IRRIGATION DIVERSIONS AND RETURN FLOWS - PINEDALE

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CHAPTER I

INTRODUCTION

The increasing demands on a scarce water supply in the western United States has placed added emphasis on improving the efficiency of water use. The prior appropriation doctrine of water rights prevalent in Wyoming and several surrounding states has served as an impetus to the development and beneficial use of water supplies. This same incentive has drawn attention to the various methods of water use being applied which has resulted, in many cases, in formal litigation. Water use practices which have received increasing attention are (1) irrigation techniques (flood, sprinkler, row), (2) reservoir storage for the water supply needs of municipalities, (3) reservoir storage for the generation of hydroelectric power and (4) environmental and recreational needs and uses. Water distribution disagreements have arisen between senior and junior water rights holders during periods of water shortage. Interstate water conflicts have become more common place. The transfer of water rights between different water users (municipalities, industries and agriculture) has become increasingly sensitized to ensure that no injuries are incurred by other appropriators. Finally, the impact of water management on instream flow conditions and the surrounding wildlife habitat has become a major environmental and political concern.

One water use application receiving increased attention is that involving flood irrigation. Flood irrigation entails supplying water to an agricultural crop until the surface area of the field, and in many instances the surface alluvial layer, are completely saturated. This water capacity is maintained until the crop is about to be harvested.

Proponents of flood irrigation argue that an aquifer artificially recharged by this technique may act as a large underground reservoir storing water that has not been consumptively used nor has returned to the surface system by means of return flows. This storage is accomplished without dam construction costs associated with surface water confinement. Additicnal benefits of groundwater storage include (1) lower evaporation losses, (2) the availability of the land surface to be put to beneficial use and (3) the slower release of the stored water to the stream system which provides a more consistent source of water to downstream users during low flow months.

The primary limitation of flood irrigation and the saturation of the alluvial aquifer is the potential loss of beneficial surface flow by means of groundwater movement through the aquifer. The potential also exists for reappropriating return flow, that has already been appropriated as surface flow, as a groundwater source. This is especially true when the aquifer response is unknown.

The uncertainty surrounding the response of an artificially recharged aquifer points out the need for a detailed study of a return flow system and provided the purpose for this thesis.

Purpose

An alluvial aquifer located in west-central Wyoming in which artificial recharge to the aquifer was provided by flood irrigation was studied. The aquifer is located on the upper region of a large watershed. The stream system has become highly regulated due to the flood irrigation practices, resulting in a relatively flood-free drainage system. This thesis evaluates the effect that this recharge had on stream-aquifer interaction over time, primarily the percentage of the diverted surface flow returning to the downstream system. The mode of transport and the rate at which this flow returned to the stream system is also analyzed.

Objective

Eight objectives had to be met in order to accomplish the stated purpose of this thesis. These objectives are listed in the order of completion:

1. The area of the alluvial aquifer had to be

outlined with all points of surface inflow, outflow and diversion noted along with potential sites for groundwater monitoring wells identified.

2. The method by which this aquifer was to be analyzed had to be determined. A water budget analysis, in this case, was determined to be the best means by which to simulate the aquifer response.
3. The methodology used for data collection had to be thoroughly researched to assure that essential information was obtained.
4. A complete, uniform collection of field data was required.
5. Field data collected was analyzed and reduced. The reduction, for this study, involved building a data base consisting of the various terms associated with the water budget equation.
6. A groundwater finite-difference modelling program was implemented to determine the change in storage of the aquifer and the percentage of the diverted water returning to the stream system as overland flow. The proper calibration of this model was essential to the success of this study.
7. The calibrated groundwater model was run using the collected field data as input. Results obtained from the model simulations and implemented in the

calculations of the return flow percentages included (1) evapotranspiration volumes, (2) change in storage volumes and (3) overland flow volumes.

8. Return flow volumes were calculated using a water budget analysis aided by the model simulated results described previously.

The boundaries of the alluvial aquifer and the monitoring methodology were determined by personal of the Wyoming Water Research Center (WWRC) early in 1984. The field data was collected from the spring of 1984 through the summer of 1988 by WWRC personal with the full cooperation of the area ranchers on whose fields the study took place. The study area and monitoring techniques will be discussed later in chapters III and V.

The groundwater model utilized in this study was determined from a comparison of several finite-difference models performed by Peck (1985). The finite-difference model implemented was developed for the United States Geological Survey (USGS) by Michael G. McDonald and Arlen W. Harbaugh and is entitled "A Modular Three-Dimensional Finite-Difference Groundwater Flow Model." Discussions of the application of this model and the model calibration appear in chapters IV and VI.

The results of the model simulation and water budget analysis in determining the return flow volumes are included in chapter VII. Chapter VIII contains the conclusions and recommendations from this thesis study.

CHAPTER II

LITERATURE REVIEW

Artificially recharging an alluvial aquifer to serve as an underground reservoir is not a new concept. This chapter is intended to cite a few of the references that pertain to studies associated with the basic ideas of this thesis and to describe the two previous return flow studies that were performed in the New Fork River valley.

David Todd (1965) described the economic benefits of groundwater recharge. Additional studies have looked into recharging an aquifer system during surplus flow periods (spring runoff) to be stored for use at a later low flow interval. A study by Davis, Lofgren and Mack (1964) analyzed the possibility of storing surface water in an alluvial aquifer in the San Joaquin Valley of California. Their study addressed the methods of recharge, areas to be artificially recharged and the rates of infiltration associated with the different recharge areas. A report by Weston and Swain (1979) investigated the possibility of recharging an alluvial aquifer system in a section of the South Platte River valley in Colorado for use as a supplemental irrigation source during the annual irrigation shortages that have historically occurred. The latter study investigated the potential of artificially recharging the alluvial aquifer, by means of infiltration ponds and the effect that this infiltration would have on the aquifer system.

Both the Davis and the Weston reports discussed the storage losses to groundwater flow. Davis calculated the net groundwater inflow (inflow minus outflow) by subdividing the perimeter of the study area into small units and computing the rate of flow across the unit based on Darcy's equation; water level contours were used as the source for the gradient (1964,97). Weston's approach to the loss of groundwater storage dealt with the volume of water returning to the surface flow system. He termed this return flow "drain out" (1979,119). The drain out was calculated based on the Stream Depletion Factor (sdf) Method which is described in the USGS Open File Report Number 74-0242 written by Jenkins and Taylor (1974). The stream depletion factor is defined as the time during which the accumulated change in streamflow volume is twenty-eight percent of the accumulated volume of steady stress, either recharge or pumpage (Weston,1979,119). The depletion of the groundwater storage used by Weston was taken from a curve developed for the South Platte River by the USGS which gives the cumulative future stream depletion (or accretion) in percent of the volume pumped (or recharged) for a given time period for a given distance of pumpage (or recharge) from the river (1979,120).

Other methods of analyzing return flows from recharged aquifer systems have been incorporated in the past. Eshett and Bittinger (1965) calculated the interchange of water between the groundwater system and the stream based on a stream-aquifer relationship equation developed by Robert E. Glover.

A more simplified approach was attempted for the return flow analysis performed on the northern section of the study area covered by this thesis. In an unpublished report to the New Fork Irrigation District, Dr. Luna B. Leopold studied the percentage of diverted water being consumptively used (1979). Leopold's study area covered the acreage of the New Fork River valley irrigated by waters from the New Fork River starting from the top of the watershed at the New Fork Lakes (Figure 1) and extending south to the bridge crossing the New Fork River located near his summer cabin (the small black triangle marked by the letter O in figure 2). Data collection was accomplished during the summers of 1977 and 1979. Recorded data were surface flows for the New Fork River and all major diversion ditches. Additional data were collected from the summers of 1980 to 1982 but these data were not included in the initial report submitted to the irrigation district (Leopold,1979).

The study by Dr. Leopold involved approximately 9500 acres of irrigated land in the upper New Fork River

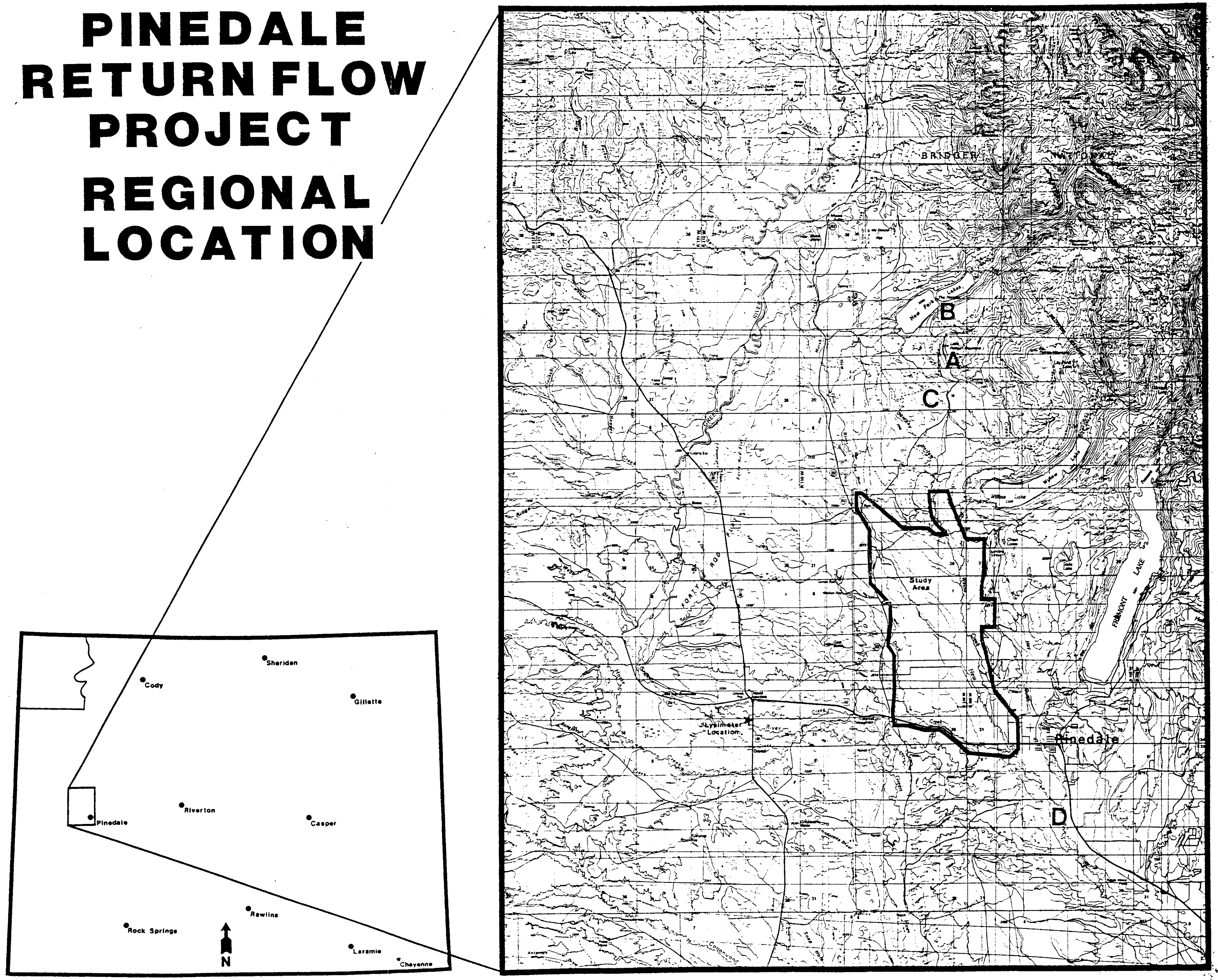
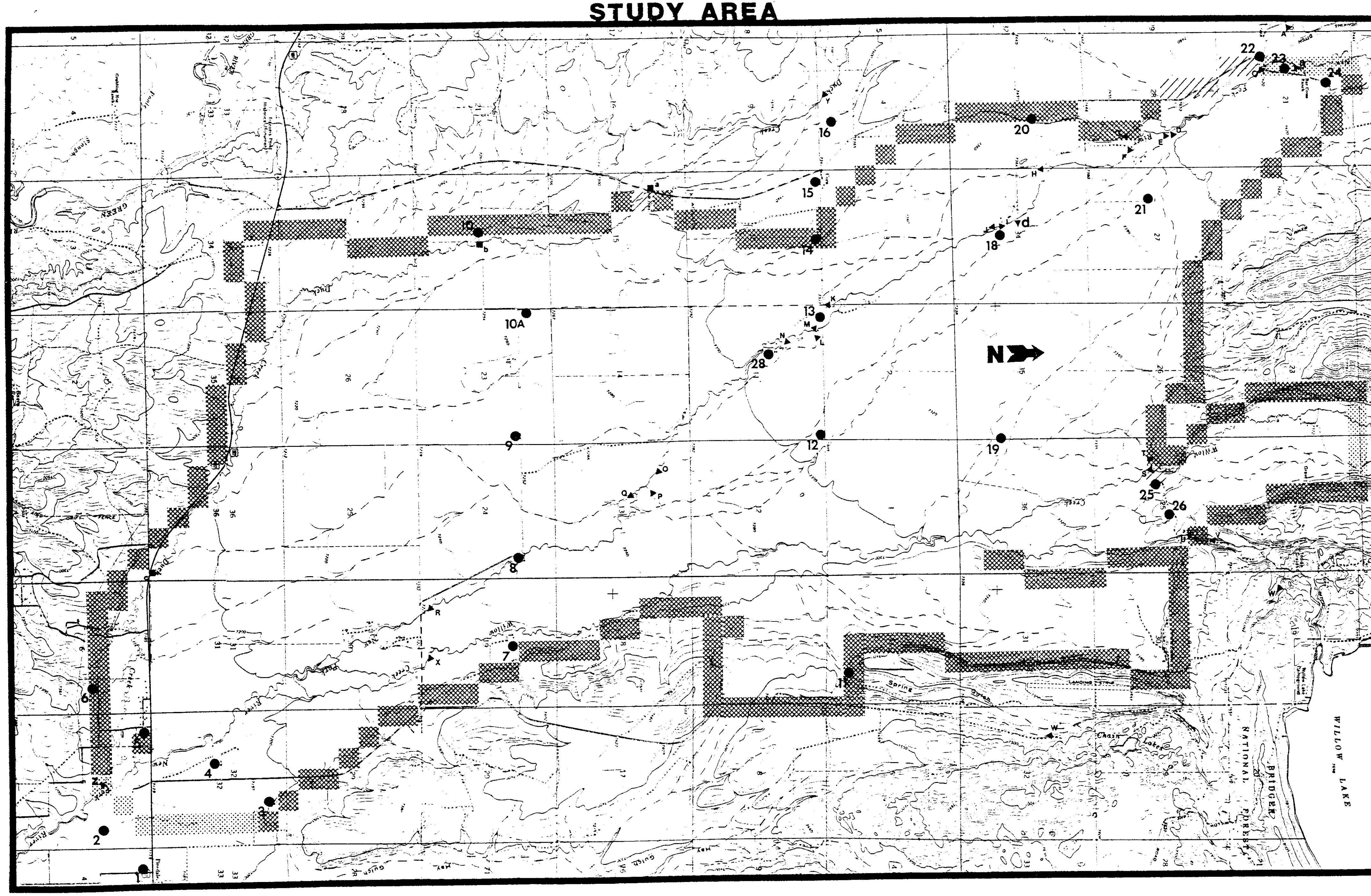


Figure 1. Pinedale Return Flow Project Regional Location

PINEDALE RETURN FLOW PROJECT

STUDY AREA



● Groundwater Monitoring Well
▲ Streamgage
▪ Staff Gage

Figure 2. Pinedale Return Flow Project Study Area Map

watershed. That area to the east of the land irrigated by the waters from the New Fork River and south of the Willow Creek Diversion - New Fork River confluence (marked by the black triangle labeled P in figure 2) was neglected because of the influence imposed by Willow Creek. The study area was divided into four reaches: the area between the New Fork Lakes and the bridge at the Bar-Cross Ranch (this is the area from New Fork Lakes to the study area boundary outlined in figure 1); The reach from the Bar-Cross Ranch (north-western boundary of the study area in figure 2) south to the bridge located at the residence of Jim Noble (small black triangle marked by letter F in figure 2); the section between Jim Noble's bridge and Dick Noble's house (small black triangle marked by the letter N in figure 2) and the reach between Dick Noble's house and the bridge across the New Fork River at Leopold's summer cabin (small black triangle marked by the letter O in figure 2). Streamgages were located at the study area inlet (New Fork River at New Fork Lakes) and at the outlet (bridge across the New Fork River at Leopold's). Streamgages were placed, in addition to the two previously mentioned, at all reach boundaries described above and on all major diversion ditches.

Consumptive use and return flow calculations by Leopold (1979) were made in the following manner.

1. The consumptive use for a subarea equalled the inflow for the reach minus the reach outflow. The

results were tabulated in units of acre-feet per acre by dividing the net inflow (inflow minus outflow) by the number of irrigated acres within the subarea.

2. The return flow was determined to be the total amount of diversion flow (measured by the diversion ditch streamgages) minus the consumptive use volume.

3. The combined results of the 1977 and 1979 field data indicate that approximately three acre-feet per acre of water was being diverted, with two out of the three acre-feet per acre being consumed. This left a return flow of one acre-foot per acre, or stated in percentages; 33 percent of the diverted water returned to the downstream channel system. This calculated return flow percentage pertained to only those summer months during which data collection occurred.

Another return flow study of the New Fork River drainage area was written by Hilaire Peck in 1985 for his master's thesis. Peck's study, which was the initial evaluation of the "Pinedale Return Flow Project" (PRFP) being completed by this thesis, involved the selection of the computer groundwater modelling program used to simulate the aquifer response.

The groundwater modelling program chosen was the USGS model written by Michael McDonald and Arlen Harbaugh (1984). This model was chosen over the modelling program by Catherine Rovey, entitled "Numerical Model of Flow in a Stream-Aquifer System" (1978). The primary reasons for the selection of the USGS model were as follows:

1. The USGS model was capable of calculating stream loss or gain to the aquifer with a two-dimensional package, while the Rovey model could only handle river data with a three-dimensional simulation (Peck,1985,36). A two-dimensional analysis was preferred because the aquifer studied was a surface aquifer with no assumed interconnection to a lower aquifer system.
2. The USGS model provided as output at the end of each simulation, a detailed water budget analysis while the Rovey model did not (Peck,1985,37). This aquifer budget output could be directly incorporated into the return flow calculations.

The field monitoring system utilized in the study written by Hilaire Peck was also that for this study and will be discussed in detail in chapter V. The groundwater model was calibrated by varying the hydraulic conductivity assigned to the finite-difference cells until the water elevations in those cells containing the monitoring wells were within one foot of the measured field elevation (Peck, 1985). An aquifer thickness of 40 feet was assumed for the entire model area and a specific yield of 0.13 was assigned for change in storage calculations (Peck,1985).

Seven model simulation periods were performed, starting with June 4, 1984 and ending with January 2, 1985. A water budget analysis, in conjunction with results from the groundwater modelling program, resulted in a final calculation of the returning diverted water to be 92 percent (Peck,1985). This return flow percentage was stated by Peck in his conclusions as being overestimated due to the unmonitored spring snowmelt influence to the aquifer-stream interaction.

A sensitivity analysis on the USGS computer model concluded the PRFP work done by Hilaire Peck. Items analyzed in this sensitivity analysis included (1) the specific yield, (2) the hydraulic conductivity, (3) river stage, (4) riverbed conductance and (5) riverbed elevation. Results of this analysis indicated that the model was insensitive to the specific yield and riverbed elevation, while being highly sensitive to the remaining parameters analyzed.

Conclusions

1. The use of an underground reservoir as a supplemental water source by artificially recharging the aquifer has been reviewed.
2. The loss of stored water in the aquifer system has also been recognized, with several different

approaches taken to determine the volume of this loss.

3. The unpublished work by Dr. Leopold (1979) is self stated to be of modest results. Leopold's study did not extend into the summer and winter months; therefore, delayed return flows associated with these periods were not measured. Leopold's work also did not incorporate any groundwater storage or precipitation data. The lack of detail involved with this study, compared with Hilaire Peck's work and that of this study, suggests that the discrepancy in return flow results can be discounted.
4. The initial work performed by Peck and subsequent personal of the WWRC, prior to that work summarized by this thesis, provided a solid background for the completion of the PRFP. Although the initial finite-difference grid configuration was modified, the initial concepts of model calibration performed by Peck and described in his thesis were utilized (1985).
5. Finally, some of the additional data outlined by the sensitivity analysis performed by Peck was gathered and has been incorporated into the completion of this study. This additional information provided a more complete set of data from

which to calculate the return flow volumes. These data included additional staff gages being placed on Duck Creek and additional recorders being located on several diversion ditches that were left unmonitored in the first year of data collection.

CHAPTER III

STUDY AREA

Area Location

The PRFP study area consists of a 28 square mile unconfined alluvial aquifer located in west-central Wyoming near the town of Pinedale (Figure 1). The study area is situated in the upper region of the large Green River watershed that encompasses much of southwestern Wyoming. The general configuration of the study area is shown in figure 2. Dimensions of the area are approximately nine miles in the north-south direction by four miles in the east-west direction. There is a surface elevation drop of 270 feet in approximately 10.25 miles, corresponding to an average gradient of approximately 0.005.

Area Hydrography

Stream System:

The major stream that flows through the study area is the New Fork River which transverses the area from the northwest corner to the southeast corner. Three additional streams flow into the study area and join the New Fork River, either directly or indirectly, before it exits the area. The largest of these three, Willow Creek, enters in the north-central portion of the area and flows near the eastern boundary of the study area before entering the New Fork River in the lower region of the study area. Lake Creek which joins Willow Creek in the northeastern section of the area, contributes, on average, minor surface inflows to the system. The small between bank flow in Lake Creek is due to the large diversion of flow above the study area. This diverted flow eventually enters the study area through the culverts near Willard Binning's ranch, which will be discussed later in chapter V. The last stream, Duck Creek, flows along the southern and southwestern boundary of the area. The outlet of the study area is located just to the east of the New Fork River - Duck Creek confluence. Duck Creek is of major importance to the area. It serves as a source of surface inflow into the region and as one of the main catchments of returning flows, both overland and return. This surfacing groundwater (return flow) has a tendency to cause Duck Creek to flow at a slightly warmer temperature than the other streams in the study area and will therefore, remain nearly ice-free over a large portion of the winter months.

All of the streams in the New Fork River valley are heavily regulated for the purpose of flood irrigation. This stream control has produced a relatively flood-free drainage system.

Irrigation System:

Cattle (with some minor sheep) ranching is the major source of revenue within the study area. All ranchers practice flood irrigation. With the sole exception of one rancher, the use of commercial fertilization is nonexistent.

