-29-75	69.7	362
24	1S-19E-26a - Silver Cr 1/4 mi. below Mud Cr.	5-20-75	38.1	306	6-24-75	85.4	367	9-30-75	71.1	371
25	1S-19E-23d - Silver Cr 1/2 mi. below Mud Cr.	5-20-75	44.3	286	6-24-75	90.8	369	9-30-75	71.6	365
26	1S-19E-23d - Silver Cr above Grove Cr.	5-20-75	49.2	310	6-24-75	90.4	375	9-30-75	73.7	366
27	1S-19E-24a - Willow Cr above Hwy 68	5-21-75	10.7	306	6-25-75	11.9	333	10-2-75	9.97	311
28	1S-19E-23b - Willow Cr at Hwy 68	5-20-75	14.1	302	6-24-75	15.0	324	9-30-75	15.3	321
29	1S-19E-10a - South Trib to Grove Cr.				6-24-75	0	--			
30	1S-19E-10a - Grove Cr below Station 9				6-25-75	22.8	504			
31	1S-19E-10c - North Trib to Grove Cr below St. 9				6-25-75	4.94	514			
32	1S-19E-15a - Grove Cr above Sec 15 Springs				6-25-75	60.3	440	10-3-75	43.2	375
33	1S-19E-10d - North Trib to Grove Cr above Sec 15				6-24-75	4.10	412			
34	1S-19E-15a - North Trib to Grove Cr below Springs				6-24-75	21.4	--	10-3-75	31.8	395
35	1S-19E-14b - Grove Cr below Sec 15 Springs	5-21-75	45.6	342	6-25-75	90.5	473	10-3-75	94.8	366
36	1S-19E-14d - Grove Cr at Hwy 68	5-20-75	54.2	364	6-24-75	105	439	9-30-75	94.6	368
37	1S-19E-23a - [illegible] Cr at Hwy 68	5-20-75	2.49	363	6-24-75	2.83	376	9-30-75	3.34	408
38	1S-19E-23d - Grove Cr at Mouth	5-20-75	74.1	308	6-24-75	116	387	9-30-75	114	370
39	1S-19E-24c - Silver Cr below Grove Cr.	5-20-75	121	324	6-24-75	114	382	9-30-75	188	351
40	1S-19E-25b - Southside Spring	5-20-75	8.36	344	6-24-75	8.50	283	9-30-75	9.17	292
41	1S-19E-11a - North Trib to Butte Cr	5-22-75	2.03	386	6-26-75	5.31	416	10-3-75	5.28	409
42	1S-19E-11a - Middle Trib to Butte Cr	5-22-75	0.48	357	6-26-75	1 e	498	10-3-75	1.01	446
43	1S-19E-11a - South Trib to Butte Cr	5-22-75	1.19	377	6-26-75	1.44	465	10-3-75	1.95	424
44	1S-19E-13b - West Branch Butte Cr at Hayspur	5-22-75	10.6	373	6-24-75	6.65	411	9-30-75	11.5	385
45	1S-19E-13b - East Branch Butte Cr at Hayspur				6-24-75	9.88	403	9-30-75	1.81	387
46	1S-19E-13c - Butte Cr below Hayspur	5-22-75	31.4	375	6-24-75	30.8	433			
47	1S-19E-13c - Loving Cr at Hwy 68	5-20-75	44.2	344	6-24-75	43.0	409	9-30-75	52.7	396
48	1S-19E-24d - Loving Cr at Mouth	5-20-75	41.6	323	6-24-75	25.8	387	9-30-75	45.5	391
49	1S-19E-25a - Silver Cr below Loving Cr	5-20-75	171	320	6-24-75	246	371	9-30-75	239	348
50	1S-20E-30b - Diversions from Silver Cr above Hwy 68	5-21-75	-0.3	--	6-25-75	-40.4	--	10-1-75	-8.28	367
51	1S-20E-30a - Silver Cr 1 mi below Loving Cr.	5-21-75	156	322	6-25-75	221	375	10-1-75	225	386
52	1S-20E-20a - Silver Cr. above Hwy 68	5-21-75	178	317	6-25-75	206	374	10-1-75	207	382
