RESEARCH TECHNICAL COMPLETION REPORT
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EVALUATION OF URBANIZATION AND CHANGES IN LAND USE ON THE WATER RESOURCES OF MOUNTAIN VALLEYS

by

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ABSTRACT

The impact of projected changes in land use on the aquifer and stream systems of the Big Wood River-Silver Creek area in southern Idaho was evaluated using a finite difference model of the groundwater system. Water budget components were measured for the 1975-76 irrigation season on the 30,000 acre area for calibration of the model. Both water table and confined aquifers were simulated. Simulated groundwater levels and spring flows were determined for several projected changes in land use including canal lining programs, subdivision development, conversion to sprinkler irrigation, groundwater development and for irrigation and artificial recharge.

Severe decreases of up to 38 percent in the discharge of Silver Creek, a productive spring fed trout stream, were projected. Groundwater levels in the water table and artesian aquifers could decline up to 16 feet. The most severe impacts will result from conversion of present flood end furrow irrigated land to sprinkler irrigation with attendant decrease in aquifer recharge. The 1977 drought, during which irrigation diversions were only 28% of the 1975 diversions, was simulated and compared with measured data. Reasonable comparisons of simulated and measured groundwater levels and spring flows supports the validity of the model as a planning tool.

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INTRODUCTION

Increase in population of mountain valleys such as has occurred in many parts of Idaho and other rural areas can present problems which do not occur under present land use patterns. Population growth in some parts of Idaho, particularly the tourist-recreation oriented areas, has been greater than any area of the state and possibly the nation. Providing living space for increased populations has crowded flood plain areas and resulted in the removal of agricultural land from production. Subdivision of prime agricultural lands with either high or low density developments in irrigated areas reduces or eliminates aquifer recharge and can adversely affect the water balance of aquifer systems. In addition, waste disposal from new developments in unincorporated areas is generally accomplished with septic tank-drainfield procedures. Excessive biological and nutrient load can cause pollution problems in aquifer systems.

Parts of the Wood River-Silver Creek area of Idaho, south of the Sun Valley resort are experiencing rapid urbanization and flood irrigated land is being converted to sprinkler irrigation. Irrigation has been practiced in this area since 1880 and currently about 31,000 acres are irrigated. Figure 1 shows the location of the study area. The alluvial aquifer underlying this triangular shaped area is recharged principally by irrigation diversions, river losses and precipitation. One of the major discharges from the aquifer is a myriad of springs which emerge at the south end of the area to form Silver Creek, one of the best known trout streams in the United States.

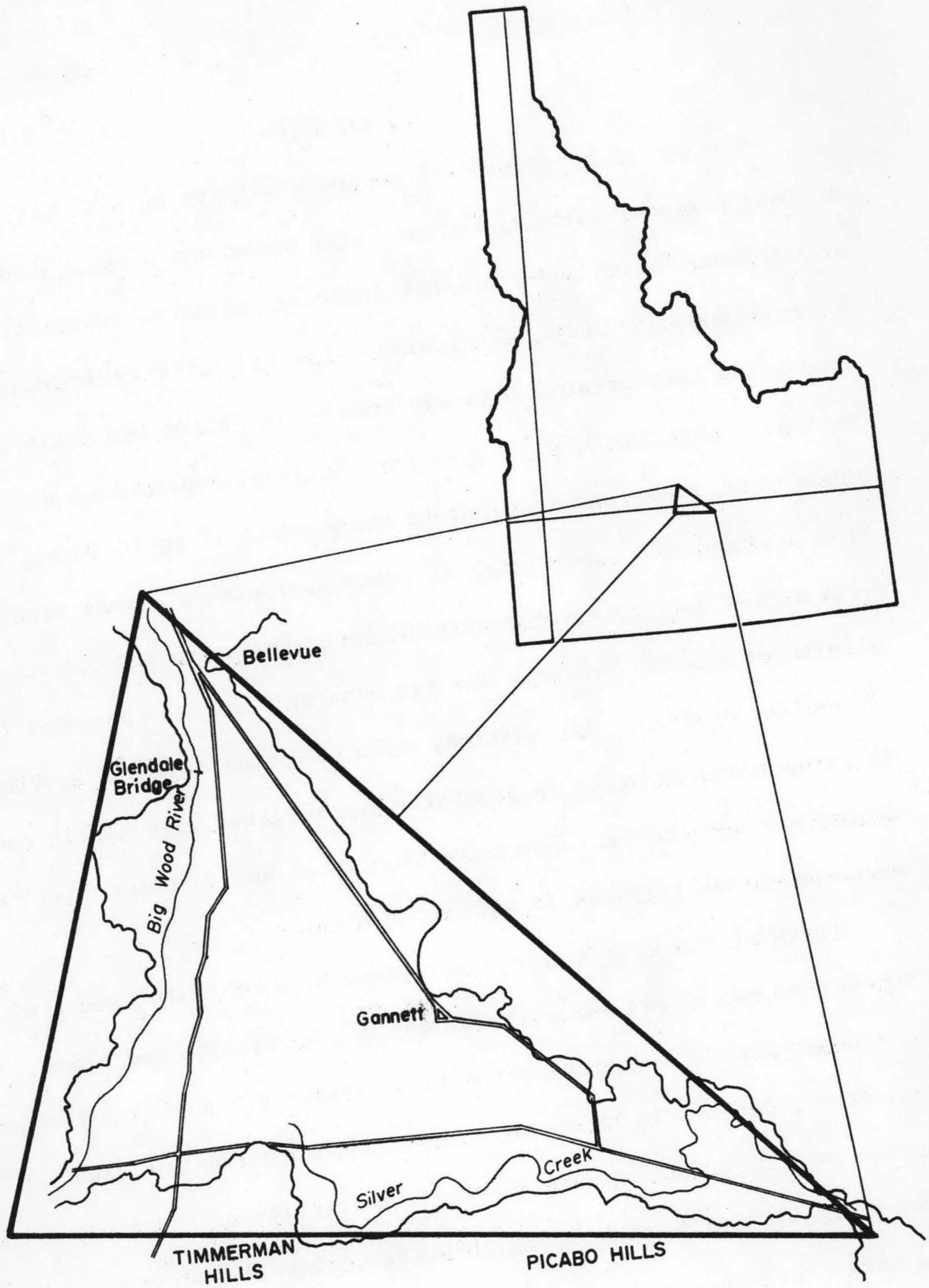


Figure 1. Location map - Big Wood River-Silver Creek area, Idaho

At present about 4,000 of the 31,000 irrigated acres have been converted to sprinkler and applications for several subdivisions ranging up to 1,100 acres in size have been submitted to the County Planning and Zoning Commission. Groundwater development to provide irrigation water supplies is also increasing. Planning officials and local farmers have expressed concern over the possible future decreases in spring and creek flows and some local residents believe that decreases have already occurred. Investigations by Idaho Fish and Game Department personnel have shown decreases in the length-weight ratio of trout in Silver Creek and these decreases have been attributed to decreased flows in the creek. Concern has also been expressed about maintenance of groundwater and stream water quality with increases in septic tank effluent from subdivisions.

Local planning officials, recognizing the need for a predictive procedure to evaluate the impact of future project developments, requested assistance in this endeavor. This area, in which rapid changes in land use are occurring, provided an excellent opportunity to evaluate and develop planning methods and data requirements for a comprehensive water resource impact study.

OBJECTIVES

The objective of the overall study, coordinated by the Idaho Department of Water Resources, was to provide a comprehensive analysis of the total water resource system in the area and to determine the effect on quantity and quality of surface and groundwater sources as affected by projected land use changes.

It was recognized that projected impacts would not be possible without a means of simulating the complex surface-groundwater system. Therefore, the specific objectives of the Idaho Water Resources Research Institute study were:

1) Obtain field data on the hydrology and geology of the area for developing a simulation model to evaluate the impacts of land use changes on the water resources.
2) Develop projections of land use changes and the potential effects on aquifer recharge patterns.
3) Determine changes in the groundwater levels and surface stream flows as affected by projected changes in recharge patterns.

The first four sections of this report outline the general land use, geologic and hydrologic characteristics of the area and a brief description of the groundwater model selected for application to the aquifer system. The fifth section on application of the groundwater model to the Big Wood River-Silver Creek area outlines in detail the field data collection and the development and calibration of the groundwater model. The section on impact of land use changes outlines procedures for projection of potential land use changes, effects on aquifer recharge patterns and results of groundwater model runs to evaluate the impact on the groundwater and Silver Creek flows.

PROJECT AREA

The area as shown in Figure 1 is located in Blaine County, Idaho. It is bounded on the north by the City of Bellevue and comprises a triangular area of approximately 30,000 acres from Stanton Crossing in the southwest to Picabo in the southeast. Mountains border all sides of the valley with the area of interest consisting of the lowlands of the Big Wood River and Silver Creek drainages. The Big Wood River flows through the western part of the area from north to south and leaves at Stanton Crossing. Silver Creek emerges as springs in the southern part of the area and leaves near Picabo in the southeast.

Water use is primarily for irrigation with diversions from the Big Wood River or from springs. Supplemental irrigation water is supplied from flowing artesian wells or pumped wells in the southern part of the area.

The Silver Creek is heavily used for fishing and wildfowl hunting. Proximity to the Sun Valley resort exerts heavy pressure on the recreational resource and there is a trend toward development to meet these needs.

Climate

The Big Wood River-Silver Creek area is located between mountain ranges which moderate winds and affect precipitation patterns. Moderate winters and warm dry summers characterize the climate. The mean annual temperature is 43.3^{o}F (6.3^{o}C) with the mean monthly maximum of 67^{o}F (19.4^{o}C) occurring in July and the mean monthly minimum of 18.7^{o}F (-7.4^{o}C) occurring in January.

Precipitation at Hailey, five miles north of the study area, averages 15.38 inches annually. Only 23 percent (3.52 inches) of the annual precipitation occurs during the 131 day frost free growing season.

Crops and Crop Water Use

Crops grown in the study area consist almost exclusively of small grains or forage. Harvested forage (alfalfa) is predominant in the northern part of the study area and grains (wheat, barley, oats) tend to predominate in the south. Pasture, irrigated both by surface water and shallow groundwater (subwater) is found throughout the area, but particularly in lowlands near the Wood River and other lands where high groundwater levels exist.

Water requirements for the 1975 season for all crops were determined by USDA SEA Agricultural Research as part of the project. This report is contained in Appendix A.

Water requirements are highest for alfalfa which is mainly irrigated by surface water. The average annual evapotranspiration (ET) for alfalfa is 28.2 inches. Grains and other forage use about 19.1 inches per year, and receive the highest percentage of water from goundwater sources, particularly in the southern part of the area where sub-irrigation is common. Irrigated pasture is largely sub-irrigated in the study area, although a significant amount is irrigated by surface water. Annual ET for irrigated pasture is estimated at 24.6 inches.

For the overall study area, surface water irrigated acreage comprises approximately 43 percent of the total irrigated area, which is continually increasing, is used on approximately 13 percent of the irrigated lands.

Current and Historical Land Use

Nearly all land in the Big Wood River-Silver Creek area has been developed for agriculture. The earliest recorded water right for irrigation is July 1, 1880. Irrigation development took place initially along the Big Wood River with small diversions to easily accessible land. Many of these original filings have been integrated into irrigation groups such as the Wood River Valley Irrigation District. This organization utilizes one major diversion from Wood River and delivers to some of the earliest water rights.

The earliest available aerial photography for the entire area was taken in 1943. A comparison of these photographs with 1975 U-2 high altitude photographs show significant changes in cropped or cultivated acreage but no other significant changes in land use within the study area. Between the period 1943 to 1975 a total of 4,760 new acres were brought under cultivation, however, 3,810 acres went out of production. The net gain in cultivated acreage for the period was only 950 acres. Most of the added acreage is in the southern part of the area with 3,670 acres being added. This reflects the increase in land reclamation near Silver Creek where non-irrigated grass land and brush has been cultivated for grain production. Over 2,000 acres have gone out of production north of the Base Line Road since 1943 reflecting the selective elimination of non-productive acreages.

Groundwater Development

Use of groundwater for irrigation commenced in the early 1940's

(Castelin and Chapman, 1972). Development of artesian wells apparently began in 1947 and as of 1975 there were 48 pumped irrigation wells and 30 flowing artesian wells in the study area (Moreland 1977). Most of the wells are used for supplemental irrigation, however, many of the flowing artesian wells and some water table wells serve as the only source for irrigation water systems. Newer sprinkler systems on previously undeveloped lands are relying predominantly on pumped groundwater.

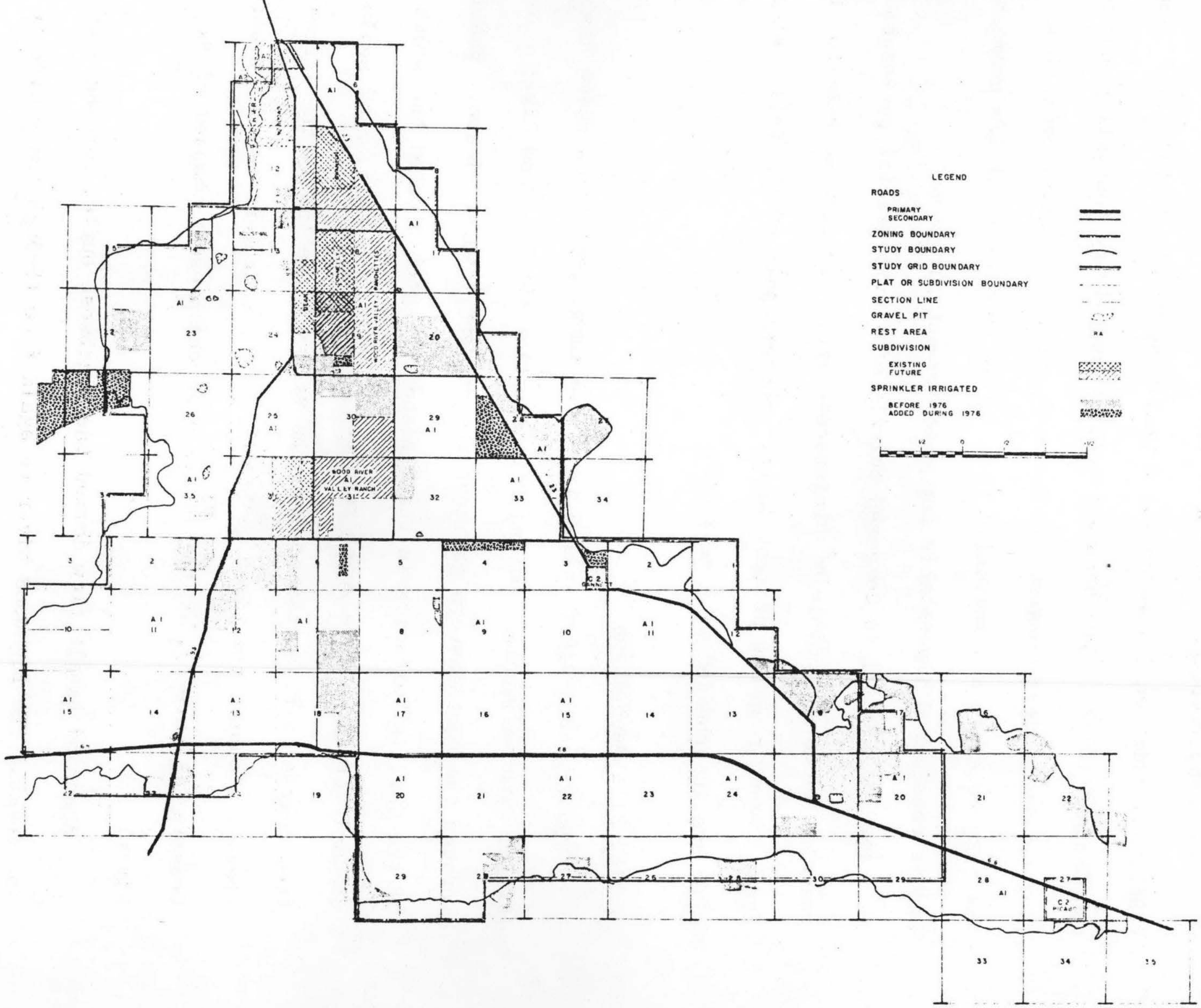
Drilling activity for irrigation wells appears to coincide with drought on low water years. In 1958 to 1961, which were dry years, a large increase was documented (Castelin and Chapman 1972) and during the 1977 drought period considerable activity took place. Groundwater pumping in 1975 supplied irrigation water for about 2,917 acres or about 9 percent of the total irrigated acreage. About 14,700 acres in the southern part of the area are subirrigated or irrigated with flowing artesian wells.

Urbanization

The demand for homesites in the Wood River Valley has resulted in several platted and planned subdivisions in the northern part of the study area. Figure 2 outlines the existing and future planned subdivisions in 1976, zoning designations, sprinkler irrigated land and other land use features. Most of the existing of planned sub-divisions call for lot sizes of 1 to 5 acres. With small lot sizes, speculative buying, and absentee landowners, a majority of the agricultural land in a new subdivision is not irrigated with surface water and, if irrigated at all, may be supplied from pumped wells.

No trend in subdivision development can be determined since development activity is influenced by economic conditions, local government policy and other factors.

Figure 2. Land use and zoning map. Big Wood River-Silver Creek area - 1976



GEOHYDROLOGIC FACTORS

The geohydrologic framework of the valley has been outlined by Schmidt (1961) and additional information supplied by Moreland (1977) and Castelin and Chapman (1972). The basement complex underlying the valley and outcropping on the borders consists of Tertiary and pre-Tertiary consolidated sedimentary volcanic and intrusive rock. This complex is of low permeability and is considered impermeable for water budget purposes.

The valley fill is composed chiefly of fluvio-glacial sediments and gravels, sands and cobble of Pleistocene age. Pleistocene basalts of the Snake River Group are present in the southern part of the valley where they are interbedded with sediment.

Valley Fill Deposition

The Big Wood River Valley is a structural depression which has been filled with sediments. During Pliocene time the Big Wood River flowed through the southeastern gap near the present town of Picabo. Basalt flows of the Challis Volcanics in the Pleistocene epoch blocked the southeast channel forming a lake which resulted in graded deposition of sediments from coarse to fine grained down the valley. Eventually the increasing lake elevation caused the river to breach at the southwest outlet, Stanton Crossing (Figure 1), at the location of the present channel of Big Wood River.

A second basalt flow dammed the southwest outlet forming a new lake and forcing the Big Wood River to again flow through the southeast outlet. This sequence apparently occurred several times with lakes forming periodically. Periods of alpine glaciation in the headwaters of Big Wood

River were concurrent with the formation of lakes and caused deposition of coarse grained, poorly sorted materials over the valley. This sequence of events caused the deposition of alternate layers of coarse and fine grained sediments which comprise the aquifer system.

The slope of the valley floor increases from south to north with a low topographic divide between the Big Wood River and Silver Creek drainages. High groundwater levels eventually formed surface springs in the southern part of the area. These spring fed streams combined to form Silver Creek which flows southeastward and out of the area.

Aquifer Systems

The lithology of the valley fill influences the direction and magnitude of groundwater movement in the aquifer. Gravels and sands transmit water easily whereas fine grained silts and clays are relatively impermeable and act as barriers to the vertical movement of groundwater. Extensive silt and clay layers can effectively confine groundwater and cause artesian aquifer conditions to exist.

Moreland (1977) analyzed all drillers' logs in the area and drilled test holes at 10 sites to identify the lithologic units and define the sequences of deposition. Figure 3 is a generalized cross section (Moreland 1977) showing the lithologic units and the relationship between permeable and confining layers.

The northern part of the aquifer consists of highly permeable coarse-grained sands and gravels. The central part is predominantly coarse grained materials, however, many fine grained materials are present. No evidence of artesian conditions exists. Fine grained

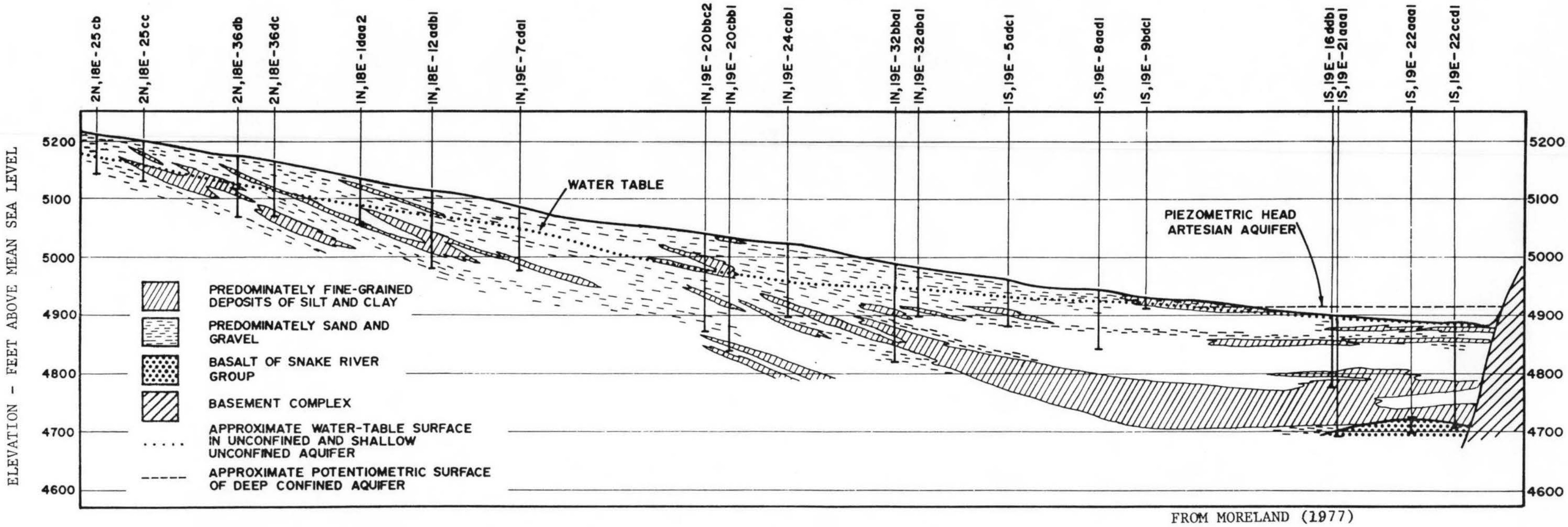


Figure 3. Generalized North to South geologic cross section - Big Wood River - Silver Creek area.

sediments are extensive in the aquifer from the Baseline Road (well IN 19E abal, 32 abal, Figure 3) south and artesian conditions exist in the lower part of the aquifer overall all the southern part of the valley. Figure 4 shows the extent of the area underlain by effective confining layers (Moreland 1977). The confined or artesian aquifer was inferred from analysis of geologic information, well logs, and water level differences between shallow and deep zones as measured in wells and test holes.

Many confining layers present in a cross section, such as exist in the Big Wood River-Silver Creek aquifer system, can effectively create a series of local confined aquifers, each possessing different relative pressures depending on the extent of confinement. It is difficult, if not impossible, to identify all of these layers and to understand or measure the relative movement of groundwater within and between each layer. Therefore, for purposes of this study, the confined aquifer is considered to include all areas where any evidence of confinement has been identified.

Differences in water levels between shallow and deep wells in the eastern part of the area near Picabo indicate the existence of a perching layer. This layer causes shallow groundwater levels to be near ground surface whereas the water levels in the deeper aquifer are as much as 130 ft. below land surface (Moreland 1977).

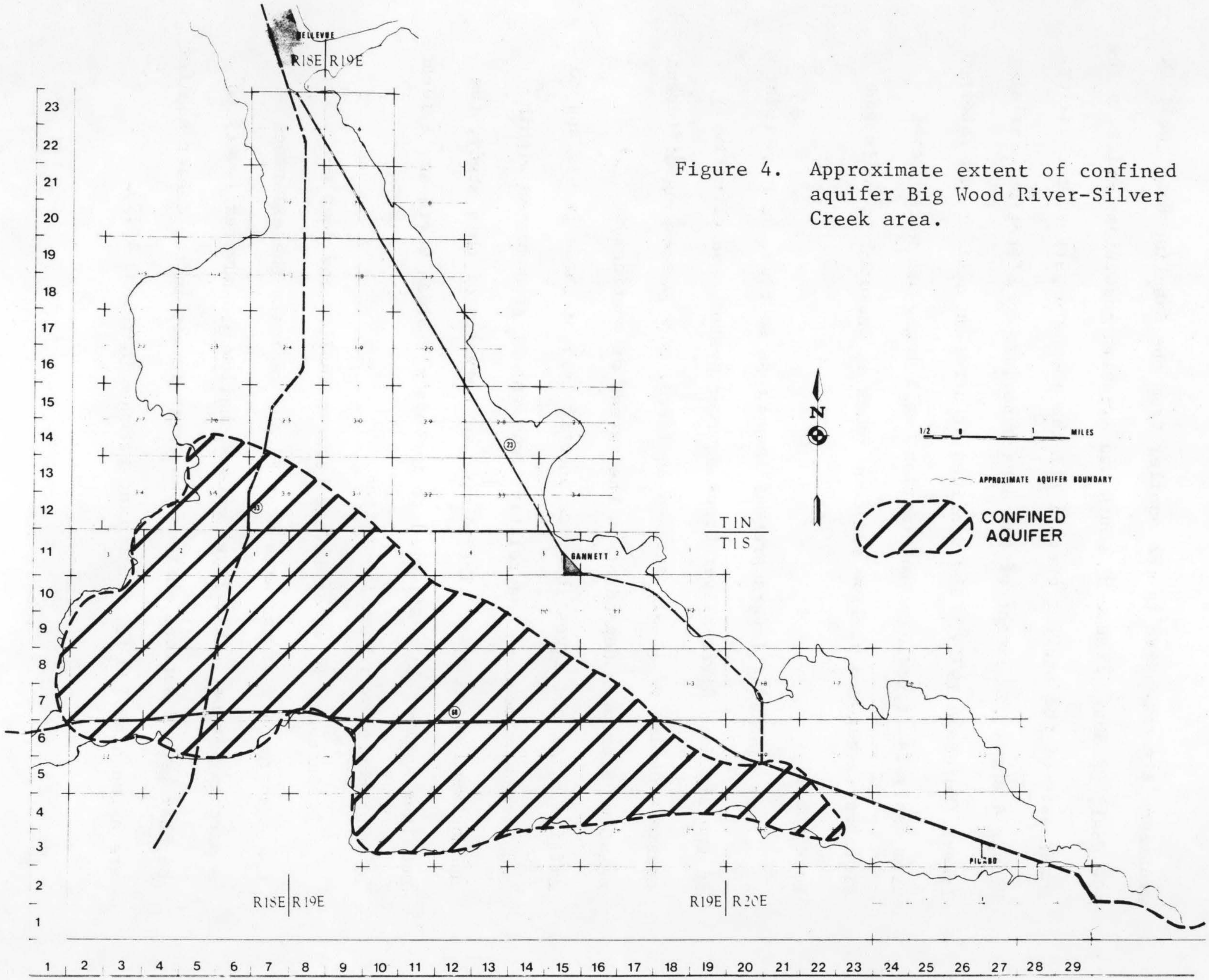


Figure 4. Approximate extent of confined aquifer Big Wood River-Silver Creek area.

GROUNDWATER

Aquifer Characteristics

Groundwater movement through an aquifer is dependent upon the gradient or slope of the water table and the transmissivity of the aquifer. Estimates of aquifer properties were made by Moreland (1977) based on published data (Smith 1959, Thomasson 1960). Generally the transmissivities of the water table aquifer in the northern part of the area ranged from 30,000 to 70,000 ft^2/d, however northwest of Gannett (Figure 4) values up to 300,000 ft^2/d were estimated. Transmissivities in the artesian aquifer south of Baseline Road were estimated at about 30,000 ft^2/d. Data were insufficient to accurately map transmissivities of the shallow water table aquifer.

General Water Budget

Figure 5 shows the general water balance components for the Big Wood River-Silver Creek Aquifer.

Groundwater underflow from the Big Wood River valley enters the aquifer system south of Bellevue. Irrigation diversions provide the majority of aquifer recharge. These diversions are from the Big Wood River and occur from approximately May 15 to October 15. Aquifer recharge from irrigation diversions is composed of canal seepage losses and percolation of excess water. Seepage losses from the Big Wood River are also a major source of recharge. In a normal year, the Big Wood River channel is a losing stream during the non-irrigation season for the entire reach from south of Bellevue to the lower end of Poverty Flat, figure 5. During the irrigation

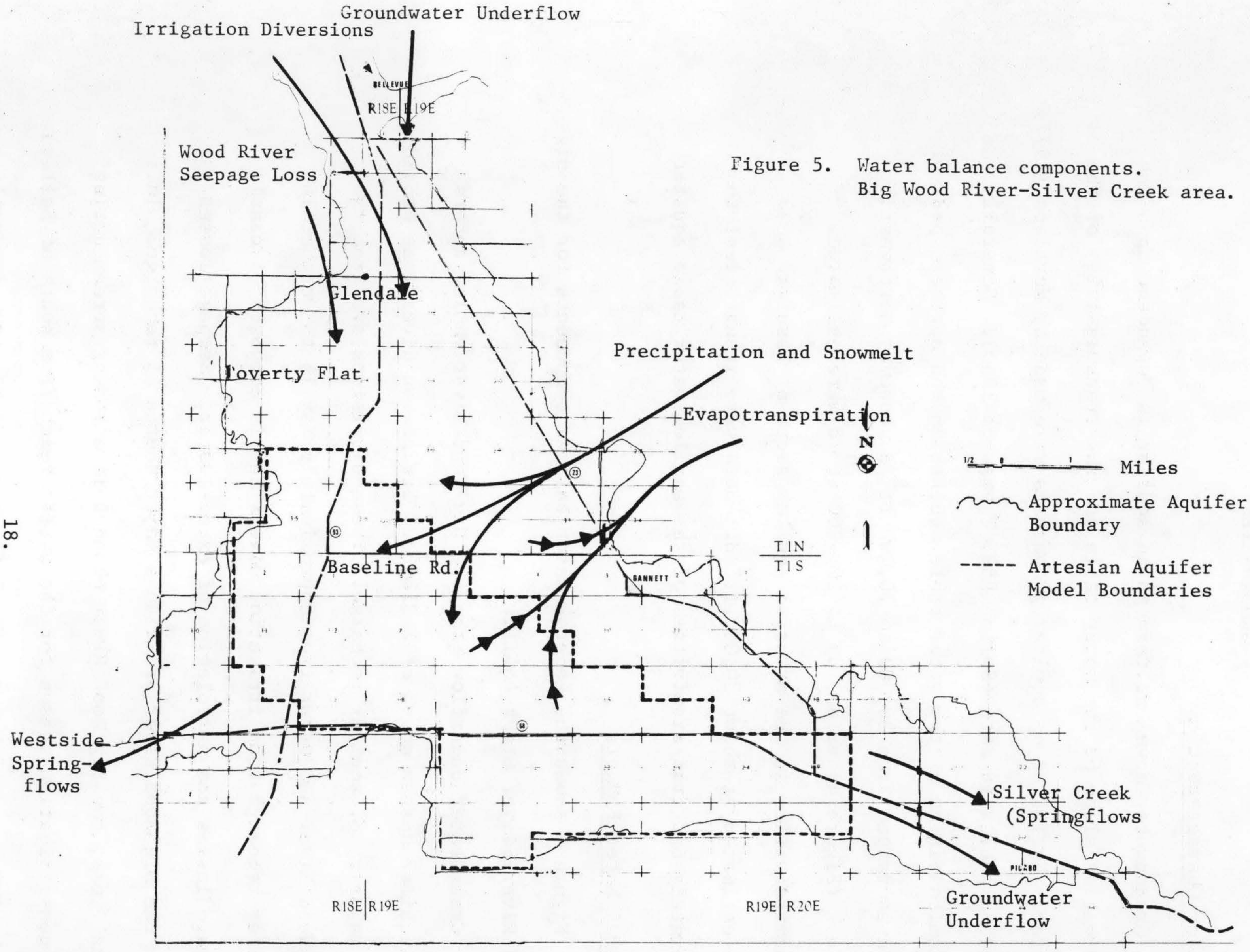


Figure 5. Water balance components.
Big Wood River-Silver Creek area.

season after flood flows have passed, the entire stream is diverted at Glendale and the channel is dry to a point at the lower end of Poverty Flat (Sec. 35, T1N, R18E). Precipitation and snowmelt constitute the other component of aquifer recharge.