The New Fork River valley irrigation season begins in early spring by clearing the diversion ditches of any debris that has accumulated during the off-irrigation season (beaver dams in many instances). This is a very important step in the overall cooperative scheme of flood irrigation. A ditch, if not cleared, will prevent the irrigation of fields lower on the watershed. The actual supplying of water to the fields begins in late May or early June. The water is diverted onto the crops (native hay, primarily timothy grass) and maintained until the surface and consequently, the alluvial aquifer are saturated. This water capacity is maintained until the hay is about to be cut, late July, when the diversion gates are closed and the water table allowed to drop. Saturation of the aquifer is needed in this area because many of the fields on the lower end of the irrigated section are supplied water directly by the overland flow from the upper saturated fields. Haying season lasts approximately a month and a half, from late July to early September. At the conclusion of the haying season, the water is again diverted onto the fields at a much less intense rate for stock watering and to prevent the rapid lowering of the alluvial phreatic aquifer. The late irrigation season lasts until the onset of cold weather, usually mid-November, at which time the headgates are closed until the next spring irrigation season. There are 17 major diversion ditches within or entering the study area (described in chapter V) which make up a large portion of the approximately 50 miles of irrigation ditches that encompass the study area.

Area Geology

Groundwater movement through the alluvial aquifer in the New Fork River valley is controlled by the geologic units that were deposited prior to that of the alluvium. The three geologic formations dominating the PRFP study area are (1) the Tertiary Wasatch Formation, (2) the glacial deposits associated with the Pleistocene Epoch and (3) the Quaternary alluvial deposits.

The present day configuration of the study area was a direct result of the geologic forces that were responsible for the deposition of these dominant rock units (Figure 3). A brief overview of the geologic history shaping the New Fork River region is as follows:

1. A downwarping of the regional basins occurred in early Paleocene time and continued through the Eocene Epoch (Bradley,1964,A1). This depression served as a catchment for the fluvial deposits of

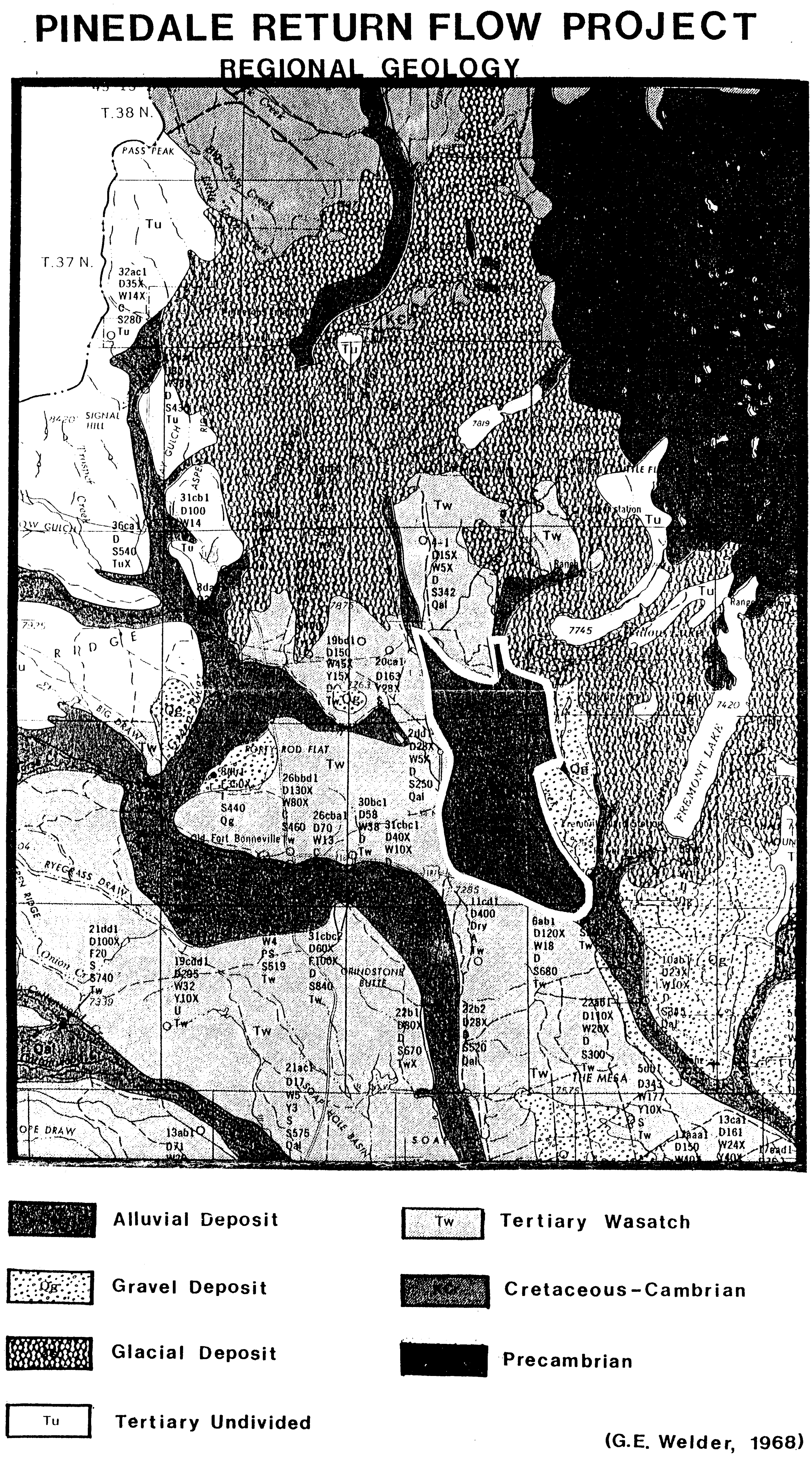


Figure 3. Pinedale Return Flow Project Regional Geology Map

the Wasatch and post-Wasatch formations. The present day mountain ranges in this region were in existence during this period and served as the source for these fluviatile sediments (Bradley, 1964,A1).

2. Erosional processes continued for approximately 30,000,000 years, up until the Oligocene Epoch, at which time the basins had been largely filled and the mountains buried, leaving only a few scattered monadnocks to indicate the highest parts of the old mountain ranges (Dunbar and Waage, 1969).
3. The Oligocene Epoch was a period of deposition. Streams radiating from the few existing high relief features deposited a layer of silts and muds over much of the region (Dunbar and Waage, 1969).
4. Erosional processes began again during the Miocene period, when the region began to rise and the rejuvenated streams found themselves superposed upon several of the buried ranges (Dunbar and Waage, 1969). An example of this superposition is the Green River cutting through the eastern end of the Uinta Mountains. Volcanic activity was also occurring in this region, starting in late Oligocene and continuing through to early Pliocene. The volcanic deposits are mostly in the form of tuffs.

5. Post Oligocene erosional episodes were responsible for the sequence of river terraces that exists in the study area today. A series of five incomplete erosional episodes produced these terraces that step easterly out of the New Fork River valley toward the Wind River Mountain Range (Baker, 1946, 509). The most recent of these benches constitutes the boundaries of the PRFP study area (Figure 2). The elevations of these terraces starting from the most recent to oldest are (1) the 7400 foot to 7700 foot bench composing the area boundaries, (2) the 8500 foot level which is marked by Little Flattop Mountain (Location A in figure 1), (3) the terrace at the 9200 to 9300 foot level, (4) a 9600 foot feature and (5) the extensive plateau at the 10,300 to 10,500 foot elevation (Baker,1946,589). The multiple-stage valley development is attributed to some combination of the following four factors: change in base levels of the drainages outside the Wind River Range, changes in climate, regional uplift and localized uplift (Baker,1946,591).
6. The erosional cycle was interrupted after the third episode, the 9200 foot level, by the onset of glaciation during the Pleistocene Epoch (Baker,1946,591). Two main glacial advances

occurred near the region of the study area, with the furthest advancement of the glaciers, relative to the study area, being to the north and west of the area boundaries (Baker,1946,591). The natural dams confining New Fork Lakes and creating "The Narrows" at New Fork Lakes (Location B in figure 1) are two recessional moraines associated with the most recent of these two glacial sequences (Baker, 1946,592). This same glacial advance is responsible for the terminal moraine which forms the dam at Fremont Lake and extends south to the east end of the town of Pinedale, Wyoming (Baker,1946,592). The large accumulation of outwash and fluvial material deposited to the east of the study area is a result of these two glacial periods (Figure 3).

7. The formation of the two most recent terrace features that dominate the topography of the study area may be attributed to the retreat stages of the last major glacial period (Baker,1946,596).
8. Finally, the recent alluvial deposits are a result of the workings of the stream systems and slope runoff within the study area.

Lithologically, the Wasatch Formation is comprised predominantly of sandy gray mudstone interfingered with sandstone lenses (Bradley,1964,A21). The glacial deposits consist of crystalline rocks, mostly in the sand and gravel size range, with an admixture of Tertiary clay (Holmes and Moss,1955). The alluvial deposits contain a combination of the latter two geologic units, the Wasatch Formation and the glacial deposits.

Summarizing, the geology of the PRFP study area is dominated by the fine grained Wasatch Formation which underlies and borders to the north, south and west, the alluvial aquifer that was studied (Figure 3). The east boundary of the study area is a combination of glacial outwash material and the Wasatch Formation. A series of erosional episodes created the regional topography that exists today.

The alluvial aquifer ranges in thickness from zero feet at the watershed boundaries to approximately 40 feet near the center of the study area (Figure 4). The delineation of the aquifer thickness is discussed in chapter IV. The aquifer is composed primarily of reworked Tertiary Wasatch material with the exception of the material deposited along the southeastern boundary of the study area which is reworked glacial outwash sands and gravels.

PINEDALE RETURN FLOW PROJECT

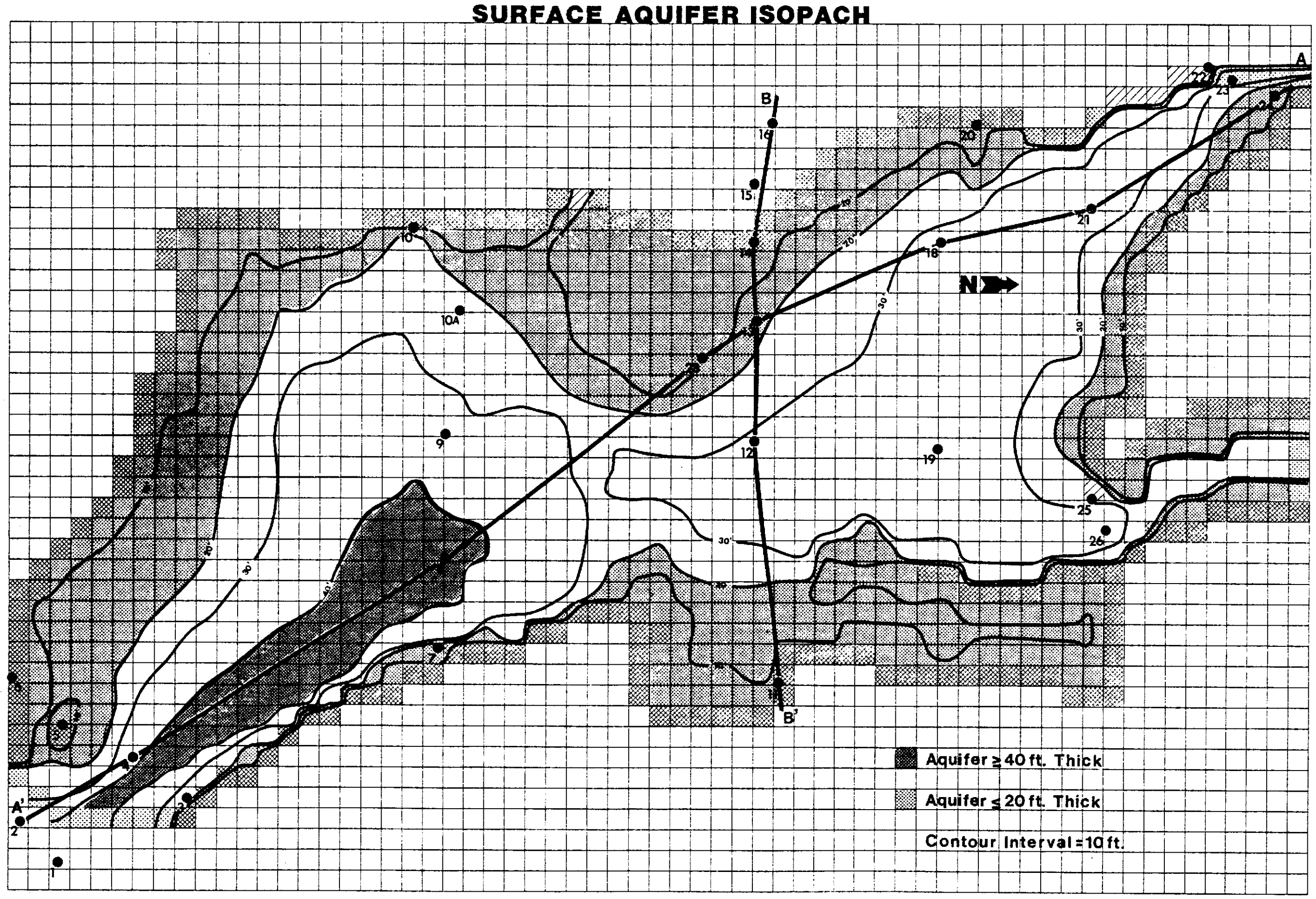


Figure 4. Pinedale Return Flow Project Surface Aquifer Isopach Map.

CHAPTER IV

METHODOLOGY

The purpose of this thesis is to determine the percentage of diverted water returning to the downstream system. The streamflow exiting the PRFP study area is comprised of the following hydrologic elements (Figure 5).

1. Channel Flow: Flow remaining within the stream banks for the entire length of the study area.
2. Surfacing Groundwater Flow: Groundwater inflow that surfaces and enters the stream system before leaving the study area.
3. Precipitation: The volume of flow exiting the study area as a direct result of precipitation.
4. Overland Flow: Diverted flow returning to the stream system along the land surface.
5. Return Flow: Diverted flow that infiltrates the alluvial aquifer before surfacing and returning to the channel network.

A water budget analysis, aided by the use of the USGS finite - difference groundwater modelling program (McDonald and Harbaugh, 1984) was used to separate these hydrologic elements from the total surface outflow.

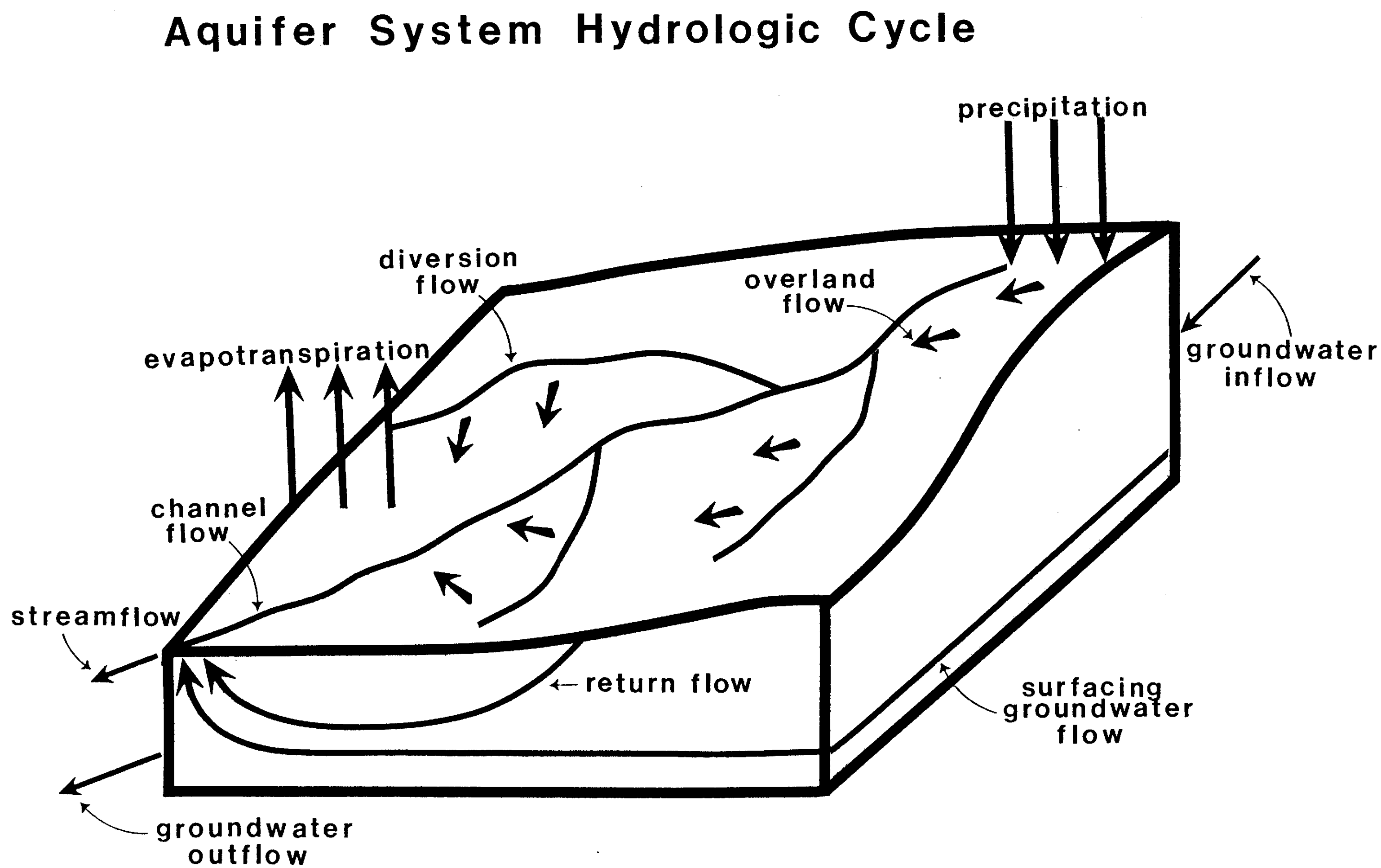


Figure 5. Schematic of Surface Aquifer Hydrologic Cycle.

Water Budget Analysis

The primary objective of the water budget analysis was to calculate the net groundwater inflow (inflow minus outflow). The water budget equation adopted for use in this thesis is

$$(I_g - O_g) = \Delta S - (I_s - O_s) - (P - Et) \qquad (4.1)$$

where:

$I_g - O_g$	is the net groundwater inflow;
ΔS	is the change in storage of the alluvial aquifer;
I_s	is the surface water inflow;
O_s	is the surface water outflow;
P	is the precipitation; and
Et	is the evapotranspiration.

Each term, on the right hand side of the above equation, was measured directly in the field, with the exception of the change in storage. The field monitoring techniques used to gather this information will be discussed in chapter V.

Finite - Difference Model

The finite-difference groundwater model was used to calculate the change in storage and recharge volume of the alluvial aquifer. The USGS finite-difference groundwater modelling program was selected by Peck (1985) over the other possible models reviewed. Reasons for this selection, as noted by Peck (1985) are summarized below.

1. The USGS program could simulate stream-aquifer interaction using a two-dimensional analysis.
2. Data input and documentation of the USGS model made this program simpler to use than the other programs researched.
3. River stage data was input directly into the USGS program. This direct data input circumvented the need for using Manning's Equation to calculate the river stage. Manning's Equation assumes a uniform flow condition which was determined to be an invalid assumption for this study area.
4. The USGS program outputs a detailed water budget that was easily incorporated into the return flow calculations.

This groundwater modelling program calculates a change in head, over time, for each of the finite-difference cells using an implicit solution to the following equation:

$$\partial/\partial x[k_x(\partial h/\partial x)b\Delta y]\Delta x + \partial/\partial y[k_y(\partial h/\partial y)b\Delta x]\Delta y = S_y\Delta x\Delta y(\partial h/\partial t) + W \quad (4.2)$$

Where:

k_x and k_y	are the hydraulic conductivity in the x and y direction, respectively;
h	is the head elevation;
b	is the saturated thickness (calculated by subtracting the elevation of the

aquifer bottom from the head);

S_y is the specific yield; and

W is the volumetric flow rate of a source or sink (i.e. injection well or pumped well).

A more detailed explanation of the means by which this model handles the various sources (or sinks) and the development of the groundwater flow equation can be found in Peck's (1985) thesis.

The PRFP finite-difference grid (Figure 6) is comprised of 2457 individual cells (63 rows by 39 columns). Cell dimensions are 800 feet by 800 feet and the hydraulic conductivity of the cell is assumed to be isotropic. Each cell is assigned a value for the following model input parameters:

1. Starting head elevations;
2. Aquifer bottom elevations;
3. River stage;
4. River bottom elevations;
5. Specific yield;
6. Hydraulic conductivity;
7. River bottom conductance;
8. General-head boundary interface conductance; and
9. Elevations of constant-head cells and the constant-head source for the general-head boundary.

The parameters that concern river and general-head boundary

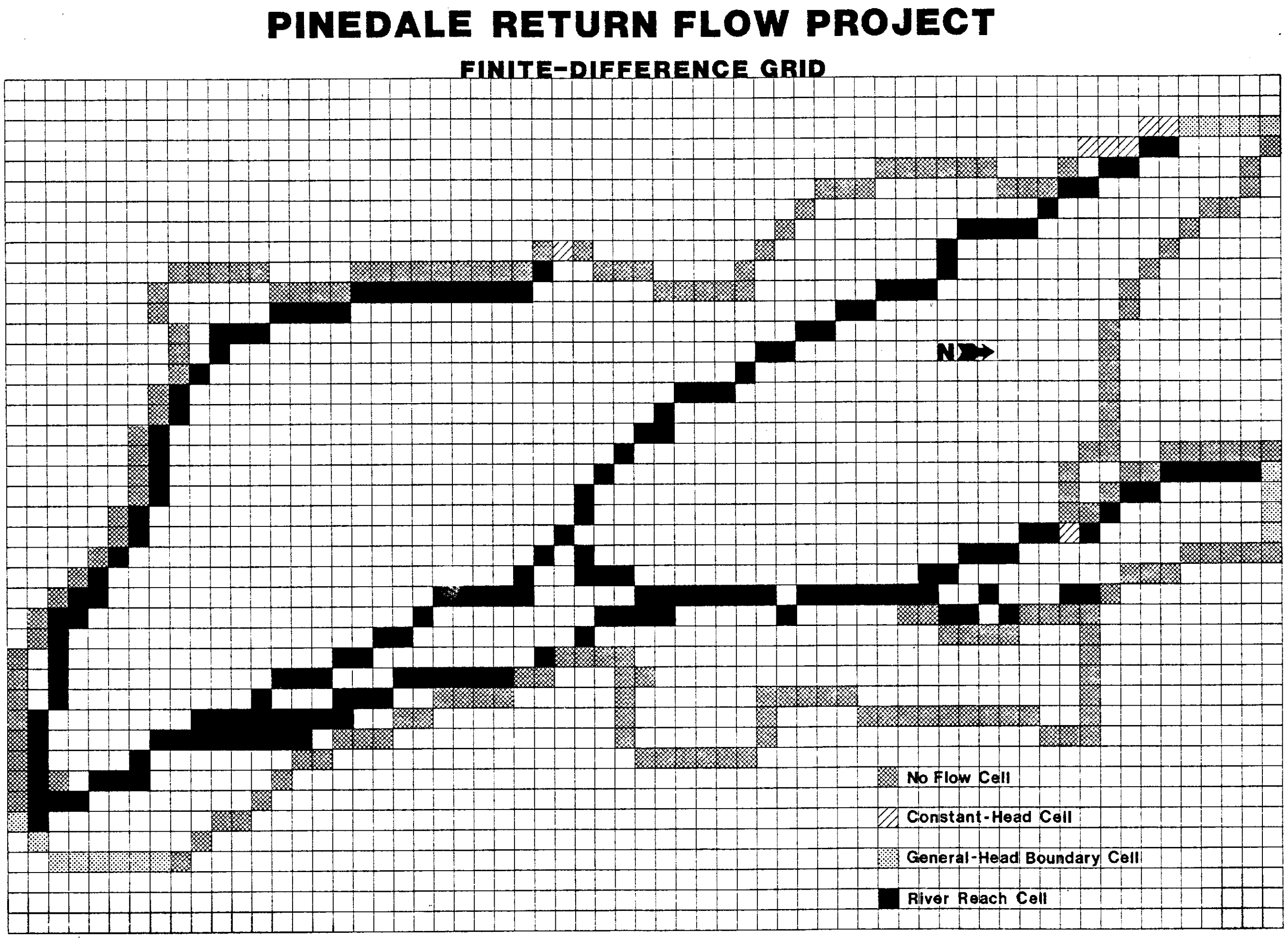


Figure 6. Pinedale Return Flow Project Finite-Difference Grid.

information are only assigned to those cells which contain a river reach or are a general-head boundary, respectively.