53	1S-20E-20d - Diversion from Silver Cr, below Hwy 68				6-25-75	-11.2	419			
54	1S-20E-20b - Silver Cr at Sportsman Access Gage	5-21-75	178	330	6-25-75	208	396	10-1-75	228	376
55	1S-20E-10c - Silver Cr. 1 mi. below Sportsman Access	5-21-75	179	324	6-25-75	220	402			
56	1S-20E-1d - Silver Cr. 4 mi below Sportsman Access	5-21-75	176	319	6-26-75	219	406	10-1-75	234	363
57	1S-20E-22b - Silver Cr. 1.5 mi. above Picabo	5-22-75	176	358	6-26-75	214	397	10-2-75	247	375
58	1S-20E-22d - Silver Cr near Picabo	5-22-75	185	318	6-26-75	208	400	10-2-75	232	360
59	1S-20E-27 - Diversions and Tailwater Returns				6-26-75	-10.9	--	10-2-75	-22.4	--
60	1S-20E-26d - Silver Cr. below Picabo	5-22-75	176	360				10-2-75	219	389
61	1S-20E-36b - Silver Cr. at Hwy 68				6-27-75	210	372			
62	1S-20E-36 - Diversions and Tailwater Returns	5-22-75	-0.3	--	6-27-75	-24.2	--	10-2-75	-3.22	--
63	2S-20E-1a - Silver Cr. at old gage near Picabo	5-22-75	174	362	6-27-75	195	405	10-2-75	267	383
64	2N-18E-?b - [illegible] Canal at Diversion							9-19-75	141	285
65	2N-18E-26b - Big Wood R. below [illegible] Canal							9-29-75	565	285
66	1N-18E-1a - Big Wood R. below Bellevue							9-30-75	529	--
67	1N-18E-12a - Upper Glendale Diversion							10-1-75	1.11	301
68	1N-18E-12a - Glendale Canal at Diversion							9-30-75	21.5	301
69	1N-18E-12a - Bypass Canal at Diversion							9-30-75	41.4	301
70	1N-18E-35c - Big Wood R. above Baseline Rd.							10-1-75	2.93	378
71	1S-18E-2b - Big Wood R. below Baseline Rd.							10-1-75	2.39	--
72	1S-18E-11a - Big Wood R. above Reed Cr							10-1-75	2.26	299
73	1S-18E-?b - Big Wood R. above Black Slough							10-2-75	7.93	320
74	1S-18E-2a - East Trib to Black Slough							10-2-75	2.66	310
75	1S-18E-9a - Crystal Creek							10-2-75	2.84	342
76	1S-18E-14a - East Trib to Crystal Cr							10-2-75	3.56	360
77	1S-18E-15b - West Trib to Big Wood R.							10-2-75	4.80	316
78	1S-18E-16d - Black Creek at Mouth							10-2-75	5.18	305
79	1S-18E-16d - Unnamed Trib to Big Wood R.							10-2-75	3.51	--
80	1S-18E-21a - Big Wood R. at Hwy 68							10-1-75	33.7	316
81	1S-19E-7c - Willow Creek at County Rd.							10-3-75	0.81	363
82	1S-18E-19d - Willow Creek at Rest Area							10-2-75	11.8	398
83	1S-18E-19d - Unnamed Trib to Willow Cr at Hwy 93							10-1-75	5.29	370
84	1S-18E-14c - Unnamed Trib to Willow Cr at Hwy 68							10-3-75	5.08	402
85	1S-18E-1?a - Spring Cr. at [illegible] Ranch							10-2-75	5.04	379
86	1S-19E-2a - Spring Cr. at Hwy 68							10-2-75	7.65	375
87	1S-18E-23b - Willow Cr. above Big Wood R.							10-2-75	29.8	392
88	1S-18E-21b - Big Wood R. at Bellevue Gage							10-2-75	762	317