Springs emerging from the aquifer system south of Baseline Road combine to form Silver Creek which exits from the study area near Picabo. Also a significant amount of groundwater underflow from the alluvial aquifer into the Snake Plain Aquifer occurs in the Picabo area. Big Wood River flows at Stanton Crossing, figure 1, on the west side of the valley are composed primarily of spring flows during the irrigation season with some surface return flow. Groundwater underflow to the west is considered negligible due to geologic boundaries.

Water discharge from the aquifer includes evapotranspiration by crops and phreatophytes. Groundwater pumping supplies supplemental water for irrigated crops and a large area in the southern part of the valley utilizes sub-irrigation.

Because of the complexity of the hydrogeology and time variation of inputs to the aquifer system, a general groundwater model was considered the best means of analyzing the system and obtaining estimates of impacts on the aquifer.

GROUNDWATER MODEL DESCRIPTION

General

The mathematical model selected for the Big Wood River-Silver Creek aquifers is a two dimensional digital model utilizing finite defference approximation to the flow equations. The model is capable of describing and obtaining solutions for non-homogeneous, anisotropic aquifers for steady or nonsteady state conditions (de Sonneville 1972, Newton 1978). This model utilizes the alternating direction implicit method for solution of the finite difference equations (Peaceman and Rachford, 1953). The model is applied to an area on a rectangular grid with each grid intersection called a node. Recharge or withdrawal from the aquifer model must be specified for each node for each selected period of time (timestep).

A properly calibrated model for a particular aquifer will, when subjected to the historical inputs, simulate within a prescribed degree of accuracy the measured historical responses to the water table of piezometric head. It also can be used to simulate aquifer responses to inputs other than measured historical values and thereby becomes a planning tool.

The first step in development of the series of computer programs which constitute the model is to determine for each node point the historical water table or piezometric head elevations over a selected period, the inflow or input, and the aquifer characteristics. Determination of these parameters generally requires an extensive field study over an extended time period as existing data are generally not of sufficient quality and quantity for model input. The input to the aquifer at each node for each timestep is determined from irrigation diversions, precipitation, evapotranspiration and pumping. These parameters are consolidated in a program called the input program which generates the net external input to each node for each timestep.

The aquifer parameters such as hydraulic conductivity and storage coefficients, boundary conditions and flow exchanges with adjacent aquifers must be determined. These parameters can be estimated from well tests and geologic data; however, the spatial variation is so extensive in most aquifers that sufficient well test data are not available to define the parameters at each node. Generally, initial estimates of aquifer parameters are made at each node and the model is run with historical inputs. Deviations of the predicted response from measured responses over the historical period are then minimized by adjusting the aquifer parameters or adjusting questionable input values where necessary. This process of adjustment to secure a good "fit" to historical data is termed calibration of the model.

Adaptations of this model have been developed for the Snake River Fan Aquifer in eastern Idaho, the 9,000 square mile Snake Plain Aquifer in southern Idaho, and the alluvial aquifer in the Boise Valley in western Idaho. The model is currently being run on an IBM 370/158 computer. Further explanation of the model is outlined by de Sonneville (1972) and Newton (1978).

Input Program

The purpose of the input program is to consolidate the various components which make up recharge to the aquifer into a single value for each node in the aquifer and for each timestep of the simulation period. The components comprising aquifer input are:

Irrigation Diversions - these flows are measured as they enter the irrigation districts or service area over which they are distributed. The magnitudes of these diversions, less the amount of canal seepage and return flows, are divided by the surface water irrigated areas within the respective districts to arrive at an average application rate. This is used to determine the amount of irrigation water applied within each node.

Canal Seepage - a value of seepage for each node is obtained by measuring the rate of seepage from canals and the wetted-perimeter area of canals within each node. The magnitude of this seepage is also related to the water level in the canal or the percentage of maximum diversion in the canal.

Evapotranspiration or Crop Consumptive Use - ET is compiled for each area which has a distinctive climate and/or cropping pattern and for each timestep of the simulation. The amount of this consumptive use then is calculated for each node.

Pumping - location of all irrigation pumps and artesian flowing wells are catalogued and the respective pumping volumes determined. These volumes are read into the input program on a node by node basis. The program then subtracts the amount of consumptive use in the node from the pumped volume and the remaining portion of water is considered.

to return directly to the aquifer. This effectively means that the amount of water removed from the aquifer by pumping is equal to the amount needed to satisfy consumptive use. Pumps which supply water for a consumptive use other than irrigation, or for irrigation on land outside of the node in which the pump is located are treated as groundwater outflow nodes. (See "Tributary Valleys" below).

River Reach Gains and Losses - streams which overlie the aquifer and have a significant interchange of water with the aquifer are divided into measurable reaches. The nodes through which each of these reaches passes are located and the values of gain/loss from the reaches to the aquifer are measured or estimated, and are divided equally between each of the nodes in the reach.

Tributary Valleys and Groundwater Inflows/Outflows - occasionally there may be areas where there is a substantial flow of groundwater to or from the aquifer which cannot be included as external input to the model. In these places the nodes which are affected are consolidated into reaches over which the flow estimates are evenly distributed.

After each of these components of recharge are determined in the input program, they are combined to produce a value of net recharge per node. Each of these values for each timestep of the simulation are then stored on magnetic tape or cards for use in the groundwater flow equations which comprise the model.

Model Program and Calibration

Operation of a groundwater model so that it simulates reality requires a knowledge of the hydraulic parameters of the aquifer. These parameters are essentially the permeability or hydraulic conductivity, K and storage coefficient, S. In most aquifers, there is extreme variability in the aquifer parameters and they must be determined by a calibration procedure. Also the magnitude of any flow from the aquifer to other aquifers through leakage must be known.

A specific period of time for which various components of recharge and discharge have been measured or estimated is selected for the model calibration period. From these data, the input program generates values of recharge to the aquifer for each node over the period. Also, groundwater surface elevation ("head values") must be determined at each node including one at the beginning and one at the end of the calibration period and one or two intermediate times. Estimates of the aquifer parameters are made and a simulation performed using these estimated parameters beginning with the initial set of head values and using the measured values of input. The head values which are calculated in simulation may then be compared with those values which were measured historically in order to determine how closely the model simulated reality. The initial parameter estimates are then adjusted according to these deviations.

These adjustments are automatically made by a computer subroutine called the "calibration routine" using an iterative process. The parameters may be continually adjusted until the deviations between measured and simulated responses are tolerable. Due to the size of most aquifers and the relative inaccuracies in input values, a perfect simulation will never be achieved; however, the parameters may be adjusted to the point where they do simulate the historical situation reasonably well.

Management Procedure

After the aquifer parameters are adjusted so that the model simulates historical responses in a reasonable fashion, it may be used to predict the response of the aquifer to theoretical changes in recharge and discharge resulting from land use changes or changes in irrigation methods. Since the projected changes which are to be studied usually occur over a considerable period of time, a procedure must be developed to produce a reasonable "starting point" or base level with which changes in water levels and spring flows will be compared. One procedure is to simulate each intermediate year between the historical (calibration) period and the time that the projected changes are in full effect. This involves determination of levels of development or changes in recharge and discharge for each timestep for an extended period of time. Another procedure is to repeat the full projected changes for several successive years until the aquifer reaches a "steady-state" condition or a point in time at which the predicted response is the same over two successive years. Differences between the historical response and the response due to the alternative recharge can be compared. In any case, once a starting point is produced, the projected changes may be modeled. Probable effects on groundwater flow resulting from changes in land use and/or water management can be evaluated with the computer program called the "management" routine.

APPLICATION OF THE MODEL TO THE BIG WOOD RIVER-SILVER CREEK AREA

General Procedure

A two year data collection period was selected beginning November 2, 1974 and ending November 5, 1976. However, because of the 1977 drought limited data was collected through April 1977. The adequacy of the data was such that a time increment or timestep length of seven days was warranted. Table 2 in the Appendix lists the timesteps and corresponding calendar dates.

Since one of the primary objectives of this study was to simulate the flow of Silver Creek, the model boundaries were chosen such that they only included the headwaters reach of that stream above the gaging station in Sec 20 T1S R20E. Figure 5 shows the study area with the model boundaries.

Field data were detailed enough to allow a grid size of one half mile square. Therefore, each 160 acre parcel described by the U.S. Public Lands Survey was considered a nodal area with the node center at the center of the parcel. Each node location was described by cartesian coordinates with the origin of the axes at the southwest corner of the study area. Figure 6 shows the nodal areas and numbering system.

Due to the existence of the multi-aquifer system throughout a large part of the study area, and because the present model will not handle a two-layer aquifer, it was decided to construct two separate models and link them together. These are of the main water-table aquifer and of the artesian or confined aquifer in the southern part of the study area. Although from a geologic standpoint it is somewhat questionable to divide the entire system into only two distinct aquifers, it was concluded that

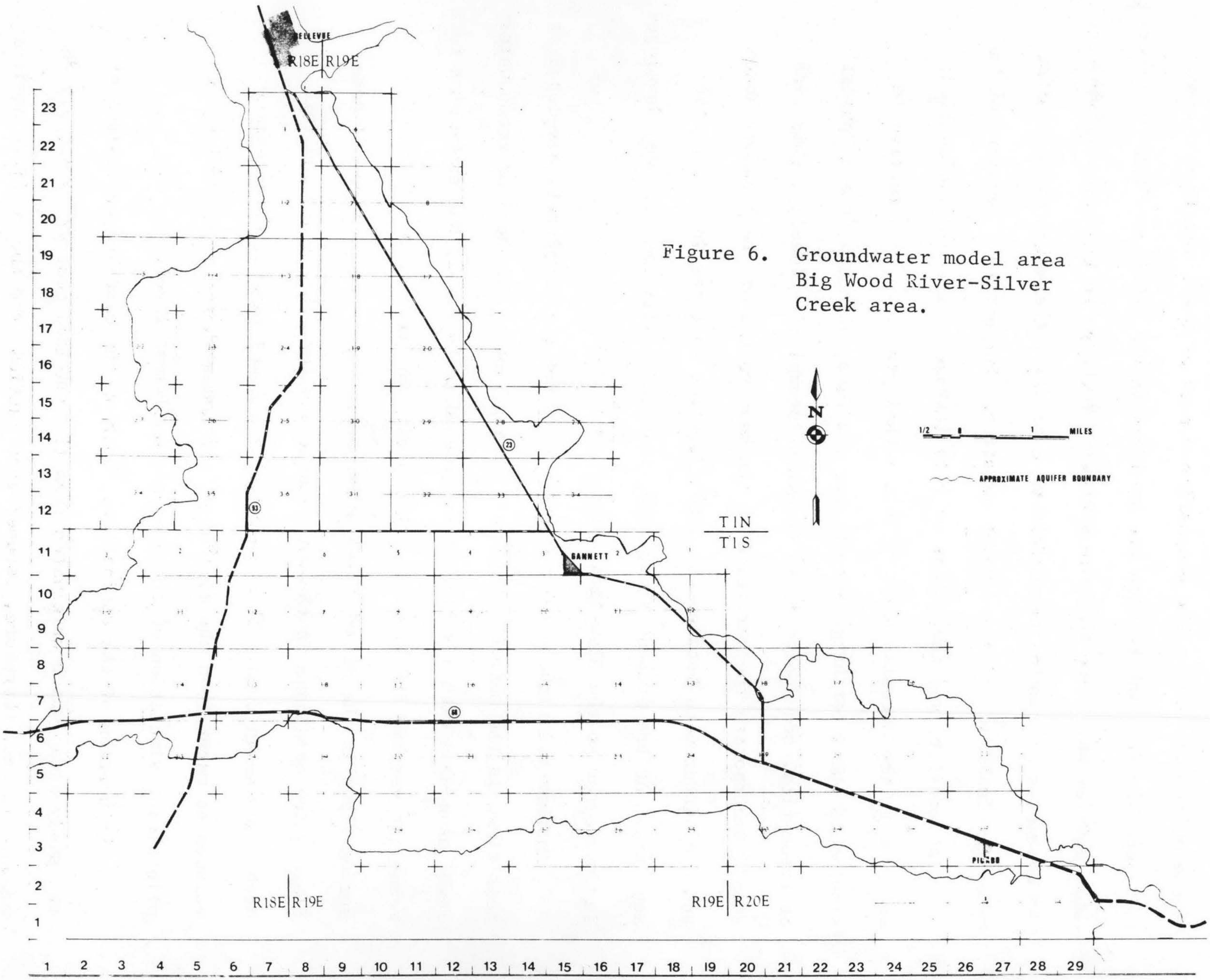


Figure 6. Groundwater model area Big Wood River-Silver Creek area.

due to the discrete and general nature of the model, this approach would be the most reasonable. The boundaries of each of these models are shown in Figure 5. The link between the aquifers is via the flows from the water-table aquifer which are the sole source of recharge to the artesian aquifer. The mechanics of running the models were to allow the water-table aquifer model to "leak" at the nodes which constitute the northern boundary of the artesian aquifer, and the values of this leakage were saved and applied as input to the artesian model. This method proved to be effective in simulating the interchange between the aquifers, although from a "purist" or theoretical standpoint it is somewhat incomplete. Ideally, this link should incorporate the variation in the head values at the boundary nodes and the differences between the potentiometric surfaces in each of the aquifers. At the present time, 1978, this capability has not been developed in the program so the flow-link approach was used.

Another technique vital to this study, but not completely developed at this time, is the method to simulate spring flows. The head or groundwater level at a node with a spring is considered to be fixed, but there must be a means for varying the flow from that node. In order to simulate the spring flows in the Silver Creek area, or at least the portion of those flows which originate in the water-table aquifer, the "leaky aquifer" method was again used. This essentially allowed removal of necessary volumes of water from the aquifer at the nodes where springs existed while maintaining simulation of the proper groundwater level.

The portion of the springflows, both on the east and west sides of the study area, which originates from the confined aquifer is largely unknown. It was, therefore, assumed that outflow from the confined aquifer at the southeastern and western boundaries emerged almost entirely as springflows, except for a small amount of sub-surface outflow in the southeastern area. By using this approach and combining the springflows from the two models, a reasonable simulation of observed springflows was obtained.

The specific procedures and adaptations which were used to construct these models are described in the following sections.

Data Collection

Input data collection was begun in November 1974 and continued to November 1977. The period May 1, 1975 to May 1, 1976 was selected for calibration of the model and data collection was concentrated during that period. Various agencies were involved in acquiring the data.

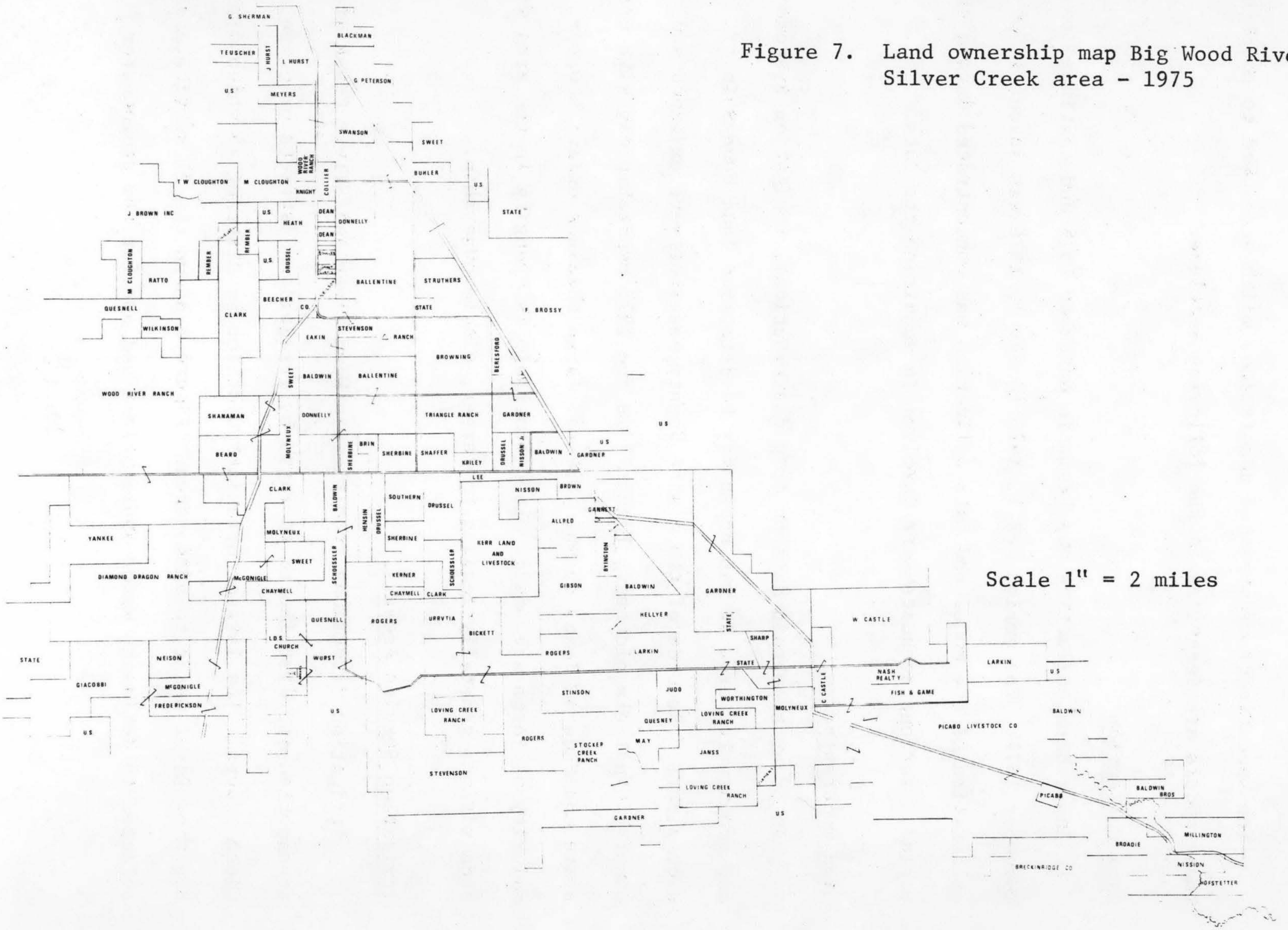
Land Ownership

In order to obtain data on crop distributions, irrigation systems and groundwater use, it was necessary to determine land ownership of each parcel. Records of the Blaine County Assessor were examined and ownership parcels plotted. Figure 7 is the 1975 ownership map with private, state and Federal lands shown. Several large holdings exist; however, the majority of farms are small. Land ownership is changing in the area with acquisitions generally leading to larger, single ownership.

Irrigation Service Areas

Irrigation diversions from the Big Wood River and Silver Creek are transported and distributed to farms by irrigation districts or cooperative ditch groups. The largest organized district is District 45 which distributes Big Wood River water to 6364 acres. Figure 8 shows the 21 service areas selected to delineate water applications and use for the groundwater

Figure 7. Land ownership map Big Wood River-Silver Creek area - 1975



Scale 1" = 2 miles

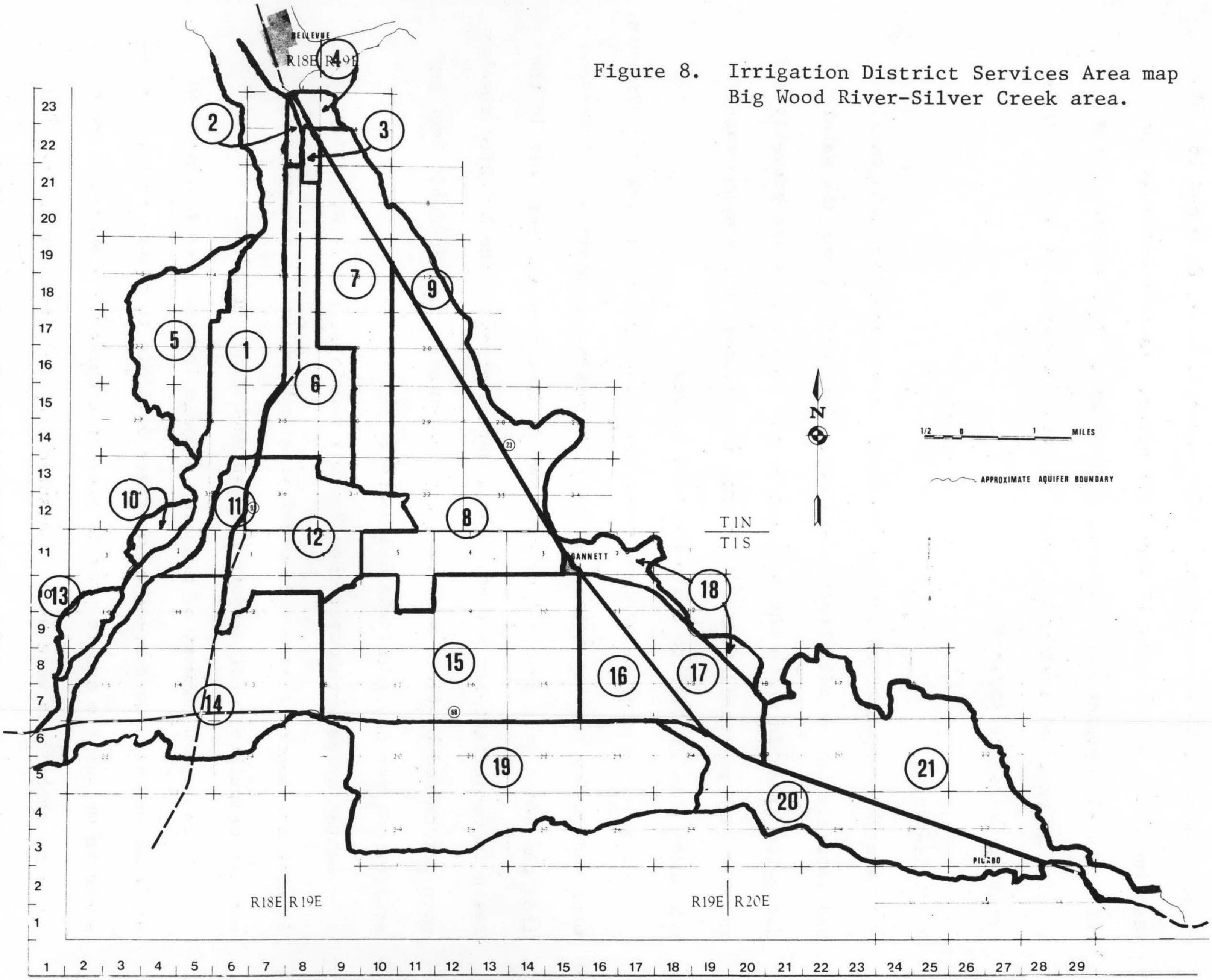


Figure 8. Irrigation District Services Area map
Big Wood River-Silver Creek area.

model. District 45 encompasses service areas 3, 6, 7, 8, 9 and 18. The Baseline Canal serves area 12 with 1518 acres. Table 1 outlines the service area designations, numbers, and acreage. Some service areas receive no external irrigation water and rely primarily on subirrigation, artesian wells, or springs.

Canal Seepage

A major component of aquifer recharge is seepage from main canals and laterals in the distribution systems. Soils in the surface water irrigated areas in which the main canals are constructed are gravelly and exhibit high permeabilities. A program to delineate the seepage rates was undertaken in 1975 to evaluate these losses.

On selected reaches of canals and laterals, inflow-outflow measurements were made using current meters or installed measuring devices. Diversions from the reach were shut off or measured to determine the net loss in the reach in cubic feet per second. Canal wetted areas in the selected reaches were determined by field measurement and a seepage rate in cubic feet per square foot per day (cfd) was calculated.

Wetted areas were determined for all remaining canals and laterals in each one-fourth square mile model area and applicable seepage rates used to calculate total seepage per two week time period.

Table 2 is a summary of measured seepage losses. Reach lengths of at least one mile were selected wherever possible to assure that net losses would be measurable and to provide greater accuracy. Standard current metering techniques were used. Measured seepage rates varied from 0.3 to 7.1 cfd. Unfortunately, too few measurements were taken to document any seasonal variation in seepage rates. Normally, early season seepage rates are higher than rates in the latter part of the season due to

Table 1. Water use service areas
Big Wood River-Silver Creek area

Area Number	Designation	Surface Water Irrigated Acreage
1	Bed of Big Wood River - not irrigated	--
2	Hurst Pump	63
3	Swanson	111
4	Seaman	113
5	Glendale	771
6	45 West	1154
7	45 Central - West	861
8	45 Central - East	2974
9	Cove	1146
10	Garff	320
11	Wood River Ranch	0
12	Baseline	1518
13	Uhrig	240
14	Dragonwood	736
15	Price	0
16	Thompson Creek	0
17	Hayspur	0
18	Cove Extension	118
19	Hillside	190
20	Kilpatrick	769*
21	Iden	443*
		11,527

*Acreage within model boundaries only.
Total surface water irrigated area within study area equals 13,497 acres.

Table 2. Canal Seepage Investigations - Summary - Big Wood River - Silver Creek Area

CANAL REACH	LENGTH OF REACH (MILES)	DATE	Measured Loss		
			CFS	% OF FLOW	CFD*
Dist. 45 canal from headgates to Hwy. 93	1.2	8-6-75	6.1	2%	3.35
East Leg of Dist. 45	1.6	9-10-75	4.3	18%	2.88
		10-20-75	3.1	49%	2.10
		6-29-76	5.9	14%	4.84
Central Leg of Dist. 45 - Upper Reach	2.9	6-11-75	8.4	4%	4.03
		8-6-75	8.0	5%	3.00
		6-29-76	21.8	18%	7.12
Central Leg of Dist. 45 - Lower Reach	1.8	8-12-75	0.5	2%	0.30
		6-29-76	1.3	3%	0.78
West Leg of Dist. 45	3.4	9-10-75	0.9	2%	0.37
		6-29-76	6.6	10%	1.18
Baseline Canal	0.5	8-27-75	2.5	7%	4.22
		9-5-75	2.0	7%	3.24
Bypass Canal - Headgates to Baseline Canal diversion	2.9	8-12-75	15.3	18%	3.89
Glendale Canal - Lower Reach	0.5	6-30-76	0.2	1%	0.68
Iden Canal	0.8	6-30-76	6.0	28%	5.41

* Cubic feet per square foot of canal area per day.

filling of bank storage and siltation.

The rate of seepage from a canal varies with the elevation of the water level in the canal. Therefore, application of a constant seepage rate throughout the irrigation season can result in calculated seepage volumes in excess of actual diversion volumes. A procedure was developed in the input program to vary the seepage as follows: If discharge measured at the canal diversion is greater than 60% of the maximum seasonal discharge or canal capacity, seepage from the canal is set at 100% of the maximum measured seepage rate. If the discharge is less than 15% of maximum, then the seepage is set at 20% of the maximum rate. If the discharge is between 15% and 60% of maximum, the seepage varies linearly between 20% and 60% of the maximum (seepage) rate (see Figure 9).

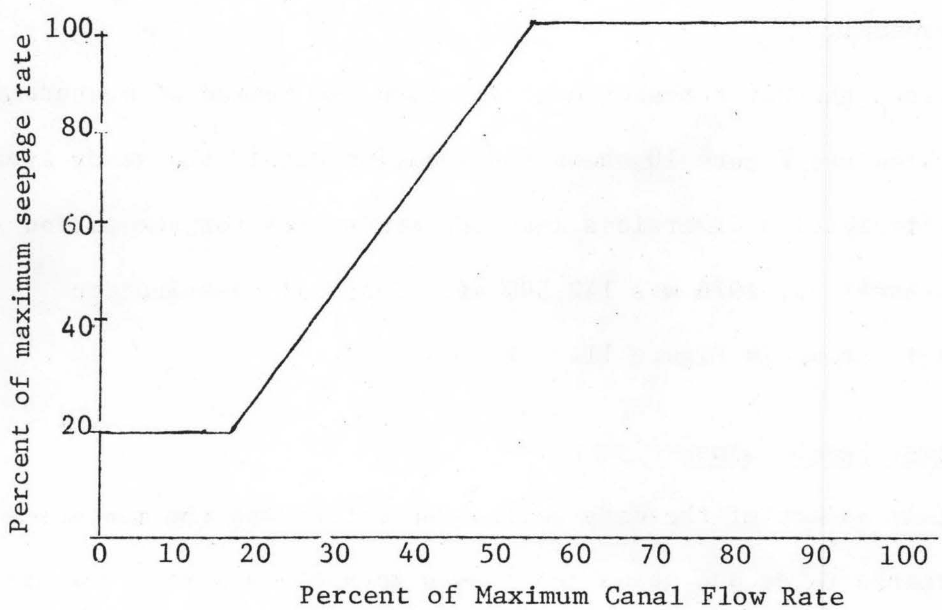


Fig. 9. Variation of canal seepage rate in groundwater model. Big Wood-Silver Creek study.

Although this approach is not thoroughly documented, it affords a more reasonable accounting for seepage than assuming a constant seepage rate.

Another modification was made to the input program to insure that, for low flows, the volume of seepage will never exceed the volume of diversion. If this occurred, the aquifer model would receive recharge which did not exist.

Irrigation Diversions

Diversions of surface water to the 21 service areas were obtained for determination of irrigation application rates. A network of measuring stations consisting of measuring devices (parshall flumes and weirs) or current-meter-rated sections was established and monitored. During the 1975 irrigation season measurements were made on all stations twice weekly. For the 1976 season continuous water stage recorders were installed at five locations and measurements made at other stations every one or two weeks.

Diversions recorded by the Watermaster for the Big Wood River were obtained which provided data for seven diversions which were not measured by project personnel.

Table 3 lists the water measurement location and method of measurement for each diversion and Figure 10 shows the location within the study area.

The total irrigation diversions into the study area for the period May 1, 1975 to April 30, 1976 was 142,580 af. Seasonal distribution of these flows is shown in Figure 11.