The three cell classifications handled by this program are (1) no-flow, (2) variable-head and (3) constant-head. No-flow cells are excluded from all flow calculations. Constant-head cells are assigned a head elevation that remains fixed for the duration of the simulation period. Groundwater elevation in a variable-head cell is allowed to fluctuate with time. This fluctuation is dependent upon the flow conditions in the surrounding cells. A detailed description of the PRFP finite-difference grid configuration and the methodology for determining the input parameters follows.

Finite-Difference Grid

The relatively impermeable Wasatch bluffs surrounding the alluvial aquifer (Figure 3) are modelled by no-flow cells (indicated by the cross-hatching in figure 6). The additional no-flow cells that exist in the northeast section model a north-south trending ridge (Figure 2). This relief feature is assumed to be comprised of Tertiary Wasatch material. The no-flow cell located near the outlet and well number five, represents a small knoll consisting of fine grained material, as was recorded by the drill log from well number five (Appendix A).

Constant-head boundary cells are located in the west-central, northwest and north-central sections of the study area (indicated by diagonal lines in figure 6). The west-central location is the cell modelling the entrance of Duck Creek into the study area. This area is generally marshy in composition, indicative of surface saturation. The surface elevation was therefore assigned as the constant-head elevation for all simulation periods. The constant-head boundary in the northwest region, above the Bar-Cross Ranch, was utilized to model the saturation of the Tertiary bluff caused by seepage through Jenkins Ditch. Jenkins Ditch diverts water from the New Fork River, north of the study area and transports it south, through this Wasatch bench, until nearly abreast of the Bar-Cross Ranch. The ditch, at this point, bends to the west and flows away from the study region. The water volume that seeps into the bluffs is held within the tight Wasatch units for long periods of time. Evidence of this soil moisture include a lush vegetation growth, mostly grasses, and noticeable escarpments caused by the slumping of the heavy, water laden, soils. The last constant-head cell, containing well number 25, is located near Willard Binning's ranch. A maximum recorded water table fluctuation in this well of 3½ feet, with an average variation of approximately 1½ feet (Appendix D), allowed this area to be modelled by a constant-head condition.

The most complex boundary condition is the general-head boundary (indicated by dots in figure 6). There are three general head boundaries associated with the PRFP study area. Each general-head boundary area will be discussed in detail later. The basic concept of this boundary condition entails a constant-head source, located outside of the model area, controlling the flow of water to the boundary cell at a rate determined by the interface conductance (Figure 7). The flow into the general-head boundary cell from the constant-head source is determined by multiplying the interface conductance value by the head variation between the constant-head source and the boundary cell. The general-head boundary cell is a variable-head cell that is dependent upon this constant-head source and the flow conditions in the surrounding cells.

General-Head Boundary at Bar-Cross Ranch:

The constant-head source for this location was the Tertiary bluff containing Jenkins Ditch. This saturated bluff supplies a constant source of water to the alluvial aquifer located in the New Fork Valley. Elevation of the constant-head source varied with each simulation period. The groundwater elevation in well number 22 (Figure 2) at the beginning of each simulation period was assigned as the constant-head source for the three southern most general-head boundary cells. The elevation for the remaining two

GENERAL-HEAD BOUNDARY DIAGRAM

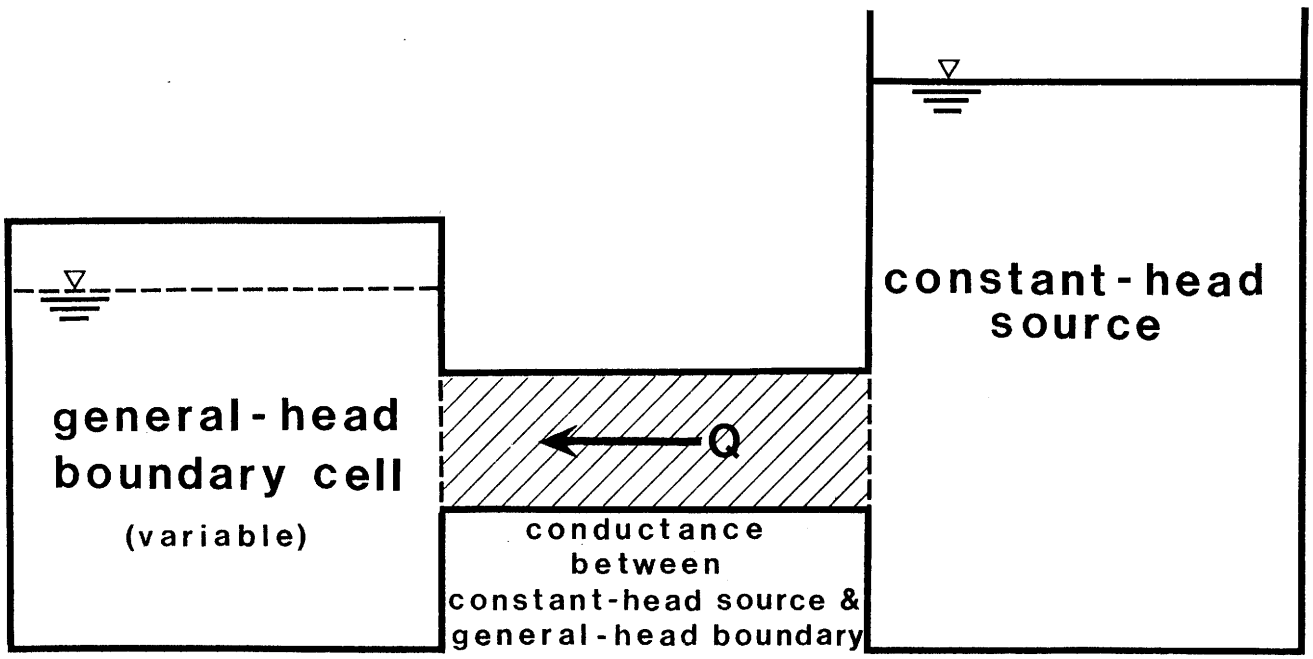


Figure 7. Schematic of the Principle of the General-Head Boundary.

boundary cells was the groundwater elevation in well number 22, plus twenty feet. Flow is transmitted through an interface with a conductance calculated by the following equation (McDonald and Harbaugh,1984):

$$C = kwd/L \qquad (4.3)$$

where:

- C is the conductance (ft^2/day);
- w is the width of the interface (ft);
- d is the depth of the interface (ft);
- L is the length of the interface (distance between the boundary cell and the constant-head source) (ft); and
- k is the hydraulic conductivity of the interface (ft/day).

The interface conductance in the Bar-Cross Ranch area ranged from 1.6 to 2.4 ft^2/day. The hydraulic conductivity of this interface material was assumed to be 0.5 ft/day. This low hydraulic conductivity value is representative of the value assigned the variable-head cells modelling the alluvial aquifer adjacent to these Tertiary bluffs.

General-Head Boundary North of Willard Binning Ranch:

A general-head boundary was used to simulate the inflow of water from the alluvial aquifer system that extends north, past the PRFP area boundary. The constant-head source at this location was the marshlands situated at an elevation of 7600 feet, approximately four miles north of the study area boundary (Location C in figure 1). This source remained fixed for all simulation periods. The low permeable aquifer material in this region was assumed to extend north to the marshlands, resulting in an interface conductance of 0.2 ft^2/day.

General-Head Boundary at the Outlet:

A general-head boundary condition was utilized at the outlet to account for the continuation of the alluvial aquifer past the study area boundary. The outflow from the aquifer system was controlled by an interface with a conductance of 40,000 ft^2/day. This large conductance value is influenced by the high aquifer transmissivity associated with the glacial outwash material deposited in this area and the narrowing of the alluvial system in the outflow region. The confluence of New Fork River and Pine Creek (Location D in figure 1) served as the steady-state source. The 7100 foot confluence elevation remained fixed for all simulation periods.

The cells within the study area boundary, including the river reach cells, are all variable-head cells. This excludes the no-flow and constant head cells that have been mentioned previously.

Model Input Parameters

Starting Heads:

Initial starting heads were calculated for the 1985 haying season (7/24/85 - 9/2/85). The groundwater level at the start of this period was at or near the land surface, allowing the use of a USGS topographic map to aid in assigning starting head elevations. The following steps were involved in establishing these starting heads.

1. The finite-difference grid was laid over the USGS 7.5 minute topographic map (the grid map matched the USGS map scale of 1:24000).
2. Well elevations recorded in the field on July 23, 1985 were assigned to those cells containing the well locations.
3. A contour map of the starting head elevations was constructed using this well information and by following the surface elevation contour pattern, where well data was lacking (Figure 8).
4. Starting heads were read directly from this contour map. Interpolated elevations were assigned to those cells falling between the ten foot contour lines.

Aquifer Bottom Elevations:

Aquifer bottom elevations were determined using the drill logs from the groundwater monitoring wells (Appendix

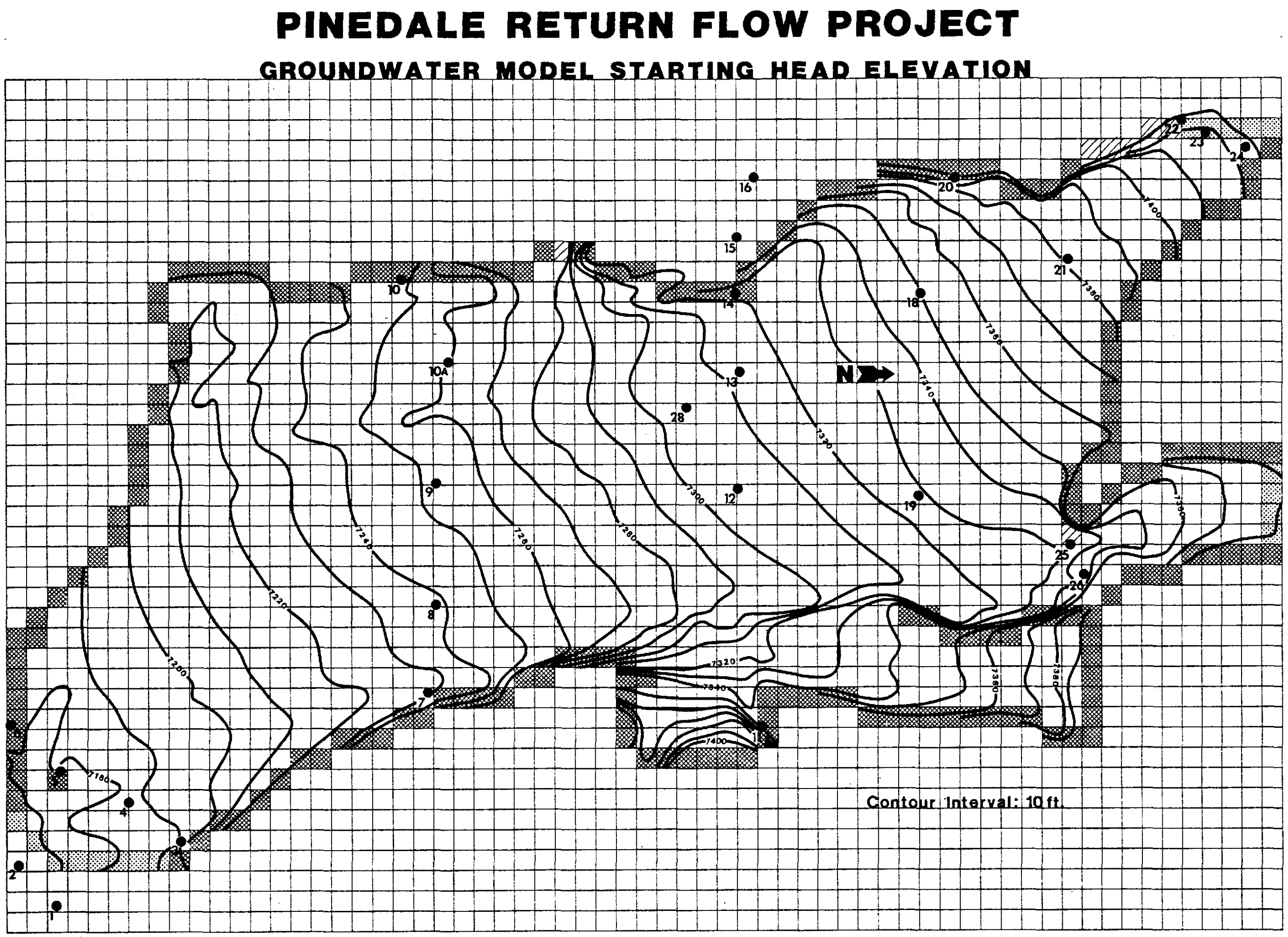


Figure 8. Pinedale Return Flow Project Groundwater Model Starting Head Elevations.

A) and by interpretation where insufficient data existed. Many of the wells in the interior of the study area did not completely penetrate the alluvial aquifer. The aquifer bottom depths were interpreted in these regions. The procedure followed in assigning aquifer bottom elevations to the PRFP study area is outlined below.

1. Bottom elevations were assigned to those cells containing wells that completely penetrated the alluvial aquifer.
2. Cross-sections of the alluvial aquifer were made from the monitoring well drill logs and the surface geology map (Welder,1968). Discussions with the area ranchers, estimates based on the surface topography and known aquifer bottom slopes were utilized in assigning aquifer thicknesses to those cross-sectional areas lacking data. Figure 9 shows two of these generalized profiles. The two profile locations can be found on figure 4.
3. An isopach map of the alluvial aquifer was made utilizing the computer program "EZCONTOUR" that is available on the Prime computer system at the University of Wyoming. The 200 data points that can be entered into the EZCONTOUR package were taken from the cross-sections.
4. The EZCONTOUR program, as an option, wrote out the isopach values for each cell (2457 values). These

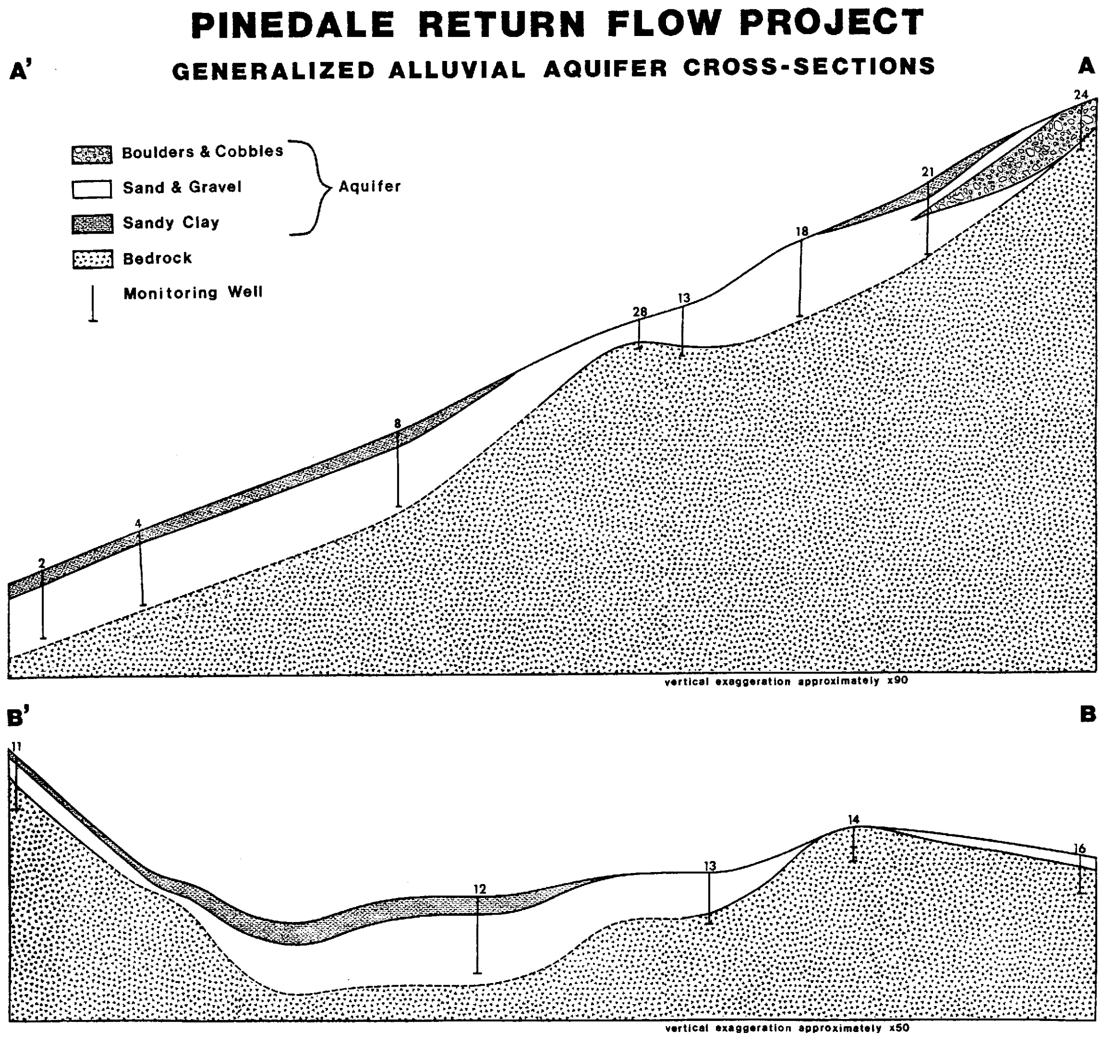


Figure 9. Generalized Cross-Sections of the Pinedale Return Flow Project Alluvial Aquifer.

data were edited to better fit the interpreted field conditions.

5. Aquifer bottom elevations were obtained by subtracting the isopach data from the surface elevations.
6. These aquifer bottom elevations were hand posted and contoured. The map was adjusted using the USGS topographic map as a guide to the general configuration of the aquifer bottom. Figure 10 is this final adjusted map.
7. The isopach data were edited to fit the modified aquifer bottom data and recontoured as a final check on the uniformity of the aquifer bottom elevations. Figure 4 is this final aquifer isopach map.
8. The aquifer bottom elevations were taken directly from the aquifer bottom contour map (Figure 10). Elevations were interpolated for those cells falling between the 20 foot contour lines.

River Stage:

River stage values were input for the major streams in the study area. These streams are (1) the New Fork River, (2) Willow Creek, (3) Lake Creek, (4) Willow Creek Diversion and (5) Duck Creek. Streamgages located along these streams recorded the river stage daily, from early spring to late

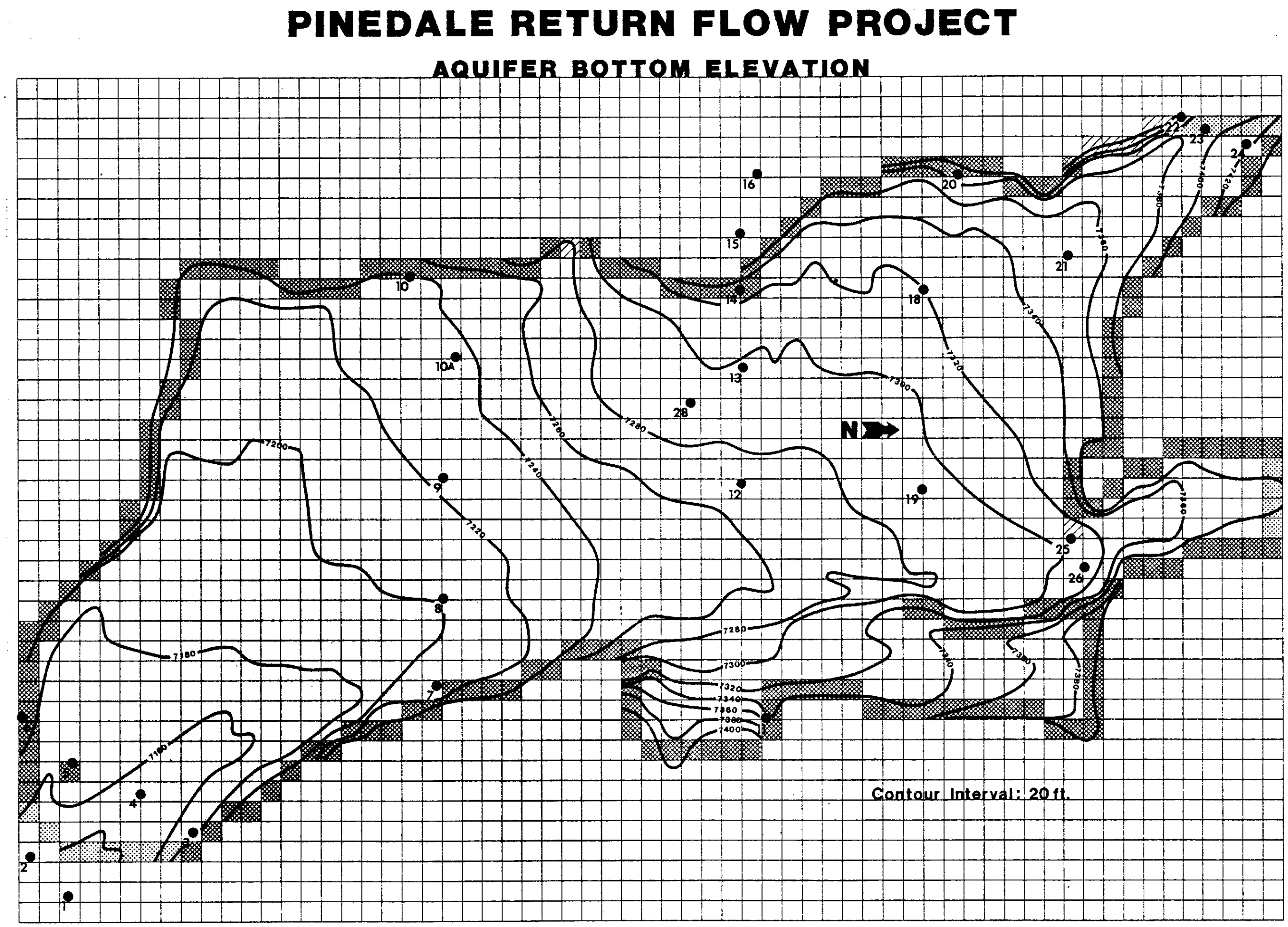


Figure 10. Pinedale Return Flow Project Aquifer Bottom Elevations.

fall, using Stevens and Leupold Type F1 continuous stage recorders. These streamgages (marked by a small black triangle) and the letter identifying their location in figure 2 are as follows:

C New Fork River below Barlow's bridge;

F New Fork River at Jim Noble's;

N New Fork River at Dick Noble's;

O New Fork River at Leopold's;

R New Fork River at the county road;

Z New Fork River below Duck Creek;

S Willow Creek at Willard Binning's ranch;

X Willow Creek at the county road;

U Lake Creek;

P Willow Creek Diversion; and

Y Duck Creek below Kitchen Reservoir.