TO CONVERT FT³/S TO M³/S, MULTIPLY BY 0.0283

e - ESTIMATED FLOW

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GEOLOGICAL SURVEY

FILE 77-456

TABLE 1a -- PUMPAGE FOR IRRIGATION, 1974 AND 1975 - TOTALS IN ACRE-FEET

¼ SECTION				1974						1974 TOTAL	1975						1975 TOTAL
				MAY	JUNE	JULY	AUG	SEPT	OCT		MAY	JUNE	JULY	AUG	SEPT	OCT	
2N-	18E-	26	SW	0	0	0	11.8	13.4	3.2	28	0	9.7	7.6	10.0	8.1	3.0	38
		36	SW	0	0	0	0	40.0	26.2	66	0	30.0	28.8	30.6	19.7	0	109
1N-	18E-	1	NW	118	178	229	222	121	34.0	902	76.9	190	261	200	93.7	47.8	869
		12	SE	52.6	72.1	75.3	74.9	72.5	36.2	384	0	79.4	72.5	69.6	65.6	30.4	318
		17	SE	12.4	18.1	13.8	16.8	6.0	1.1	74	0	18.2	15.4	14.4	9.2	3.2	60
		-35	SE	40.6	99.6	85.7	69.6	54.7	32.6	383	18.1	51.5	69.8	73.0	36.5	0	249
		-36	NW	0	0	0	0	0	123 (a)	128	0	0	0	62.4	64.6	2.7	130
1N-	19E-	6	SW	0	0	0	145	49.0	0	194	0	0	0	78.3	0	0	78
		-17	NW	0	0	0	0	117	0	117	0	0	13.3	15.6	2.2	0	31
		-19	SW	118	94.2	115	120	93.6	41.9	583	0	130	110	106	79.5	35.2	461
		-20	NE	0	0	119	133	14.6	0	267	0	0	46.9	46.9	0	0	94
		-20	NW	0	29.6	171	281	144	0	626	0	0	125	308	260	77.9	771
		-20	SW	157	301	249	219	235	130	1291	177	136	0	0	0	0	313
		-28	NW	204	277	259	309	262	19.1	1330	200	294	289	255	115	0	1153
		-28	SW	0	0	156	162	5.4	0	323	0	0	95.3	95.3	0	0	191
		-29	NW	0	0	42.1	42.2	28.0	21.6	134	0	0	0	0	0	0	0
		-31	SW	0	0	247	529	438	170	1,384	0	0	170	365	321	116	972
		-32	NW	0	34.5	77.3	77.3	57.2	21.0	267	0	117	133	208	96.2	0	554
		-32	SW	0	0	36.5	83.1	49.3	2.3	171	0	0	0	25.1	30.6	5.0	61
		-32	SE	0	28.6	87.9	78.7	0	0	195	0	0	0	0	0	0	0
		-33	SW	0	0	79.5	32.1	13.3	8.0	133	0	0	54.7	109	62.9	101 (a)	327
		-33	SE	0	0	0	138	61.1	0	199	0	0	0	113	22.5	0	136
1S-	19E-	2	SW	0	182	184	183	68.7	0	618	58.6	195	293	257	110	0	914
		-3	NW	0	0	56.5	61.6	15.5	10.4	144	0	0	0	68.9	28.3	24.5	122
		-3	SW	600	504	311	90.8	0	0	1506	260	387	357	237	12.2	0	1253
		-3	SE	301	333	314	323	217	58.8	1547	0	348	335	339	159	0	1181
		-4	NW	0	0	0	0	0	0	0	0	0	87.8	87.8	2.5	2.5	181
		-4	SE	0	0	65.4	117	129	77.3	389	0	0	0	85.6	118	56.9	260
		-5	NE	0	0	137	156	39.2	21.1	353	0	0	155	232	82.5	0	470
		-5	NW	0	0	43.9	43.9	8.9	8.9	106	0	0	0	0	0	0	0
		-6	NE	0	0	24.1	111	79.0	0	213	18.7	68.3	140	145	61.9	5.8	441
		-10	NE	155	94.4	55.9	23.3	12.0	11.6	352	0	131	50.3	35.7	8.3	0	225
		-11	NW	25.3	21.8	21.2	16.1	12.9	8.0	105	0	21.8	13.2	8.3	4.0	2.3	50
		-14	SW	24.6	51.7	47.6	17.2	0	0	141	0	27.7	43.9	30.3	0	0	102
		-24	NW	40.2	88.9	126	99.4	0	0	354	0	56.9	139	88.9	6.1	0	290
		-25	NE	48.3	100	105	72.6	21.3	0	347	0	89.6	103	78.7	30.8	5.2	307
		-26	NE	0	28.6	33.4	4.7	0	0	67	0	37.7	76.0	45.8	7.7	0	167
		-26	SW	19.4	32.1	36.8	18.2	0	0	110	9.0	28.2	19.9	0	0	0	57
1S-	20E-	16	SE	26.6	65.9	77.0	54.3	41.1	0	265	0	17.5	35.7	55.9	63.6	0	173
		-17	SW	68.0	118	116	120	64	0	486	0	94.0	117	168	106	0	485
		-18	SE	34.2	54.1	56.2	39.9	14.9	0	199	0	14.4	0	0	0	0	14
		-19	NW	4.7	16.4	27.1	24.7	14.3	4.8	93	0	33.5	46.3	37.7	6.9	0	124
		-19	SE	134	237	235	221	167	56.2	1,055	82.5	189	223	240	125	0	860
		-20	NE	0	35.1	18.5	0	0	0	54	0	24.0	71.7	101	50.3	0	247
		-20	SE	72.5	147	139	93.6	179	0	631	25.1	88.7	77.9	148	116	0	456
		-22	SE	64.7	84.5	93.5	87.2	43.2	0	373	0	96.7	91.2	83.0	44.2	5.7	321
		-26	SW	1.8	2.3	2.3	2.5	2.2	0.8	12	0	1.8	1.4	1.4	1.2	0.4	6
		-30	NW	150	218	118	91.6	44.4	6.8	624	11.5	99.2	162	96.5	14.6	4.7	388
						TOTALS (ROUNDED)				19,300							16,000

(a) INCLUDES PUMPAGE IN NOVEMBER

TO CONVERT ACRE-FEET TO CUBIC METRES, MULTIPLY BY 1233

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