Springs and River Reach-Gains

An important aspect of the data collection effort was the measurement of spring discharge rates and gains and losses to various stream reaches. On the eastern side of the study area, in the headwaters region of Silver Creek, a series of observations were made by the United States Geological Survey to determine spring flows and reach-gains in the tributaries and main Silver Creek. A summary of these findings is given by Moreland (1977). On the western side, there are two main springs which were measured by

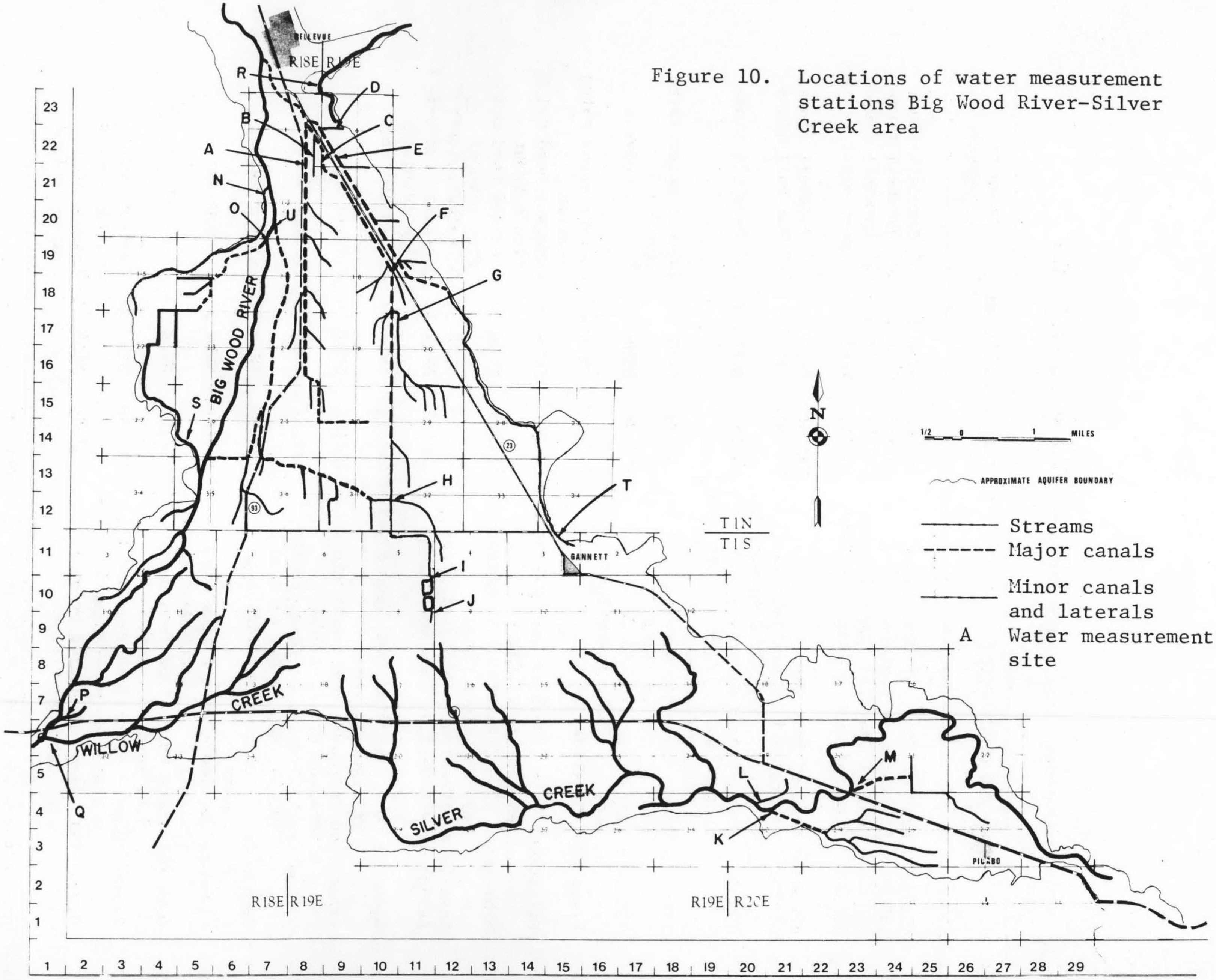


Figure 10. Locations of water measurement stations Big Wood River-Silver Creek area

Table 3. Water Measurement Locations - Big Wood River-Silver Creek Area 1975-76

NUMBER	NAME AND DESCRIPTION	LEGAL DESCRIPTION		METHOD OF MEASUREMENT
A	450101 - Head of Dist. 45 West Canal	1N/18E	SENE 1	8' Parshall flume
B	450001 - Diversion to Swanson	1N/18E	SWNE 1	30" Parshall flume
C	450201 - Head of Dist. 45 Central Canal	1N/18E	NESE 1	15' Parshall flume
D	450303 - First diversion from East Canal	1N/18E	NESE 1	Current meter rated
E	450303 - Head of East Canal	1N/18E	NESE 1	10' Parshall flume
F	450205 - Diversion from Central Canal at jct. of Hwy 23, Kingsbury Ln.	1N/19E	SENE 18	30" Parshall flume
G	450206 - Head of main diversion into 45 Central East - on east side of Kingsbury Lane	1N/19E	NWNW 20	10' Parshall flume
H	455501 - Waste flow from Baseline into 45 Central East	1N/19E	SWNW 32	Current meter rated section
I	450299 - Waste flow from 45 Central East into Price Ponds	1S/19E	SENE 8	1' rated culvert
J	Price Pond Overflow	1S/19E	SENE 8	Current meter rated section
K	Kilpatrick 18 - Diversion from Kilpatrick Res. on Silver Creek	1S/20E	SENW 30	Constant head ori fice turnout
L	Albrethsen 17 - Diversion from Kilpatrick Res. on Silver Creek	1S/20E	NENW 30	Constant head orifice turnout
M	Iden 19 - Diversion from Silver Creek	1S/20E	SESE 20	3' rated culvert
N	Bannon 49 - Diversion from Wood River	1N/18E	NWSW 12	Constant head orifice turnout
O	Glendale 50 - Diversion from Wood River or Black Slough	1N/18E	SWSW 12	Double 10' Rect. Weirs
P	Dragonwood Outflow - Meas. near old Stanton Crossing Bridge	1S/18E	SESE 16	Current meter
Q	Willow Creek* - Meas. at foot of hill 1/2 mi. SSE of Hwy 68/Wood R. Bridge	1S/18E	SWNE 21	Current meter
R	Seaman Cr. - Intermittent inflow to Seaman	2N/19E	SWSW 31	Current meter
S	Glendale Outflow - Return flow from Glendale into Wood River	1N/18E	SWSW 26	Current meter
T	Cove Outflow - Waste flow from Cove S.A. into Cove Ext.	1S/19E	NWSE 3	2' rated culvert
U	Bypass Canal - Diversion from Wood R., measured below headgates	1N/18E	SESW 12	Current meter rated section
V	Bypass Extension - Measured below Baseline Canal diversion	1N/18E	SENW 25	Current meter rated section

* Name in accordance with U.S.G.S. Bellevue 15' quad map.

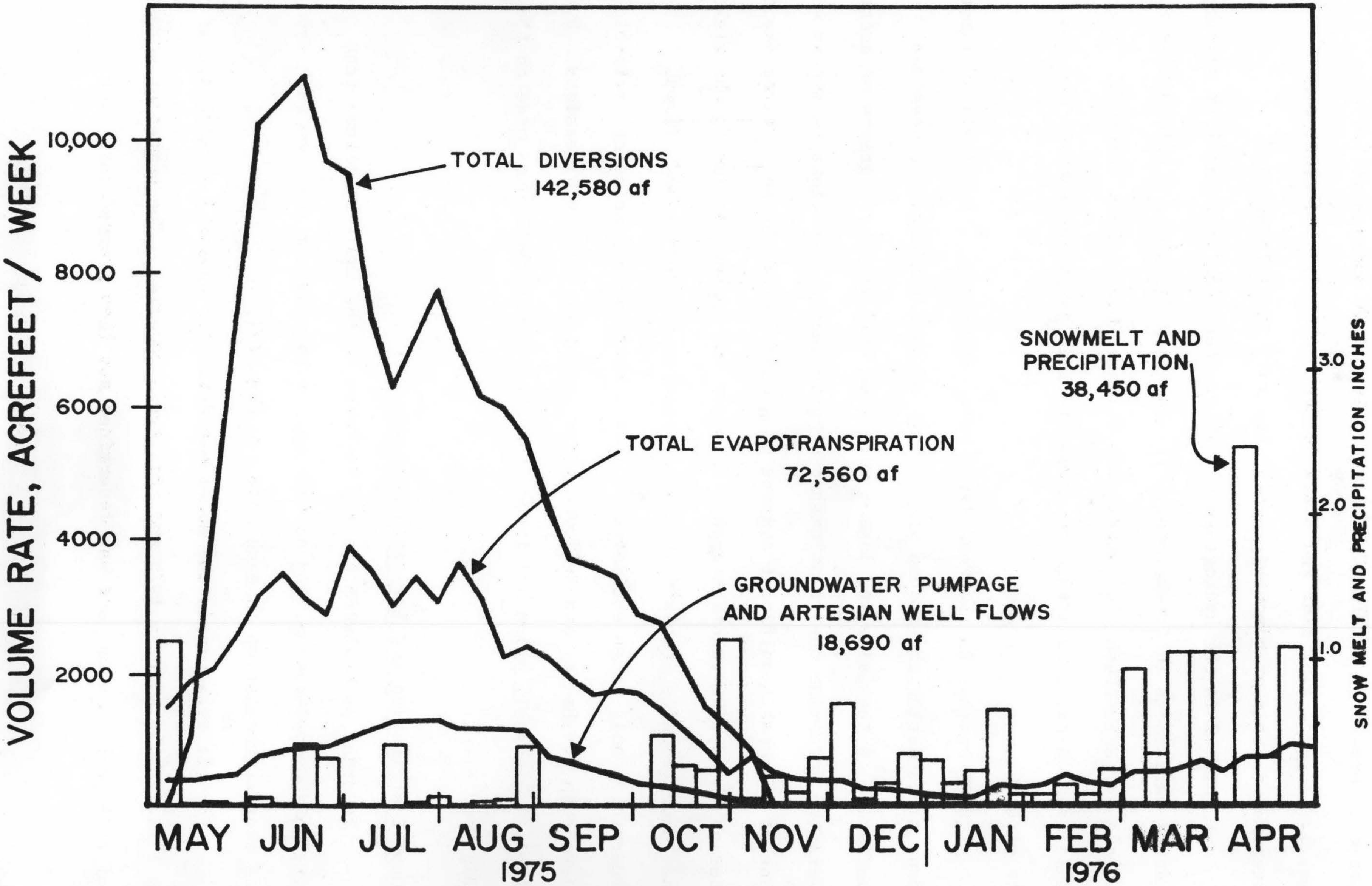


Figure 11. External water budget components.
Big Wood River-Silver Creek area. 1975-76

project personnel. Willow Creek, which is fed by springs in Sections 14, 15, 22, 23, T1S, R18E and Black Slough, Sec. 15, T1S, R18E, were measured monthly or bimonthly during the 1975 and 1976 seasons.

Figure 12 is the hydrograph of Willow Creek for 1975 and 1976 showing annual variations in discharges. Flow in Black Slough is stable with very little surface return flow justifying a longer measurement interval. High infiltration rates on irrigated areas preclude any major surface returns to streams.

Three reaches in the Wood River were measured for reach/gain at least four times during the second year of the study. Estimates of seasonal variation of the gains and losses were made utilizing hydrographs of nearby wells to determine the relationship of groundwater elevations to stream elevation. One of the most significant sources of groundwater recharge is river seepage during the spring runoff season. This was not measurable due to the risks and uncertainties involved in making measurements during high flows. Therefore, only rough estimates of this seepage were made using available data from the Hailey and Bellevue gages and other data on diversions. Table 4 lists all gains and losses computed from measurements made on the Big Wood River.

Crop Distribution and Irrigated Acreage

In order to evaluate the net recharge to the aquifer systems from irrigation application, the acreage and evapotranspiration from each type of crop or vegetation in each node are required.

For the area within the model boundaries, a physical examination of all fields was made in 1975 and crop types recorded. The number of acres of each crop in each node was determined and then grouped into each

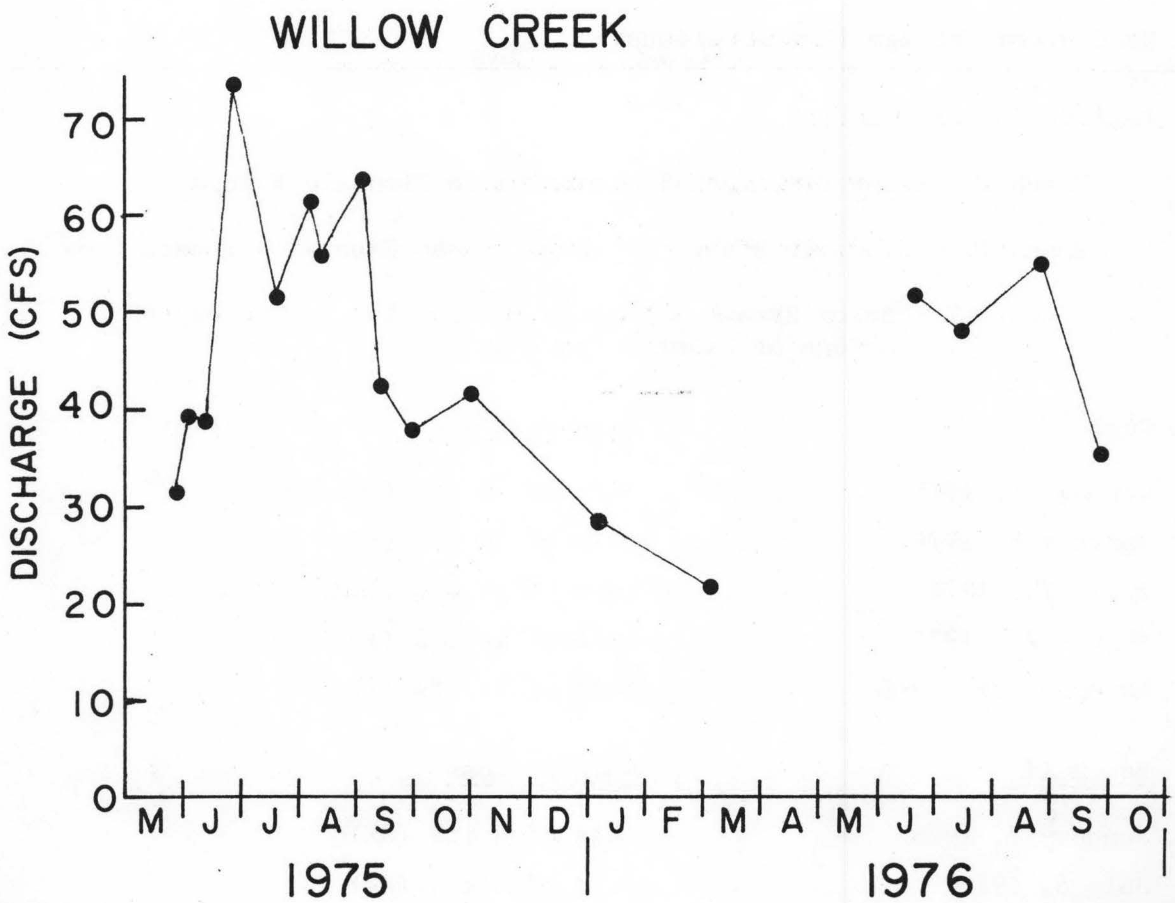


Figure 12. Hydrograph of Willow Creek
Big Wood River-Silver Creek area, 1975-76

Table 4. Wood River Seepage Investigations.

Description of Reaches:

Reach I - Below District 45 diversion to Glendale Bridge

Reach II - Glendale Bridge to above Bypass Extension return flow

Reach III - Below Bypass Extension return flow to Highway 68 bridge at Stanton Crossing

Reach I	Gain or Loss*
October 1, 1975	Gain of 12 cfs (24%)**
January 6, 1976	Gain of 12 cfs (9%)
April 14, 1976	Loss of 64 cfs (11%)
August 25, 1976	Gain of 18 cfs (15%)
November 30, 1976	Loss of 15 cfs (14%)

Reach II	Gain or Loss
January 7, 1976	Loss of 8 cfs (8%)
July 6, 1976	Gain of 3 cfs (4%)
December 10, 1976	Loss of 53 cfs (47%)

Reach III	Gain or Loss
October 1, 1975	Gain of 10 cfs (345%)**
January 7, 1976	Loss of 4 cfs (5%)
August 13, 1976	Gain of 50 cfs (208%)
December 1, 1976	Stable (no gain or loss)

Reach II and III, combined
(Glendale Bridge to Highway 68)

Date	Gain or Loss
April 14-15, 1976	Loss of 32 cfs (6%)

* Gain or loss in cfs or percent of inflow.

** U.S. Geological Survey Measurements.

service area. Crop classifications were: wheat, barley, oats, alfalfa, irrigated pasture, potatoes, and phreatophytes. The phreatophyte classification included willows, cottonwood, cattails and other water-loving vegetation along water courses. The types of irrigation on each field and the water source were documented.

Surface water irrigated acreage is considered to be those lands receiving water from canals and streams by gravity. Groundwater irrigated acreage is land served from pumped wells, artesian wells or sub-irrigated lands. Some lands receive surface water and also have wells for supplemental supplies.

Table 5 is a summary of crop survey data. A total of 31,120 irrigated acres were documented, with surface irrigated acres comprising 43 percent or 13,500 acres. Sub-irrigation is utilized on approximately 15,000 acres or 47 percent of the irrigated area. Table 1 in the Appendix contains a detailed list of crops and irrigation methods in 1975 on each 160 acre unit within the model area.

Evapotranspiration

Evapotranspiration for the 1975 season was estimated by the Agricultural Research Service (Wright and Jensen, 1976).

Climatic data were obtained from a meterological station located on the Harvey Bickett farm in the SW½SW¼, Sec. 16, T1S, R19E. Solar radiation, air temperature, humidity, windspeed and wind direction were determined. Potential ET was determined using a modified Penman equation and daily ET estimates were made for each crop type. Accumulated values of daily ET were used to determine biweekly ET values for the period November 9, 1974 to November 7, 1975 for use in the model input program.

Table 5. Crop Distribution and Irrigated Acreage - Big Wood River-Silver Creek Area - 1975 Irrigation Season

CROP	ACREAGE	% OF TOTAL
Wheat	730	2.4
Barley	6,740	21.7
Oats	510	1.6
Alfalfa	9,500	30.5
Irrigated Pasture	12,610	40.5
Phreatophytes	960	3.1
Potatoes	70	.2
Total	31,120	100.0

Total Surface Water Irrigated Acreage	Total Groundwater Irrigated Acreage		Total Irrigated Acreage
13,500	17,620		31,120
	Pumped	Sub-irrigated	
	2,920	14,700	

Table 6. Estimated Monthly and Seasonal ET for Crops in the Big Wood River-Silver Creek Area - 1975 (after Wright and Jensen, 1976)

CROP								Total	
	Apr.	May	June	July	Aug.	Sept.	Oct.	mm	inches
Alfalfa	34	101	186	152	172	104	52	715	28.2
Small Grain	34	59	97	201	101	28	38	486	19.1
Irrigated Pasture	34	106	142	149	129	99	45	625	24.6
Willows	34	106	142	149	129	99	45	625	24.6
Potatoes	34	65	43	89	141	96	38	434	17.1
Waste (Dryland)	34	98	41	18	16	7	25	180	7.1

Table 7. Monthly recharge from precipitation or snowmelt Big Wood River-Silver Creek Area 1974-1976

MONTH	RECHARGE (Inches)
Nov 1974	.15
Dec	.72
Jan 1975	.92
Feb	.60
Mar	1.85
Apr	8.11
May	1.05
June	.71
July	.44
Aug	.42
Sept	.00
Oct	2.00
Nov	.79
Dec	1.17
Jan 1976	1.13
Feb	.74
Mar	3.61
Apr	4.42
May	1.08
June	.73
July	.18
Aug	1.00
Sept	1.09
Oct	.07

Groundwater Pumping and Artesian Wells

Significant withdrawals from the aquifer are caused by pumping of large amounts of groundwater for irrigation purposes. Irrigation application of water flowing from wells in the southern part of the area is also very significant. The input program to the groundwater model has provisions to account for these extractions in the water balance for each node point.

For the first irrigation season of the study period, determination of the volumes and location of groundwater pumpage was made by the U.S. Geological Survey. Their sources of data were Idaho Power Company irrigation

The estimated potential ET was 33 inches for the period May 1 through September 30, 1975 and ET for alfalfa for the same period was 28 inches. This estimate is considerably higher than the average annual ET for alfalfa of 22 inches estimated by the widely used Blaney Criddle method (Sutter and Corey, 1970). Table 6 lists the monthly and seasonal estimates of ET for crops grown in the area as determined by Wright and Jensen (1976).

The 1975 ET values were used for both the 1975 and 1976 seasons with appropriate adjustments for the lateness of the 1976 season. The input program to the groundwater model was modified to enable the actual values of consumptive use for each of the service areas to be calculated internally (within the program) on the basis of the crop distribution and evapotranspiration data.

Based on the crop distribution, ET estimates and total acreage in the study area, the annual evapotranspiration was estimated at 72,560 af. The seasonal distribution of the ET estimate is shown in figure 11.

Precipitation and Snowmelt

Precipitation and snowmelt account for 15 percent of the external recharge to the aquifer system. Precipitation during the growing season is only 23 percent of the total seasonal precipitation and does not contribute significantly to aquifer recharge. Snowmelt during the spring season accounts for the majority of recharge.

A snow survey network was installed and three precipitation gage sets were set out in the fall of 1974. These facilities were installed and monitored by the Agricultural Research Service for the period November 1974 to November 1975, (Zuzel 1975). The University assumed the data collection responsibilities and monitored snowmelt and precipitation at one site from December 1975 through October 1976. Precipitation gages were of the recording type with resolution sufficient to compute point precipitation amounts to within 0.02 inches.

The snow water storage network consisted of 21 locations where utility posts, rain gage posts and fence posts were marked with 10, 2-inch metal squares painted fluorescent orange and located at 4 inch intervals from ground surface. These were read every two weeks during the accumulation and ripening period and every other day during snowmelt. Snow density samples were taken at each site or at representative sites near each depth measuring location. Water content was determined at each site and the changes in the weighted average water content for each two week period during snowmelt were used as recharge to the aquifer. This procedure assumes that no surface runoff from snowmelt occurred which, because of high soil infiltration rates, is the case over most of the area. Some runoff from snowmelt near Silver Creek does occur as evidenced by the rapid rise of the hydrograph of Silver Creek during the snowmelt period. It was not possible to determine the spatial variation of recharge from snowmelt so the average was uniformly applied to the entire area.

Monthly recharge from snowmelt and precipitation which was determined from the snow and precipitation monitoring program is shown in Table 7. Recharge from precipitation and snowmelt by two week timestep as used in the groundwater model is shown in Table 2 in the Appendix. The Appendix also includes a copy of the Agricultural Research Service report on Precipitation and Snowmelt Data for the Silver Creek-Wood River Triangle Area.

Seasonal distribution of total recharge to the aquifer from snowmelt and precipitation is included on figure 11.

account records and measurement of the actual discharge rates of pumps wherever possible. Determination of artesian flows was also made by the U.S. Geological Survey on the basis of field measurements and interviews with irrigators. Further explanation of the methods used by the Geological Survey as well as results of their investigation may be found in Moreland (1977).

Records were made available by the Power Company for the second season to the Idaho Water Resources Research Institute and pumpage quantities were calculated using techniques similar to those used by the Geological Survey. Artesian flows were not measured for the second season; values from the first season were assumed. Total water use from pumping and artesian wells for the May 1975 to April 1976 year was 18,690 af (fig. 11).

Water Table Measurement

In order to provide historical data for calibration of the groundwater model, a well network was selected and measured over the study period. The main portion of this selection and measurement was undertaken by the Geological Survey (Moreland 1977). A total of 51 wells including domestic, stock, irrigation and observation wells were measured. Their spatial distribution was relatively uniform, with one exception: in the southwest corner of the study area west of Highway 93 there was a notable lack of wells to be measured. Of the wells observed, 15 were flowing. To provide a continuous record of groundwater fluctuations, groundwater level recorders were installed at three of the well sites. A map showing the location of wells in the network is included on fig. 13.

Monitoring of these wells was started in November 1974 by the Idaho Department of Water Resources and by the Geological Survey from May 1975

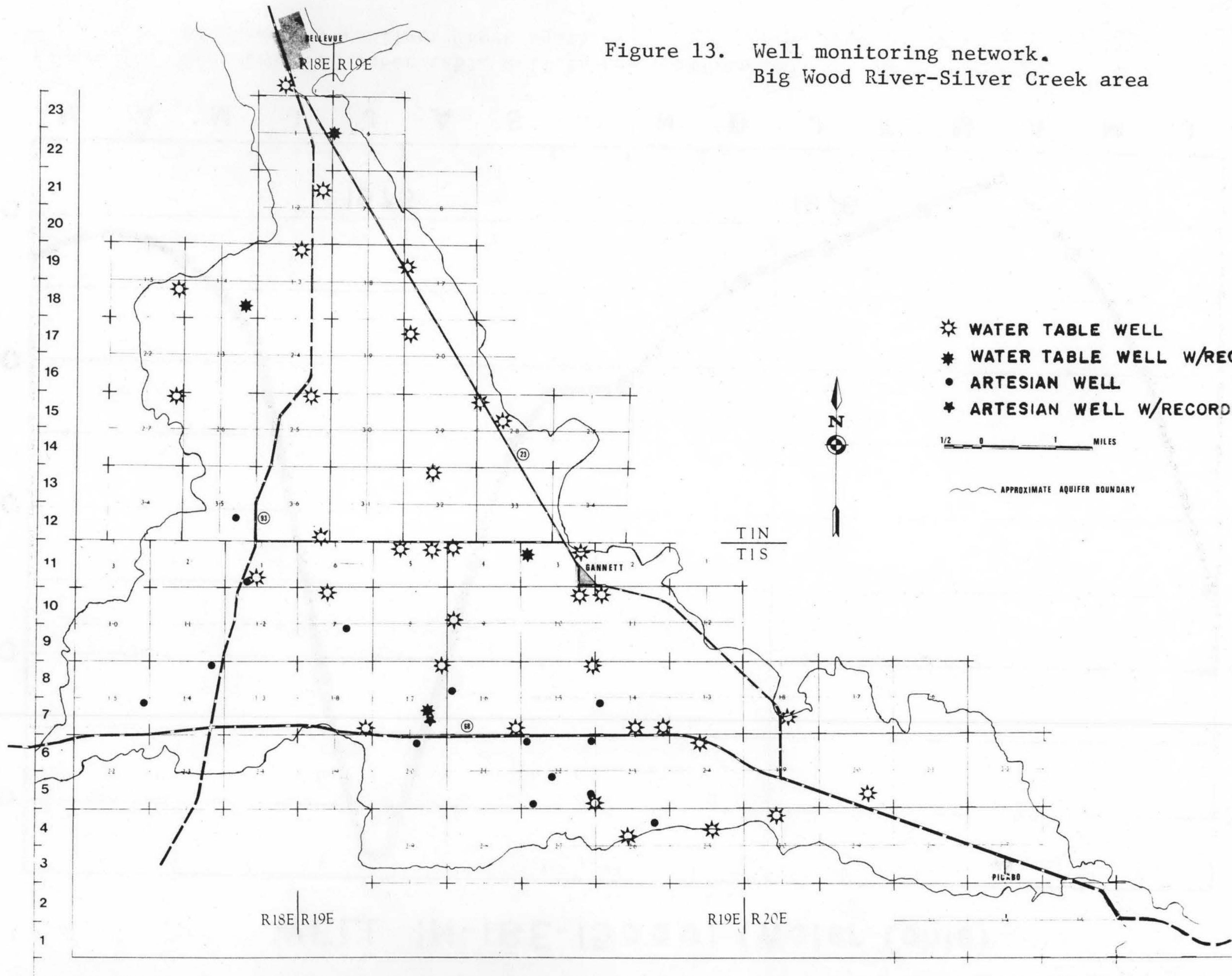


Figure 13. Well monitoring network. Big Wood River-Silver Creek area

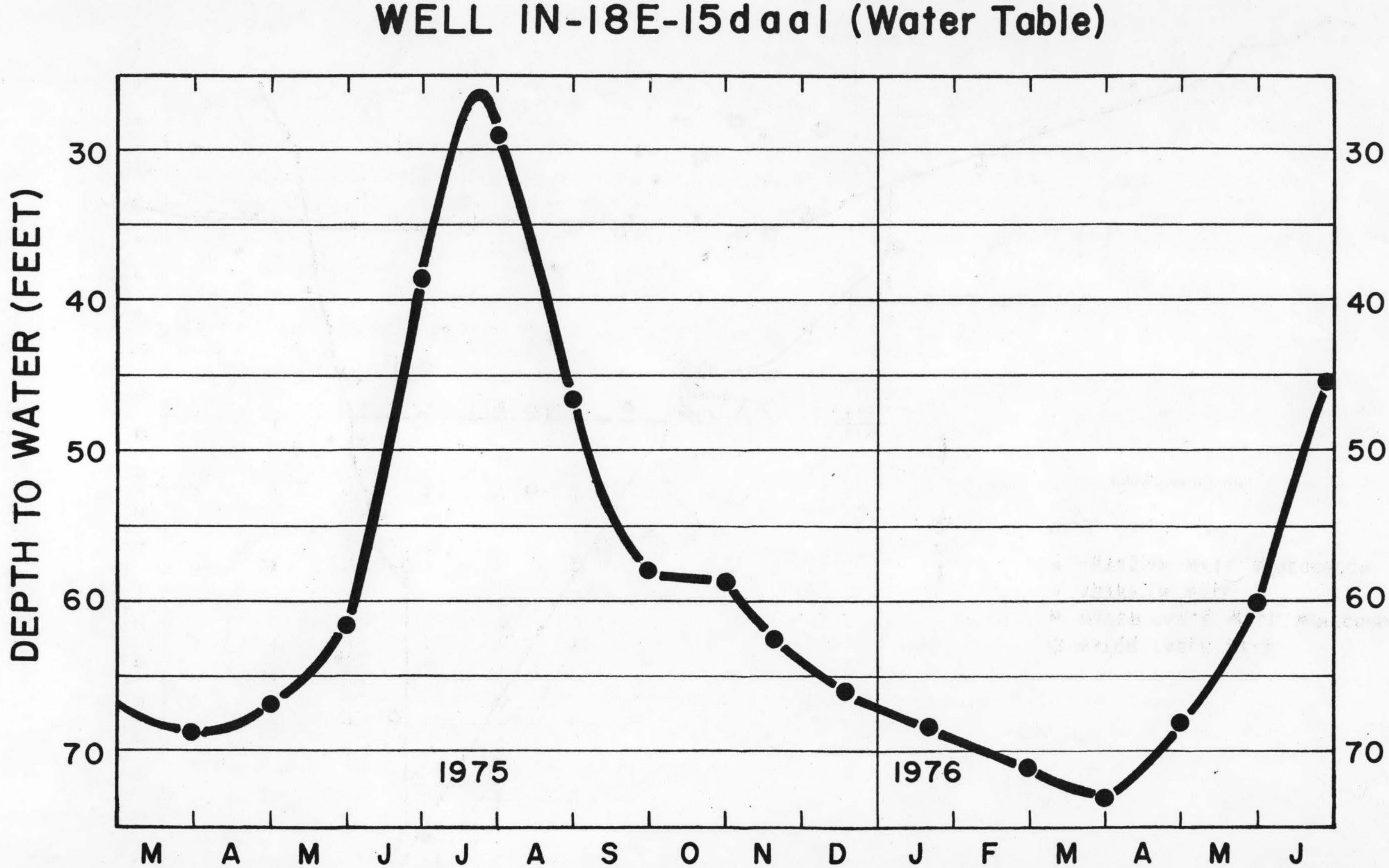


Figure 14. Hydrograph of water table well in the northern part of the Big Wood River-Silver Creek aquifer.