Three additional staff gages, without recorders, were established along Duck Creek (Figure 2). These staff gages (symbolized by a small black square) are

a Duck Creek at Cora Highway,

b Duck Creek at the county road, and

c Duck Creek at Highway 191.

Stage elevations were recorded weekly at these three locations. A level circuit, performed in 1985, established the PRFP staff gage elevations. Linear interpolation determined the river stage elevations for those river reach cells located between the cells containing staff gages.

River Bottom Elevations:

River bottom elevations were established by subtracting the water depth (taken from stream discharge measurement data) from the staff gage reading. The river bottom elevations were assigned by linear interpolation for those cells in between staff gage locations.

Adjustment of River Stage and River Bottom Elevations:

Initial program executions calculated a substantial volume of groundwater entering the stream system. A large discrepancy between the true riverbed elevation (obtained by the level circuit) and that of the initial starting head elevation (an average surface elevation for the 640,000 square foot finite-difference cell) was found. This discrepancy, in many instances, was as much as 17 feet. The modelling program was erroneously calculating an influx of water into the stream system from a aquifer water table standing 17 feet above the river bottom. This error was adjusted by establishing a new riverbed and stage elevation. The riverbed elevation was adjusted by subtracting 1½ feet from the initial starting head elevation. The new river stage was determined by adding the initial stream depth of each cell to this adjusted river bottom elevation.

Hydraulic Conductivity:

Constant-rate pump tests were conducted during the summer of 1988 to determine the aquifer hydraulic conductivity values. The drawdown was measured in the pumped well in all tests, allowing only transmissivity values to be calculated. Appendix B lists the wells that were tested and the associated aquifer transmissivities. The hydraulic conductivity value was determined by dividing the calculated transmissivity by the saturated aquifer thickness. Hydraulic conductivities were assigned to those cells that do not contain a monitoring well by a trial and error technique to be discussed later in the model calibration section of chapter VI. Hydraulic conductivity values range from 0.5 ft/day to 32,000 ft/day (Figure 11). The distribution of these values appears to be heavily dependent upon the pre-Quaternary geologic formations. The low permeability areas are located next to, and radiate away from, the Tertiary Wasatch benches. The alluvium has buried a lower extension of the terrace containing wells 14, 15 and 16 (Figure 2). This feature is evident in well numbers 13 and 28 (Figure 9) and appears to strongly influence the aquifer transmissivity in this area. The high transmissivity area is concentrated in a narrow band extending from the east-central to southeast section of the study area (Figure 11). Explanation for this anomalous feature is found in the glacial deposits located to the east of the PRFP study area. The large cobbles and gravels associated with this outflow material constitutes a much less resistive

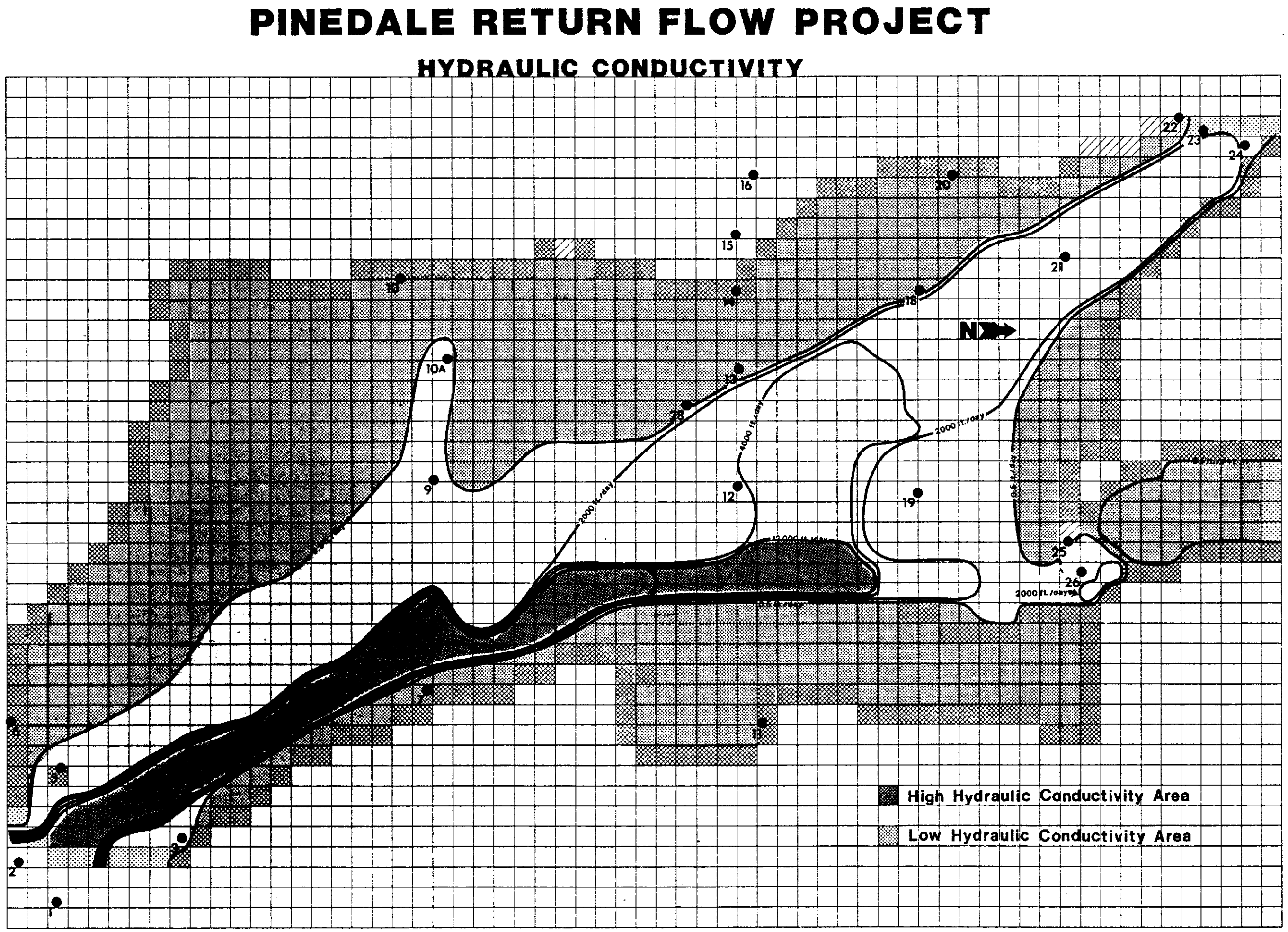


Figure 11. Pinedale Return Flow Project Hydraulic Conductivity Map.

path to water movement.

The general configuration of the hydraulic conductivity values, with the highest values located at the lower end of the drainage basin, is contrary to a majority of alluvial aquifer systems. Generally the large, heavy sediment loads are deposited first, high on the watershed, with the lighter, less permeable material being transported further downstream. The regional geology and the flood control in the study area; however, provides sufficient evidence for the feasibility of this anomalous transmissivity distribution.

Riverbed Conductance:

Riverbed conductance is defined by the following equation (McDonald and Harbaugh,1984):

$$C = kwL/d \qquad (4.4)$$

Where:

- C is the conductance (ft^2/day);
- k is the hydraulic conductivity of the riverbed (ft/day);
- w is the riverbed width (ft);
- L is the reach length (ft); and
- d is the thickness of the riverbed (ft).

The riverbed conductance controls the discharge from the aquifer into the stream or from the stream into the aquifer in the following manner:

$$Q = \Delta hC \tag{4.5}$$

where:

Δh is the head variation between the river stage and the phreatic head elevation (ft.) and

C is the riverbed conductance value (ft^2/day).

Reach length and riverbed width were obtained from the USGS 7.5 minute topographic map and field measurements, respectively. The hydraulic conductivity and the riverbed depth however, were not measured. An iterative process was used to assign riverbed conductance values. Several combinations of riverbed conductance and aquifer hydraulic conductivity values yielded groundwater model results that matched the field measured groundwater elevations. The actual riverbed conductance/aquifer hydraulic conductivity combination that accurately describes the alluvial aquifer was undeterminable due to a lack of time and data. The iterative process was instead simplified by assigning a constant riverbed conductance to the reach cells and varying the aquifer hydraulic conductivities for each simulation period until the field recorded data was matched. This calibration process will be discussed in more detail in chapter VI. The riverbed conductance values assigned were determined using the following observations and calculations:

1. Visual observation identified a significant amount

of fine grained material contained in the riverbed.

2. The tight flood control on the river discharge has cut down on the disturbance of the river bottom sediments.
3. The major streams within the study area cut through the fine grained soils of the alluvial aquifer or are directly adjacent to them (Figure 11).
4. A hydraulic conductivity of 0.5 ft/day was assigned to the riverbed based upon the three previously mentioned observations.
5. An estimated riverbed depth of 0.75 feet was assigned to each river reach cell.
6. A reach length and stream width of 800 feet and 30 feet were assigned each reach cell (a more detailed calculation of the reach length and stream width was unwarranted due to the previous generalization of the riverbed depth and hydraulic conductivity).
7. A final riverbed conductance of 12,000 ft^2/day was calculated for the majority of the reach cells using equation 4.4.
8. The conductance of the reach cells in the vicinity of well number 26 were determined by varying the conductance value associated with these cells for

each individual simulation run until the model results matched the measured well elevations. This process will be described in more detail in the model calibration section of chapter VI.

Specific Yield:

Specific yield values were not obtainable from the field data gathered; therefore, the generally accepted value for an unconfined aquifer of 0.2 was used for the entire modelled area (Freeze and Cherry,1979). A sensitivity analysis performed by Hilaire Peck (1985) indicated that the model was relatively insensitive to the specific yield parameter and that the time and expense involved to more accurately establish the specific yield would be unjustified.

CHAPTER V

FIELD MONITORING SYSTEM

Data needed to perform the water budget analysis and to perform the simulation models were obtained from an extensive field monitoring system established in the spring of 1984 and operated through the summer of 1988. This system included: streamgages, staff gages, groundwater monitoring wells and precipitation gages, with lysimeters being utilized from a nearby site.

Field data collected for the water budget analysis included (1) surface inflow, (2) surface outflow, (3) groundwater levels, (4) precipitation and (5) evapotranspiration. The recorded data for the groundwater model input was (1) river stage, (2) riverbed elevation, (3) groundwater elevations and (4) hydraulic conductivity values. A measurement of the total diversion flow volume within the study area was the final monitoring setup. A detailed description of the individual data acquisition methods will now be discussed.

Surface Inflow:

Thirteen sources of inflow into the PRFP study area were identified. Ten of these inflows were monitored using

Type F1 continuous stage recording streamgages manufactured by Leupold and Stevens, Inc. These inflow sources (marked by a small black triangle) and the letter identifying their location are listed below (Figure 2):

C	New Fork River below Barlow's bridge;
B	Lane Ditch;
_	Wright Ditch (located off of map area);
_	Rahm Ditch (located off of map area);
T	Ditch at Willard Binning's ranch;
S	Willow Creek at Willard Binning's ranch;
V	Binning Ditch;
U	Lake Creek;
W	Highline Ditch, upper (1984-1985);
W'	Highline Ditch, lower (1985-1988); and
Y	Duck Creek below Kitchen Reservoir.

The three additional surface inflow sources were (1) the spring in the northeast corner of the study area entering near the Binning Ranch, (2) the spring water from Spring Gulch flowing into the PRFP area near well number 11 and (3) the culvert flow entering the study area near wells 25 and 26. The culvert flow originates from water diverted from Willow Creek and Lake Creek north of the study area boundary. The culvert locations marked the original northern boundary in this section of the study area. However, due to the difficulty in the modelling of this region, the boundary was moved further north to the present location, at the expense of accurately measuring the surface inflow.

Surface inflow data was collected from early spring to late fall. The continuous stage recorder charts were changed weekly (monthly in the early spring and late fall) and weekly recordings of the inflows from the springs and culverts taken. Discharge values were assigned to the recorded stage values by rating curves developed from the gaged streamflow. A velocity-area method of stream gaging was implemented; stream velocity was measured using Price AA and Pygmy current meters.

Culvert flow was estimated by placing staff gages at the entrance and exit of the culverts and using culvert hydraulics. The United State Department of Commerce publication "Hydraulics Charts for the Selection of Highway Culverts" (1965) was used in the estimation of culvert flow.

The inflow contributed by the springs was minimal throughout the study period; therefore, flow volumes were obtained by visual estimation only. A check on the flow estimation was performed sporadically by gaging the spring discharge using the velocity-area gaging technique.

Inflow into the study area during the winter months was not monitored. The average monthly discharge rate of the last month monitored (usually October/November) was assumed to remain constant through the winter months. This constant rate multiplied by the number of winter days established the winter inflow volume.

Surface Outflow:

A servo-manometer stage recorder, operational year around, was used to measure the surface outflow. This station and the letter identifying its location in figure 2 are

Z New Fork River below Duck Creek.

Recorded stage values during the winter months were questionable due to the heavy buildup of ice above the servo valve. This additional pressure resulted in erroneous stage values. The outflow discharge for the winter months was estimated using the same procedure described for the surface inflow calculations. The velocity-area gaging method was used to build the rating curve for this streamgage station. Appendix C contains the rating curves for all of the recorder locations and the data used to construct them.

Precipitation:

Precipitation data were obtained from three raingages. A standard eight-inch diameter bucket-type raingage was installed at Floyd Briggs' home near the center of the study area (Figure 12). Weather stations operated by the National Oceanic and Atmospheric Administration (NOAA) recorded precipitation for the rest of the study area. Precipitation data in the northern end were supplied by station "Cora 4N" located at the Bar-Cross Ranch and the southern section by

PINEDALE RETURN FLOW PROJECT

THIESSEN POLYGONS

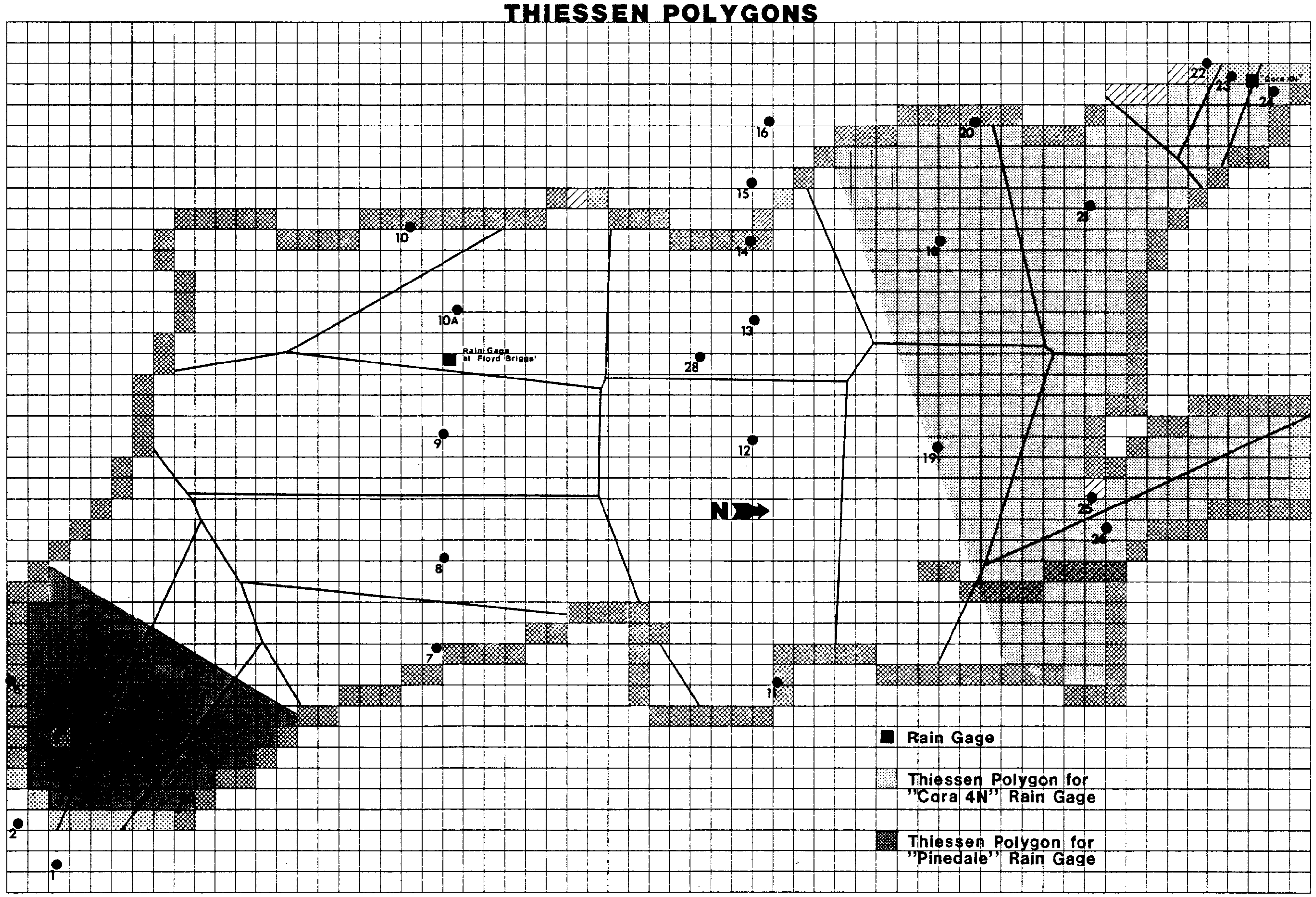


Figure 12. Map Showing the Thiessen Polygons Used to Calculate the Change in Storage of the Pinedale Return Flow Project Alluvial Aquifer and the Raingage Locations.

station "Pinedale", located in the town of Pinedale. Precipitation was applied to the study area using the Thiessen Polygon Method (Figure 12). The polygons in figure 12 for precipitation distribution are the two shaded areas and the large unshaded region in the center portion of the study area. The small individual polygons surrounding the groundwater monitoring wells are the Thiessen polygons used in calculating the change in aquifer storage volume, which will be discussed at the end of chapter VI. Daily precipitation amounts were recorded at the NOAA stations while weekly records were maintained at the raingage located at Floyd Briggs' house.

Evapotranspiration:

Evapotranspiration estimates were made from lysimeter data taken at a nearby site. The lysimeter site, near Daniel, Wyoming, approximately 5 miles from the PRFP study area (Figure 1), was affiliated with the study performed by the Agricultural Engineering Department of the University of Wyoming termed the "Green River Project." This project was funded by the Wyoming Water Development Commission (WWDC) and the Wyoming Water Research Center (WWRC). The purpose of the Green River Project was to develop a method for estimating the evapotranspiration throughout the Green River Basin of Wyoming and to determine irrigation water requirements from the Green River (Peck,1985,41). The major hay crop at both the lysimeter location and the PRFP study area is timothy grass. The uniqueness of the hay crops and the similarities between the two areas, allowed the implementation of these data into the PRFP study.

The evapotranspiration volumes associated with the riparian vegetation was neglected. The area covered by vegetation of this type constitutes a small percentage of the total study area and would therefore have very little effect on the overall evapotranspiration volume. The average evapotranspiration rate for the riparian vegetation plus the sagebrush covered benches contained within the study area was also assumed to be nearly that of the rate assigned to the irrigated hay fields.

Groundwater Elevations:

A grid of 27 wells located throughout the study area was utilized to monitor groundwater levels (Figure 2). These data were input into the finite-difference model in an effort to determine the storage response times of the aquifer. Twenty-five of these wells were installed at the beginning of the project. These wells were drilled (8" hole) by Chen and Associates, Inc. Casper, Wyoming, in the spring of 1984. The wells were screened (4" PVC screen) the entire depth of the well with the exception of the top five feet, which was cased with four-inch PVC pipe. These wells were drilled to a maximum depth of 30 feet or until the alluvial aquifer was completely penetrated. The remaining two wells (numbers 10A and 15) were existing water wells that were incorporated into the study. Groundwater levels were measured weekly during the spring through fall period and measured monthly during the winter months. The elevation of the top of the well casing was established by a level circuit performed in the summer of 1984. Measurements were taken using a chalked steel tape. Appendix D contains the well data.

Hydraulic Conductivities:

A one-half horsepower submersible pump capable of 16 gpm pump rate was used in the pump tests. The drawdown was measured, in the pumped well, using a cloth tape with a water contact beeper attached to the end. Tests were carried out on two separate occasions. The first tests were conducted during the 1988 aquifer recharge period when the water table was at or near the land surface. The submersible pump could not draw down several of the wells during this period. Pump tests were repeated during the 1988 haying season when the water elevation had lowered, in an attempt to obtain data for those wells that could not be previously drawn down. Several of the wells could still not be drawn down, resulting in an unobtainable transmissivity value. Hydraulic conductivity values were assigned to these locations by the trial and error technique to be discussed in chapter VI.

River Stage and Riverbed Elevation:

The techniques used to obtain these data were described in the model input section of chapter IV.

Diversion Flow:

Twelve streamgages, located on the major diversion ditches, measured the total volume of diverted stream flow within the study area (Figure 2). These diversion ditch recorders (marked by a small black triangle) were:

D Ulrica Ditch;

E West Fork Ditch;

G Densley-Merritt Ditch;

H McDonough Ditch:

d Harry Rahm Ditch;

I Alexander Ditch;

J Edmundson Ditch;

K Converse Ditch;

L Yampa Ditch;

M Bel-Knap Noble Ditch;

P Willow Creek Diversion; and

Q Bee-Line Ditch.

Daily stage values were recorded for the above ditches from early spring to late fall or, until the headgates were closed, at which time the recorders were removed. Rating curves were established as described for the surface inflow/outflow and a discharge rate assigned to the average daily stage value.

The streamgages located along the major streams could be used as a check on the diversion flow. The streamflow variation between the gages would be a fair representation of the diversion flow volume. This method of estimating the diversion flow will be affected by any return flow/overland flow that enters the stream between the two streamgage locations.

Seepage Adjustment:

The last part of the field acquisition was an analysis of the seepage rate associated with Jenkins Ditch. This seepage volume was obtained by establishing two streamgages along Jenkins Ditch, approximately three miles apart (Lower Jenkins Ditch recorder is location A in figure 2). There were no diversion points located between the two streamgage locations; therefore, any difference in discharge between these two streamgages could be attributed to seepage. A maximum seepage adjustment, to the flow volume, of 33 percent per mile of ditch was noted in three out of the four data collection years. This seepage rate was applied to the flow volumes in Wright Ditch, Rahm Ditch and Highline Ditch to adjust for the distance between the PRFP study area boundary and the respective recorder locations. The field monitoring method is summarized below.