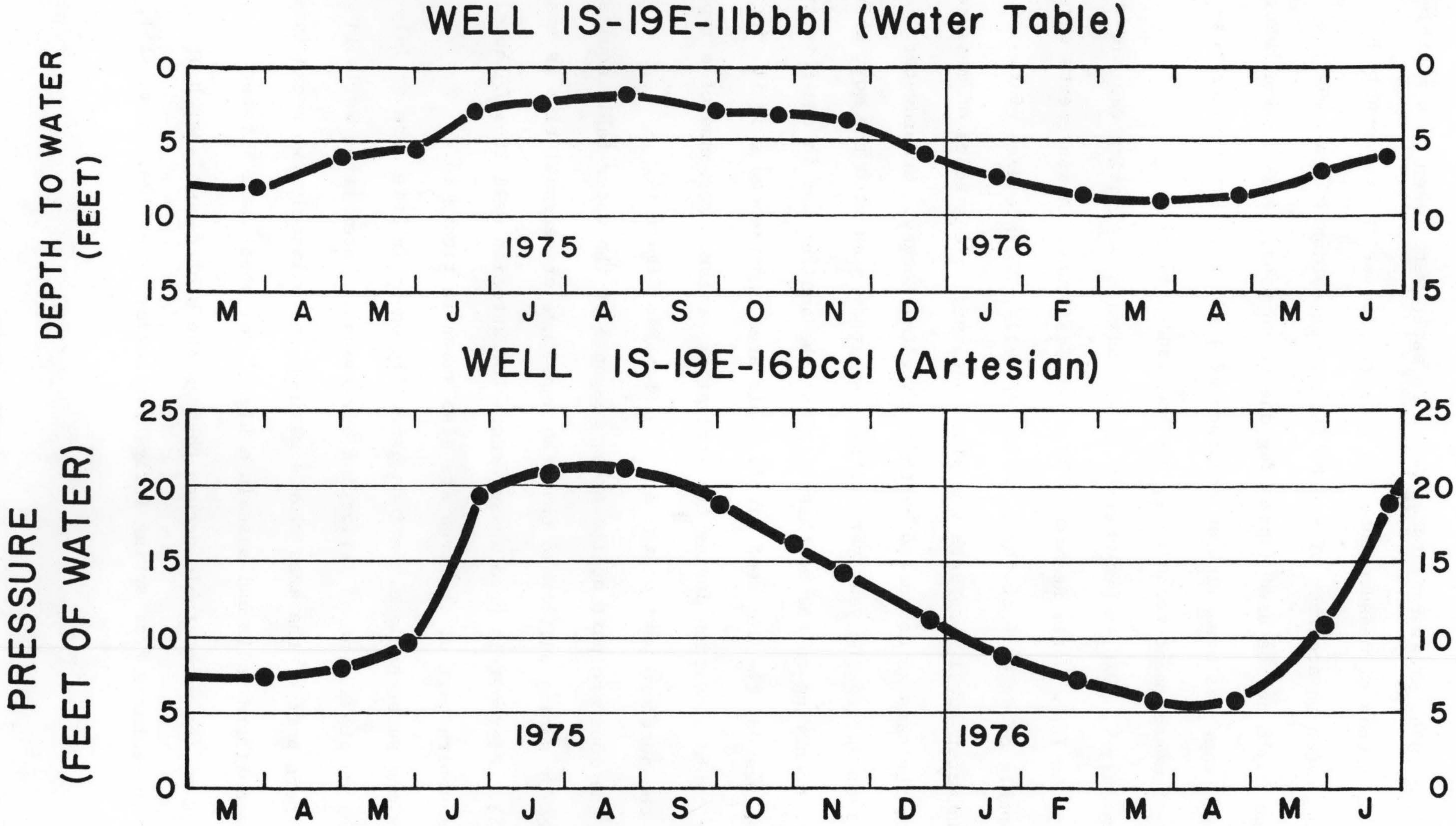


Figure 15. Hydrographs of water table and artesian wells in southern part of Big Wood River-Silver Creek area.

through June 1976. Measurements of depth to water were taken on a monthly basis. The method of measurement, for non-artesian wells, was mostly by steel tape, with an accuracy of $\pm$ 0.02 ft. In exceptional cases where a steel tape could not be used (splashing due to pumping, leaky casing, etc.) an electric tape was used, with an accuracy of $\pm$ 0.1 ft. For further description of measurement techniques, see Moreland (1977).

From July 1, 1976 to December 1976, groundwater monitoring was continued by the Idaho Water Resources Research Institute. Measurements were taken monthly on only 16 of the 51 original wells. Maintenance of two of the groundwater level recorders was also continued. Techniques of measurement were the same as conducted by the Geological Survey. Groundwater fluctuations during the year vary within the study area with the most abrupt responses occurring in the northern part of the aquifer and in the Poverty Flat area west of the Big Wood River. This area experiences a 35 ft. increase in water table elevation during the irrigation season. Response of a typical well in the northern part of the area is shown in figure 14.

In the southern part of the area, response of the water table aquifer is damped by spring outflow so that the amplitude of seasonal rise is small (fig. 15). Piezometric head measurements for artesian well 1S-19E-16bcc1 in the southern part of the area are also shown in figure 15.

Maximum water table elevations generally occur in late June or July depending on the advent of irrigation diversions. Water table wells in the southern part of the area show a maximum approximately two weeks later than the northern wells and sustain a high level until late October. Recession of the water table occurs through the winter until March or April when recharge from spring irrigation begins (see figs. 14 and 15).

Calibration of the groundwater model requires determination of water table elevations or piezometric heads at each node point for periods near the minimum and near the maximum elevation. In the model for these aquifers, timestep 79 (May 1, 1976) was selected for the minimum and timestep 40 (August 1, 1975) was determined to be the most representative time period for maximum water table elevations.

For each time period, water table elevations were determined from hydrographs of observations wells. Manual adjustment of certain water table contours was necessary to produce rational configurations.

Figure 16 is a water table contour map for the water table aquifer in May 1976. The contours show steep gradients (40 feet per mile) in the northern part of the triangle with more gradual gradients (12 feet per mile) in the central and eastern parts of the area. In the southwest corner the gradient increases to about 25 feet per mile.

Watertable contours for the water table aquifer in August of 1975 are shown in Figure 17. Comparison of Figures 16 and 17 show increases in the gradient in the central part of the water table aquifer in August and an average increase in elevation of 20 feet in this same area.

Depth to water contours for the water table aquifer are shown in Figure 18 for May 1, 1976. These depths should represent maximum depths to water during an average recharge year.

The artesian aquifer exhibits much less change in the configuration of the piezometric head from minimum to maximum during the season. Figure 19 shows contours of piezometric head in May 1976 which show general gradients toward the southeast of 15 feet per mile. Contours for August 1975 (Figure 20) which represent maximum or near maximum values indicate approximately the same gradient and configuration except for a general

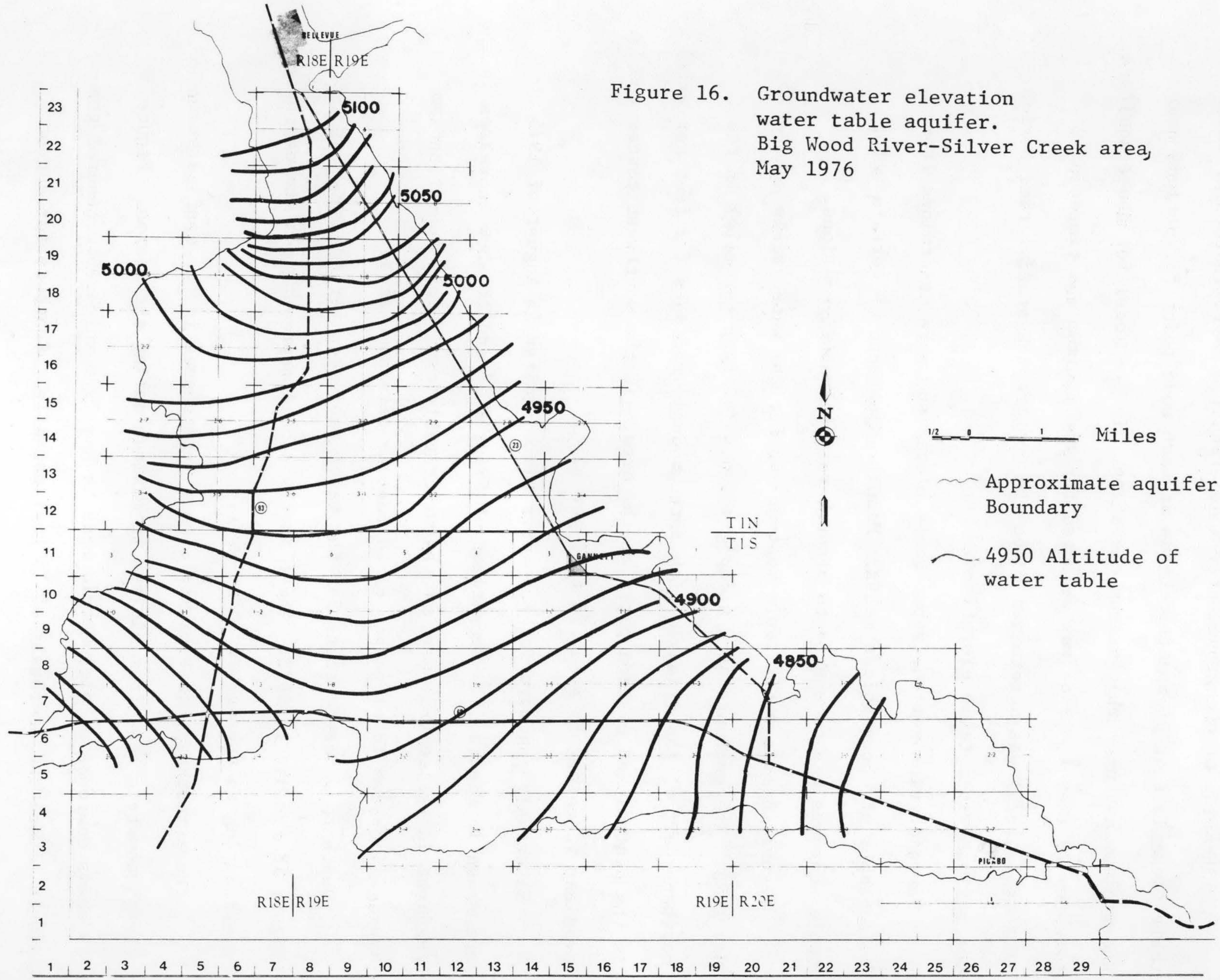


Figure 16. Groundwater elevation water table aquifer. Big Wood River-Silver Creek area, May 1976

Figure 17. Groundwater elevation contours,
water table aquifer.
Big Wood River-Silver Creek aquifer
August 1975

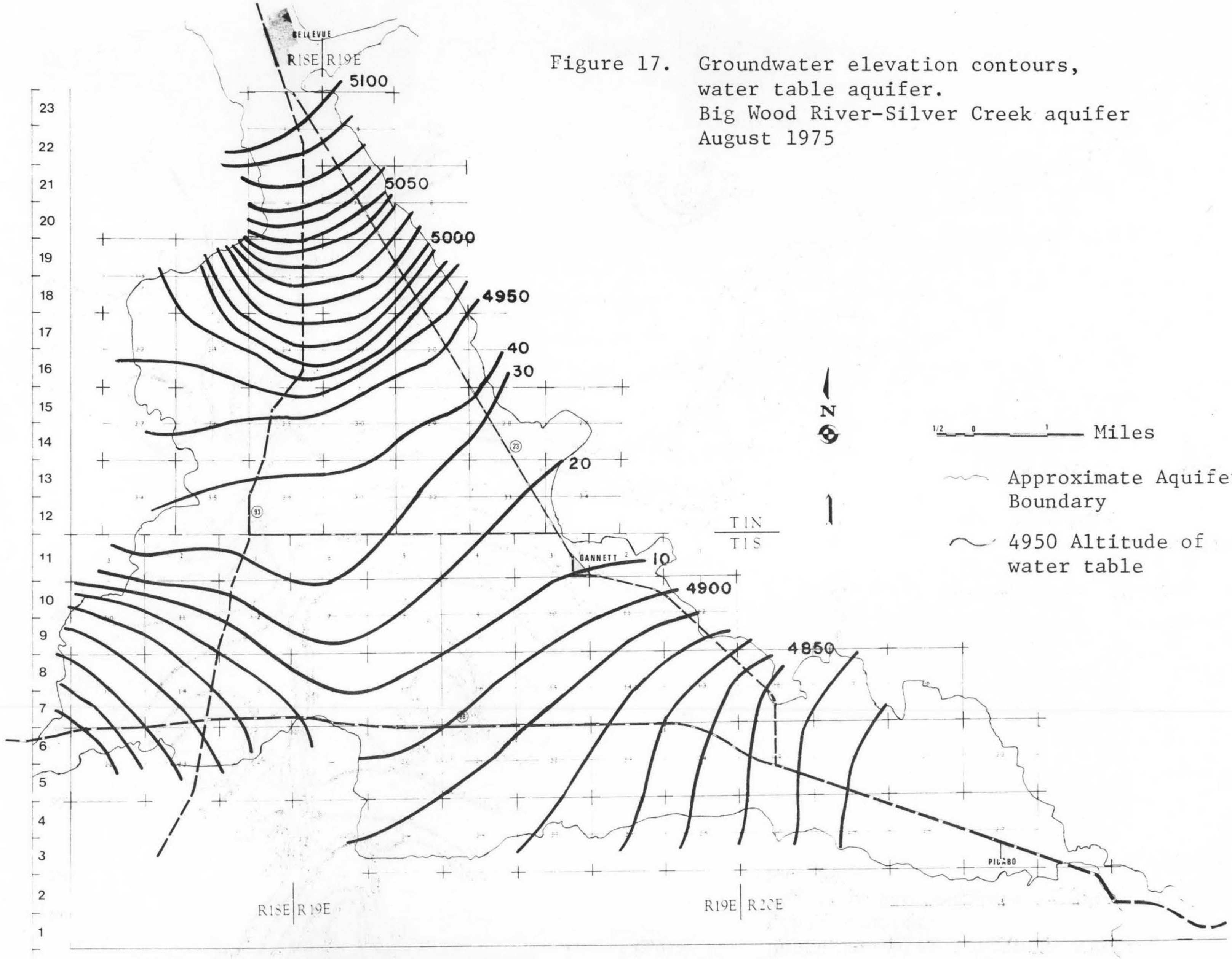
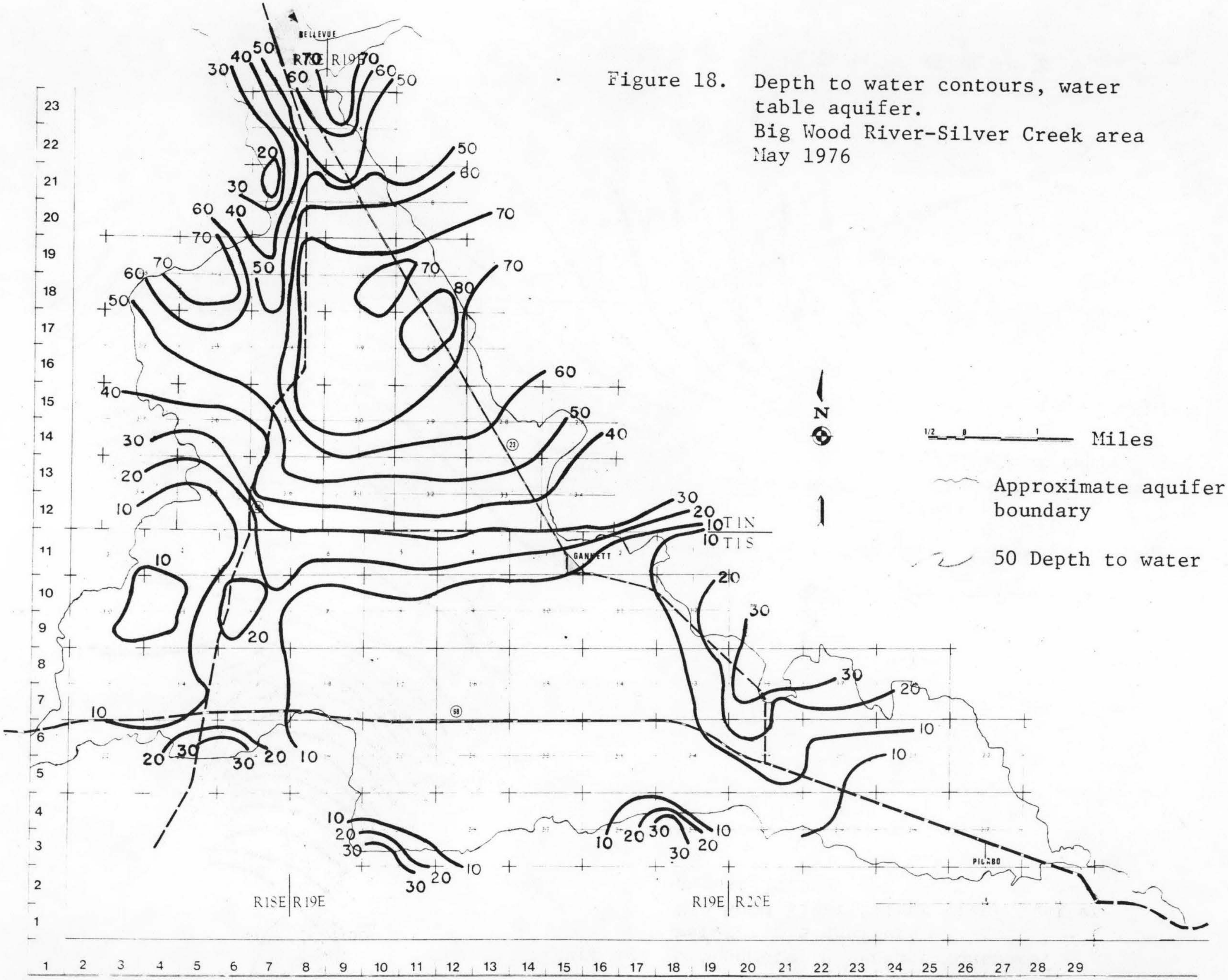


Figure 18. Depth to water contours, water table aquifer.
Big Wood River-Silver Creek area
May 1976



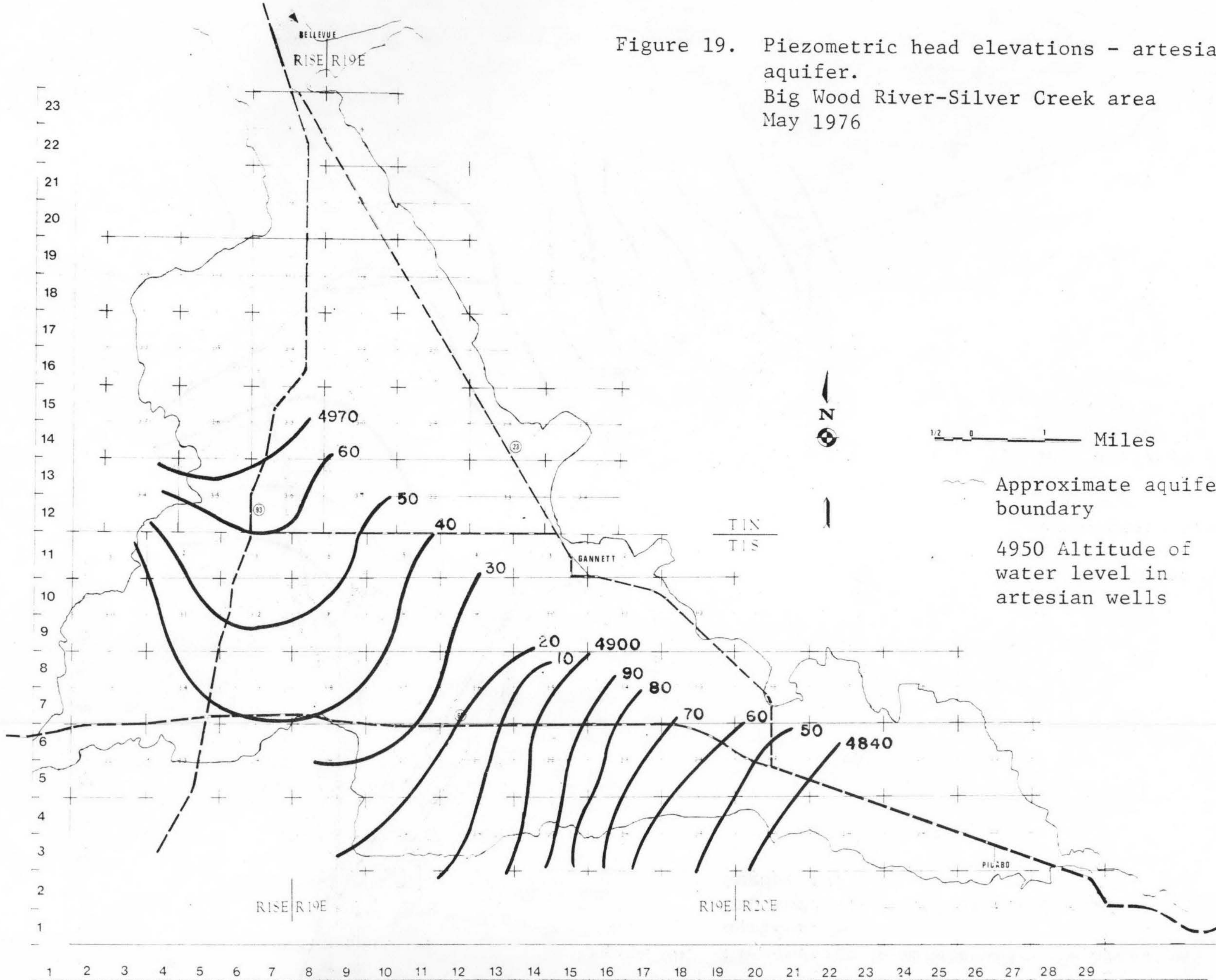


Figure 19. Piezometric head elevations - artesian aquifer.
Big Wood River-Silver Creek area
May 1976

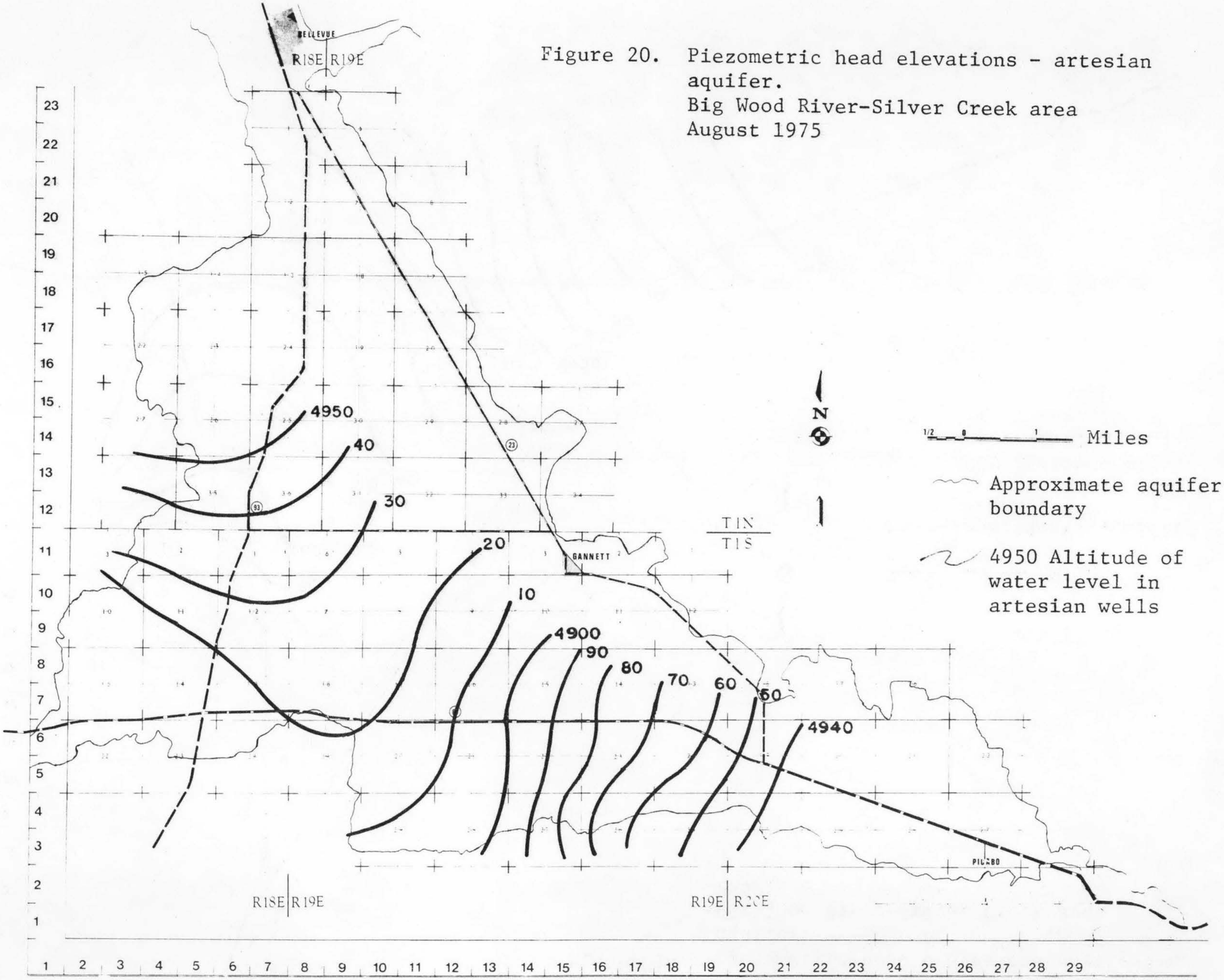


Figure 20. Piezometric head elevations - artesian aquifer.
Big Wood River-Silver Creek area
August 1975

rise in piezometric head of between 10 and 20 feet. Figure 21 shows the level in artesian wells or piezometric head relative to groundsurface in the artesian aquifer for May 1976.

Calibration

Data for the period May 3, 1975 to July 2, 1976 was used to calibrate the model. Computed groundwater levels were compared and adjusted to measured water levels on August 1, 1975 and May 1, 1976. Comparisons of springflows from the eastern and western springs in the study area were also used to determine the validity of the aquifer parameters used in the model.

The artesian aquifer is recharged only by exchange from the water table aquifer along the northern boundary and the volume of the interchange between the aquifers is unknown. In calibrating the artesian aquifer the northern (inflow) boundary was allowed to pass as much water as needed to maintain the historical artesian pressure levels. After a reasonable fit of calculated to historical water levels was obtained, the values of those inflows were saved and entered in the input program for the water table aquifer.

After calibrating the water table model for several iterations, the flows to the artesian aquifer were removed from the input program and replaced by "leaky aquifer" nodes. Several more calibration runs were then made after which the values of the "leakage" to the artesian aquifer were saved and entered as input to that model. The northern boundary of the artesian model was fixed so that only the flows prescribed by the water-table model were used as input, and calibration was completed with several more iterations.

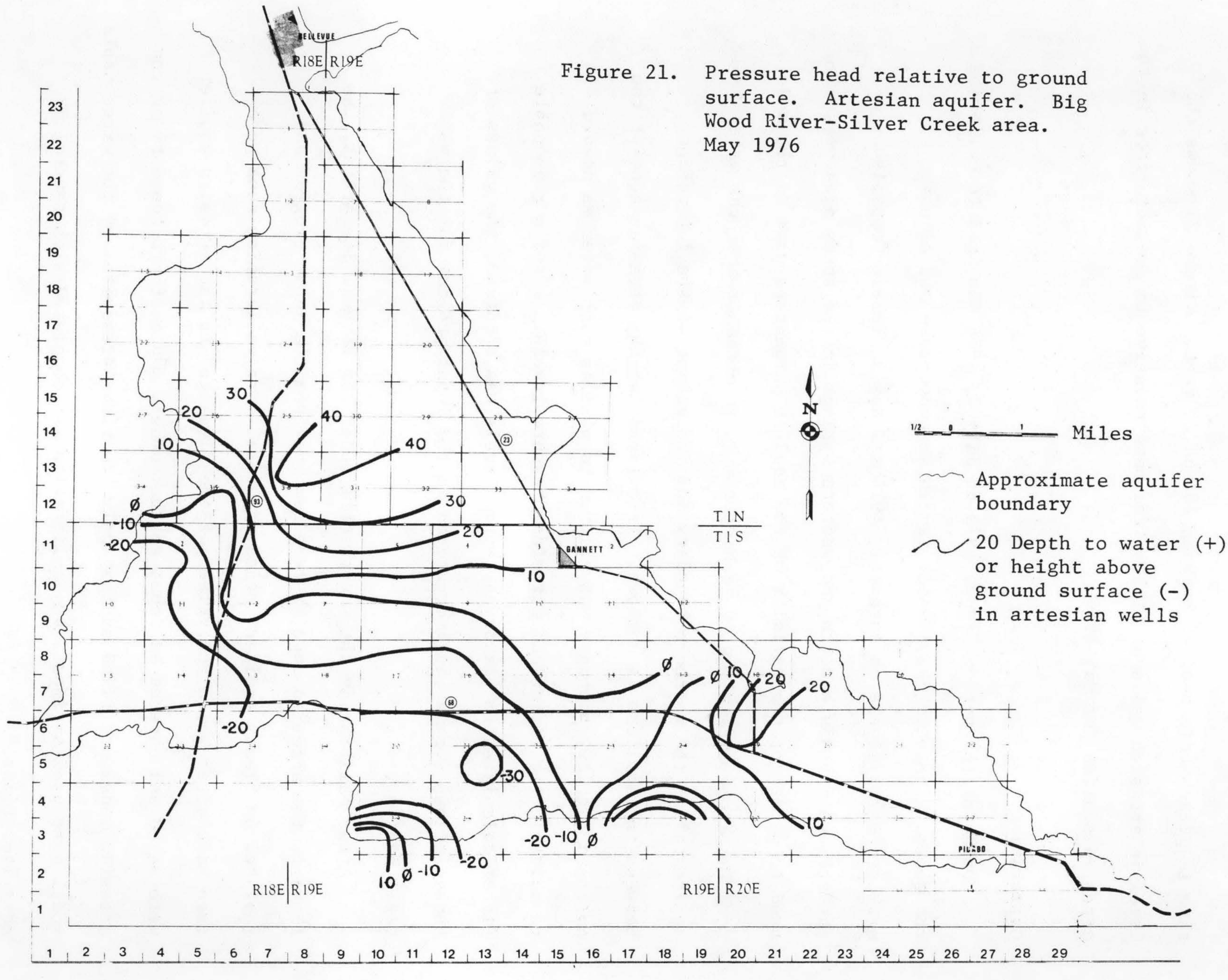


Figure 21. Pressure head relative to ground surface. Artesian aquifer. Big Wood River-Silver Creek area. May 1976

A special computer program was used to generate the input arrays to the artesian aquifer model rather than the standard input program. This program combined the artesian well or pump flows and the northern boundary groundwater "inflows" generated by the water table aquifer model.