1. Surface inflow was measured using 10 continuous stage recorders, culvert hydraulics and visual estimation of spring flow.
2. A seepage rate was determined by measuring the change in flow volume between two streamgages located along Jenkins Ditch.
3. Riverbed elevation and river stage were measured daily by 11 continuous stage recorders and supplemented by the weekly reading of three additional Duck Creek staff gages.
4. Transmissivity values were obtained from constant-rate pump tests.
5. Precipitation data were supplied by 3 raingages located at the north, south and center of the study area.
6. Evapotranspiration data were estimated using lysimeter data from the Green River Project study site located near Daniel, Wyoming.
7. Daily diversion flow records were obtained by locating 12 continuous stage recorders on the major diversion ditches within the study area.
8. Groundwater levels were measured in 23 monitoring wells located throughout the study area. Two of the unmonitored wells were determined to not accurately measure the aquifer response (Numbers 6

and 11). The remaining two wells were left unmonitored because (1) the landowner refused access after the initiation of the project (Number 14) and (2) the well was in direct contact with the New Fork River (Number 28).

CHAPTER VI

MODEL SIMULATION AND CALIBRATION

Model Simulation

The response of the alluvial aquifer to artificial recharge from flood irrigation was simulated by the USGS groundwater modelling program. The simulation of the aquifer response was broken down into seven modelling periods, starting with the spring runoff interval. These modelling periods were established based on the groundwater level fluctuations associated with each period. Figure 13 shows the relationship of the simulation periods and the measured groundwater level response in well number 19. The seven simulation periods are described as follows:

1. Spring Runoff: This period incorporates the aquifer response to the spring snowmelt and early spring showers and is marked by a rise in the groundwater elevation.
2. End of Spring Runoff: This is the period between the heavy spring runoff and the flood irrigated recharge of the aquifer. The water table elevation in this period shows a slight decline.
3. Recharge: The recharge period simulates the artificial recharge of the alluvial aquifer due to

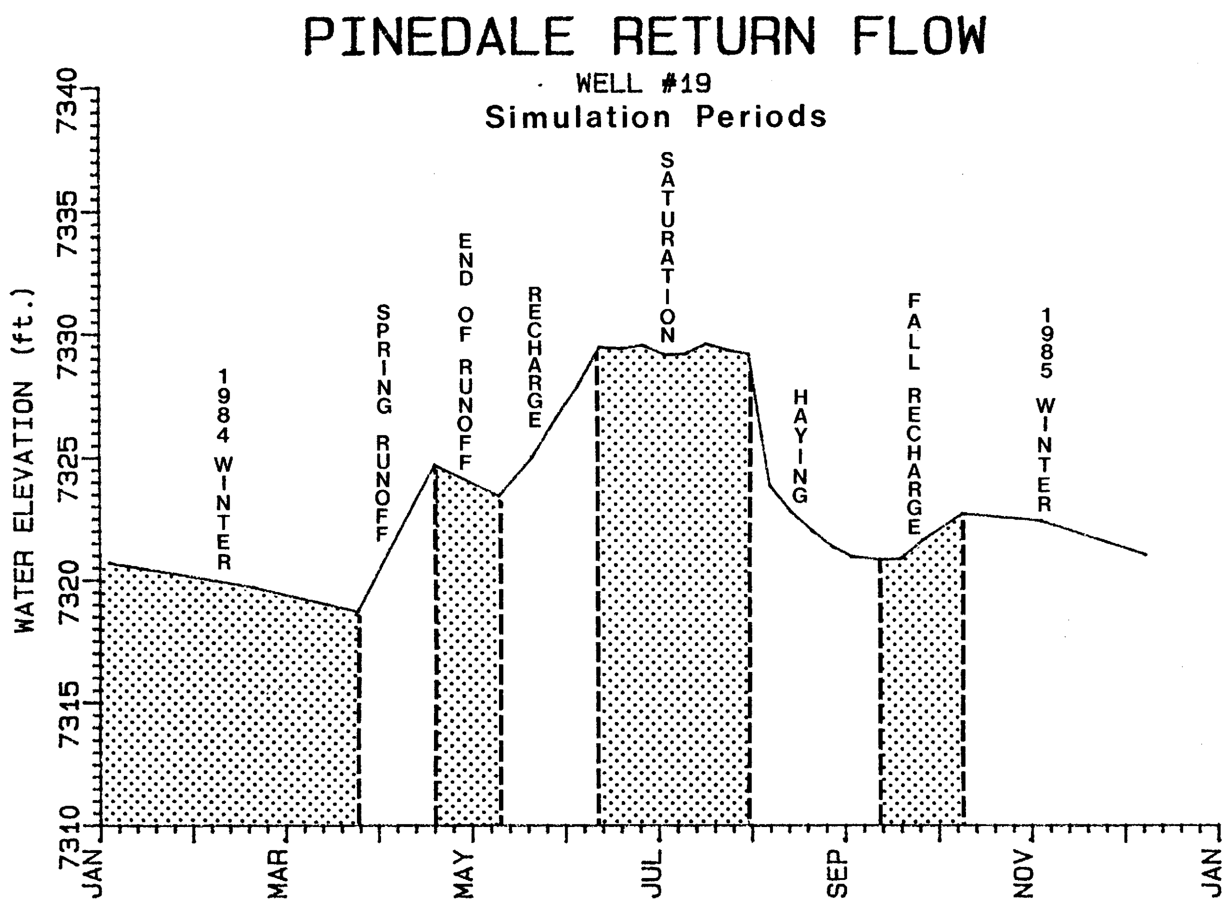


Figure 13. Groundwater Model Simulation Periods and the Associated Water Table Elevation Characteristics as measured in Well #19.

flood irrigation. This period lasts until the groundwater elevation has leveled off (usually at the surface elevation).

4. Saturation: The saturation simulation period models the response of the aquifer to the flood irrigation practices that maintains the groundwater level at or near the land surface.
5. Haying: This period simulates the haying season, when the groundwater level drops, allowing the fields to dry and the hay to be cut.
6. Fall recharge: This interval is identified by the slight rise in the water table due to the fall irrigation practices (which are much less intense than the earlier recharge periods). This recharge is primarily for stock watering and to prevent the rapid drop of the alluvial aquifer water table.
7. Winter: The winter period, showing a slight decline of the groundwater elevation, models the winter season which lasts from the end of the fall recharge until the next spring runoff.

The proper calibration of the USGS groundwater model was required in order to simulate the aquifer response from one year to the next while maintaining a reasonable amount of accuracy.

Model Calibration

The calibration of the model involved one complete set of simulation periods. The initial calibration interval was the haying period of 1985 (7/24/85-9/2/85). This period was chosen for the following reasons:

1. A more complete set of input data was acquired in 1985 as a result of the recommendations outlined in Peck's thesis (1985).
2. Starting head values were more accurately obtainable for all cells within the finite-difference grid. The groundwater elevation at the start of this period was at or near the land surface and the starting heads could be established with the aid of a USGS topographic map. This procedure has been described previously in chapter IV.
3. No artificial aquifer recharge was occurring during this period, which simplified the input parameters. Precipitation that occurred was accounted for by subtracting the precipitation rate from the evapotranspiration rate. This adjusted evapotranspiration rate was then input into the model evapotranspiration package.

An initial assumption in the calibration of the model was that the river seepage occurring during this period would not contribute significantly to the aquifer storage volume.

Calibration proceeded by executing the model for the 1985 haying period without implementing the river package. The hydraulic conductivity values, as estimated from the pump test results, were input into this first model run. The model-calculated elevations of those cells containing the monitoring well locations, were compared with the field-measured elevations (Appendix E shows the model/field well elevation comparisons for the final simulation runs). The variation between the field-measured and model-calculated elevations were noted and the model adjusted by changing the hydraulic conductivities in those areas showing discrepancies. The adjusted model was again executed for this same simulation period. This process was repeated until the model-calculated groundwater elevations were within 0.3 feet of the measured well elevations.

The river stage data was incorporated next. The aquifer hydraulic conductivities were adjusted to account for any variation in groundwater levels caused by the introduction of the river data, with the exception of the area near well number 26. The model was adjusted in the vicinity of well number 26 by varying the riverbed conductance values for the cells containing Lake Creek reaches until the groundwater elevations at well number 26 were again within 0.3 feet of the field-measured elevation.

The hydraulic conductivities of the general-head boundary interfaces were changed in accordance to the alterations occurring within the study area near these boundaries. This was a very intense iterative process. The general-head boundary interface conductance was left constant until the hydraulic conductivities of the variable-head cells within the study area were established. The conductance was then changed to reflect the new hydraulic conductivity of the interface material as was indicated by the change to the associated cells within the study area. The process was repeated until changing the general-head boundary interface conductance did not affect the model results.

The head values calculated by the model were then subtracted from the surface elevations. This step ensured that the model was representing the total aquifer response with a fair amount of accuracy. The model calculated head values were subtracted from the surface elevation to show the fluctuation in the head elevation for the entire modelled region. An example of why this was critical would be if the model-calculated head values were showing an increase in elevation during the haying period. This would indicate that the model was not accurately simulating the aquifer response and the hydraulic conductivities needed to be changed.

The hydraulic conductivities, riverbed conductances and general-head boundary conductances, as determined by the adjustments made in the calibration of the initial period, were held constant for the remainder of the next six simulation periods. All adjustments remained consistent with the geologic information and the original hydraulic conductivity trend mapped out using the pump test data. The calculated head elevation at the end of each simulation was input as the starting head elevation for the following period. The model output head elevations were, again, subtracted from the surface elevations, to monitor the total model response for that simulation period.

The final check on the model calibration was to execute the 1986 haying simulation period using the input parameters calibrated for the 1985 haying period. The calculated head elevations from the 1986 saturation period were input as the starting heads for the 1986 haying simulation. A tolerance level of one foot between the model-calculated and field-measured water table elevations was established. This tolerance level was met in all but 5 of the 18 wells which directly measure the alluvial aquifer response. These wells are listed in appendix E. Two of these five wells were within 1.3 feet. The remaining three wells were located at the Bar-Cross Ranch and Willard Binning's ranch. The discrepancy between the model calculated and field measured water table elevations was discounted at these locations due to a lack of field control.

Recharge was applied to the model by subdividing the study area into small recharge zones (Figure 14). A recharge rate was assigned to each of these zones for a part of, or for the duration of the simulation period. These recharge rates were adjusted in the same manner as that of the hydraulic conductivities. An initial recharge rate for each zone was estimated and the program executed. The recharge rates were then adjusted to account for any discrepancy between measured and model-calculated head elevations. The process was repeated until the cells containing the monitoring wells had calculated groundwater elevations within 0.5 feet of the field-measured value. This final model-calculated recharge volume was incorporated into the equation to determine the overland flow which will be discussed in the next section of this chapter. Well over 1000 model runs were required to calibrate the finite-difference model.

Return Flow Equations

The initial step in calculating the return flow percentage was to determine the net groundwater inflow. This inflow was calculated by incorporating the model-calculated change in storage of the aquifer into the water budget equation (equation 4.1). The net groundwater inflow value (if positive) was then introduced into the following

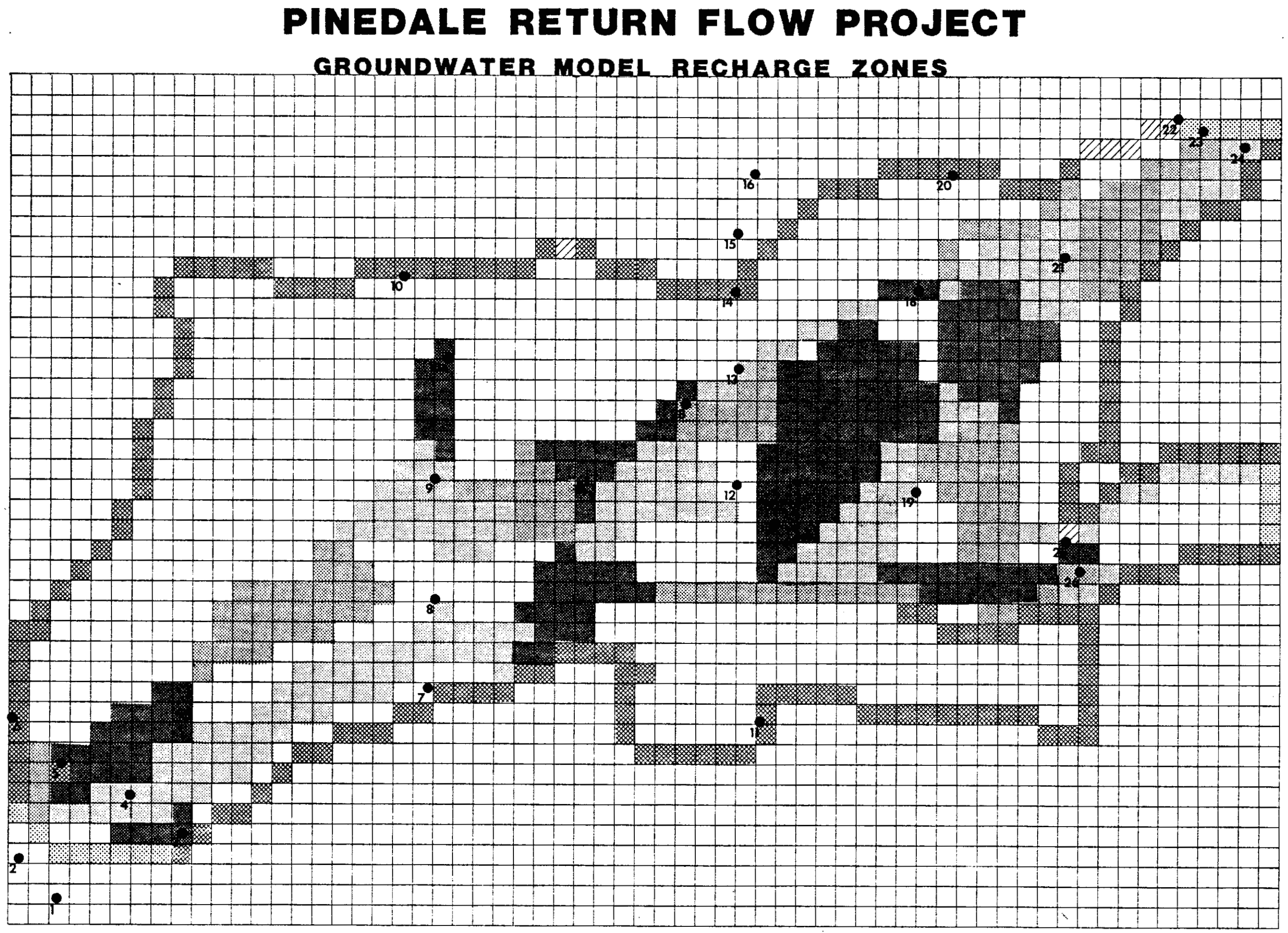


Figure 14. Pinedale Return Flow Project Groundwater Model Recharge Zones.

equation to calculate the return flow volume:

$$RF = O_s - O_{ch} - OF - (I_g - O_g) \qquad (6.1)$$

where:

RF	is the return flow;
O_s	is the field-measured surface outflow;
O_{ch}	is the channel flow;
OF	is the overland flow; and
(I_g-O_g)	is the net groundwater inflow.

The net groundwater inflow term, if negative, indicates more water is leaving the study area through the aquifer than is entering; therefore, there is no groundwater flow returning to the surface flow system.

The overland flow volume is determined by the following equation:

$$OF = (I_D+P) - (Et+R_m) \qquad (6.2)$$

where:

OF	is the overland flow;
I_D	is the field measured diversion flow plus the following inflow sources: culverts, springs, Binning Ditch, Rahm Ditch, Wright Ditch, Highline Ditch, Ditch at Willard Binning's ranch and Lane Ditch;
P	is the precipitation;
Et	is the evapotranspiration; and

R_m is the model calculated recharge volume.

The channel flow volume was calculated in the following manner:

$$O_{ch} = I_s - D - R_s \quad (6.3)$$

where:

- O_{ch} is the channel flow volume;
- I_s is the field measured surface inflow for the New Fork River, Willow Creek, Duck Creek and Lake Creek;
- D is the diversion flow measured in the field; and
- R_s is the volume of seepage from the aquifer into the stream channel as calculated by the groundwater flow program.

The river seepage term was neglected if it was negative. A negative term indicates groundwater flow from the aquifer into the stream system, which is the return flow volume being calculated.

A Thiessen Polygon Method was used as a check on the computer model calculated change in storage volume (Figure 12). Table 1 lists the comparison between the two change in storage calculations. The large discrepancy is attributable to the extension of the Thiessen polygons containing wells which have large drawdown values, into the low hydraulic conductivity areas of the finite-difference model, which have very little water table fluctuations. The computer generated change in storage volume more accurately represented the aquifer response and was therefore, the value incorporated into the return flow calculations.

Table 1.
Comparison of the Two Methods
Used to Calculate the Change in Storage Volume

Simulation Period	Dates	Thiessen Polygon ΔS (ac-ft)	USGS Model ΔS (ac-ft)
1984 Recharge	6/4/84 - 6/25	5924	602
1984 Saturation	6/26 - 7/23	-1282	2478
1984 Haying	7/24 - 9/14	-14485	-10126
1984 Fall Recharge	9/15 - 9/29	369	1329
1984-1985 Winter	9/30 - 3/24/85	-6676	-3020
1985 Runoff	3/25/85 - 4/18	6603	2425
1985 End of Runoff	4/19 - 5/9	667	-401
1985 Recharge	5/10 - 6/11	12656	9560
1985 Saturation	6/12 - 7/23	-2047	3151
1985 Haying	7/24 - 9/2	-12634	-8564
1985 Fall Recharge	9/3 - 10/8	3610	1648
1985-1986 Winter	10/9 - 3/22/86	-3757	-4331
1986 Runoff	3/23/86 - 4/13	7069	3400
1986 End of Runoff	4/14 - 5/27	2039	1803
1986 Recharge	5/28 - 6/10	10740	7236
1986 Saturation	6/11 - 7/22	-4342	4028
1986 Haying	7/23 - 9/13	-11997	-8154
1986 Fall Recharge	9/14 - 11/4	2012	707
1986-1987 Winter	11/5 - 3/5/87	-6425	-3776

Table 1, continued

Simulation Period	Dates	Thiessen Polygon ΔS (ac-ft)	USGS Model ΔS (ac-ft)
1987 Runoff	3/6/87 - 4/25	9270	737
1987 End of Runoff	4/26 - 5/19	3245	830
1987 Recharge	5/20 - 6/2	5024	3379
1987 Saturation	6/3 - 7/21	-1662	-2784
1987 Haying	7/22 - 10/3	-13682	-10844
1987 Fall Recharge	10/4 - 10/30	2585	1353
1987-1988 Winter	11/1 - 2/27/88	-8487	-3835

CHAPTER VII

DISCUSSION OF RESULTS

The results of the PRFP are divided into two separate sections. Each year is looked at in detail and an average yearly value for the returning diverted flow calculated. The second section analyzes the individual modelling period results. An average overland flow plus average return flow value is calculated for each period and the total of these returning flow values compared with the average yearly flow value described above. A general overview of the response of the alluvial aquifer as an underground reservoir is the last subject summarized in this chapter.

Yearly Analysis

1984-1985 Study Year:

Table 2 lists the total volume of diverted water and the returning flow volume for the simulation periods of the initial year of the PRFP study. The calculations used to determine the overland and return flow volumes can be found in appendices F and G. The large volume of overland flow and return flow associated with the spring recharge period is attributed to the heavy spring snowmelt. The winter of 1983-1984 (November to April) had an average monthly snowfall of 10.25 inches (NOAA precipitation records at

Table 2.
1984 Simulation Period Diversion Flow Volumes and Returning Flow Volumes

Simulation Period	Dates	Diversion Flow Volume (ac-ft)	Overland Flow Volume (ac-ft)	Return Flow Volume (ac-ft)	Total Returning Flow Volume (ac-ft)
1984 Recharge	6/4/84 - 6/25/84	23610	5991	5767	11758
1984 Saturation	6/26/84 - 7/23/84	29220	13905	4338	18243
1984 Haying	7/24/84 - 9/14/84	4014	6492	5408	11900
1984 Fall Recharge	9/15/84 - 9/29/84	1088	0	0	0
1984-1985 Winter	9/30/84 - 3/24/85	2112	0	2136	2136
Cumulative		60044	26388	17649	44037

Cora 4N and Pinedale) which recharged the aquifer during the spring snowmelt/runoff. The diverted water returned to the stream system quicker, both overland and through the surface region of the aquifer, because of the existing high water table. The total volume of diversion flow for the 1984 year was 60,044 acre-feet. The volume of overland flow and return flow during this same year was 26,388 acre-feet and 17,649 acre-feet, respectively. Table 3 lists the percentage of the total diversion flow returning to the stream system as overland flow and return flow for each simulation period. The cumulative percent of water returning to the stream for the 1984 study year was 73.34 percent (43.95 percent as overland flow and 29.39 percent as return flow).

1985-1986 Study Year:

A total of 53,630 acre-feet of water was diverted during this study year. The percentage of this flow returning to the stream was calculated to be 51.56 percent. The overland flow volume was 11,651 acre-feet (21.73 percent) and the return flow volume was 15,996 acre-feet (29.83 percent). A breakdown of these flow volumes and the percentage of the total diversion flow volume for each simulation period are tabulated in Tables 4 and 5, respectively.

The larger return flow volumes for the fall and winter periods, during this study year as compared to that of 1984, are believed to be caused by recharge to the aquifer from

Table 3.
Percentage of Total Diversion Flow
Returning to the Stream System for the 1984 Study Year

Simulation Period	Dates	Overland Flow Percentage	Return Flow Percentage	Total Returning Flow Percentage
1984 Recharge	6/4/84 - 6/25/84	9.98	9.60	19.58
1984 Saturation	6/26/84 - 7/23/84	23.16	7.22	30.38
1984 Haying	7/24/84 - 9/14/84	10.81	9.01	19.82
1984 Fall Recharge	9/15/84 - 9/29/84	0.00	0.00	0.00
1984-1985 Winter	9/30/84 - 3/24/85	0.00	3.56	3.56
Cumulative		43.95	29.39	73.34

Table 4.
1985 Simulation Period Diversion Flow Volumes and Returning Flow Volumes

Simulation Period	Dates	Diversion Flow Volume (ac-ft)	Overland Flow Volume (ac-ft)	Return Flow Volume (ac-ft)	Total Returning Flow Volume (ac-ft)
1985 Spring Runoff	3/25/85 - 4/18/85	0	0	0	0
1985 End of Runoff	4/19/85 - 5/9/85	9	0	0	0
1985 Recharge	5/10/85 - 6/11/85	15490	0	0	0
1985 Saturation	6/12/85 - 7/23/85	31254	10022	5405	15427
1985 Haying	7/24/85 - 9/2/85	1932	1629	2051	3680
1985 Fall Recharge	9/3/85 - 10/8/85	3080	0	3525	3525
1985-1986 Winter	10/9/85 - 3/22/86	1865	0	5015	5015
Cumulative		53630	11651	15996	27647

Table 5.
Percentage of Total Diversion Flow
Returning to the Stream System for the 1985 Study Year

Simulation Period	Dates	Overland Flow Percentage	Return Flow Percentage	Total Returning Flow Percentage
1985 Spring Runoff	3/25/85 - 4/18/85	0.00	0.00	0.00
1985 End of Runoff	4/19/85 - 5/9/85	0.00	0.00	0.00
1985 Recharge	5/10/85 - 6/11/85	0.00	0.00	0.00
1985 Saturation	6/12/85 - 7/23/85	18.69	10.08	28.77
1985 Haying	7/24/85 - 9/2/85	3.04	3.83	6.87
1985 Fall Recharge	9/3/85 - 10/8/85	0.00	6.57	6.57
1985-1986 Winter	10/9/85 - 3/22/86	0.00	9.35	9.35
Cumulative		21.73	29.83	51.56

the early fall snowmelt. The winter of 1985-1986 was the heaviest snowfall year during the five year study period (Appendix H). An average monthly snowfall rate of 12.3 inches was measured at the NOAA Cora 4N and Pinedale weather stations from September to April. The fall accumulation (September to November) was 45.25 inches with an average maximum monthly temperature for this period of 45.59 degrees Fahrenheit. The measured depth of snow at the end of November was approximately 17.5 inches; therefore, 20 plus inches of snow had melted and infiltrated into the aquifer. The snowmelt data was not reduced to the percentage of water infiltrating the aquifer or the percentage sublimating. The generalized data was instead used as a source of reasoning to explain the calculated return and overland flow volumes. This snowmelt inflow biased the return flow calculations. The groundwater model indicated more recharge was needed, than that of the diverted flow volume measured, in order to match the field-measured water table elevations during the end of runoff and fall recharge periods. This discrepancy in recharge volumes was attributed to the snowmelt infiltration. Adjustment for the spring and fall snowmelt in the return flow calculations was carried out by subtracting the absolute value of the overland flow volume from the measured surface outflow (Appendix G).