At the end of the calibration process, the average of the deviations between the calculated head values and the historical heads at three comparison timesteps was 3.6 feet for the artesian aquifer model and 2.2 feet for the water-table aquifer model. The maximum seasonal rise at any node point in the water table aquifer was 37 feet with an average of 10.7 feet. For the artesian aquifer the maximum rise in head was 29 feet with an average of 8.2 feet.

A comparison of the May 1975 - April 1976 groundwater level simulations at six selected nodes with nearby well measurements is shown in Figure 22. It is important to note that the simulated hydrographs are for node centers, while the wells indicated are not necessarily at node centers. In areas with steep topography significant differences between groundwater levels at node centers and at wells within the one half mile square node area can occur. For instance, at node 18/06 the land surface datum for the node center is 8.0 feet below the well land surface datum. The top four graphs on Figure 22 are of water-table wells and the bottom two are artesian.

The simulated flows of the east side springs compared with the flow of Silver Creek at Sportsman's Access for the same period and simulated west side spring flows are shown in Figure 23. It should be noted also that the measured values of Silver Creek flow are not always the same as the springflows due to diversions and surface-water runoff above the gage. Moreland (1977) estimated the groundwater component of Silver Creek as compared with

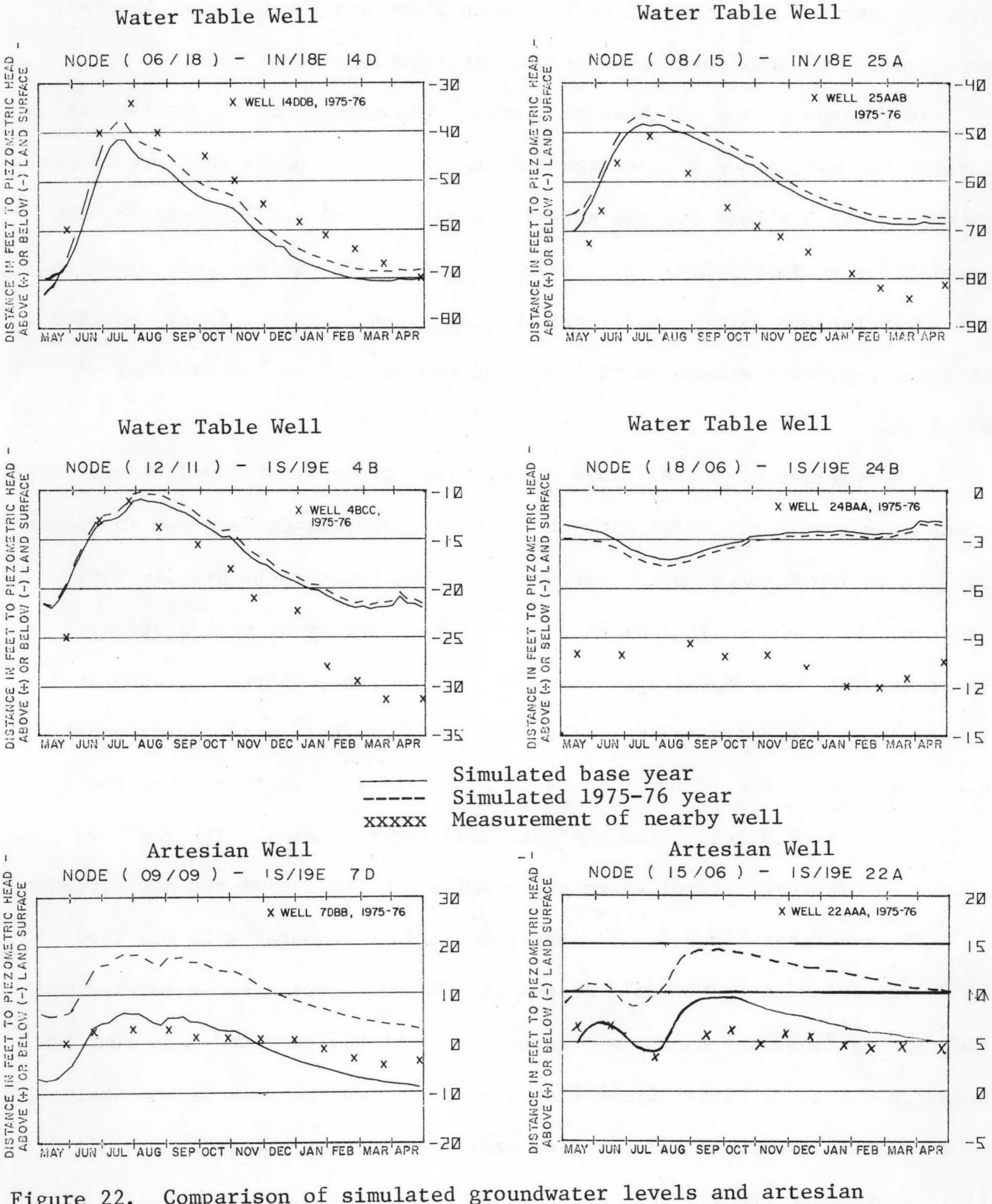
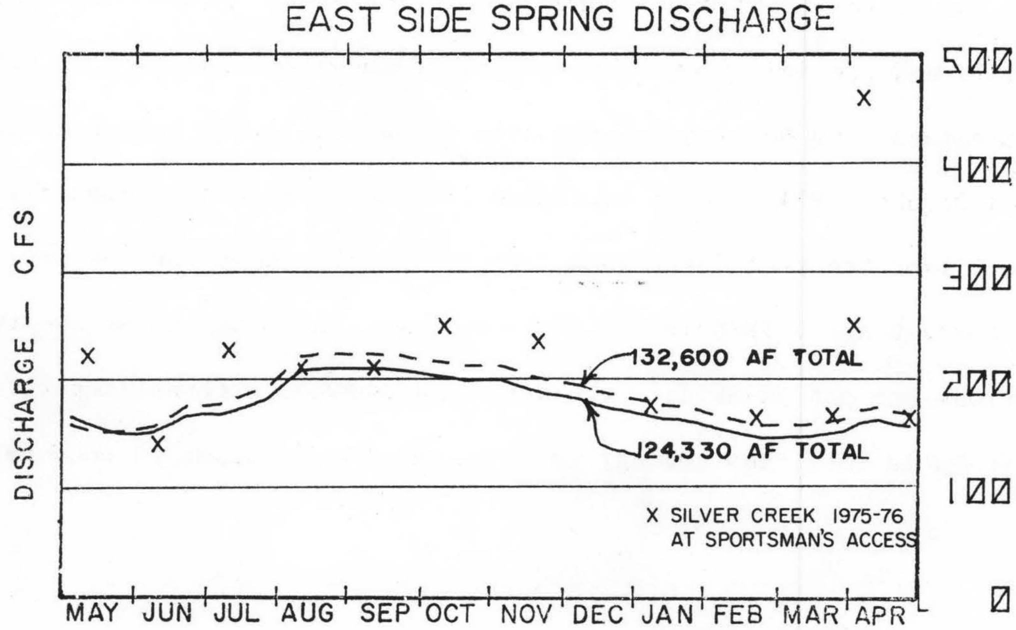


Figure 22. Comparison of simulated groundwater levels and artesian pressures with historical measurements of nearby wells in the Big Wood River-Silver Creek area.



——— Simulated base year
------- Simulated 1975-76 year

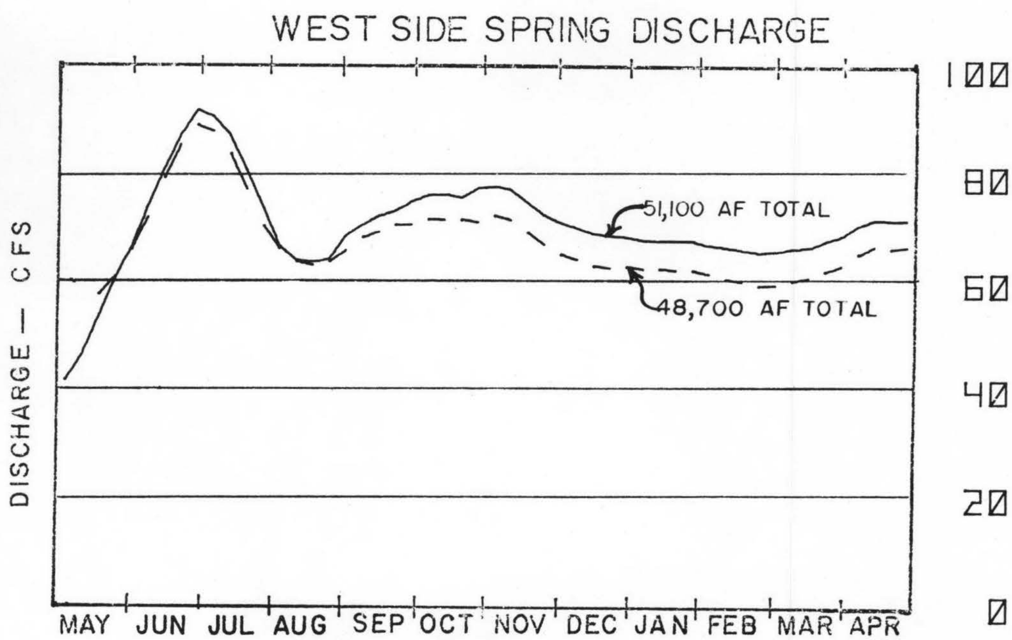


Figure 23. Comparison of simulated springflows with historical flow measurements in the Big Wood River-Silver Creek area.

the discharge as measured at Sportsman's Access for the 1974-75 water year. Figure 24 shows the relationship between the groundwater component, discharge, and snowmelt and precipitation. The annual groundwater discharge in Silver Creek determined from Moreland's estimated curve is 133,350 acre feet for the period October 1974 through September 1975. The simulated groundwater inflow to Silver Creek as determined from the water budget for the period May 1975 through April 1976 is 132,680 acre feet. Although these two twelve month periods are not identical, the deviation between external inputs for the two years is small and the agreement of the model output is encouraging.

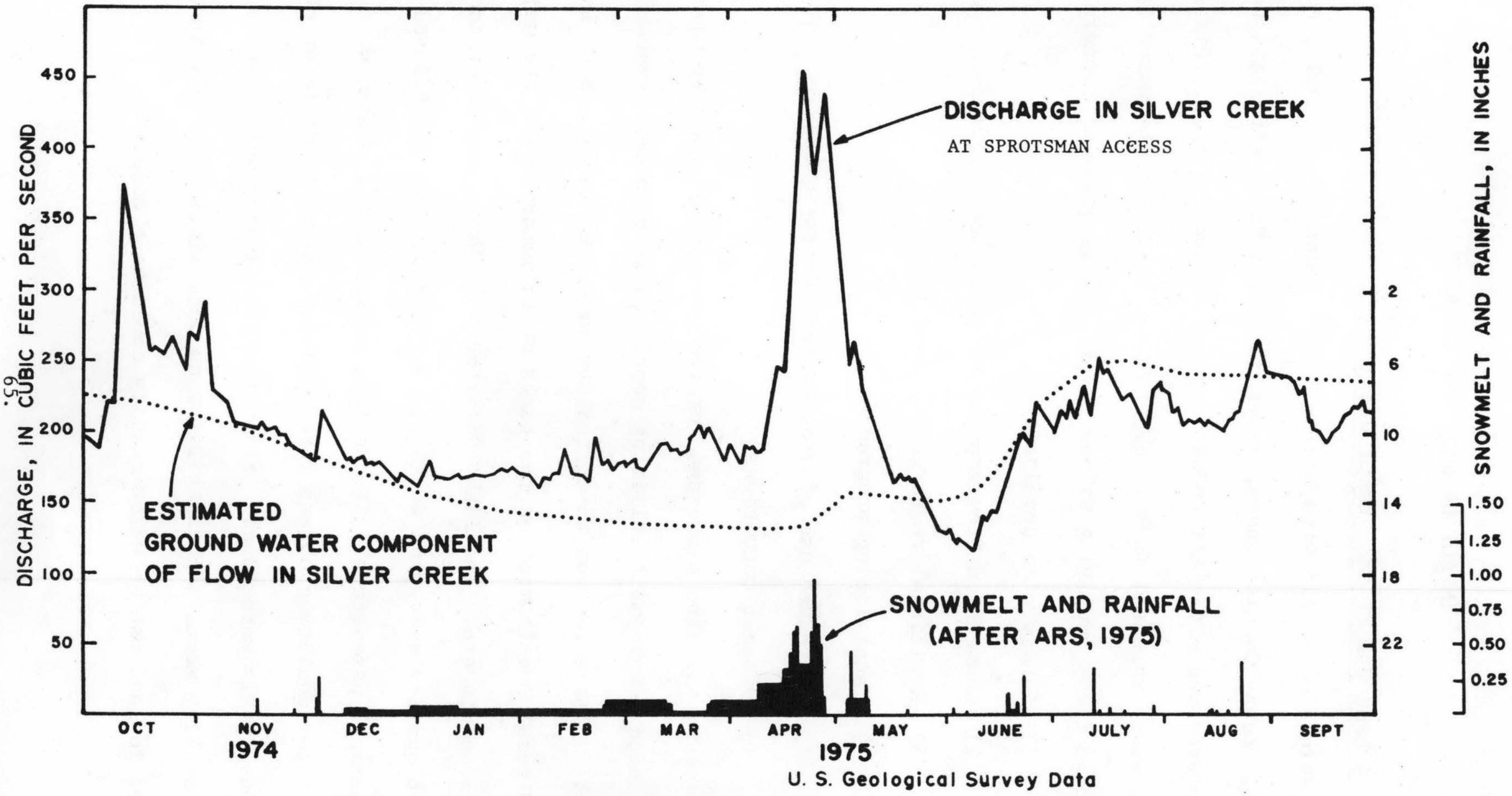


Figure 24. Flow in Silver Creek, groundwater component of flow and snowmelt and rainfall, 1975 water year.

IMPACT OF LAND USE CHANGES

Potential Land Use or Management Changes

Meetings were held with Blaine County Planning and Zoning Administrators, County Commissioners, water users and State officials to determine the concerns and potential trends in land use in the area. Six areas of concern were expressed as having potential impact on the water tables and spring flows supplying Silver Creek. These areas of concern are:

1) Subdivision development
2) Conversion from gravity to sprinkler irrigation
3) Artificial recharge of flood flows
4) Canal lining programs
5) Increased use of groundwater for irrigation
6) Drought conditions

Concern was also expressed for the groundwater quality aspects of subdivision development utilizing septic tank-drainfield systems for sewage disposal. The effect on water quality in Silver Creek due to increased agricultural development on the banks of tributaries and the main channel was also a concern. The Idaho Department of Water Resources conducted a water quality survey of wells and surface streams in 1975 and compared the chemical parameters with previous measurements. There were no areas where water quality problems were apparent and no significant changes from previous levels were found. Since the groundwater model does not include water quality modelling capability, no determination of the impact of changes in land use on water quality could be predicted.

Procedure

In order to evaluate the effect on aquifer recharge due to the various land use changes, determinations were made of the magnitude of the potential changes in land use over a specified time period. In discussion with local planners and residents, conceivable developments which might take place over a 50 year period were estimated. In some cases, where no estimates could be made, the maximum possible development was assumed in order to provide an estimate of the maximum impact on the system. For instance, since the level of potential canal lining could not be determined, it was assumed that all of the major canals on a system were lined and seepage reduced to zero. Similarly determinations were made for various probable levels of sprinkler development up to a maximum of total conversion.

The calibration period May 1975 to July 1976 does not represent a "steady state" condition for the aquifer. Furthermore, the calibration achieved does not constitute a "perfect" fit at every node point. If the calibration period input is repeated or iterated in an attempt to duplicate the measured 1975-76 responses, small differences in simulated ground-water levels will occur with each iteration until a simulated steady state condition is reached. It is more realistic to evaluate the impact of changes in aquifer recharge over a long period of time compared to a steady state base year response than to a single year response such as the 1975-76 calibration period. Therefore, a simulated base year was determined by first combining the calibration input for the 52 timesteps from May 1, 1975 to May 1, 1976 into 13 four week periods. The management model was then run for four consecutive cycles, equivalent to four years of duplicate input, in order to reach a "steady state". Finally, another run was made using the 52 weekly timestep inputs starting with the calculated "steady state" head values. This run, called the "base year", generated simulated "well hydrographs" for six different nodes and groundwater "flow hydrographs" of the eastside and westside springs to be used for comparisons with simulated responses of the same nodes and flows due to projected recharge conditions.

Input programs incorporating the variations in recharge due to land use changes or other conditions were generated and run with the management model using the same procedure. This process may be approximately analogous in reality to the following: All the changes for the particular alternatives are made "instantaneously", immediately prior to May 1, 1975. The resulting recharge to the system occurs for five consecutive years--each year having equal recharge. On the fifth year, groundwater levels are recorded on a weekly basis for the six nodes and the groundwater outflows or spring-flows are tabulated.

The limitations to this process must be realized. Five consecutive years of identical input conditions will never occur. Changes resulting from the kinds of alternatives that were studied will never occur "instantaneously" but rather over a period of many years. If after full development of the changes, four or five consecutive years of similar input are experienced, a repeatable seasonal response should occur. Similarly, in the simulation procedure used, the aquifer should recover from the initial shock and produce a reasonable simulation by the fifth year. The process used in evaluating the effects of these alternatives provides a useful basis for comparison if these limtations are recognized.

The simulated "base year" responses for the selected six nodes are shown along with the 1975-76 calibration period responses on Figure 22. Small variations between the 1975-76 and base year simulated hydrographs are evident in the water table aquifer (nodes 06/18, 08/15, 12/11 and 18/06). Larger differences are indicated for nodes in the artesian aquifer (nodes 09/09 and 15/06). These differences indicate that the simulated 1975-76 response of the water table aquifer represents closely the "normal" seasonal response and that little change in storage occurs from year to year. In the confined or artesian aquifer small changes in outflow due to pumping or inaccurate estimates of natural outflows are reflected in large changes in piezometric head. Therefore, larger differences in simulated response after five repeated periods are expected. Figure 25 shows the generated aquifer water budget components for the base year or "steady state".

Responses of the aquifer were simulated only for specific load use changes and no combinations of alternatives were evaluated concurrently. For instance, artificial recharge of the aquifer would likely be undertaken to alleviate potential effects of conversion to sprinkler irrigation. Estimates of the combined effects could be made by examining the responses of individual alternatives but the changes in water levels and spring flows will not be exactly additive. The model should be run with the combined inputs to accurately predict the combined response.

Simulated Land Use and Management Changes

Canal Lining

All seepage factors for all major canals were set to zero simulating the effective sealing of all canals in the study area. Diversions to most service areas to compensate for reduced seepage were cut by 15%. In District 45 service areas, where seepage rates are somewhat higher, diversions were cut by 25%. Service areas in District 45 are numbers 3, 6, 7, 8, 9, and 18 (Figure 8 and Table 1).

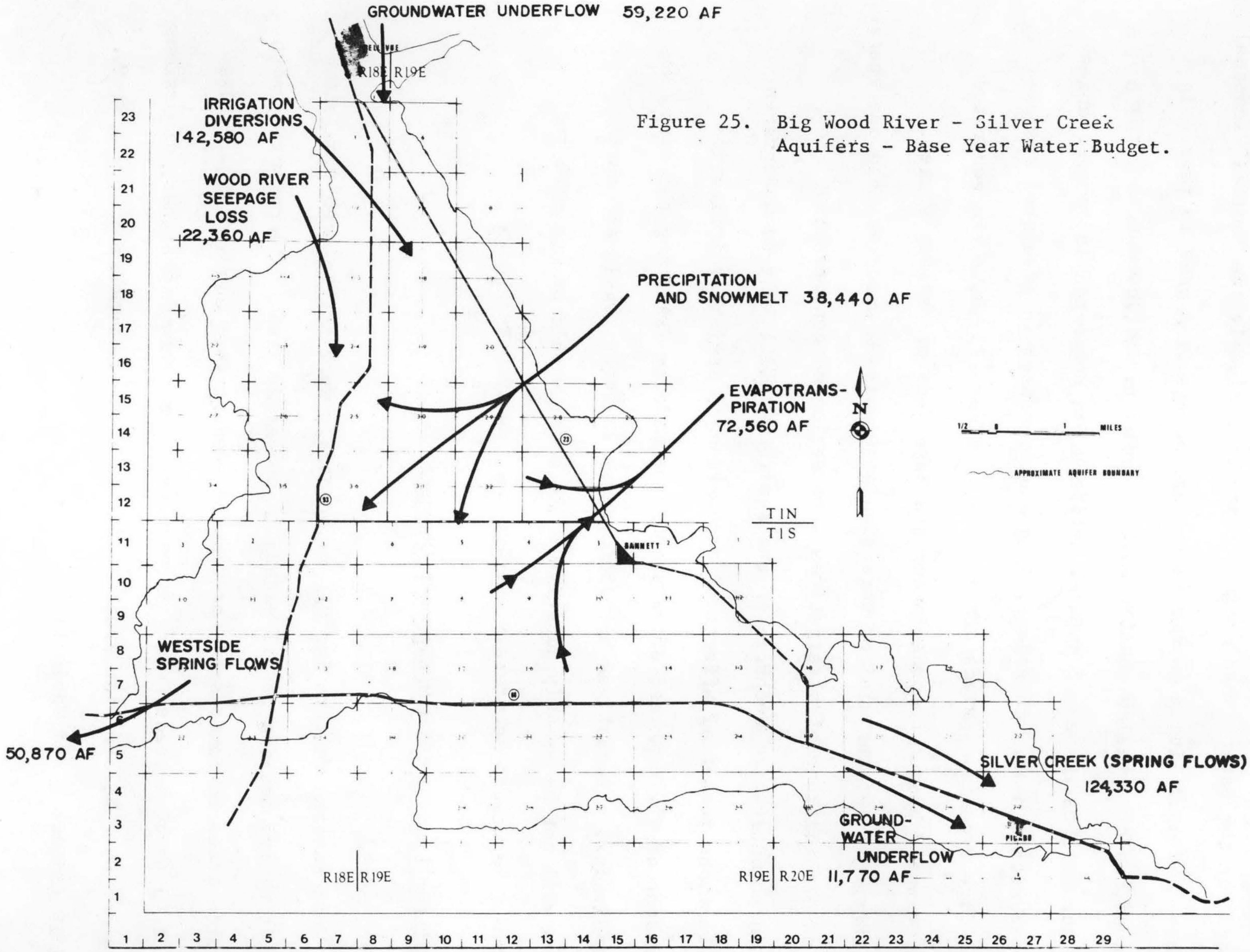


Figure 25. Big Wood River - Silver Creek Aquifers - Base Year Water Budget.

Figures 26 and 27 show the simulated effect on groundwater levels and spring flows due to canal lining compared with the base year. Minimal effect is indicated on the groundwater levels for the water table aquifer. However, in the artesian aquifer at nodes 09/09 and 15/06, a decrease of up to 10 feet in piezometric head could occur. Eastside spring flows would be decreased slightly; however, westside spring flows are predicted to increase over base year simulated flows.

Artificial Recharge

An 800 acre site located in the SW¼ of Sec. 20 and in all of Sec. 29, T1N, R19E, was chosen as a potential floodwater recharge site (Nodes 11/16, 11/15, 11/14, 12/15, 12/14). Based on Idaho Department of Water Resources studies of available flood flows, an application of 1200 cfs to this site for a period of five consecutive weeks corresponding approximately to the period June 1 - July 4 was simulated. The total amount of water recharged was 83,000 acre-feet. An average sustained seepage rate of 3.0 feet/day was assumed for the recharge ponds. This rate is somewhat below measured seepage losses of canals in that area.

Since recharge of this nature could only be accomplished under present water-rights laws by floodwaters during high runoff years, this alternative was not run (as the others were) to reach a "steady state" condition. Rather, the May 1, 1975 water table was used as a starting point and a one-year simulation made. Figures 28 and 29 show the effects of artificial recharge.

Marked increases of up to 50 feet in water levels in the water table aquifer are evident during the recharge period, however recessions are rapid indicating only small amounts of annual carryover storage would occur.

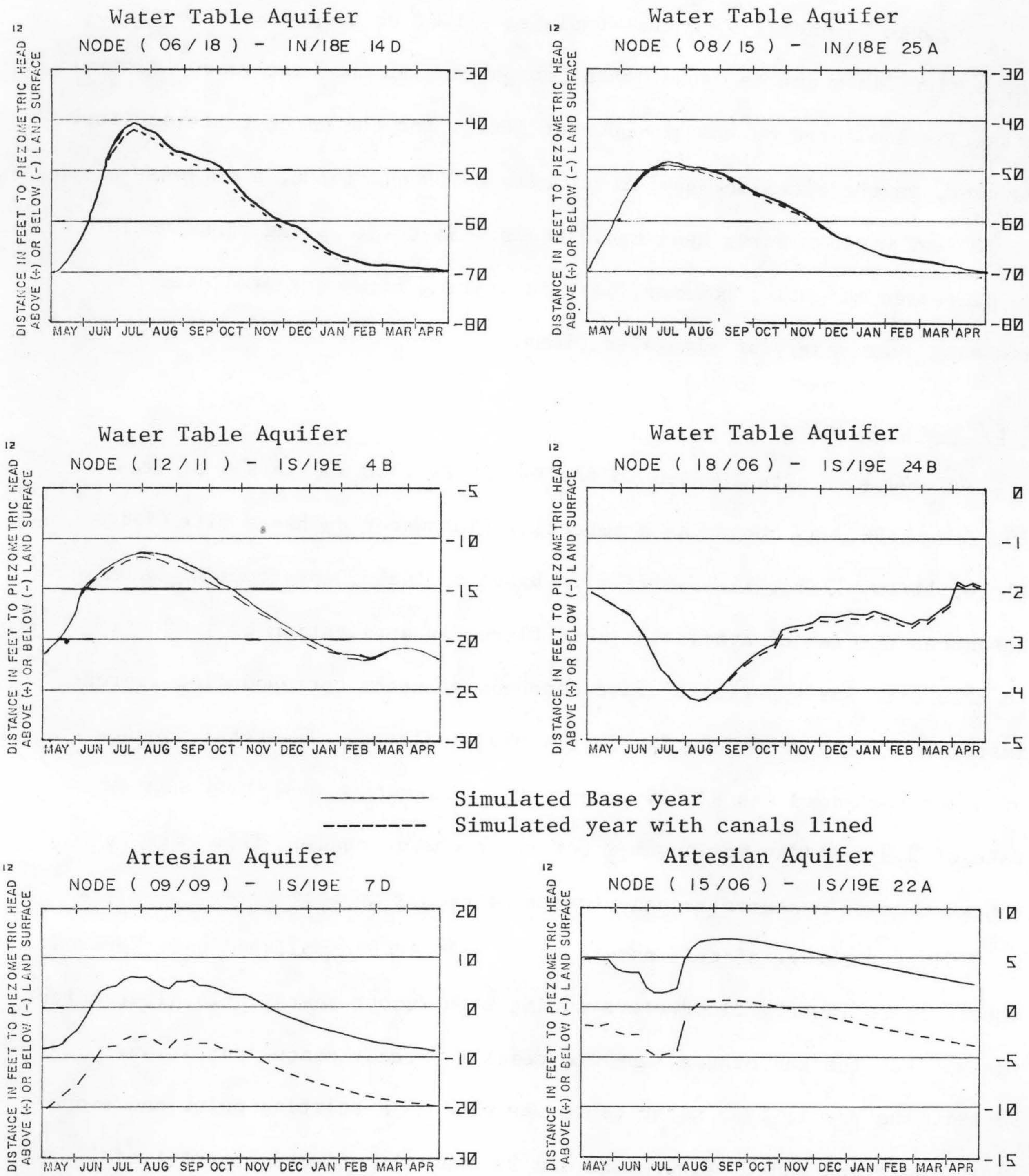
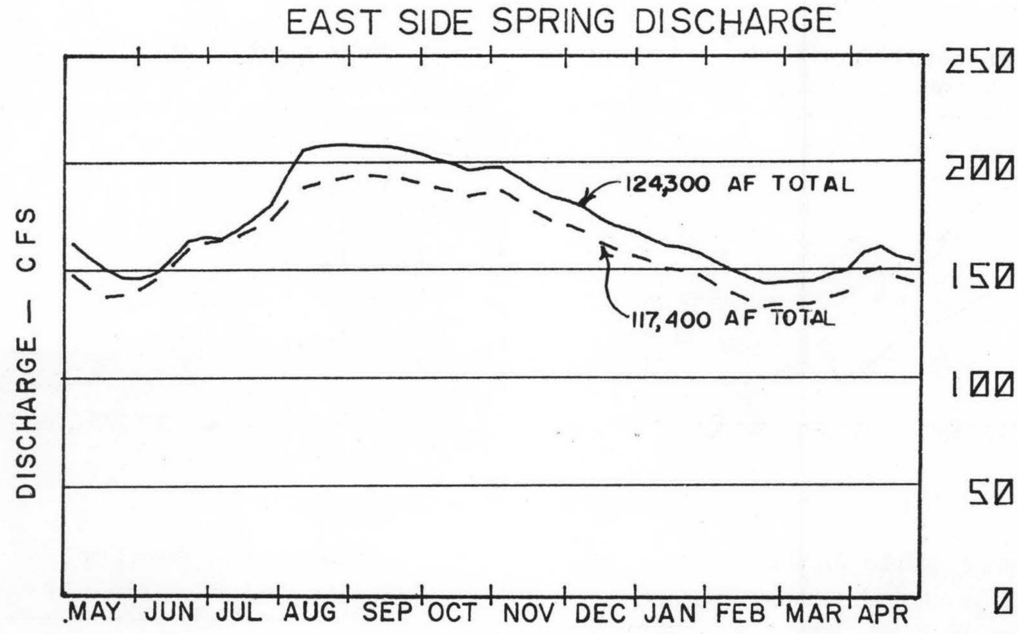


Figure 26. Effects of canal lining on groundwater levels and artesian pressures in the Big Wood River-Silver Creek area.