1986-1987 Study Year:

The 1986-1987 study year recorded the largest volume of diverted flow and the second largest percentage of this flow returning to the stream system (75.54 percent). The total volume diverted was 81,901 acre-feet. This volume was almost 21,000 acre-feet more than the second highest diversion year, 1987-1988, which had a diversion volume of 60,335 acre-feet. Overland flow volume during this period was 33,282 acre-feet which was 40.64 percent of the total diversion flow. The return flow volume was 28,584 acre-feet or 34.90 percent of the total diversion volume. Table 6 lists the flow volumes for each simulation period. The large overland flow returning during the saturation period is due to the large volume of water being diverted onto the saturated fields (53,236 acre-feet). The average recharge rate during this period for the other three analyzed study years is 848 acre-feet/day, while in the 1986-1987 year this recharge rate was 1268 acre-feet/day. The recharge volume for the saturation period was almost equal to the total diversion flow volume for the 1985-1986 study year (53,630 acre-feet). Table 7 summarizes the percentage of the total diversion flow returning as overland flow and return flow for each simulation period.

1987-1988 Study Year:

The 1987-1988 study year was the second largest

Table 6.
1986 Simulation Period Diversion Flow Volumes and Returning Flow Volumes

Simulation Period	Dates	Diversion Flow Volume (ac-ft)	Overland Flow Volume (ac-ft)	Return Flow Volume (ac-ft)	Total Returning Flow Volume (ac-ft)
1986 Spring Runoff	3/23/86 - 4/13/86	0	0	0	0
1986 End of Runoff	4/14/86 - 5/27/86	2450	0	0	0
1986 Recharge	5/28/86 - 6/10/86	14955	82	4516	4598
1986 Saturation	6/11/86 - 7/22/86	53236	29329	11186	40515
1986 Haying	7/23/86 - 9/13/86	4696	3871	3842	7713
1986 Fall Recharge	9/14/86 - 11/4/86	6067	0	2889	2889
1986-1987 Winter	11/5/86 - 3/5/87	497	0	6151	6151
Cumulative		81901	33282	28584	61866

Table 7.
Percentage of Total Diversion Flow
Returning to the Stream System for the 1986 Study Year

Simulation Period	Dates	Overland Flow Percentage	Return Flow Percentage	Total Returning Flow Percentage
1986 Spring Runoff	3/23/86 - 4/13/86	0.00	0.00	0.00
1986 End of Runoff	4/14/86 - 5/27/86	0.00	0.00	0.00
1986 Recharge	5/28/86 - 6/10/86	0.10	5.51	5.61
1986 Saturation	6/11/86 - 7/22/86	35.81	13.66	49.47
1986 Haying	7/23/86 - 9/13/86	4.73	4.69	9.42
1986 Fall Recharge	9/14/86 - 11/4/86	0.00	3.53	3.53
1986-1987 Winter	11/5/86 - 3/5/87	0.00	7.51	7.51
Cumulative		40.64	34.90	75.54

diversion flow volume year (60,335 acre-feet) and the wettest year out of the five study years. This heavy precipitation accounted for the large volume of return flow associated with the saturation period (17,374 acre-feet). Tables 8 and 9 list the recorded volumes and associated return flow and overland flow percentages for the simulation periods. The precipitation rate for the spring recharge and saturation periods for this study year was 174 acre-feet/day compared with an average for this same period over the three remaining study years analyzed of 55 acre-feet/day. The second highest precipitation rate at 67 acre-feet/day occurred in 1984. This heavy precipitation allowed a larger volume of diverted water to flow through the aquifer without being consumptively used by the hay crops. The total volume of returning flow for this study year was 46,281 acre-feet (13,379 acre-feet as overland flow and 32,902 acre-feet as return flow) which amounts to a 76.71 percent return of the total diversion flow. The 1987-1988 study year produced the largest returning flow percentage of the four analyzed study years, due mainly to the volume of return flow during the saturation period.

Fall of 1987 was very hot and dry. The October average maximum temperature was 54 degrees Fahrenheit while the precipitation rate was only 8 acre-feet/day, compared with the average fall recharge period precipitation rate for the other three analyzed years of 108 acre-feet/day. The first

Table 8.
1987 Simulation Period Diversion Flow Volumes and Returning Flow Volumes

Simulation Period	Dates	Diversion Flow Volume (ac-ft)	Overland Flow Volume (ac-ft)	Return Flow Volume (ac-ft)	Total Returning Flow Volume (ac-ft)
1987 Spring Runoff	3/6/87 - 4/25/87	0	0	0	0
1987 End of Runoff	4/26/87 - 5/19/87	3698	0	0	0
1987 Recharge	5/20/87 - 6/2/87	10376	4153	3969	8122
1987 Saturation	6/3/87 - 7/21/87	37013	7652	17374	25026
1987 Haying	7/22/87 - 10/3/87	4955	1574	5987	7561
1987 Fall Recharge	10/4/87 - 10/31/87	2655	0	0	0
1987-1988 Winter	11/1/87 - 2/27/88	1638	0	5572	5572
Cumulative		60335	13379	32902	46281

Table 9.
Percentage of Total Diversion Flow
Returning to the Stream System for the 1987 Study Year

Simulation Period	Dates	Overland Flow Percentage	Return Flow Percentage	Total Returning Flow Percentage
1987 Spring Runoff	3/6/87 - 4/25/87	0.00	0.00	0.00
1987 End of Runoff	4/26/87 - 5/19/87	0.00	0.00	0.00
1987 Recharge	5/20/87 - 6/2/87	6.88	6.58	13.46
1987 Saturation	6/3/87 - 7/21/87	12.68	28.80	41.48
1987 Haying	7/22/87 - 10/3/87	2.61	9.92	12.53
1987 Fall Recharge	10/4/87 - 10/31/87	0.00	0.00	0.00
1987-1988 Winter	11/1/87 - 2/27/88	0.00	9.24	9.24
Cumulative		22.17	54.54	76.71

three years of the study recorded substantial amounts of snowfall in the early fall, while the first significant snowfall in the fall of 1987 did not occur until November 18th (NOAA precipitation records). The lack of aquifer recharge, due to the melting of these early fall snow accumulations, accounts for the absence of the return flow volume for this period in 1987. The lack of return flow during the 1984 fall recharge period is attributed to a colder fall, creating a seal against snowmelt infiltration. Table 10 lists a summary of the flow volumes for the PRFP study years, while the percentage of the diversion flow volume returning to the stream system is shown in Table 11.

Table 12 shows the summary of the yearly diversion flow volumes, the cumulative flow volumes returning to the stream system and the associated percentage of the diversion flow that returns. An average percentage of returning diverted flow of 69 percent was calculated for the four study years analyzed in this thesis. This figure is based on the values listed in Table 12.

The individual simulation periods for the four study years, starting with the spring recharge period, are analyzed next. The volumes and return flow percentages for this analysis are listed in Tables 10 and 11, respectively. The spring runoff and end of runoff periods are neglected due to the lack of data and because there is no significant artificial recharge of the aquifer taking place during these

Table 10.
Pinedale Return Flow Project Overland and Return Flow Volumes

Simulation Period	1984		1985		1986		1987	
	Overland Flow Volume (ac-ft)	Return Flow Volume (ac-ft)	Overland Flow Volume (ac-ft)	Return Flow Volume (ac-ft)	Overland Flow Volume (ac-ft)	Return Flow Volume (ac-ft)	Overland Flow Volume (ac-ft)	Return Flow Volume (ac-ft)
Spring Runoff			0	0	0	0	0	0
End of Runoff			0	0	0	0	0	0
Recharge	5991	5767	0	0	82	4516	4153	3969
Saturation	13905	4338	10022	5405	29329	11186	7652	17374
Haying	6492	5408	1629	2051	3871	3842	1574	5987
Fall Recharge	0	0	0	3525	0	2889	0	0
Winter	0	2136	0	5015	0	6151	0	5572
Cumulative	26388	17649	11651	15996	33282	28584	13379	32902

Table 11.
Pinedale Return Flow Project Percentage of Total Diverted Flow Returning to the Stream System for the 1984 - 1987 Study Years

Simulation Period	1984		1985		1986		1987	
	Overland Flow %	Return Flow %	Overland Flow %	Return Flow %	Overland Flow %	Return Flow %	Overland Flow %	Return Flow %
Spring Runoff			0.00	0.00	0.00	0.00	0.00	0.00
End of Runoff			0.00	0.00	0.00	0.00	0.00	0.00
Recharge	9.98	9.60	0.00	0.00	0.10	5.51	6.88	6.58
Saturation	23.16	7.22	18.69	10.08	35.81	13.66	12.68	28.80
Haying	10.81	9.01	3.04	3.83	4.73	4.69	2.61	9.92
Fall Recharge	0.00	0.00	0.00	6.57	0.00	3.53	0.00	0.00
Winter	0.00	3.56	0.00	9.35	0.00	7.51	0.00	9.24
Cumulative	43.95	29.39	21.73	29.83	40.64	34.90	22.17	54.54

Table 12.
Pinedale Return Flow Project Results Summary

Flow Volumes and Return Percentages	Study Years 1984	1985	1986	1987
Diversion Flow Volume (ac-ft)	60044	53630	81901	60335
Total Returning Flow Volume (ac-ft)	44037	27647	61866	46281
Percentage of Total Diverted Flow Returning to the Stream System	73.34	51.56	75.54	76.71

periods. The response of the stream system to the spring runoff was unmonitored during all five data acquisition years because of logistics involved with the location of the study area. Recorders could not be set while the streams and ditches were frozen; yet, they could not be placed quick enough to accurately measure the runoff (when WWRC personal were notified of the occurrence of the spring runoff by the area ranchers) due tc the distance from Laramie to Pinedale and the difficulty in placing the recorders in muddy conditions.

Simulation Period Analysis

Recharge:

The natural recharge of the alluvial aquifer from spring snowmelt strongly influences the return flow volumes for this period. The largest total returning flow volume occurs in 1984 when the largest diversion flow volume for this period (23,610 acre-feet) was diverted onto the snowmelt recharged alluvial aquifer. The large returning flow volume in 1987 is attributable to the snowmelt recharge and the heavy precipitation occurring during this period. The lack of returning flow for the 1985 year is a combination of a high evapotranspiration rate, moderate precipitation rate and an average flood irrigation recharge rate, resulting in high consumptive use losses. The average diversion flow volume, returning flow volumes and percentage of the diversion flow volume returning to the stream system for each simulation period are shown in Table 13.

Saturation:

Results of this period were fairly consistent for the first two years of the study. An average overland flow volume and return flow volume of approximately 12,000 acre-feet and 4900 acre-feet, respectively, were recorded in 1984 and 1985. The returning flow volumes were more than doubled in 1986 because of the large volume of water that was diverted onto the hay fields during this period. This large amount of water combined with only a moderate evapotranspiration rate (Appendix F) resulted in additional flow volumes returning to the stream system. The anomalous results in 1987, particularly the volume of return flow, is attributable to the high precipitation volume occurring during and prior to this period. The precipitation in this case was consumptively used allowing more diverted water to return to the streams. This period shows the largest percentage of flow returning to the stream system. An average total percentage of the diverted flow returning to the downstream system during this period is approximately 40 percent.

Haying:

This is the most difficult period to analyze. The

Table 13.
Pinedale Return Flow Project Average Flow Volumes and Percentages for the Model Simulation Periods

Simulation Period	Diversion Flow Volume (ac-ft)	Overland Flow Volume (ac-ft)	Return Flow Volume (ac-ft)	Total Returning Flow Percentage
Recharge	16108	2556	3563	9.80
Saturation	37681	15227	9576	39.72
Haying	3899	3391	4322	12.35
Fall Recharge	3222	0	1604	2.57
Winter	1528	0	4718	7.56
Cumulative	62438	21174	23783	72.00

results in general are fairly consistent. The large volume of overland flow in 1984 however, is unexplainable. This appears to be a phenomenon of the measured data and the calculations used to determine the overland volume. The low overland and return flow volumes in 1985 are caused by the low diversion flow volumes and high evapotranspiration rates during and prior to this period. The low return flow volume in 1986 is due to an increased loss to evapotranspiration. This period records the second largest volume of flow returning to the stream system. An average return plus overland flow percentage of the average total diverted volume of 12.35 percent was calculated for this period.

Fall Recharge:

The early snowfall years of 1985 and 1986 were the only study years recording a return flow volume during this period. The natural recharge of the alluvial aquifer allows more of the diverted water to flow through the aquifer. One explanation for this increase in return flow volume during the wet years, besides being less susceptible to consumptive use, would be attributed to a quicker flowrate caused by an increased hydraulic gradient. Snowfall records (NOAA weather stations Cora 4N and Pinedale) indicate that more snow falls on the upper watershed region. This melting snow infiltrates the aquifer and raises the groundwater elevation more in the upper study area region than in the lower;

therefore, creating a larger hydraulic gradient. This same theory could be used to explain the lack of return flows during the fall recharge period. The aquifer, during the dry, and/or wet and cool fall seasons, is not significantly recharged naturally. The artificial recharge that does occur is not enough to create the hydraulic gradient needed to transport the released water from storage through the aquifer in this short time period. Figures 47 through 64 in Appendix D illustrate this increased head in the upper region of the aquifer, especially for the 1986 fall season. An average return flow volume of 1604 acre-feet (2.57 percent) was calculated for this simulation period.

Winter:

The winter period has the most consistent returning flow results. The low return flow volume associated with the 1984 study year may be caused by the underestimation of the surface outflow rate. The slow rate of return associated with the winter months is theorized to be due to the lower hydraulic gradient and because of the lower groundwater elevations. The lower water table elevation increases the travel distance and therefore, the travel time from the aquifer to the stream system. Approximately 7.5 percent (4700 acre-feet) of the average diverted flow was calculated to return during the winter period.

The cumulative percentage of diverted flow returning to the stream system, from this simulation period analysis, is 72 percent. This figure is fairly consistent with the average yearly percentage of 69 percent discussed in the previous section of this chapter.

Aquifer Storage Response

The earlier analyses point out that the stream-aquifer response is fairly rapid during the spring and summer recharge periods when the groundwater elevation is at or near the land surface. Table 13 lists an average diversion flow volume of 62,438 acre-feet and a total annual overland and return flow percentage of 72 percent (44,957 acre-feet). A volume of 40,239 acre-feet returns within the first 3 to 4 months from the initiation of the irrigation season. This quick returning flow volume amounts to approximately 90 percent of the total flow volume that returns to the stream system. The remaining 10 percent of this return flow volume re-enters the stream system over a length of time lasting approximately 6 to 7 months.

An average volume of diverted flow stored in the alluvial aquifer during the four analyzed study years was 23,783 acre-feet. The greatest volume stored was 32,902 acre-feet in 1987 and the least amount in 1985 (15,996 acre-feet).

CHAPTER VIII

CONCLUSIONS AND RECOMMENDATIONS

This chapter describes the final conclusions to the PRFP drawn from the results recorded in Chapter VII. The recommendation section lists a series of suggestions intended to aid in future work on this project and/or in establishing the monitoring system for a study similar in nature to the PRFP.

Conclusions

The study of the alluvial aquifer in the New Fork River valley of west-central Wyoming, termed the Pinedale Return Flow Project, was successful. Calculations of the return and overland flows for the four study years analyzed resulted in an average of 70 percent of the diverted water volume returning to the stream system. The stream-aquifer interaction is rapid during the high water table recharge periods in the spring and summer. Approximately 90 percent of the returning water volume occurs during this time period. The remaining 10 percent of returning flow volume is slowly released from aquifer storage to re-enter the stream system during the low flow winter months. This volume is relatively insignificant in quantity (4700 acre-feet) but does aid in maintaining a consistent streamflow. The 19,000 acre-feet of water that was released from storage during the spring and summer is profitable to the downstream users for the following reasons:

1. Evaporation losses are minimized due to the underground storage.
2. The water is stored without the expense of dam construction.
3. The release is rapid enough for beneficial use of the water downstream during the same irrigation season; and
4. The land surface above the alluvial aquifer is able to be put to productive use, which increases the economic stability of the region.

The general conclusions that can be drawn from a yearly analysis of the returning flow volumes is that during an average precipitation year a return plus overland flow percentage of approximately 75 percent can be expected. During the drier years, when more of the diverted flow is lost to consumptive use, a return plus overland flow percentage of approximately 50 percent (1985 study year) can be expected. The following is a generalized summary of the aquifer response noted from the analyses of the four study years.

1. The volume of overland flow and return flow is greater during the spring recharge period when the

aquifer has been previously recharged by a large volume of spring snowmelt.

2. The overland flow percentage of the total diverted flow during the irrigation year following a heavy snowfall winter averages approximately 40 percent.
3. The overland flow percentage for average snowfall years and spring precipitation volumes is approximately 22 percent of the total diverted flow volume.
4. The return flow volume for most years averages approximately 30 percent. The exception to this was noted in the 1987 study year when a large volume of precipitation during the spring recharge and saturation periods dramatically increased the return flow volume.

The final conclusion drawn from this study is that the practice of flood irrigation does not appear to have a negative impact on the downstream system. A large percentage of the diverted water returns to the stream system so there is no loss of beneficial surface flow to the downstream users and the release of stored water during the low flow winter months will help maintain a constant supply of water to the channel system. The saturated aquifer acts as a 24,000 acre-feet underground reservoir that releases most of this volume to the downstream users during the same irrigation season, without excessive evaporation losses.

Recommendations

The following list of recommendations are intended to aid in the future analyses of the PRFP.

1. Groundwater modelling of the aquifer system during the winter months needs additional work. Computer simulation required an average recharge volume of 18,000 acre-feet during this period (Appendix G). Several theories that may possibly explain this anomalous recharge value that still need studied are:

   a. The constricted river flow, due to ice jams, backs up the water and falsely indicates a rising water table in the monitoring wells that are in direct contact with the river system. These wells are (1) number 7, (2) number 8, (3) number 18 and possibly numbers 4 and 13 (Figures 50,51,57,48 and 56).

   b. The narrow band of high transmissivity material becomes constricted due to an icing of the pore spaces, causing the flow to back up in the upper watershed region. This theory could be tested by reducing the hydraulic conductivity values in the narrow band of high conductivity material near the outlet region (Figure 11).

2. The recharge application zones should be decreased in size to maintain a more uniform recharge response for the entire model area. This would allow the groundwater elevations in most of the finite-difference cells to be maintained at or near the surface elevation during the saturation simulation period. This was not possible with the present recharge zone configuration; therefore, the initial starting head values (1985 haying period) were input as the starting head values for the 1984, 1986, and 1987 haying period simulation runs. The recharge volume for the saturation period was checked by executing the haying period simulation using the head elevations calculated in the prior saturation periods as starting heads. The change in storage volume results obtained using the two different starting head data files (1985 haying period and the prior saturation period) were compared and the saturation period simulations were repeated using different recharge rates until the change in storage volume was within 10 percent of the value calculated using the 1985 haying period starting heads. The 1985 starting heads were used because the groundwater elevations in the cells containing the monitoring

wells more accurately represented the water table elevations measured in the field.

3. The partial data acquired in the 1988 study year should be reduced and analyzed in order to calculate the returning flow volumes for a very dry year. This will not be as detailed an analysis as that done using the data from the first four study years. The 1988 data is not as complete as that of the 1984-1987 data.
4. Hydraulic conductivities assigned to the finite-difference cells could be varied to simulate the response of a more, or less, permeable aquifer system.

The following is a list of observations that are felt would aid in monitoring a similar study project.

1. Perform a seismic refraction survey to help locate the monitoring wells and to further delineate the size and shape of the alluvial aquifer.
2. Perform stream bottom conductance tests and more accurately establish the river stage and riverbed elevations along the stream system. The USGS model is highly sensitive to these parameters (Peck, 1985) and the above data should be accurately established if the USGS modelling program is to be utilized in the future.
3. The last recommendation resulting from the work

done on the PRFP would be to better establish elevation control for the monitoring wells and staff gages. This is especially critical when the project is designed to last longer than a single data collection season.

APPENDIX A

GROUNDWATER MONITORING WELLS
DRILL LOGS

Well #1

Date Drilled: 5/29/84

Drilled Depth: 30 feet

Well Depth: 30 feet

Screened Length: 25 feet

Casing Length: 5 feet

Description of Cuttings

Depth	**Material**
0 - 5 feet	Sandy Clay
5 - 30 feet	Sand and Gravel

Well #2

Date Drilled: 5/29/84

Drilled Depth: 30 feet

Well Depth: 27 feet

Screened Length: 25 feet

Casing Length: 2 feet

Description of Cuttings

Depth	**Material**
0 - 5 feet	Sandy Clay (some rocks)
5 - 30 feet	Sand and Gravel

Well #3

Date Drilled:	5/29/84
Drilled Depth:	17 feet
Well Depth:	16 feet
Screened Length:	10 feet
Casing Length:	6 feet

<u>Description of Cuttings</u>

Depth	**Material**
0 - 2 feet	Topsoil
2 - 7 feet	Clay
7 - 13 feet	Clay with Cobbles
13 - 15 feet	Sand and Gravel
15 - 17 feet	Claystone Bedrock

Well #4

Date Drilled: 5/29/84

Drilled Depth: 30 feet

Well Depth: 30 feet

Screened Length: 25 feet

Casing Length: 5 feet

Description of Cuttings

Depth	**Material**
0 - 5 feet	Sandy Clay
5 - 30 feet	Sand and Gravel

Well #5

Date Drilled: 5/29/84

Drilled Depth: 15 feet

Well Depth: 15 feet

Screened Length: 10 feet

Casing Length: 5 feet

Description of Cuttings

Depth	**Material**
0 - 11 feet	Sand and Gravel
11 - 15 feet	Silty Clay

Well #6

Date Drilled:	5/29/84
Drilled Depth:	16 feet
Well Depth:	0 feet
Screened Length:	0 feet
Casing Length:	0 feet

<u>**Description of Cuttings**</u>

Depth	**Material**
0 - 9 feet	Silty Clay (Layer very similar to the clay material hit in well #5. This layer could be sloping down from surface at #6 to approximately 11 feet in well #5. Due to the minimum amount of sands and gravel and because of the aforementioned condition, pipe was not installed in this well.)
9 - 10 feet	Sand and Gravel (possible confined layer)
10 - 16 feet	Sandstone Bedrock

Well #7

Date Drilled:	5/30/84
Drilled Depth:	17 feet
Well Depth:	15 feet
Screened Length:	10 feet
Casing Length:	5 feet

Description of Cuttings

Depth	**Material**
0 - 3½ feet	Topsoil
3½ - 7 feet	Clay
7 - 15 feet	Sand and Gravel
15 - 17 feet	Bedrock

Well #8

Date Drilled: 5/30/84

Drilled Depth: 30 feet

Well Depth: 30 feet

Screened Length: 25 feet

Casing Length: 5 feet

<u>Description of Cuttings</u>

Depth	**Material**
0 - 1 feet	Topsoil
1 - 7 feet	Clay and Rocks (very dense with silt and sand streak)
7 - 30 feet	Sand with Cobbles

Well #9

Date Drilled: 5/30/84

Drilled Depth: 30 feet

Well Depth: 30 feet

Screened Length: 25 feet

Casing Length: 5 feet

Description of Cuttings

Depth	Material
0 - 6 feet	Topsoil
6 - 30 feet	Sandy Gravel

Well #10

Date Drilled: 5/30/84

Drilled Depth: 25 feet

Well Depth: 25 feet

Screen Length: 20 feet

Casing Length: 5 feet

Description of Cuttings

Depth	Material
0 - 25 feet	Sand
25+ feet	Bedrock

Well #11

Date Drilled:	5/26/84
Drilled Depth:	20 feet
Well Depth:	20 feet
Screened Length:	15 feet
Casing Length:	5 feet

Description of Cuttings

Depth	**Material**
0 - 4 feet	Clay (sandy)
4 - 6½ feet	Sand
6½ - 12 feet	Sand and Gravel
12 - 20 feet	Sandstone Bedrock

Well #12

Date Drilled: 5/28/84

Drilled Depth: 30 feet

Well Depth: 30 feet

Screened Length: 25 feet

Casing Length: 5 feet

Description of Cuttings

Depth	**Material**
0 - 7 feet	Sandy Clay Loam
7 - 30 feet	Gravelly Sand with some Clay

Well #13

Date Drilled:	5/31/84
Drilled Depth:	20 feet
Well Depth:	17 feet
Screened Length:	15 feet
Casing Length:	2 feet

Description of Cuttings

Depth	**Material**
0 - 2½ feet	Topsoil
2½ - 20 feet	Sandy Clay with Cobbles
20+ feet	Yellow Clay with Sand Bedrock

Well #14

Date Drilled:	6/1/84
Drilled Depth:	13½ feet
Well Depth:	13½ feet
Screened Length:	10 feet
Casing Length:	5 feet

Description of Cuttings

Depth	**Material**
0 - ½ foot	Black Topsoil
½ - 7 feet	Light Tan Clay
7 - 13½ feet	Rocky Grey Clay
13½+ feet	Consolidated Bedrock

Well #16

Date Drilled: 5/31/84

Drilled Depth: 15 feet

Well Depth: 15 feet

Screened Length: 14 feet

Casing Length: 1 foot

<u>Description of Cuttings</u>

Depth	Material
0 - 1 foot	Topsoil
1 - 5 feet	Silty Sand and Gravel
5 - 10 feet	Weathered Claystone Bedrock
10 - 15 feet	Bedrock

Well #18

Date Drilled: 5/28/84

Drilled Depth:	30 feet
Well Depth:	30 feet
Screened Length:	20 feet
Casing Length:	10 feet

Description of Cuttings

Depth	**Material**
0 - ½ foot	Topsoil
½ - 30 feet	Gravel mixed with Sandy Clay

Well #19

Date Drilled: 5/28/84

Drilled Depth: 30 feet

Well Depth: 28 feet

Screened Length: 20 feet

Casing Length: 8 feet

Description of Cuttings

Depth	Material
0 - ½ foot	Topsoil
½ - 7 feet	Sandy Clay with Cobblestones
7 - 16 feet	Sand and Gravel with Cobblestones
16 - 30 feet	Sand and Gravel

Well #20

Date Drilled: 5/31/84

Drilled Depth: 8 feet

Well Depth: 8 feet

Screened Length: 8 feet

Casing Length: 0 feet

Description of Cuttings

Depth	Material
0 - 1 foot	Rocky Topsoil
1 - 5 feet	Clay Gumbo
5 - 8 feet	Sandstone Bedrock

Well #21

Date Drilled:	5/28/84
Drilled Depth:	30 feet
Well Depth:	30 feet
Screened Length:	20 feet
Casing Length:	10 feet

Description of Cuttings

Depth	**Material**
0 - 5 feet	Sandy Clay
5 - 10 feet	Silty Sand and Gravel
10 - 11 feet	Rocks
11 - 30 feet	Silty Sand and Gravel

Well #22

Date Drilled: 5/27/84

Drilled Depth: 20½ feet

Well Depth: 20½ feet

Screen Length: 15 feet

Casing Length: 5 feet

Description of Cuttings

Depth	**Material**
0 - 7 feet	Sandy Silt with some Gravel
7 - 20½ feet	Sandy Silt with Cobbles
20½+ feet	Claystone Bedrock

Well #23

Date Drilled:	5/27/84
Drilled Depth:	22 feet
Well Depth:	22 feet
Screened Length:	15 feet
Casing Length:	5 feet

Description of Cuttings

Depth	**Material**
0 - 1½ feet	Topsoil
1½ - 20 feet	Gravelly Sand
20 - 22 feet	Claystone Bedrock

Well #24

Date Drilled:	6/1/84
Drilled Depth:	18 feet
Well Depth:	18 feet
Screen Length:	15 feet
Casing Length:	2 feet

Description of Cuttings

Depth	**Material**
0 - ½ foot	Rocky Topsoil
½ - 15 feet	Cobbles and Boulders
15 - 18 feet	Sandy Clay Lense (Bit twisted off and had to be retrieved. Before this happened, driller thought he had hit a layer of clay and was in a layer between upper and lower aquifers. In the process of bit retrival, driller thought the sand had been mixed with the clay on the bit or else he had penetrated most of the way through the confining layer and had sand mixed with the clay because he was starting into the lower aquifer. Because of the possibility of penetrating the lower aquifer, the driller was told to stop at the 18 foot depth).

Well #25

Date Drilled: 5/26/84

Drilled Depth: 27 feet

Well Depth: 27 feet

Screen Length: 22 feet

Casing Length: 5 feet

Description of Cuttings

Depth	**Material**
0 - ½ foot	Sandy Loam
½ - 6 feet	Sand and Pea Gravel
6 - 14 feet	Gravel and Cobbles
14 - 25 feet	Gravel
25 - 27 feet	Clay Bedrock

Well #26

Date Drilled:	5/27/84
Drilled Depth:	30 feet
Well Depth:	30 feet
Screened Length:	25 feet
Casing Length:	5 feet

Description of Cuttings

Depth	**Material**
0 - ½ foot	Topsoil
½ - 15 feet	Sandy Gravel (Poorly graded sand and gravel with sand lenses up to 2 feet thick)
15 - 30 feet	Sandy Pea Gravel

Well #28

Date Drilled:	5/31/84
Drilled Depth:	15 feet
Well Depth:	15 feet
Screened Length:	10 feet
Casing Length:	5 feet

Description of Cuttings

Depth	**Material**
0 - 10 feet	Sand and Gravel
10 - 15 feet	Sandstone

APPENDIX B

PUMP TEST RESULTS

Well Number	Test Date	Pump Test T (ft^2/day)	Recovery Test T (ft^2/day)	Saturated Aquifer Thickness (feet)	Pump Test k (ft/day)	Recovery Test k (ft/day)
1	6/16/88	Could not drawdown				
3	6/16/88	1278	1718	11	114	153
4	6/16/88	Could not drawdown				
8	8/3/88	35297		35	1018	
9	8/5/88	Could not drawdown				
10	6/17/88	1261	5883	23	55	258
	8/4/88	4519	6765	19	241	361
13*	6/16/88	104		19	5	
	8/4/88	93		17	5	
18	6/15/88	Could not drawdown				
19	6/15/88	1390		30	47	
	8/3/88	2353		23	101	

* Results are based on a rough estimate using specific capacity charts (Walton,1962)

T is the Transmissivity and k is the Hydraulic Conductivity

Well Number	Test Date	Pump Test T (ft^2/day)	Recovery Test T (ft^2/day)	Saturated Aquifer Thickness (feet)	Pump Test k (ft/day)	Recovery Test k (ft/day)
23	6/15/88	258		20	13	
	8/3/88	331	91	17	19	5
24	8/2/88	21		8	2	
25	6/14/88	774	762	24	32	31
	8/2/88	724	926	22	33	42
26	6/14/88	Could not drawdown				

APPENDIX C

STREAM GAGING RECORDS
AND
ASSOCIATED RATING CURVES

RECORDER LOCATION: Alexander Ditch

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
5/22/85	0.76	6.35
6/12/85	1.53	22.97
7/10/85	1.40	19.08
8/29/85	0.47	2.25
5/28/86	0.46	2.23
6/18/86	1.52	23.36
7/16/86	1.15	13.68
2/20/87	1.11	12.57
6/3/87	1.34	17.94
6/10/87	1.56	23.52
7/15/87	1.64	24.72

REGRESSION EQUATION: $\log(Q) = 1.00 + 1.93[\log(SG)]$

Where:

Q is the discharge rate in cfs.

SG is the staff gage height feet.

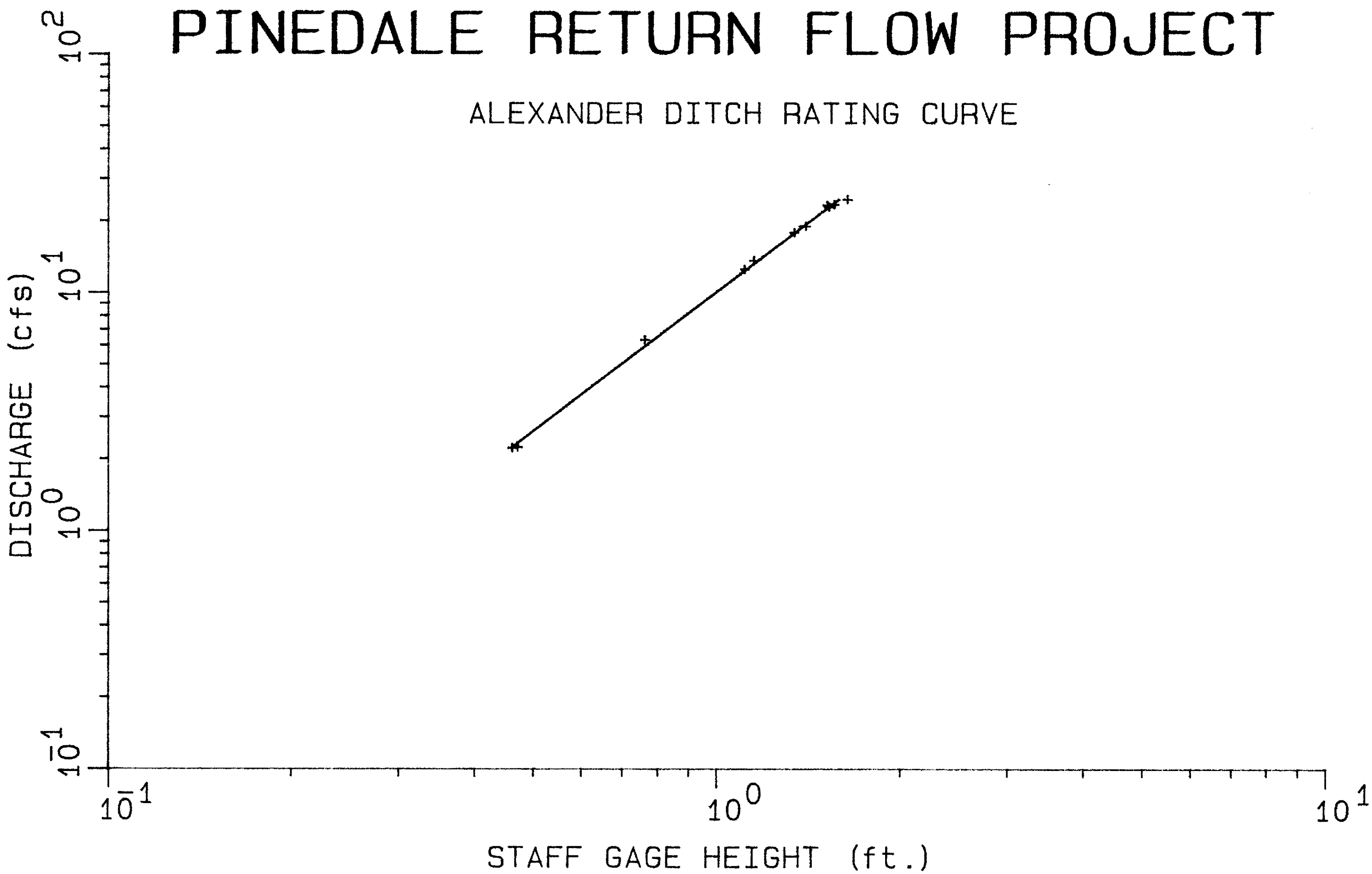


Figure 15. Alexander Ditch Rating Curve.

RECORDER LOCATION: Bee-Line Ditch

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
5/22/84	0.38	0.41
6/19/84	1.60	26.20
6/28/84	2.00	41.90
6/5/85	0.99	9.53
6/20/85	1.81	34.82
7/17/85	2.02	36.00
5/28/86	1.20	14.32
7/2/86	2.29	49.19
5/14/87	0.59	3.50
6/4/87	1.30	19.70
6/25/87	1.84	33.02

REGRESSION EQUATION: $\log(Q) = 1.01 + 1.96[\log(SG)]$

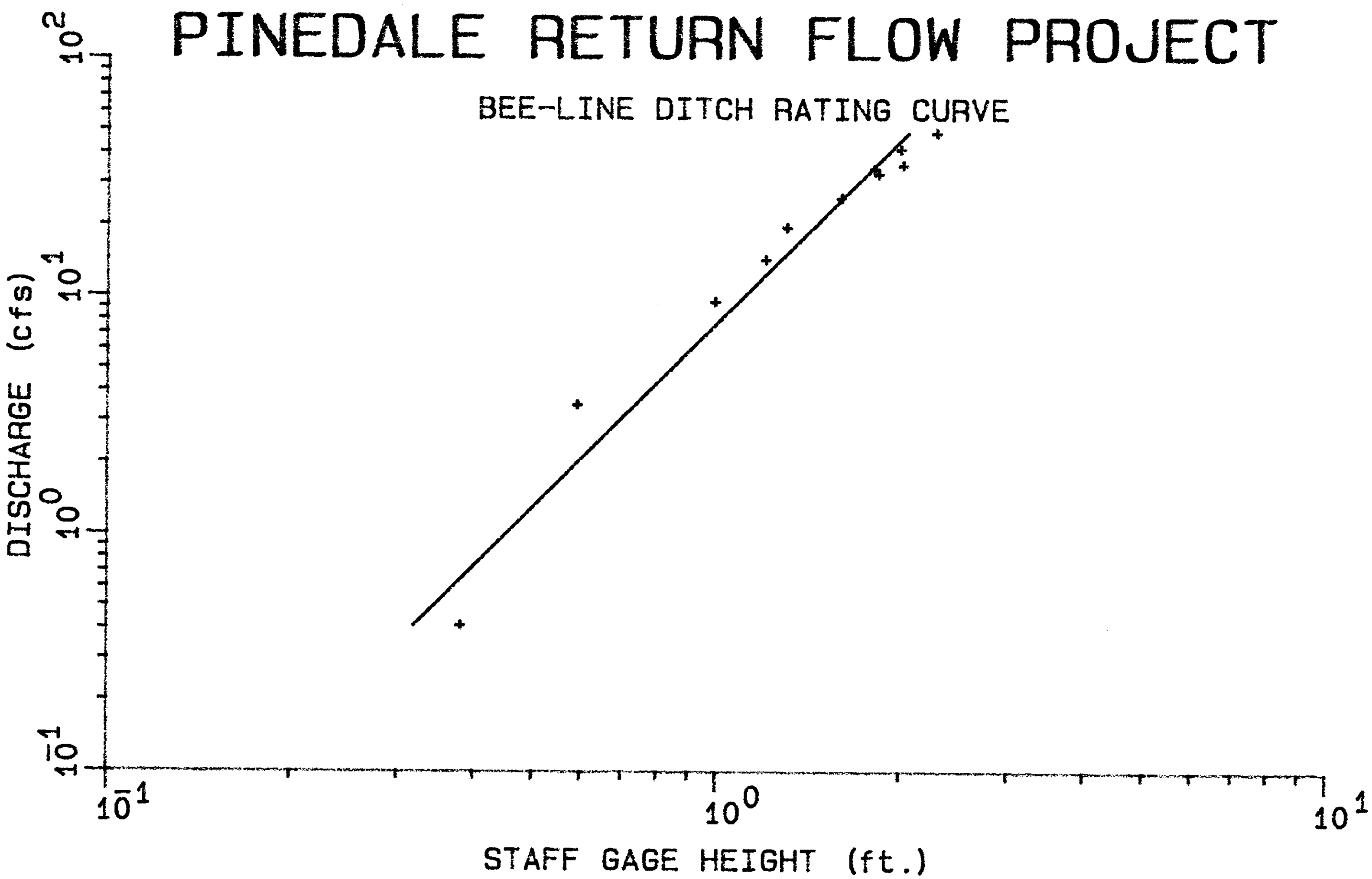


Figure 16. Bee-Line Ditch Rating Curve.

RECORDER LOCATION: Bel-Knap Noble Ditch

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
6/19/84	1.30	9.71
6/29/84	0.63	4.32
7/5/84	1.72	12.00
7/19/84	0.93	7.17
7/6/84	1.94	11.90
9/15/84	0.50	2.37
6/5/85	1.47	10.78
6/15/85	1.27	9.86
7/10/85	1.19	9.59
8/14/85	0.21	0.46
6/4/86	0.74	4.67
7/9/86	2.21	14.54
6/4/87	1.31	9.20
6/18/87	0.32	1.31
6/25/87	1.17	8.90

REGRESSION EQUATION: log(Q) = 0.961 + 1.85[log(SG)]

Staff Gage Readings 0.1 to 0.86

REGRESSION EQUATION: log(Q) = 0.896 + 0.787[log(SG)]

Staff Gage Readings 0.87 to 2.5

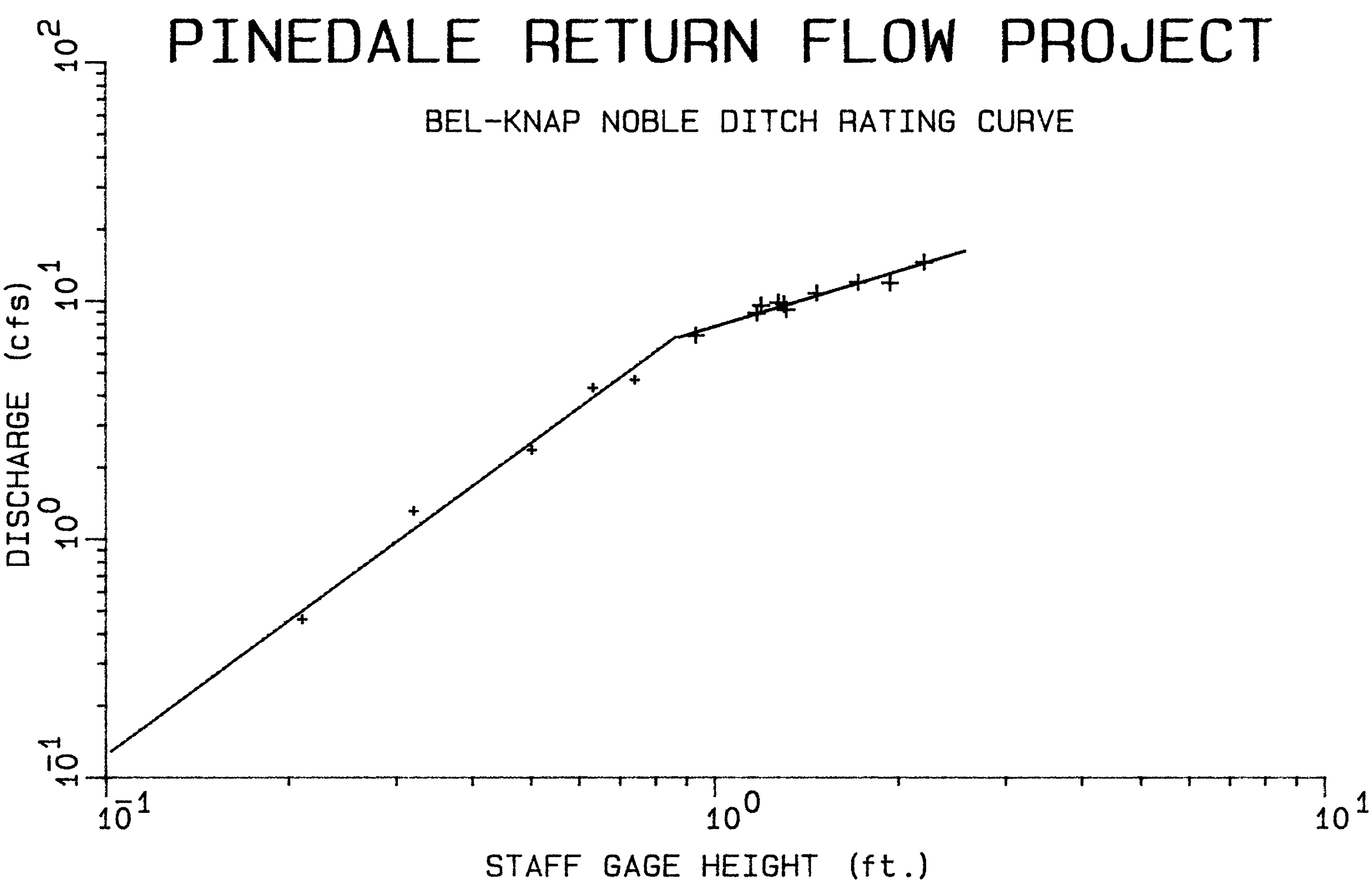


Figure 17. Bel-Knap Noble Ditch Rating Curve.