———————— Simulated base year
------------ Simulated year with canal lined

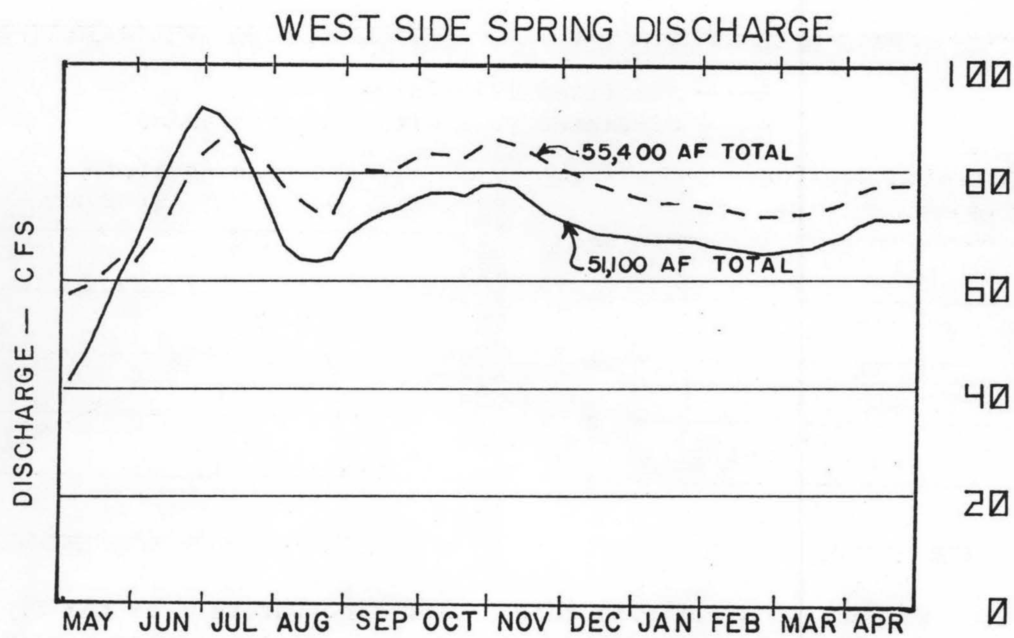


Figure 27. Effects of canal lining on springflows in the Big Wood River-Silver Creek area.

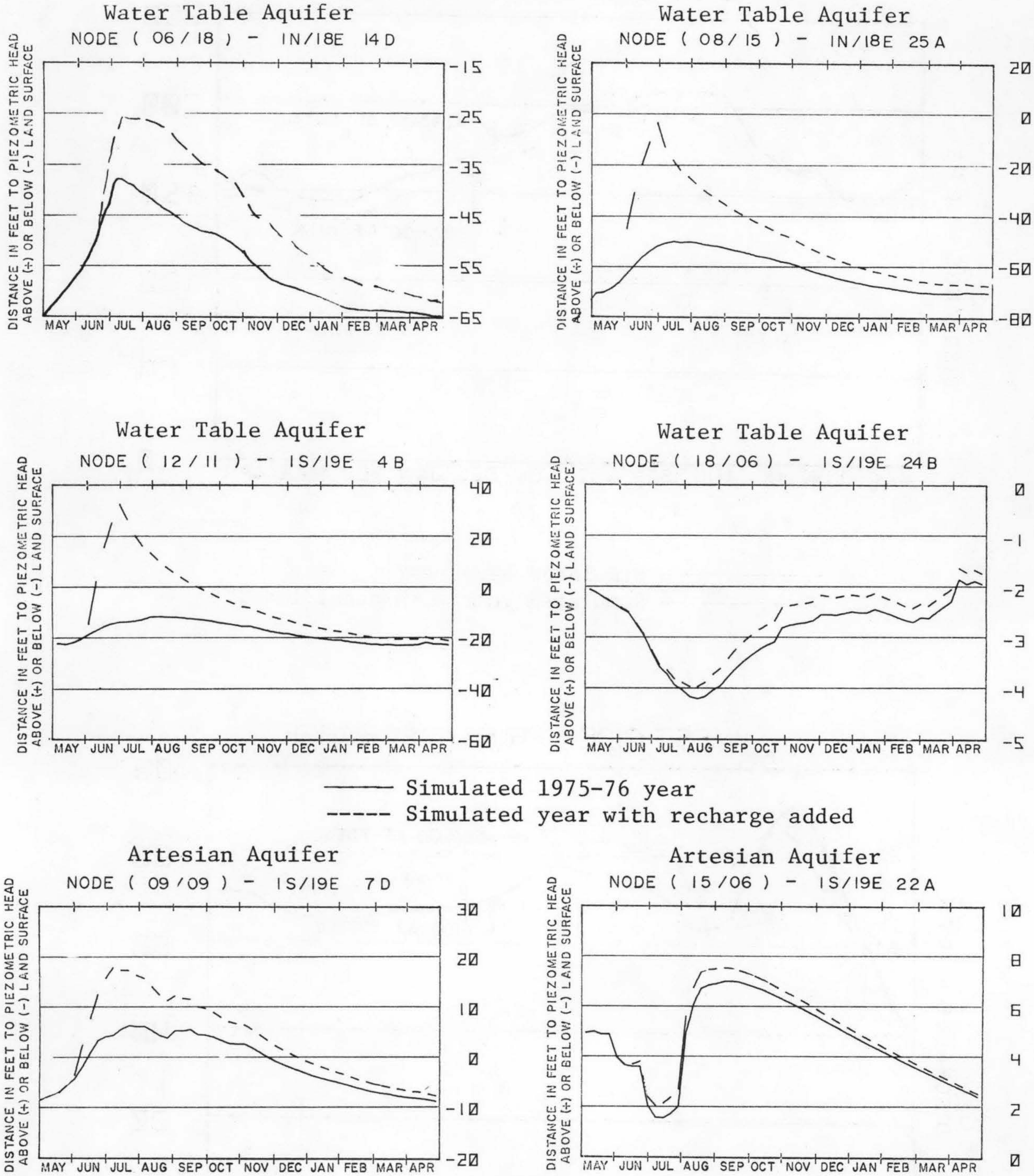


Figure 28. Effects of artificial recharge of floodwaters from the Big Wood River on groundwater levels and artesian pressures in the Big Wood-Silver Creek area.

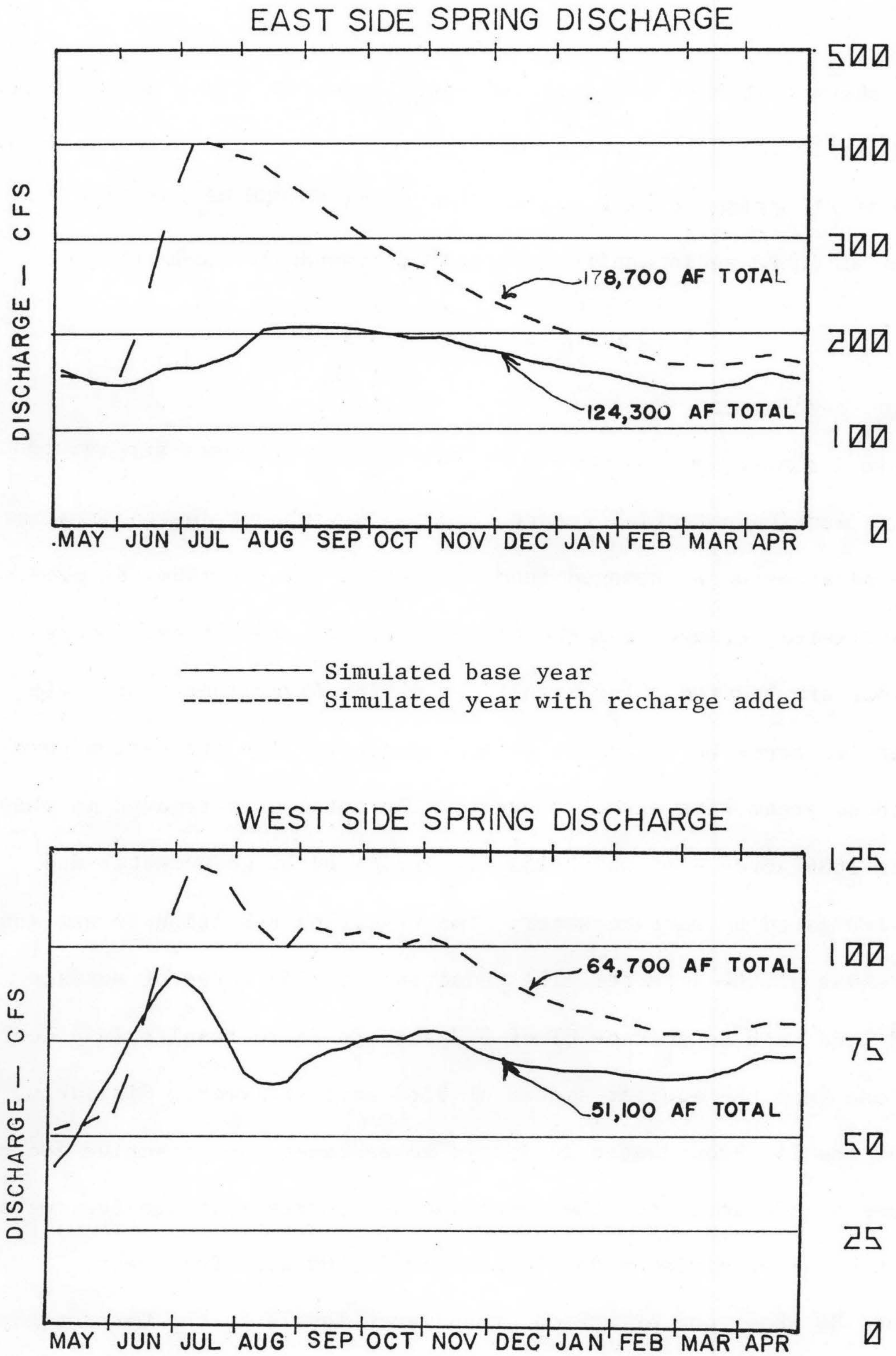


Figure 29. Effects of artificial recharge of flood waters from the Big Wood River on springflows in the Big Wood-Silver Creek area.

Figure 29 shows that both eastside and westside spring flows would increase with very little lag time between recharge and response. An annual increase of 68,000 af of spring outflow due to recharging 83,000 af was simulated indicating an increase in aquifer storage or groundwater underflow of 15,000 af.

Subdivision Development

Figure 2 showing all areas having existing or proposed subdivisions, was used to develop potential future changes in recharge due to urbanization. These areas were "removed from irrigation" in the model by eliminating the irrigated acreage from the nodes where the present and future subdivisions are located. The magnitudes of the diversions to the affected service areas were reduced proportionately. Any irrigation pumps serving these areas were also "removed". The total area removed in this manner was 1636 acres - of which 153 are irrigated by groundwater and 1483 are irrigated by surface water. The resulting reduction in net annual diversions was 31,000 acre-ft. The reduction of 1483 acres of surface irrigated land with an average ET of 2.2 acre ft./acre results in a decrease in water use from the aquifer system of 3263 acre ft./year. Similarly, removal of the 153 groundwater irrigated acres causes an effective decrease in wateruse of 334 acre ft. The resulting net decrease in aquifer recharge due to potential subdivision development is 27,400 acre feet/year.

Figure 30 shows the effect on groundwater levels in the water table and artesian aquifers. Water levels nearest the major subdivision areas, nodes 06/18, 08/15 and 12/11, show decreases in maximum elevations of 6 to 8 feet whereas the more southerly areas, as indicated by node 18/06 would experience little change. The piezometric heads in the artesian aquifer, however, would decrease 6 to 12 feet.

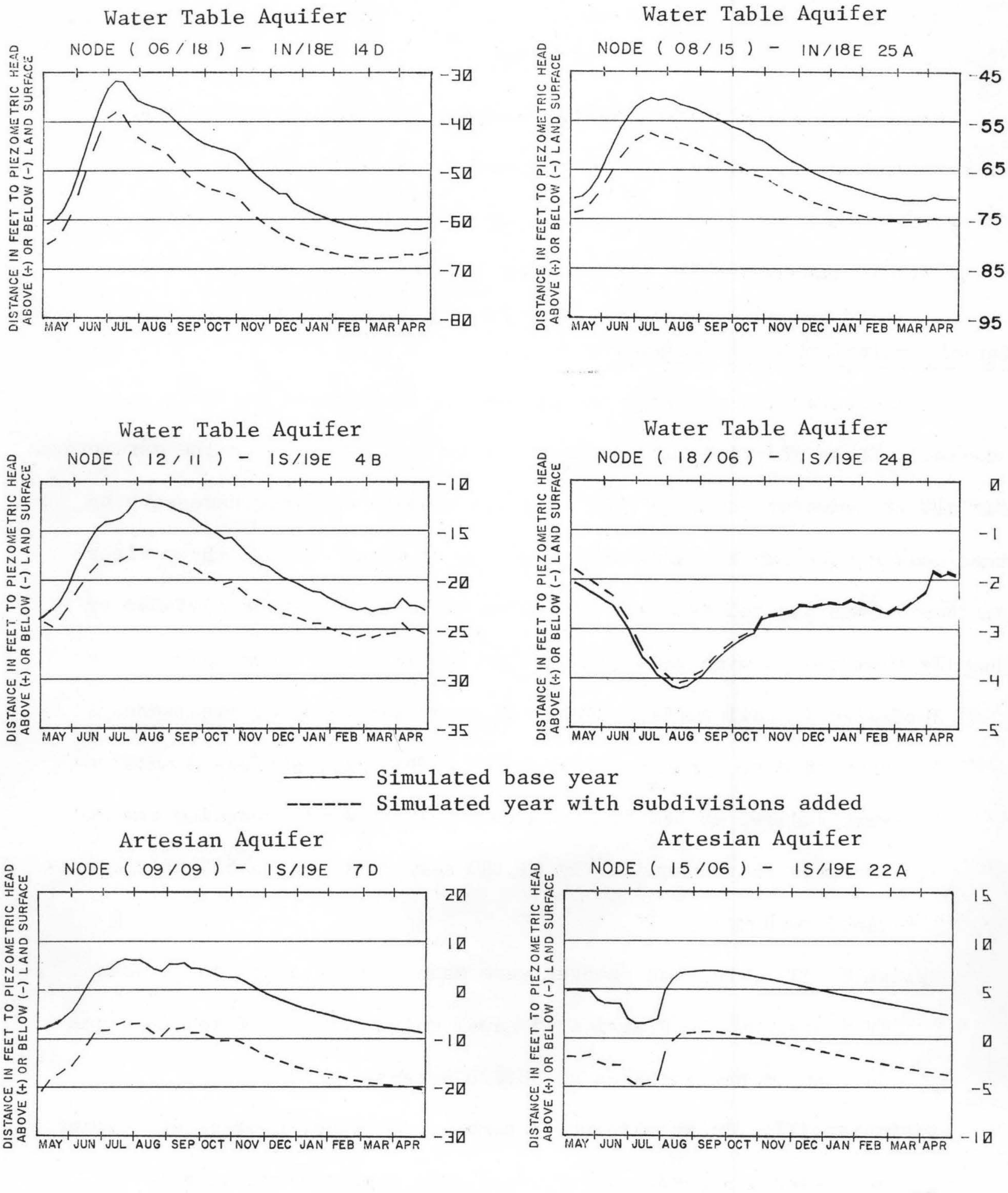


Figure 30. Effects of subdivision development on groundwater levels and artesian pressures in the Big Wood River-Silver Creek area.

The simulated hydrograph showing changes in eastside and westside spring flows due to subdivision development is shown in Figure 31. The eastside springs (Silver Creek) would decrease an average of 25 cfs or 18,600 af annually while the westside springs would increase slightly.

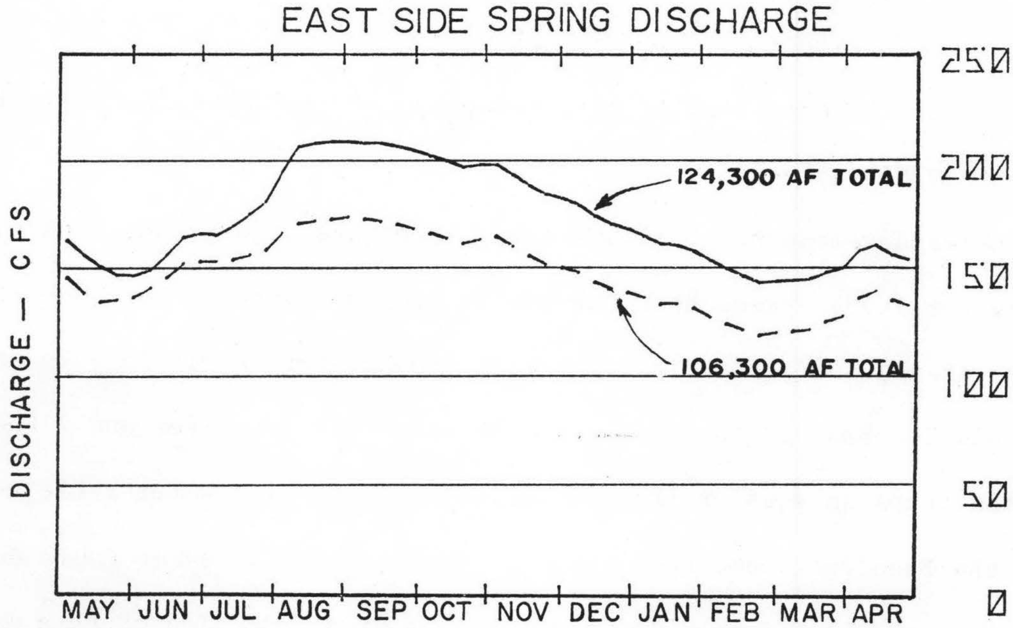
Sprinkler Irrigation Development

Three variations of sprinkler irrigation development patterns were studied. These affected only surface-irrigated areas - since the assumption for all groundwater areas is that only the amounts of water necessary to meet consumptive use are withdrawn from the aquifer. In all three alternatives it was assumed that all sprinkler conversion was accomplished by pumping from canals with subsequent reduction in canal diversions.

Sprinkler I: All surface irrigated areas in the study area were converted to sprinkler irrigation. The total surface diversions were reduced by 56% from the base year, thereby reducing the net recharge to the aquifer by 63,180 acre-feet, or to 55% of the original recharge.

Sprinkler II: The same changes were made for the approximate area irrigated by the District 45 canal only. This resulted in a reduction in net recharge of 38,830 acre-ft.

Sprinkler III: In an attempt to simulate a random pattern of scattered sprinkler irrigation development, the same changes were made only for nodes whose indices when added together resulted in an odd number. This produced a "checkerboard" pattern of projected sprinkler development. Diversions to the service areas were reduced by 28% -- assuming that each service area would include an equal amount of sprinkler and non-sprinkler land. The simulation



———— Simulated base year
------- Simulated year with subdivisions added

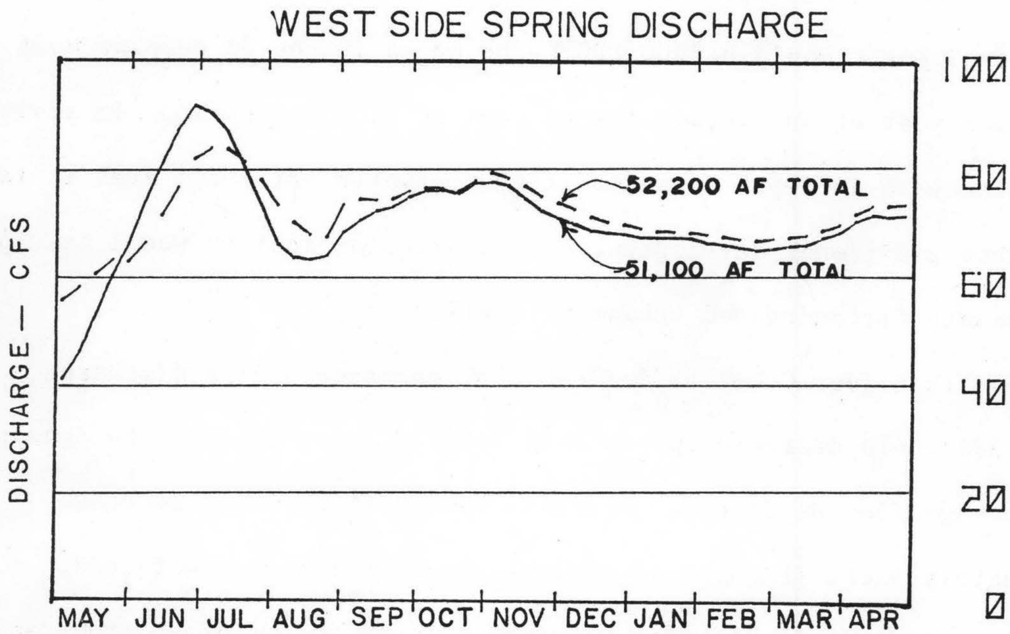


Figure 31. Effects of subdivisions development on springflows in the Big Wood River-Silver Creek area.

of this alternative led to a reduction of net input to the aquifer of 55,650 acre-ft.

Sprinkler development utilizing canal water has significant effects on groundwater levels throughout the entire aquifer system. For complete conversion of all surface irrigated areas, groundwater levels in July and August would decrease 12 to 16 feet in the water table aquifer and 7 to 15 feet in the artesian aquifer (Figure 32). In the shallow water table aquifer south of the Baseline Road, node (18,06), (Figure 32) the water table decrease would be less than 1.0 foot. The implications of a reduction of this magnitude are most pronounced in the change in energy requirements for groundwater pumping. For the 1975 season 18,690 acre-ft. were pumped from the aquifer or utilized from artesian wells. Assuming an average increase in pumping depth of 15 feet due to sprinkler development, the increase in energy requirement would be 500,000 kw-hr or an increased pumping cost of $10,000 per year at an average energy cost of $.02 per kw-hr. In addition, with an increase in depth to water in the subwater irrigated area it is likely that additional development of the artesian aquifer would take place to compensate for decreased subwater levels.

Flows in Silver Creek as indicated by eastside spring discharge (Figure 33) would decrease approximately 36,700 acre-ft. for the season or an average flow of 51 cfs. Westside spring flows would decrease approximately 9 cfs if complete sprinkler conversion were effected.

Conversion of all District 45 service areas to sprinkler from canals would result in increases in depths to water of 9 to 10 feet in the water table aquifer beneath and adjacent to the service area but very small changes in the southern part of the area where the water table aquifer is shallower. Figure 34 shows the comparison of simulated well hydrographs

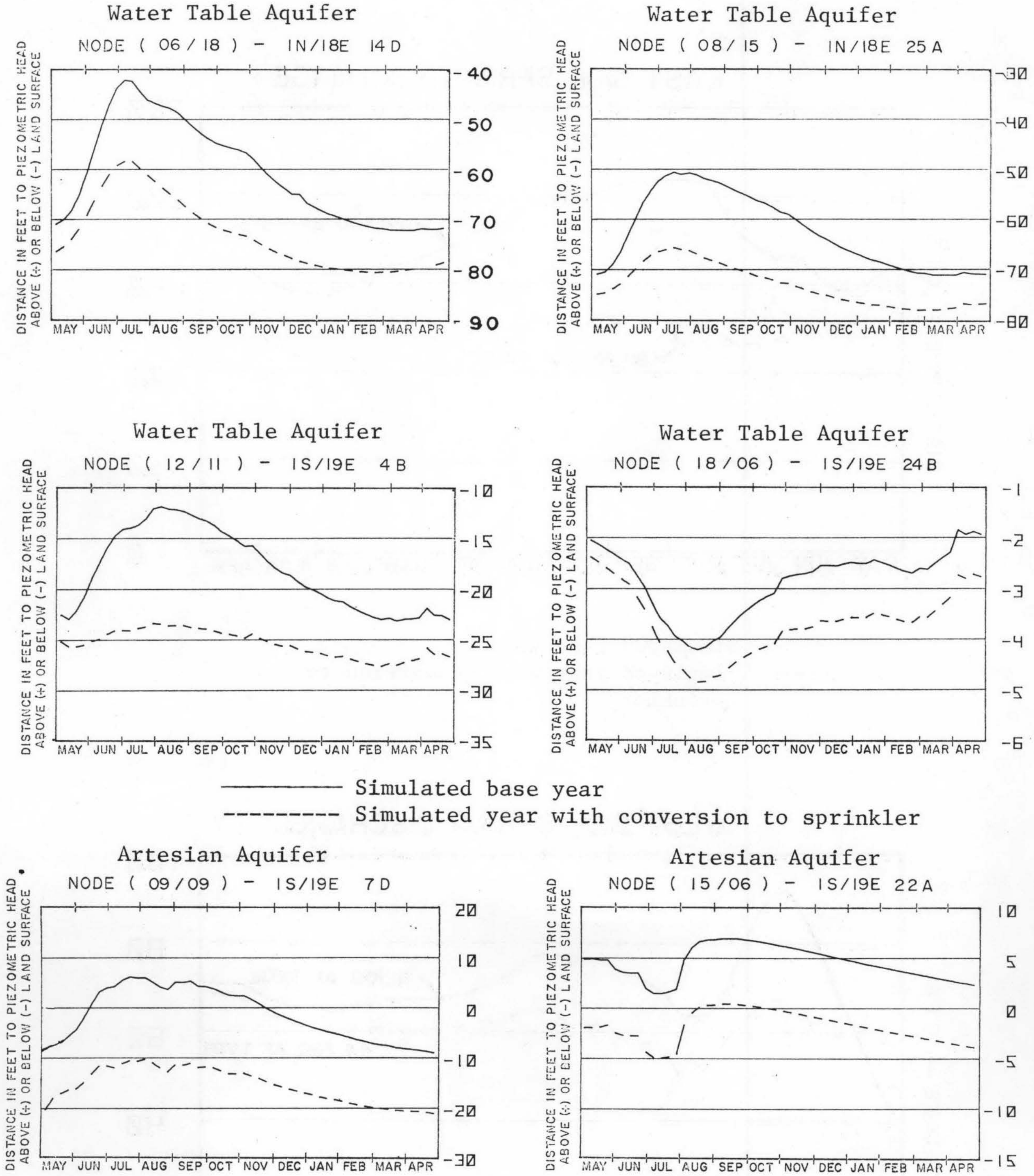
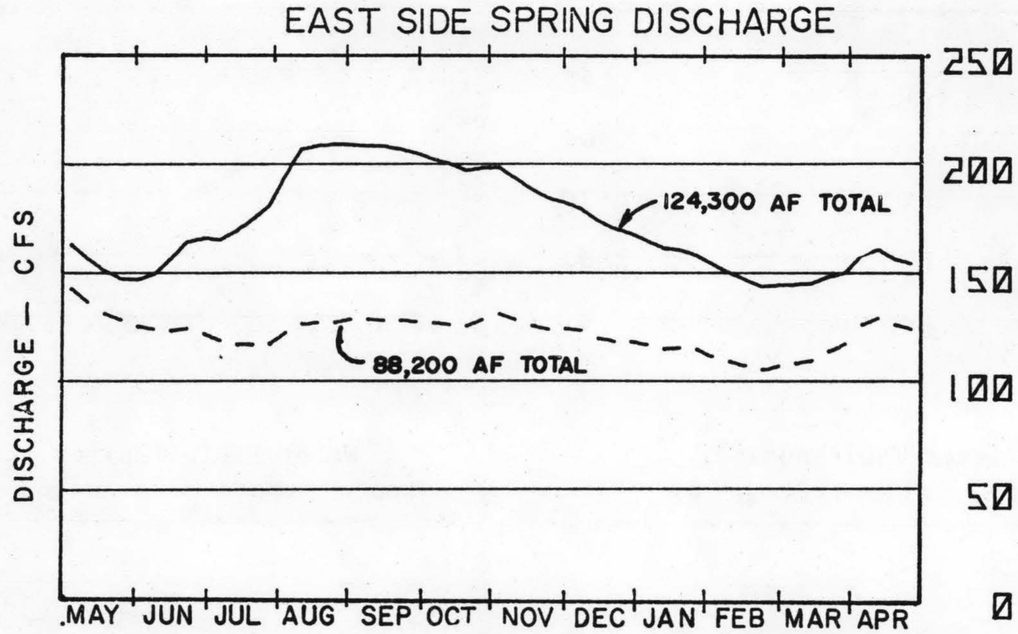


Figure 32. Effects of complete conversion from gravity to sprinkler irrigation on groundwater levels and artesian flows in the Big Wood River-Silver Creek area.



——— Simulated base year
------- Simulated year with conversion to sprinkler

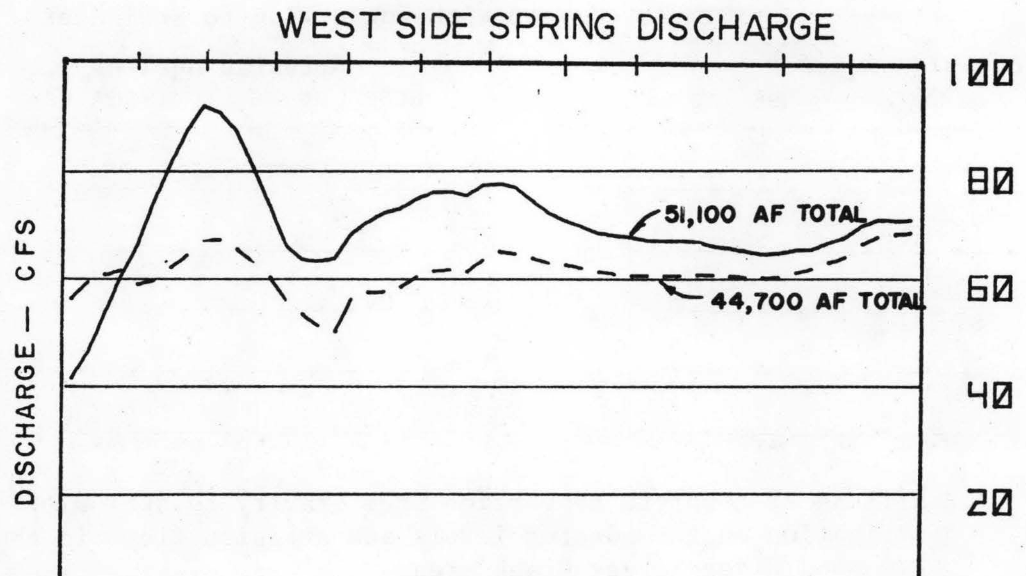


Figure 33. Effects of complete conversion from gravity to sprinkler irrigation on springflows in the Big Wood River-Silver Creek area.

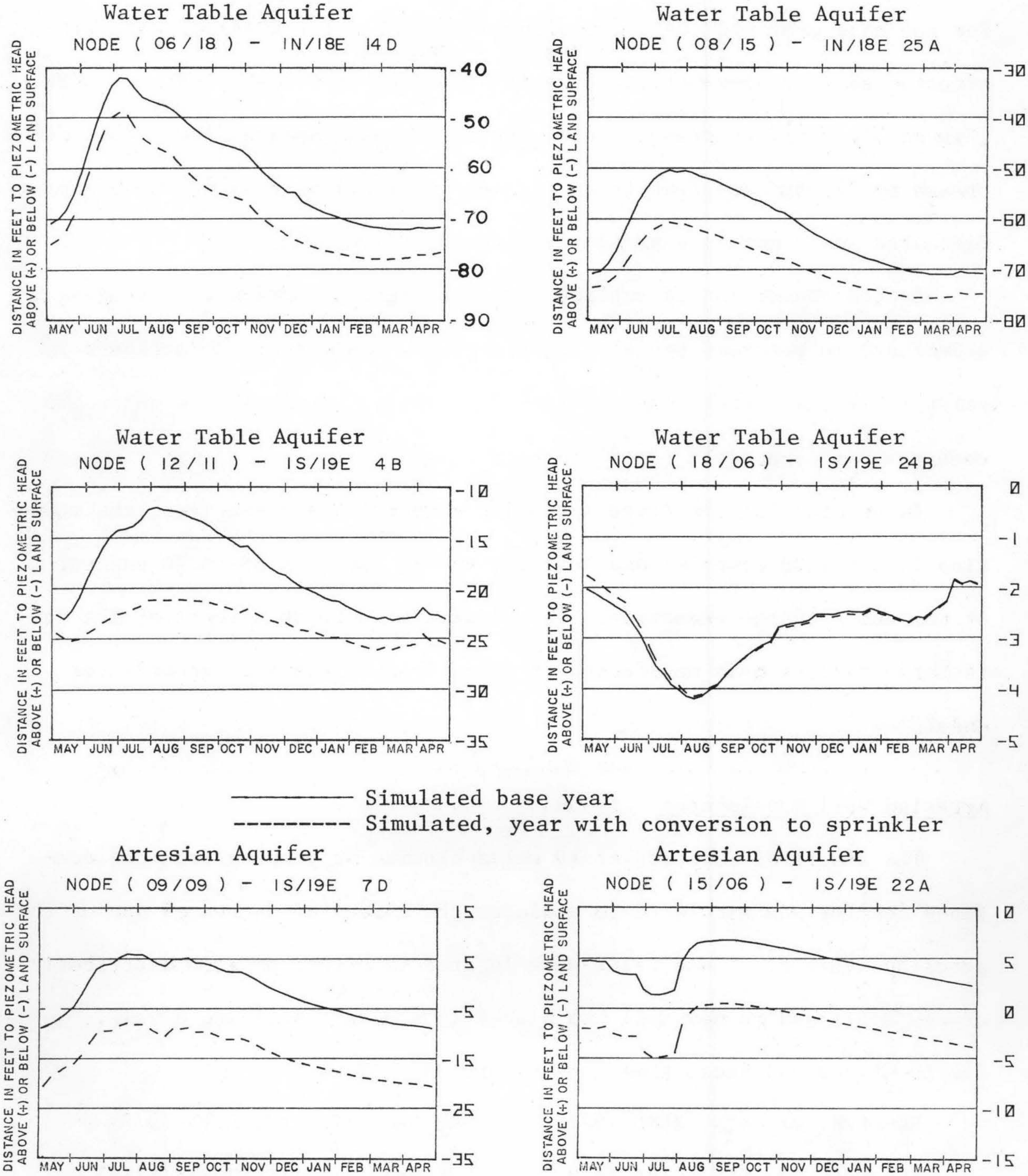


Figure 34. Effects of complete conversion from gravity to sprinkler irrigation in the District 45 Irrigation District on groundwater levels and artesian pressures in the Big Wood River-Silver Creek area.

for the base year and the conversion to sprinkler for District 45. The artesian aquifer piezometric heads as indicated by nodes 09/09 and 15/06 (Figure 34) would decrease 6 to 13 feet. Eastside spring flows would decrease by 27,000 acre feet or an average of 37 cfs whereas westside spring discharge would not be appreciably affected (Figure 35).

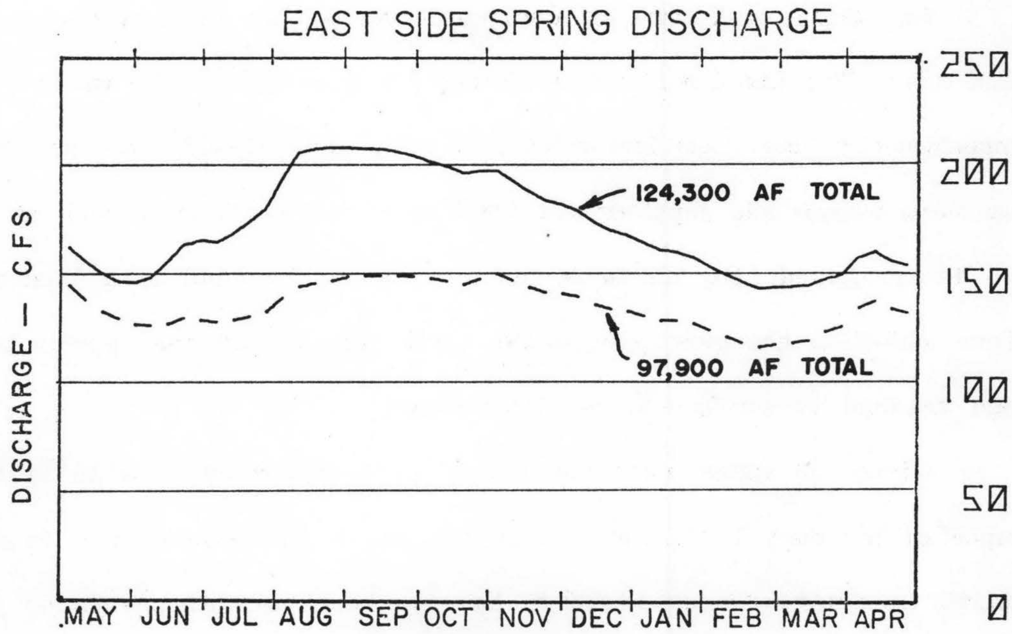
Random conversion of surface irrigated land to sprinkler resulting in a decrease in net recharge of 55,650 acre-ft. would produce decreases in water table and spring flows similar to complete conversion in which the recharge was reduced by 63,180 acre-ft.

In general for the three sprinkler conversion alternatives, the reduction in combined eastside and westside spring flows is 68 to 70 percent of the net recharge reduction. The remaining 28 to 30 percent of the net recharge reduction is manifested in reductions of eastside groundwater underflow.

Artesian Well Development

The simulated addition of 10 wells flowing or pumping from the confined aquifer was simulated to evaluate the effect of increased use of the artesian aquifer. These wells were located to effect an even distribution of new wells and no new well was placed in a node containing a well. The locations and nodes thus chosen were as follows:

NW¼ Sec. 35, T1N, R18E (5/13)	SE¼ Sec. 19, T1S, R19E (9/5)
SW¼ Sec. 12, T1S, R18E (6/9)	NW¼ Sec. 21, T1S, R19E (12/6)
SE¼ Sec. 1, T1S, R18E (7/11)	NE¼ Sec. 27, T1S, R19E (15/4)
NE¼ Sec. 7, T1S, R19E (9/10)	NW¼ Sec. 24, T1S, R19E (18/6)
NE¼ Sec. 18, T1S, R19E (8/8)	NW¼ Sec. 30, T1S, R20E (20/4)



——————— Simulated base year
----------- Simulated year with conversion to sprinkler

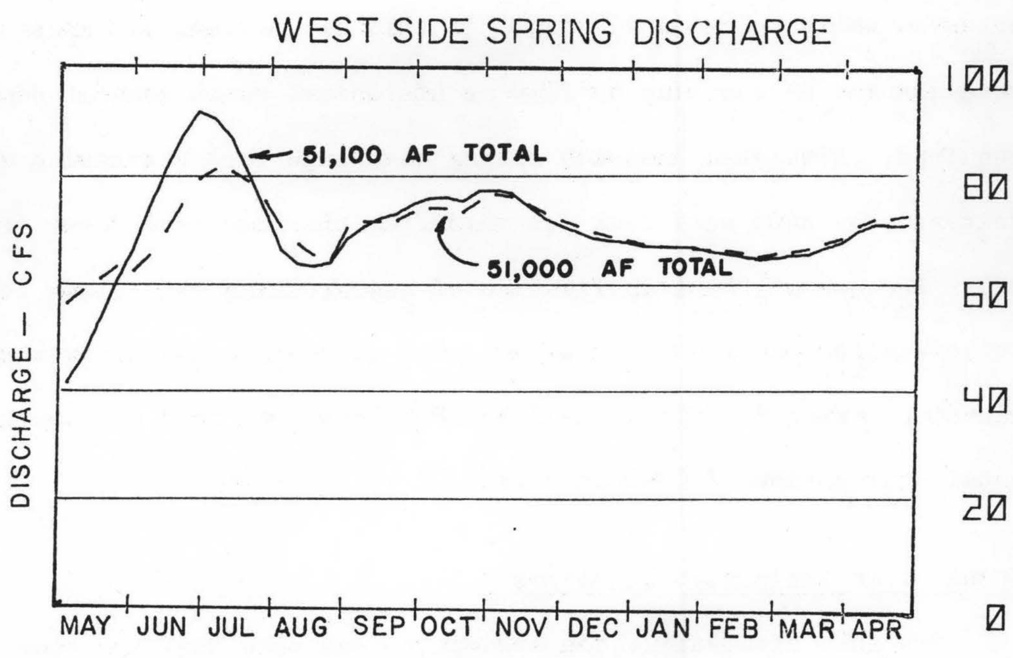


Figure 35. Effects of complete conversion from gravity to sprinkler irrigation in the District 45 Irrigation District on springflows in the Big Wood River-Silver Creek area.

The withdrawal rate of each well was set at 30 acre-ft. per week, or 2.6 cfs. The simulated wells flowed for a period of 15 weeks (from approximately June 7 to September 19, timesteps 32-46), so the total amount withdrawn from the aquifer was 4500 acre feet. No new land was assumed to be irrigated from these artesian flows. The 4500 acre feet was therefore added to the overlying water table aquifer at the appropriate locations and treated as surface water diversions.

Figure 36 shows that the effect of development of wells in the artesian aquifer has very little effect on the water table aquifer. In fact, the depth to water at node 18/06 in the southern part of the water table aquifer increased slightly because of the addition of flows from the artesian aquifer.

Piezometric heads in the artesian aquifer decreased 9 to 11 feet over most of the season. A decrease of this magnitude would cause some existing artesian wells to cease flowing. In this simulation, all existing wells were assumed to continue to flow at historical rates even if pumping were required. Simulated eastside spring discharge for the artesian development decreases by 6400 acre feet per year from the base year flows (Figure 37). Because of the reapplication of new artesian well flows to the water table aquifer in areas with water table gradients toward the west, simulated westside spring flows increased by 4800 acre feet or a net decrease in total spring flow of 1600 acre feet.

Groundwater Irrigation Development

For this simulation, the assumption was made that any node with more than 20 acres of non-irrigated land would be brought into cultivation and receive 150% of the consumptive use requirement for that land from

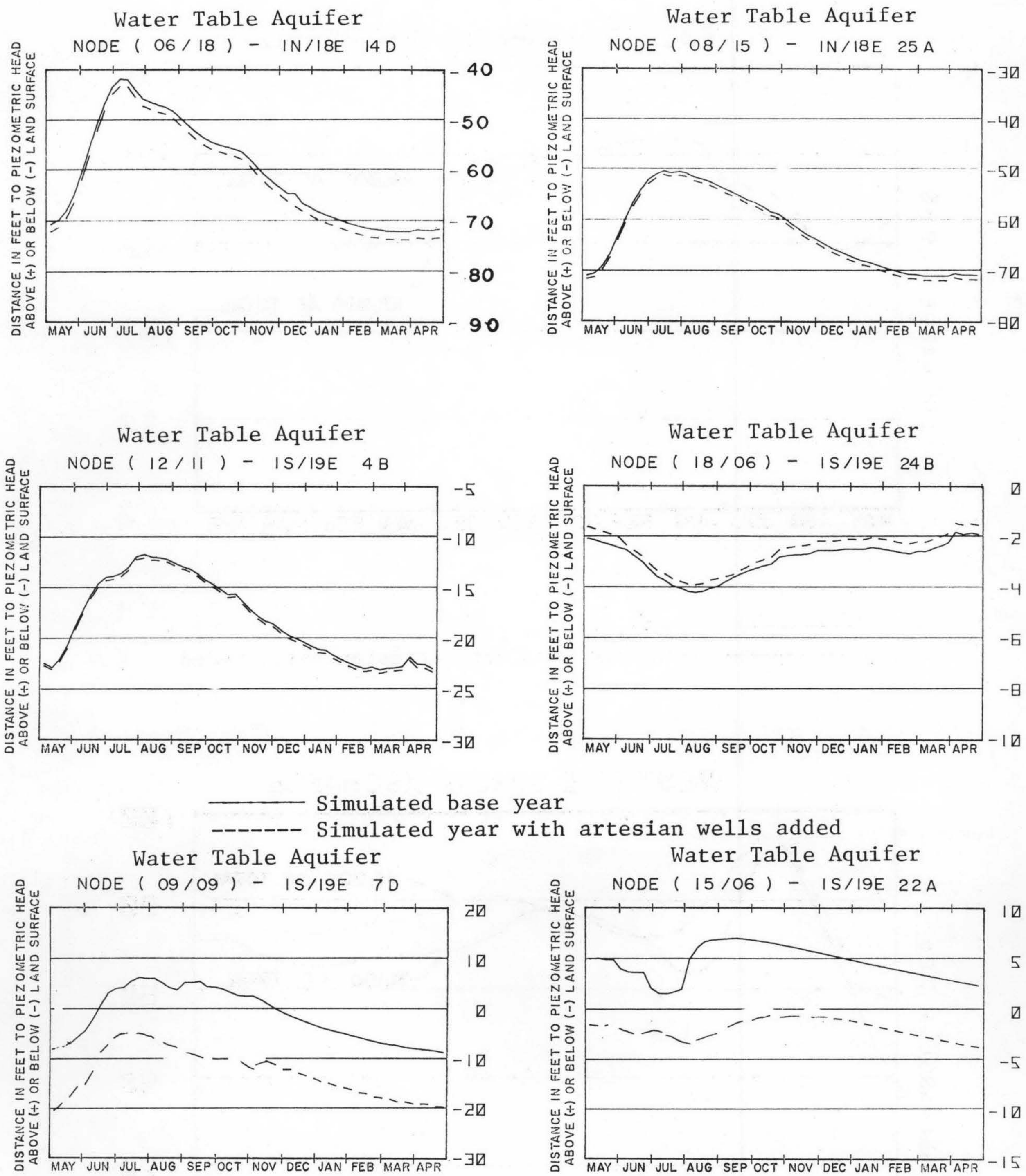


Figure 36. Effects of additional artesian wells on groundwater levels and artesian pressures in the Big Wood River-Silver Creek area.

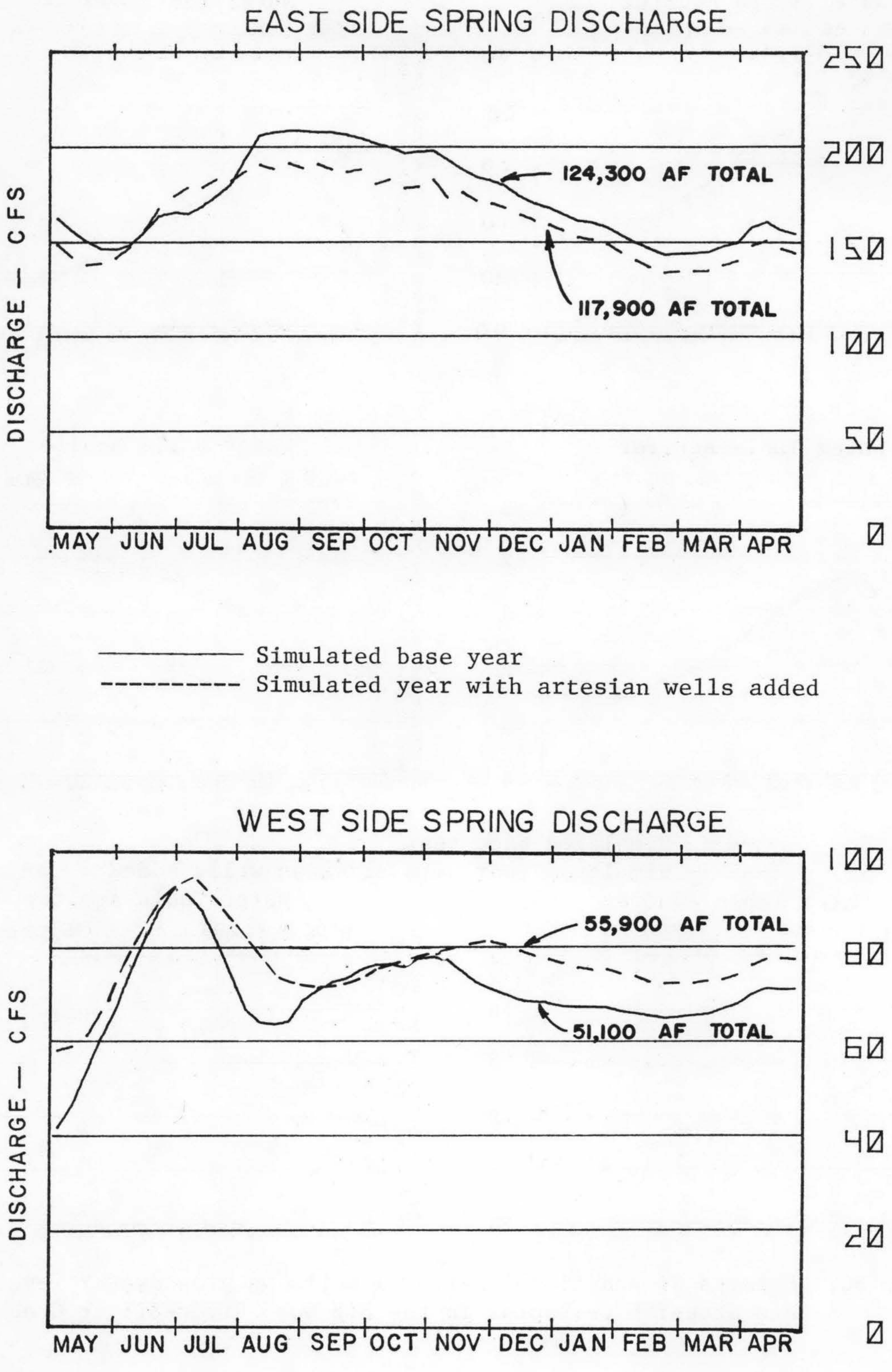


Figure 37. Effects of additional artesian wells on springflows in the Big Wood River-Silver Creek area.

groundwater. It was also assumed that no pump would be added to a node which contained an existing pump that could successfully satisfy the irrigation requirements of the additional land. The locations of nodes which met these criteria for additional groundwater irrigation are those shown in Figure 38.

The original assumption made in construction of the model was that any water pumped from nodes underlain by the confined aquifer has its source in that system. Therefore, the amounts needed to satisfy consumptive use were withdrawn from the confined aquifer at nodes where that situation existed.

The total amount of land irrigated by surface water and groundwater in this simulation was 36,002 acres which represents an increase in groundwater irrigated area of 8,062 acres or 48%. The total consumptive use was 90,878 acre-ft. or an increase of 18,320 acre-ft. over the base year conditions. The resulting change in net recharge to the water-table aquifer was a decrease of 5,670 acre-ft; a total of 33,984 additional acre-ft. was pumped from the artesian aquifer compared with base year conditions.

This assumption represents the maximum groundwater development of new lands that might be imposed on the aquifer system. Other alternatives such as conversion from canal source to groundwater on presently irrigated lands could have a more severe impact since recharge from canal diversion would be decreased and withdrawal from wells increased.

Figure 39 shows the simulated impact on the indicator hydrographs due to groundwater irrigation development. Minimal impact on the water table aquifer is evident with declines of less than 5 feet in the northern areas. In the shallow water table aquifer overlaying the confined aquifer (node 18/6) an increase in water table elevation should occur. This is because a large amount of new irrigated land overlies the confined aquifer and the excess water pumped from the confined aquifer is applied to the water table aquifer.

The piezometric head in the artesian or confined aquifer would be significantly affected by this development, especially during the high use periods of July and August. Decreases of 25 feet (node 09/09) and 17 feet (node 15/06) could occur in the artesian aquifer due to development of new lands from groundwater as indicated in Figure 38.

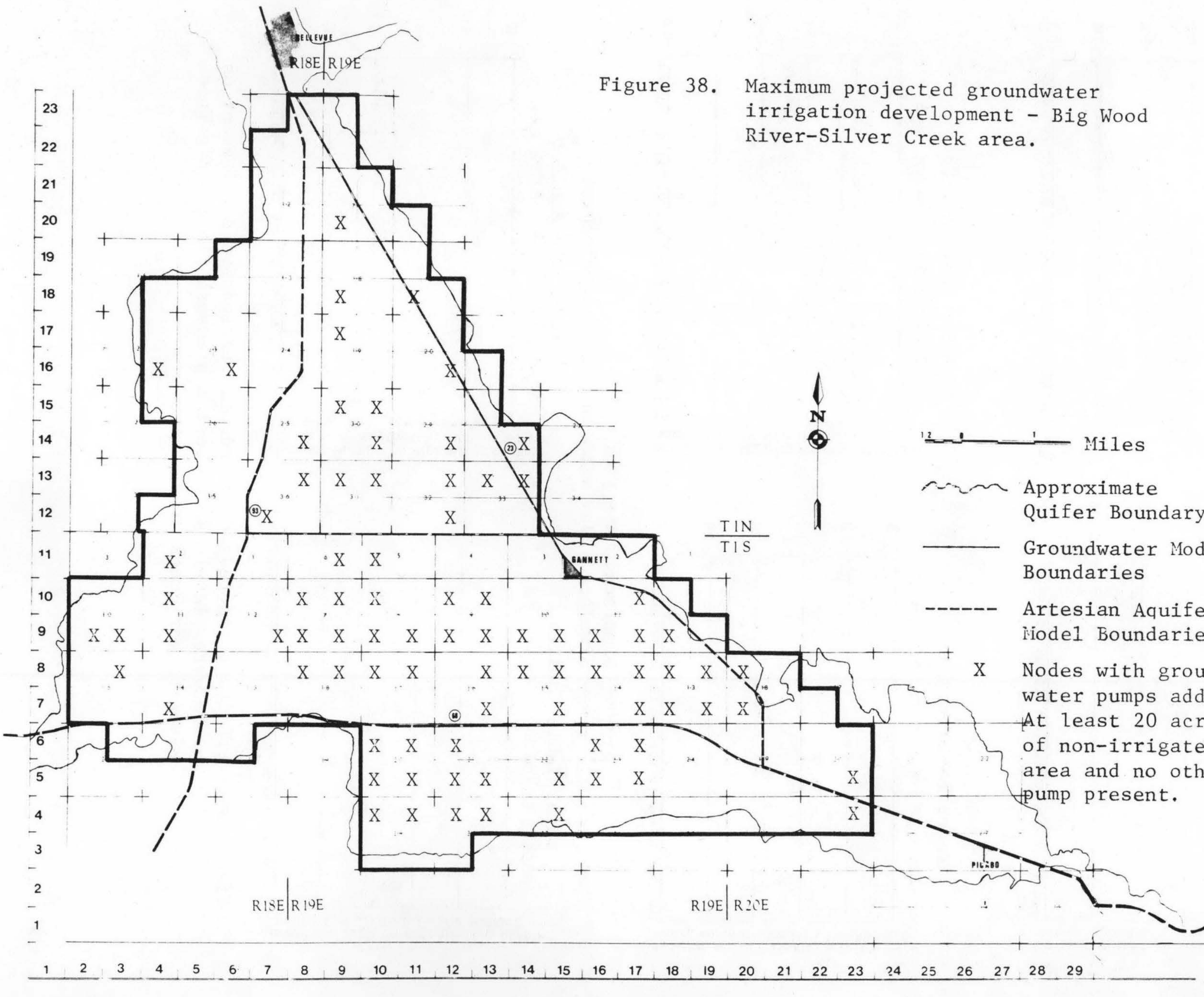
Flows from the eastside springs are projected to decrease by 21,500 acre-ft. annually from the base year with a maximum decrease in flow of 50 to 60 cfs in the heavy use months of July and August (Figure 40). Westside springs will exhibit substantial decreases in discharge of 25 to 30 cfs during the summer months but small increases after the irrigation season.

Drought Simulation

The drought conditions of 1977 provided a unique opportunity to test the ability of the model to predict the response of the aquifer to extreme hydrologic conditions. Two separate but similar runs, called drought study I and II were made. The period simulated was from July 1, 1976 to November 15, 1977 for both runs. Data representing inputs from July 1, 1976 to the end of the 1976 irrigation season were collected by the Idaho Water Resources Research Institute as part of the original data collection program. Estimates of inputs for the remainder of the simulation period were determined as follows:

Diversions: The starting dates and estimates of diversion in the early 1977 irrigation season were obtained by personal interviews with farmers.

Figure 38. Maximum projected groundwater irrigation development - Big Wood River-Silver Creek area.



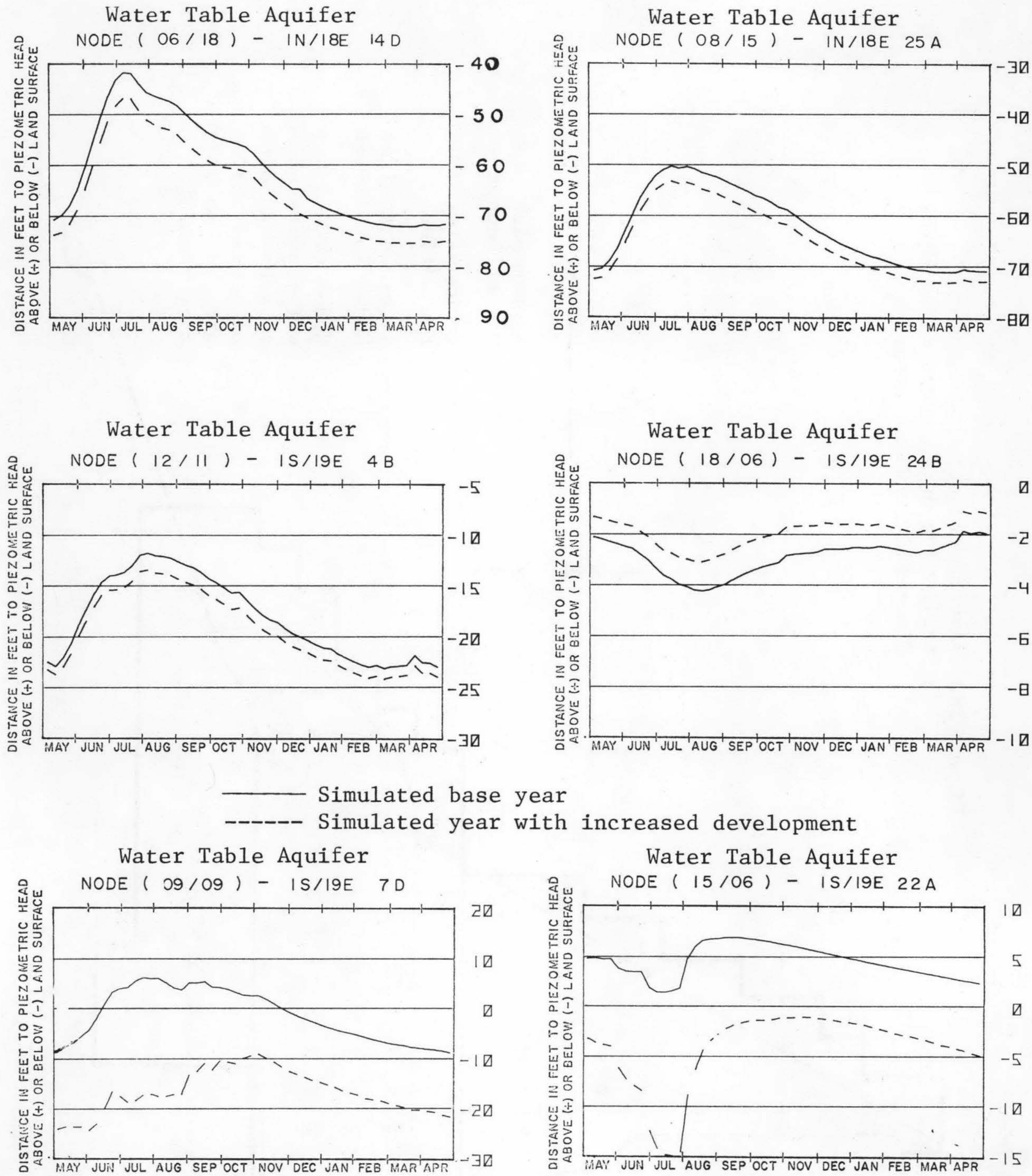
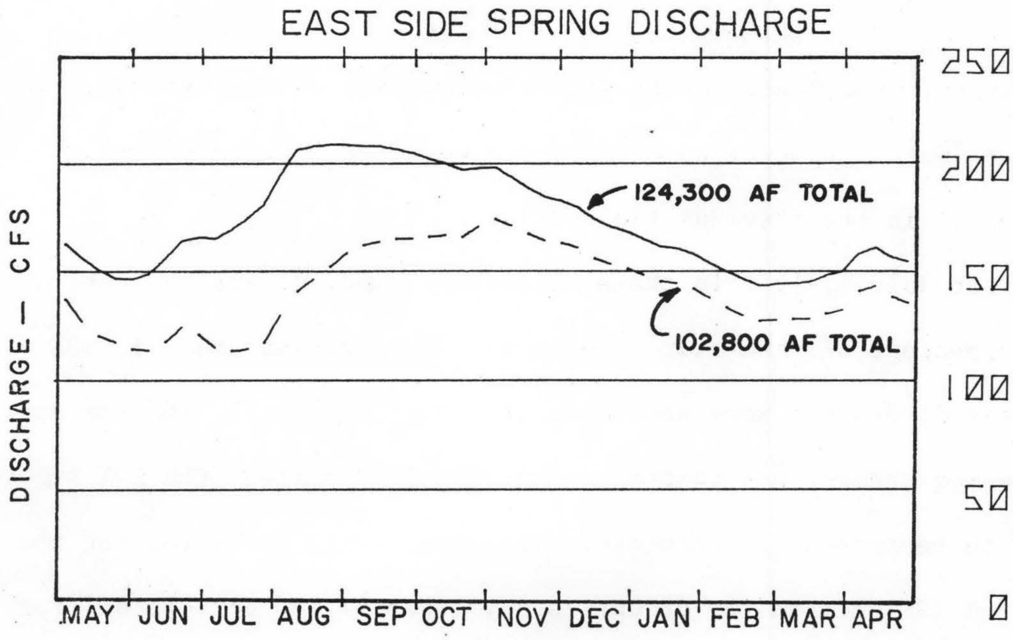


Figure 39. Effects of increased groundwater irrigation development on groundwater levels and artesian pressures in the Big Wood River-Silver Creek area.



———————— Simulated base year
-------- Simulated year with increased development

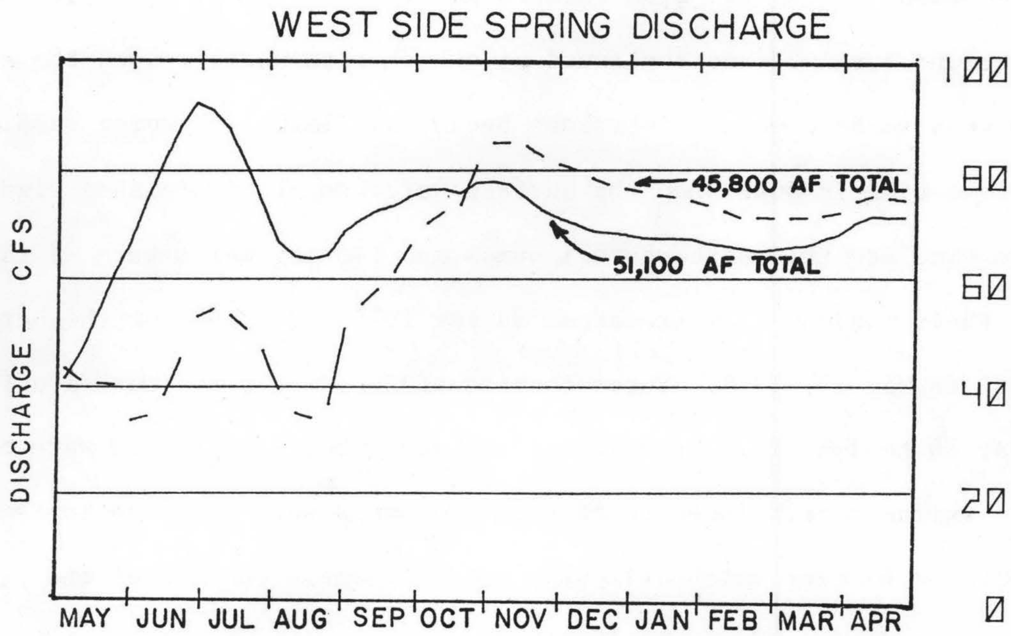


Figure 40. Effects of increased groundwater irrigation development on springflows in the Big Wood River-Silver Creek area.

In addition, spot measurements of representative canals were made to validate these estimates, however no extensive program of flow measurement was undertaken as in the previous two years.

After July 1, 1977 in the simulation period, diversions were estimated as a percentage of base year diversions. For drought study I, 50% of the base year diversions were used and for drought study II, 10% was used. As flow measurement was continued over the 1977 season, the 10% figure proved to be reasonably accurate. The total gross diversion for the simulated 1977 season for drought study I was 77,559 acre-ft and for drought study II was 40,276 acre-ft. These compare with a gross diversion of 142,583 acre-ft during the 1975 irrigation season.

Irrigation Pumpage

According to reports from farmers in the area, pumping for irrigation began around April 22 and continued at a high rate until around the end of May when surface water diversions became available. Pumping subsided until some time in June when the surface water supply diminished significantly.

To simulate this pattern, all pumps and flowing wells were "turned on" to their maximum flow (recorded during 1975 and 1976) for the period April 22 to May 19, 1977. Three-fourths of the pumps were "turned off" from May 20 to June 16. From June 17 to September 1 all pumps were on at the maximum rate. Three-fourths of the pumps were off from September 2 to October 6 after which all pumps were off until the end of the simulation period on November 15, 1977.

Reach Gains

The major difference in reach gains and losses for the 1977 drought year was the absence of the spring flood and resulting seepage losses which contribute significantly to aquifer recharge in a normal year. No previous measurements of these losses during flood season have been made due to the difficulty of obtaining accurate measurements and no measurements could be made in 1977. Instead, the estimates of gains and losses for 1975 were duplicated except for the period from timestep 122 (February 18) to timestep 152 (September 22). During that period the estimates were revised according to the relative magnitudes of flows in the Big Wood River.

Evapotranspiration

Since no new data for 1977 were available, the values of ET for 1975 were used for the drought studies.

Precipitation

Records of precipitation at Ketchum Ranger Station were obtained for 1975 and compared with 1975 Silver Creek data. Estimates of precipitation and snowmelt rates for the study area were made using the Ketchum Ranger Station for the period November 1976 through April 1977. After May 1, 1977 until November 15, 1977 the 1975 precipitation data were used.

Simulated water table levels and springs flows were generated for both drought studies. Since input for drought study II most nearly duplicates the actual irrigation diversions, results of that study are presented. Figure 41 shows simulated hydrographs generated for six node points compared with nearby measured wells for the July 1976 through December 1, 1977 period. The wells measured for comparison purposes are the same as those used in showing the response during the calibration period (Figure 22). These wells are located in the one-half mile square area but because of topographic differences may not represent the node center as simulated in the model.

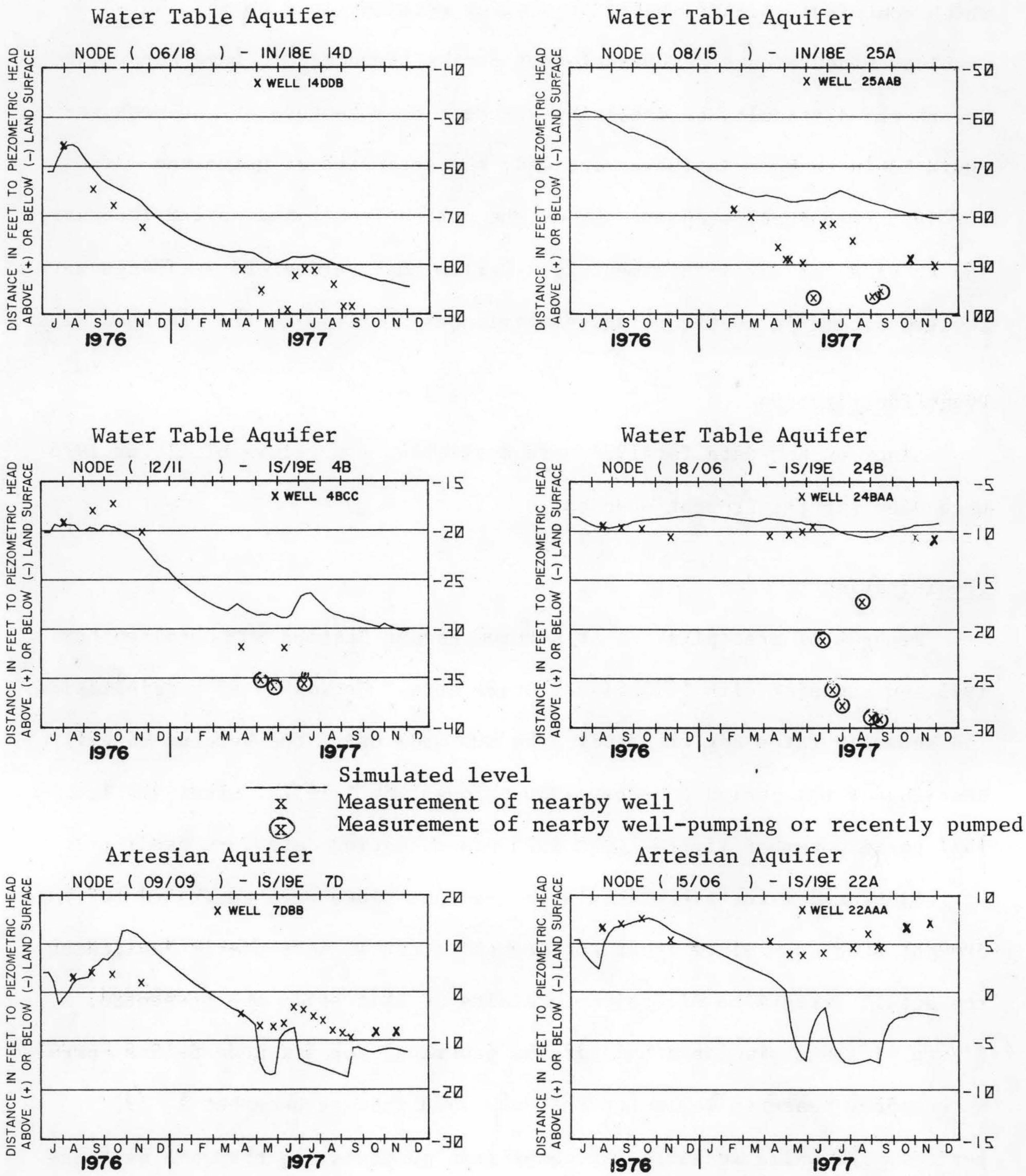


Figure 41. Comparison of simulated groundwater levels and artesian pressures with historical measurements of nearby wells during the 1977 drought in the Big Wood River-Silver Creek area.

Conspicuously absent in the hydrographs for the drought period is the normal rebound in May due to the advent of irrigation applications. The water levels at nodes (06/18) and (08/15) normally increase 20 to 30 feet in May and June (Figure 22) whereas very little rebound is evident in 1977 (Figure 41).

In the shallow groundwater area, little response to the lowered inputs due to drought is evident. The simulated hydrograph for node (18/06) (Figure 41) agrees very well with the measured response in wells 1S, 19E, 24BAA.

Artesian well simulated response to 1977 drought conditions indicates declines from 5 to 15 feet in piezometric head during August which is normally a period of maximum head. The simulated response of the confined aquifer to variations in input is very rapid and exaggerated compared to measured responses (Figure 41). The simulated hydrograph for node (09/09) in the artesian aquifer agrees well with the measured response; however, agreement at node (15/06) is not as good. The measured response of the well at node (15/06) is similar to node (18/06) in the shallow water table aquifer and it may be that the well in the confined aquifer is influenced moreby the shallow water table than is shown in the simulation.

Figure 42 shows the simulated eastside and westside spring flows compared with actual measurements of Silver Creek and indicator springs on the westside. Simulated seasonal changes in the eastside spring discharge are not as pronounced as the measured flow of Silver Creek at Sportsman's Access. However, the simulated and measured flows are not always the same due to diversion and surface-water runoff above the gage. Simulated westside spring flows vary rapidly due primarily to the simulated pattern at artesian well flows (see Irrigation Pumpage, page 91). In

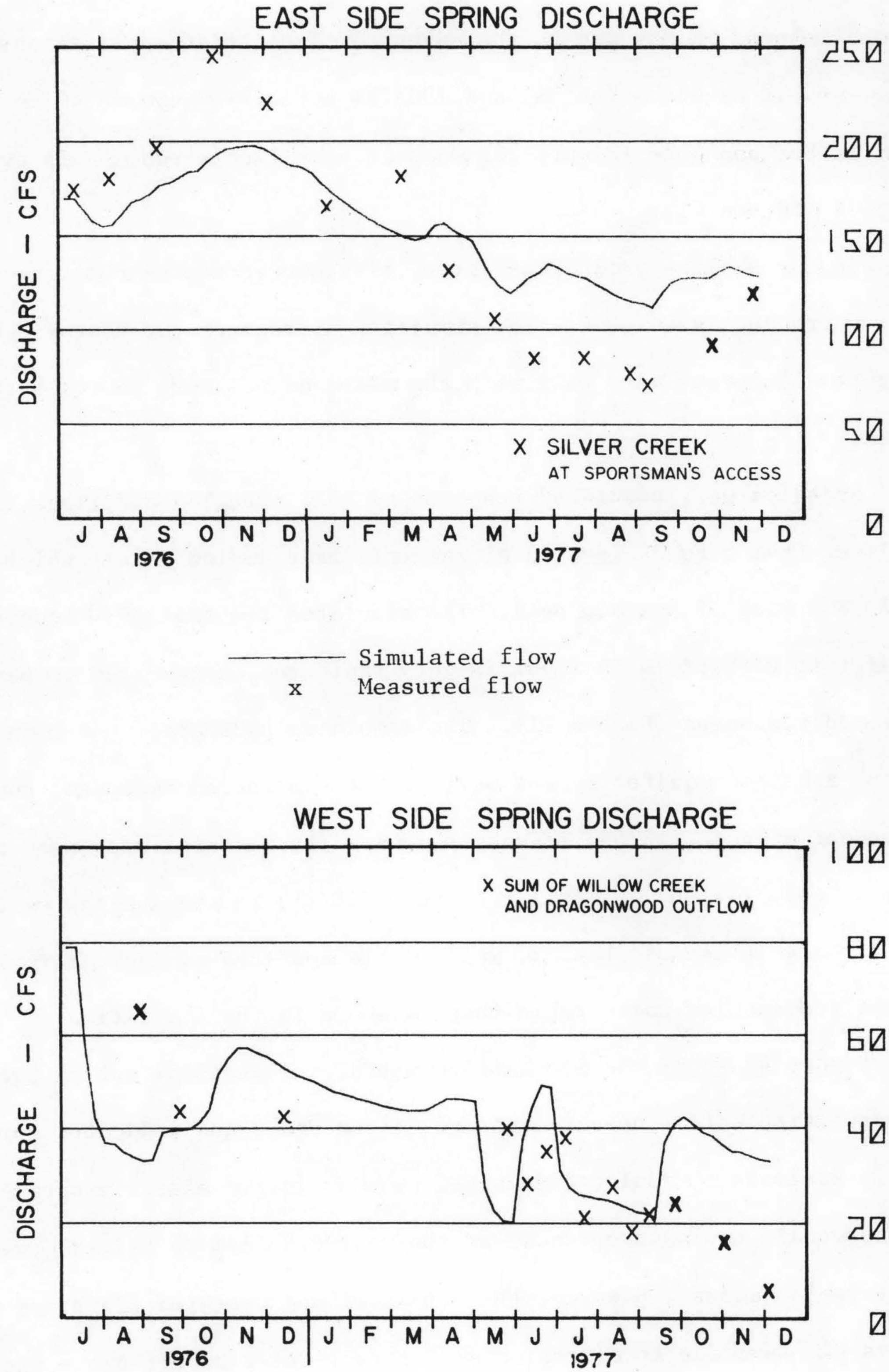


Figure 42. Comparison of simulated springflows with historical flow measurements during the 1977 drought in the Big Wood River-Silver Creek area.

general the model simulation of the aquifer response during the 1977 drought is satisfactory.

SUMMARY AND CONCLUSIONS

Simulation of the aquifer systems of the Big Wood River-Silver Creek area was achieved and the resulting model is adequate for estimates of impacts on the aquifer system due to land use changes. Simulation of the water table aquifer is considered more reliable than the artesian aquifer. This is caused by the lack of geologic definition of the formations comprising the artesian aquifer and the fact that the water table and artesian aquifers are not "linked" in a single model. Exchange between the two aquifers is affected by alternately running each submodel with generated boundary flows but not on a timestep basis as could be affected with a "linked" system.

Comparisons of aquifer responses due to simulated changes in recharge patterns with steady state or base year aquifer responses are reasonable for planning purposes. Simulated severe decreases or increases in aquifer recharge can "stress" a model to a point where the simulated response is no longer valid unless the calibration period has included a period in which moderate or severe stress occurs. Unfortunately, most historical record periods used for calibration do not include such stress periods and the magnitude of recharge change which overstresses a model is unknown. However, the 1977 drought during which the Big Wood River flows and subsequent irrigation diversions were less than 28 percent of normal provided the opportunity to check the ability of the modelling procedure for the Big Wood River-Silver Creek aquifer to predict aquifer response under severe decreases in recharge. Simulated responses of the water table and springs to the 1977 drought were more than adequate and enhance the validity of the model.

Determinations of potential long term land use changes are difficult. Lining of all irrigation canals is not likely to occur since a small number of farmers are involved in a rather long distribution system. If all canals were lined (zero seepage) the gross diversions could be cut by 15 to 20 percent with minimal reduction in water levels in the water table aquifer; however, significant decreases in artesian pressures could occur. Silver Creek flows would decrease a maximum of 15 cfs and yearly flow would decrease approximately 6 percent.

Artificial recharge of the aquifer system using Big Wood River flood flows would not materially benefit groundwater levels in the long term. Carryover aquifer storage from artificial recharge of 83,000 acre-ft of water would be less than 15,000 acre feet. Significant increases in water table elevations would occur during the recharge period; however, recession is rapid. Eastside and westside spring flows would increase on an average of 35 percent, thus benefiting Silver Creek flows.

Development of the 1636 acres of plotted or planned subdivisions would decrease water levels in the northern part of the study area by as much as 10 feet and decrease artesian pressures by similar amounts. Prediction of the amount and type of subdivision development on the planning horizon is difficult. These estimates represent effects of known and planned development only and probably do not represent ultimate development.

Conversion of flood irrigated land to sprinkler is rapidly occuring in the valley. Conversion of all surface irrigated land to sprinkler from canal water will produce decreases of up to 16 feet in groundwater levels in both water table and artesian aquifers and decrease average Silver Creek flows by 51 cfs. If groundwater pumping is used to convert surface irrigated areas to sprinkler, the impact on groundwater levels would be significantly greater.

Withdrawal of an additional 4500 acre-ft per season from the artesian aquifer for irrigation of overlying lands would decrease artesian pressures by 9 to 11 feet causing some wells to cease flowing. Eastside spring flows would decrease by 6400 acre-ft per year while westside flows are projected to increase by 4800 acre-ft.

Development of essentially all non-irrigated land from groundwater sources results in an increase in groundwater irrigated area of 8060 acres. The resulting increase in consumptive use is predicted to cause decreases in pressures of up to 25 feet in the artesian aquifer during high use periods, however, the water table aquifer declines would be only five feet or less. Eastside spring flows could exhibit decreases of 50 to 60 cfs in July and August with decreases of 25 to 30 cfs in the westside springs for the same months.

Successful simulation of the 1977 drought conditions provided further assurance of the validity of the model calibration. Actual irrigation diversions, groundwater pumpage, and other inputs were simulated and predicted responses of groundwater levels and spring flows compared reasonably with measured values. Significant rebounds of increases in groundwater levels normally associated with spring runoff and recharge are absent in all wells. Some slight increases in the June-July period are simulated and verified by actual measurement. Comparisons of predicted to measured groundwater responses for the water table aquifer were somewhat better than for the artesian aquifer. Comparisons of predicted and measured spring discharges were reasonable. The model did not predict maximum and minimum spring flows (Figure 42) but did successfully reproduce the trends in the 18 month simulation period.

Conversion to sprinkler irrigation from gravity appeared to be rapid during the 1977-78 period, however no documentation was made. If the trend continues, measured groundwater responses and spring flows could be used to check the validity of the model prediction.

Groundwater and surface water quality monitoring should be continued to ascertain trends and to determine at an early date whether degradation from development or change in landuse is occurring.

The groundwater model could be improved by providing better procedures for time dependent interchange between the water table and artesian aquifers or linking the submodels. As additional geohydrologic data becomes available model parameters should be adjusted as necessary to improve the calibration.

Also, as better estimates of trends and projections of development and land use changes become available, additional simulation runs could be performed to update the projections from this report.

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APPENDIX

Township, Range, Section,	1/4 Section	Surface Water Irrigated	Groundwater Irrigated Acreage	Total Irrigated Acreage	Wheat	Barley	Oats	Alfalfa	Irrigated Pasture	Phreato-phytes	Potatoes
T1NR18E	Sec. 1										
	NE	97	0	97				71	26		
	SE	111	0	111					111		
	SW	0	153	153					53	100	
	Sec. 12										
	NE	135	0	135				127		8	
	NW	0	106	106					74	32	
	SE	61	29	90				84		6	
	SW	0	98	98					49	49	
	Sec. 13										
	NE	68	0	68			32	36			
	NW	0	1	1						1	
	SE	82	0	82				82			
	SW	0	1	1						1	
	Sec. 14										
	NE	86	0	86				86			
	NW	28	0	28				28			
	SE	38	0	38				38			
	SW	113	0	113				113			
	Sec.15										
	SE	128	0	128				128			
	SW	30	0	30				30			
	Sec. 22										
	NE	0	70	70				70			
	NW	34	0	34				34			
	SE	72	71	143				143			
	SW	13	0	13				13			
	Sec. 23										
	NE	20	0	20		20					
	NW	80	0	80				80			
	SW	111	0	111				111			
	Sec. 24										
	NE	139	0	139				126	13		
	NW	0	1	1						1	
	SE	109	0	109			9	100			
	SW	0	1	1						1	
	Sec. 25										
	NE	110	0	110				50	60		
	NW	0	2	2						2	
	SE	157	0	157				157			
	SW	78	2	80	7			71		2	
	Sec. 26										
	NE	0	1	1						1	
	NW	63	57	120				62	58		
	SE	0	1	1						1	
	SW	0	2	2						2	
	Sec. 27										
	NE	61	28	89				61	28		
	NW	7	0	7				7			
	SE	0	82	82					80	2	

Township, Range, Section,	1/4 Section	Surface Water Irrigated	Groundwater Irrigated Acreage	Total Irrigated Acreage	Wheat	Barley	Oats	Alfalfa	Irrigated Pasture	Phreato-phytes	Potatoes
T1NR18E	Sec. 34										
	SE	100	0	100					100		
	Sec. 35										
	NE	0	10	10						10	
	NW	0	18	18						18	
	SE	18	145	163		15		75	73		
	SW	73	68	141					73	68	
	Sec. 36										
	NW	135	0	135		60		8	67		
	SE	132	0	132		86		42	4		
	SW	158	0	158	80	78					
T1NR19E											
	Sec. 6										
	NW	66	0	66		66					
	SE	5	0	5				5			
	SW	123	0	123	53			68	2		
	Sec. 7										
	NE	78	0	78				78			
	NW	131	0	131		34		97			
	SW	152	0	152		38		35	79		
	SE	138	0	138				134	4		
	Sec. 8										
	SW	72	0	72				72			
	Sec. 17										
	NE	43	0	43			16	27			
	NW	156	0	156			28	128			
	SW	143	0	143			54	89			
	SE	104	0	104			7	97			
	Sec. 18										
	NE	77	0	77				77			
	NW	75	0	75					75		
	SE	94	0	94				94			
	Sec. 19										
	NE	105	0	105				105			
	SW	80	18	98	80			18			
	SE	76	0	76				76			
	Sec. 20										
	NE	275	0	275		134		141			
	NW	128	0	128		3		125			
	SW	120	0	120				120			
	SE	152	0	152		48		104			
	Sec.27										
	NE	1	0	1					1		
	NW	27	0	27					27		
	SW	145	0	145					145		
	SE	15	0	15					15		
	Sec.28										
	NW	14	0	14					14		
	NE	115	0	115				34	81		

Township, Range, Section,	1/4 Section	Surface Water Irrigated	Groundwater Irrigated Acreage	Total Irrigated Acreage	Wheat	Barley	Oats	Alfalfa	Irrigated Pasture	Phreato-phytes	Potatoes
	Sec. 28										
	SW	118	0	118		33	23	53	9		
	SE	146	0	146				32	114		
	Sec. 29										
	NE	70	0	70		28		42			
	NW	30	0	30				30			
	SW	33	0	33				33			
	SE	147	0	147		56		91			
	Sec. 30										
	NE	147	0	147		147					
	NW	80	72	152					127	25	
	SW	49	0	49				49			
	Sec. 31										
	NW	50	0	50				50			
	SW	144	0	144				98	46		
	SE	144	0	144	30			105	9		
	Sec. 32										
	NE	150	0	150				150			
	NW	136	0	136				136			
	SW	67	0	67	33			34			
	SE	155	0	155	75			80			
	Sec. 33										
	NE	145	0	145				54	91		
	NW	153	0	153		41		112			
	SW	150	0	150				150			
	SE	141	0	141		91		50			
	Sec. 34										
	NW	42	0	42					42		
	SW	24	0	24				24			
T1SR18E											
	Sec. 1										
	SE	175	0	175	51			87	37		
	SW	54	112	166				166			
	Sec. 2										
	SE	15	172	187					135	52	
	SW	132	40	172					132	40	
	Sec. 3										
	SE	0	2	2						2	
	Sec. 10										
	NE	35	93	128					63	65	
	SW	98	46	144					110	34	
	SE	146	2	148					130	18	
	Sec. 11										
	NE	156	0	156				140	16		
	NW	146	4	150				125	21	4	
	SW	158	0	158				158			
	SE	80	80	160				80	80		

Township, Range, Section,	1/4 Section	Surface Water Irrigated	Groundwater Irrigated Acreage	Total Irrigated Acreage	Wheat	Barley	Oats	Alfalfa	Irrigated Pasture	Phreato-phytes	Potatoes
	Sec. 12										
	NE	7	153	160				7	143	10	
	NW	80	72	152				88	62	2	
	SW	54	97	151	11			59	81		
	Sec. 13										
	NE	0	155	155					155		
	NW	0	160	160					157	3	
	SW	0	152	152			10	9	118	15	
	SE	0	152	152				29	116	7	
	Sec. 14										
	NE	0	147	147					147		
	NW	0	155	155					155		
	SW	0	152	152					152		
	SE	0	160	160					146	14	
	Sec. 15										
	NE	0	155	155					155		
	NW	31	99	130					103	27	
	SW	0	15	15						15	
	SE	0	152	152					152		
	Sec. 22										
	NE	0	137	137					137		
	Sec. 23										
	NE	0	125	125				92	33		
	NW	0	91	91				20	71		
	Sec. 24										
	NE	0	43	43				43			
	NW	0	123	123				123			
T1SR19E											
	Sec. 2										
	SW	0	150	150				56	94		
	SE	0	87	87				53	34		
	Sec. 3										
	SE	74	40	114				114			
	SW	106	81	187		13		174			
	Sec. 4										
	SE	80	40	120		40		64	16		
	SW	181	0	181		31		150			
	Sec. 5										
	SE	186	0	186	27	28	21	89	21		
	SW	187	0	187	38			132	17		
	Sec. 6										
	SE	183	0	183		25		141	17		
	SW	163	0	163	93			40	30		
	Sec. 7										
	NE	39	120	159				60	99		
	NW	32	123	155				32	123		
	SW	50	108	158					158		
	SE	0	154	154		154					

Township, Range, Section,	1/4 Section	Surface Water Irrigated	Groundwater Irrigated Acreage	Total Irrigated Acreage	Wheat	Barley	Oats	Alfalfa	Irrigated Pasture	Phreato-phytes	Potatoes
	Sec. 8										
	NE	51	80	131				51	80		
	NW	0	157	157					157		
	SW	0	157	157					157		
	SE	0	154	154					154		
	Sec. 9										
	NE	0	160	160					160		
	NW	0	151	151				16	135		
	SW	0	153	153		81	72				
	SE	0	160	160		50			110		
	Sec. 10										
	NE	110	40	150				150			
	NW	0	113	113					113		
	SW	0	160	160					160		
	SE	0	152	152					150	2	
	Sec, 11										
	NE	0	150	150			19	12	119		
	NW	0	144	144					144		
	SW	0	149	149					149		
	SE	0	150	150					150		
	Sec. 12										
	NW	0	52	52		52					
	SW	0	156	156		14		24	118		
	SE	44	25	69	14	30			25		
	Sec. 13										
	NE	0	136	136					136		
	NW	0	145	145		9			136		
	SW	0	144	144		36		11	97		
	SE	0	149	149					149		
	Sec. 14										
	NE	0	154	154		128			26		
	NW	0	157	157		93			64		
	SW	0	153	153		87		15		51	
	SE	0	155	155		113			14	28	
	Sec. 15										
	NE	0	154	154					154		
	NW	0	159	159					159		
	SW	0	129	129		57		10	62		
	SE	0	151	151		90			54	7	
	Sec. 16										
	NE	0	154	154					154		
	NW	0	159	159		127			32		
	SW	0	158	158		158					
	SE	0	154	154		80			74		
	Sec. 17										
	NE	0	154	154					154		
	NW	0	157	157					157		
	SW	0	159	159		72			87		
	SE	0	156	156		156					

Township, Range, Section,	1/4 Section	Surface Water Irrigated	Groundwater Irrigated Acreage	Total Irrigated Acreage	Wheat	Barley	Oats	Alfalfa	Irrigated Pasture	Phreato-phytes	Potatoes
Sec. 18											
	NE	0	156	156		156					
	NW	0	155	155					152	3	
	SW	0	99	99					99		
	SE	0	114	114		88			26		
Sec. 19											
	NE	31	0	31				31			
	SE	23	26	49			49				
Sec. 20											
	NE	0	154	154		154					
	NW	0	147	147		85			62		
	SW	12	145	157		142	14		1		
	SE	0	159	159		80			79		
Sec. 21											
	NE	0	157	157		35		106	16		
	NW	0	158	158		120			38		
	SW	0	157	157		103			54		
	SE	0	149	149		95			54		
Sec. 22											
	NE	0	147	147		116			30	1	
	NW	0	158	158		135			23		
	SW	0	158	158		126			32		
	SE	0	157	157		136			21		
Sec. 23											
	NE	0	153	153		88			43	22	
	NW	0	157	157		139				18	
	SW	0	155	155		28			16	111	
	SE	0	148	148		26			88	34	
Sec. 24											
	NE	0	67	67				61	6		
	NW	0	142	142		96			43	3	
	SW	0	133	133		128			5		
	SE	39	40	79		40			28	11	
Sec. 25											
	NE	21	74	95		9		41	45		
	NW	0	79	79		17		25		7	30
Sec. 26											
	NE	0	86	86		11		42	18	15	
	NW	0	139	139		113			26		
	SW	0	79	79		76			3		
Sec. 27											
	NE	62	91	153		104			49		
	NW	40	88	128		106			22		
	SW	0	31	31		31					
	SE	0	49	49		49					
Sec. 28											
	NE	0	140	140		140					
	NW	0	155	155		139			16		
	SW	0	73	73		30			43		

Township, Range, Section,	1/4 Section	Surface Water Irrigated	Groundwater Irrigated Acreage	Total Irrigated Acreage	Wheat	Barley	Oats	Alfalfa	Irrigated Pasture	Phreato-phytes	Potatoes
	Sec. 28										
	SE	0	75	75		75					
	Sec. 29										
	NE	0	158	158		145			13		
	NW	21	137	158		139			19		
	SW	55	24	79		79					
	SE	0	77	77		63			14		
T1SR20E											
	Sec. 16										
	SW	80	0	80	40			28	12		
	SE	0	104	104	20	34			50		
	Sec. 17										
	NE	0	36	36				36			
	NW	0	117	117		40		58	19		
	SW	140	20	160	78	32		50			
	SE	0	36	36				36			
	Sec. 18										
	NE	0	122	122				122			
	NW	75	40	115		67		48			
	SW	0	140	140				140			
	SE	65	53	118				118			
	Sec. 19										
	NE	52	100	152		24		128			
	NW	0	151	151		31		114	6		
	SW	147	15	162		40	80	42			
	SE	72	58	130		100		30			
	Sec. 20										
	NE	20	98	118					111	7	
	NW	120	29	149				132	17		
	SW	66	54	120		36		43	41		
	SE	10	130	140					140		
	Sec. 21										
	NE	142	18	160		80			80		
	NW	101	39	140					140		
	SW	138	15	153					153		
	SE	130	27	157					157		
	Sec. 22										
	NE	0	14	14				14			
	NW	33	100	133		53			80		
	SW	140	14	154					154		
	SE	0	136	136			32	64			40
	Sec. 26										
	NW	0	86	86				56	30		
	SW	19	69	88				20	68		
	SE	0	60	60					60		

Township, Range, Section,	1/4 Section	Surface Water Irrigated	Groundwater Irrigated Acreage	Total Irrigated Acreage	Wheat	Barley	Oats	Alfalfa	Irrigated Pasture	Phreato-phytes	Potatoes
	Sec. 27										
	NE	36	114	150					150		
	NW	104	52	156					156		
	SW	13	5	18					18		
	SE	33	33	66					66		
	Sec. 28										
	NE	46	60	106					106		
	NW	8	32	40					40		
	SW	128	0	128		30		38	60		
	Sec. 29										
	NE	141	8	149					149		
	NW	136	0	136					136		
	SE	119	0	119			37		82		
	Sec. 30										
	NE	136	0	136					136		
	NW	47	0	47			7		40		
	SW	3	0	3					3		
	SE	8	0	8					8		
	Sec. 34										
	NE	34	0	34		28		6			
	NW	29	0	29				29			
	Sec. 35										
	NW	91	0	91				91			