RECORDER LOCATION: Binning Ditch

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
5/19/84	1.16	8.20
6/12/84	2.95	70.00
6/26/84	3.26	80.20
6/6/85	2.83	57.28
6/13/85	2.93	59.17
7/17/85	2.56	47.64
7/25/85	0.85	0.67
8/1/85	0.89	0.88
8/15/85	0.80	0.18
6/2/86	3.30	87.58
6/23/86	3.21	83.16
7/22/86	0.96	4.84
8/5/86	1.02	6.00
6/2/87	2.01	28.56
6/23/87	2.57	48.79
7/14/87	0.78	0.21
7/28/87	0.95	1.78

REGRESSION EQUATION: $\log(Q) = 0.735 + 14.0[\log(SG)]$

Staff Gage Readings 0.6 to 1.00

REGRESSION EQUATION: $\log(Q) = 0.764 + 2.24[\log(SG)]$

Staff Gage Readings 1.01 to 4.0

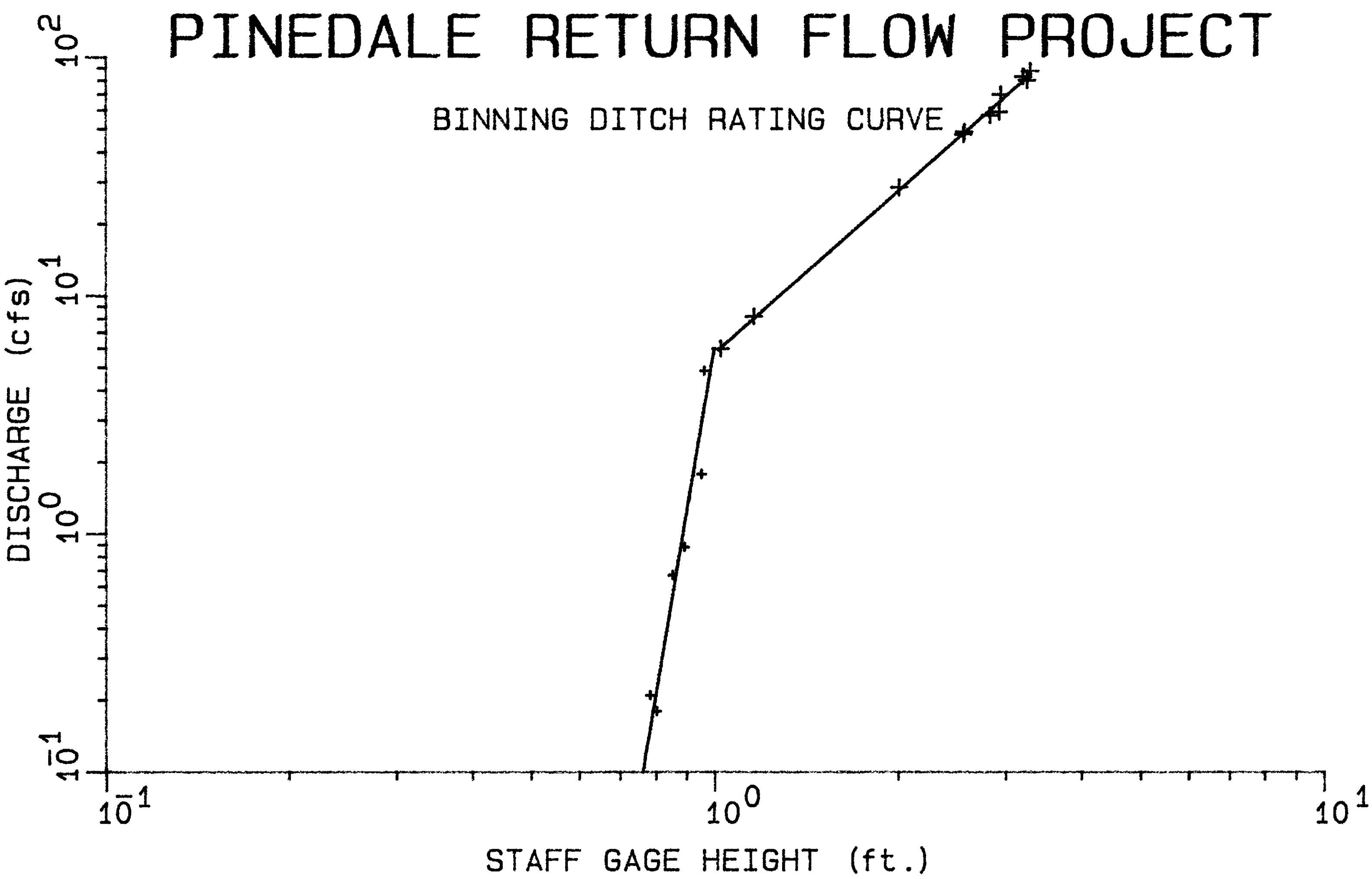


Figure 18. Binning Ditch Rating Curve.

RECORDER LOCATION: Converse Ditch

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
5/21/84	0.78	15.70
6/12/84	1.52	43.90
6/20/84	1.38	41.40
7/5/84	1.78	52.70
7/14/84	1.00	26.00
5/22/85	0.85	18.04
6/19/85	1.36	40.91
7/17/85	1.13	31.73
8/21/85	0.30	2.02
8/28/85	0.47	6.07
5/28/86	0.58	8.66
6/25/86	1.84	60.73
7/23/86	1.00	23.09
5/15/87	1.14	30.41
6/18/87	0.56	8.88
6/25/87	1.40	41.64
7/23/87	0.27	1.32

REGRESSION EQUATION: $\log(Q) = 1.55 + 2.46[\log(SG)]$

Staff Gage Readings 0.1 to 0.67

REGRESSION EQUATION: $\log(Q) = 1.39 + 1.51[\log(SG)]$

Staff Gage Readings 0.68 to 2.00

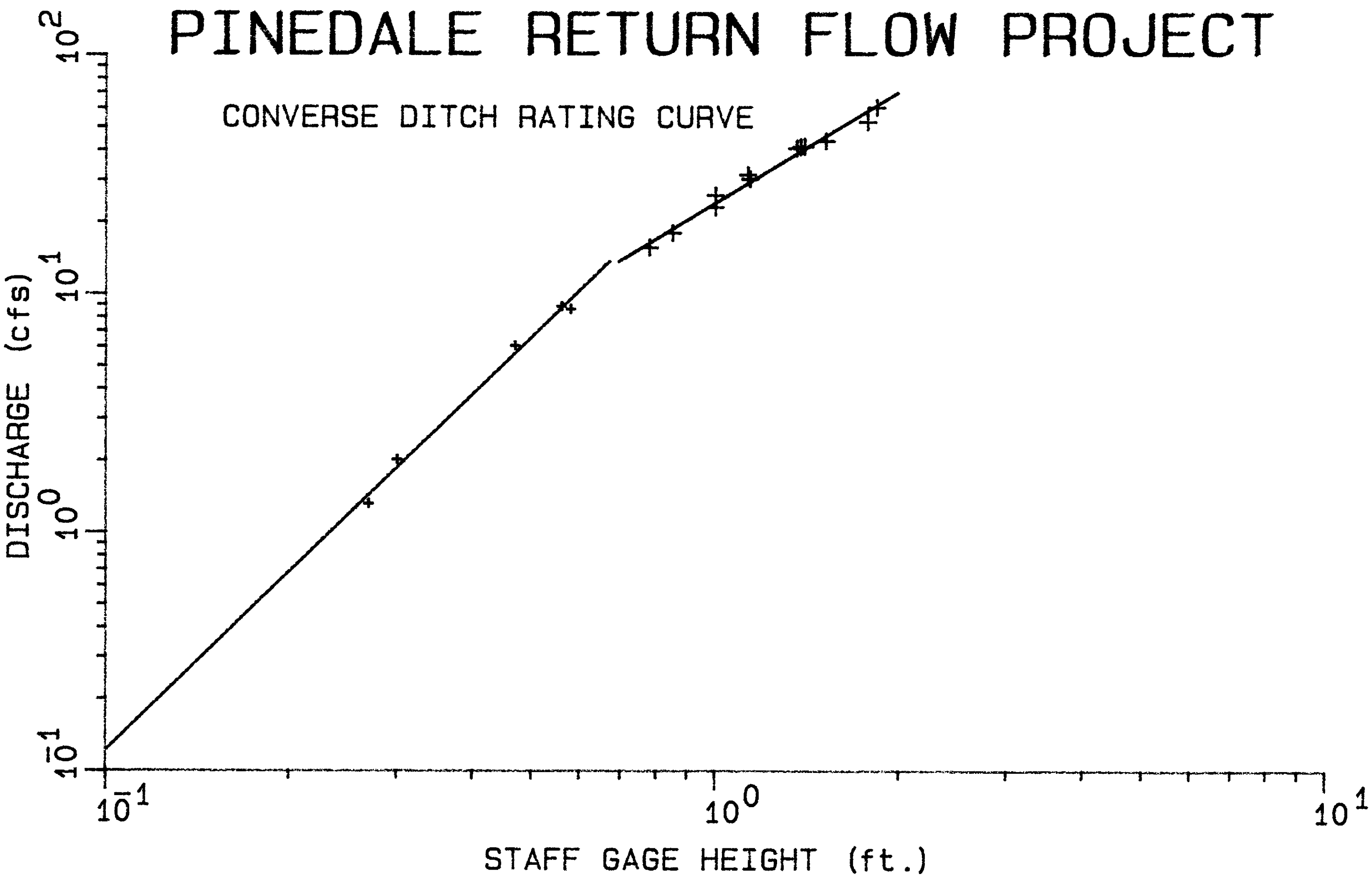


Figure 19. Converse Ditch Rating Rating.

RECORDER LOCATION: Densley - Merritt Ditch

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
5/20/84	3.73	0.12
6/14/84	5.45	19.40
7/17/84	5.19	15.10
7/17/84	4.88	10.90
8/21/84	4.66	7.33
6/5/85	5.37	19.04
6/19/85	5.29	16.71
7/10/85	4.82	10.70
7/17/85	4.62	8.18
8/7/85	3.84	0.26
8/28/85	3.96	0.86
6/4/86	5.01	12.98
6/18/86	5.20	15.78
7/16/86	3.99	0.98
5/20/87	5.16	15.45
6/17/87	4.11	2.18
10/4/87	4.21	2.54

REGRESSION EQUATION: $\log(Q) = -16.2 + 26.8[\log(SG)]$

Staff Gage Readings 3.6 to 4.27

REGRESSION EQUATION: $\log(Q) = -2.93 + 5.76[\log(SG)]$

Staff Gage Readings 4.28 to 5.6

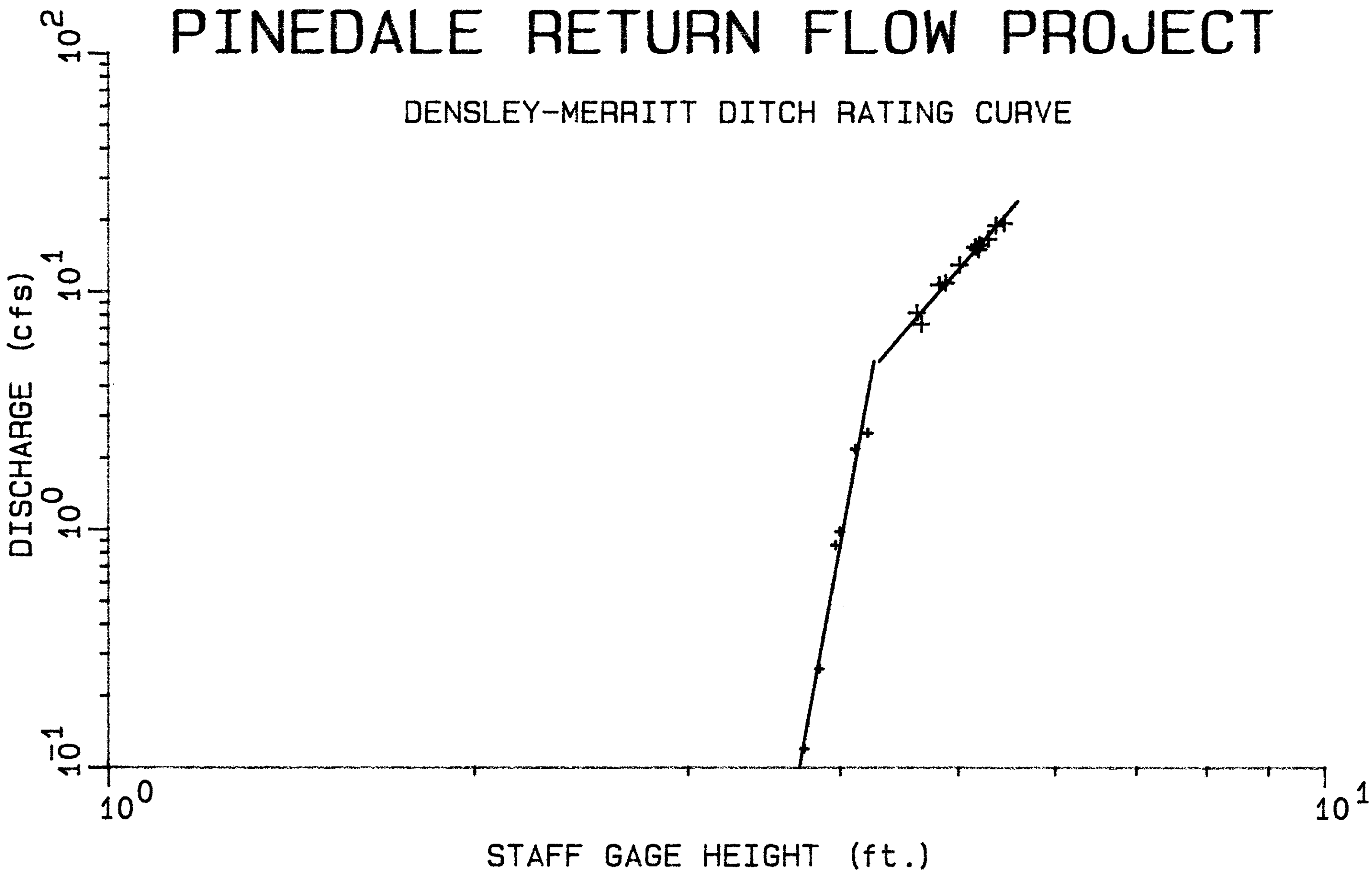


Figure 20. Densley-Merritt Ditch Rating Curve.

RECORDER LOCATION: Ditch By Willard Binning's Ranch

GAGING RECORD

DATE	**STAFF GAGE HEIGHT** (feet)	**DISCHARGE** (cfs)
5/18/84	1.56	1.37
7/10/84	2.93	11.20
5/23/85	1.86	3.11
6/6/85	2.32	7.74
6/20/85	2.18	4.17
5/27/86	2.89	16.24
6/2/87	2.78	11.89

REGRESSION EQUATION: $\log(Q) = -0.523 + 3.60[\log(SG)]$

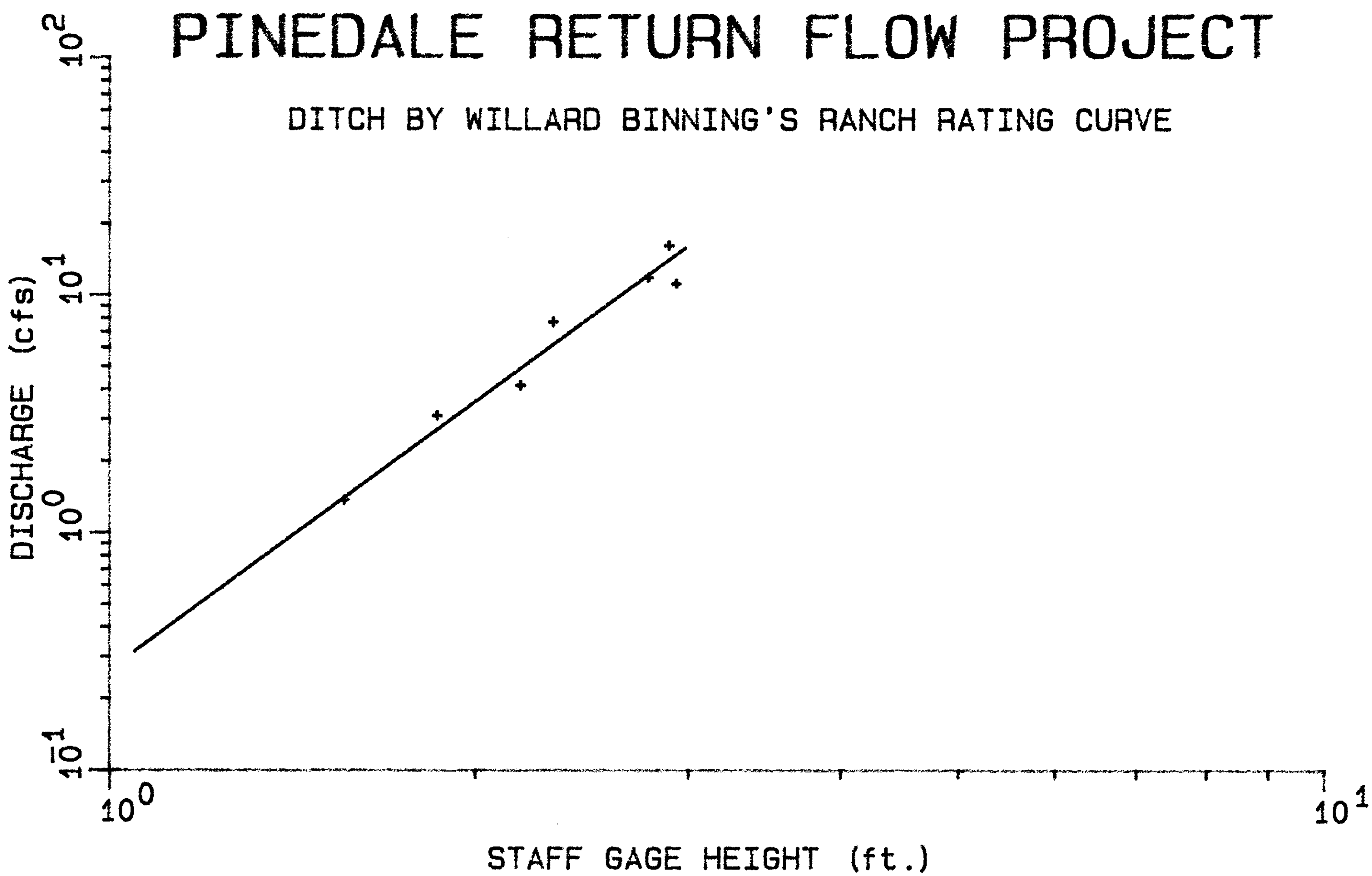


Figure 21. Ditch By Willard Binning's Ranch Rating Curve.

RECORDER LOCATION: Duck Creek Below Kitchen Reservoir

GAGING RECORD

DATE	**STAFF GAGE HEIGHT** (feet)	**DISCHARGE** (cfs)
5/18/84	0.68	9.10
6/22/84	0.74	11.20
7/26/84	0.82	15.64
9/15/84	0.76	12.17
5/27/86	0.67	8.70
6/24/86	0.74	10.81
5/15/87	0.67	8.89
7/9/87	0.74	10.53
7/16/87	0.88	18.53

REGRESSION EQUATION: $\log(Q) = 1.42 + 2.77[\log(SG)]$

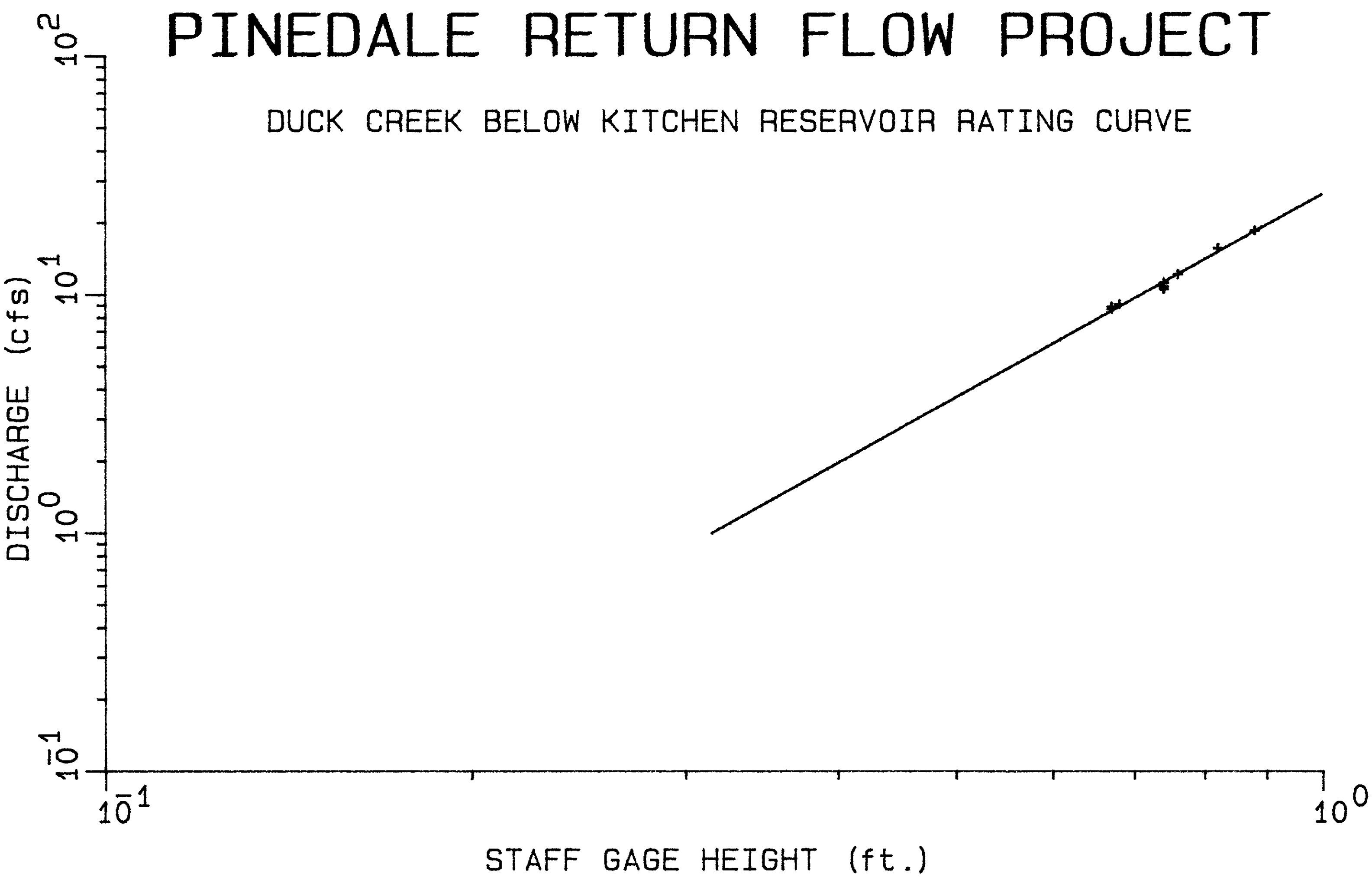


Figure 22. Duck Creek Below Kitchen Reservoir Rating Curve.

RECORDER LOCATION: Edmundson Ditch

GAGING RECORD

DATE	**STAFF GAGE HEIGHT** (feet)	**DISCHARGE** (cfs)
6/15/84	1.21	9.49
6/20/84	1.07	6.70
7/19/84	0.92	4.60
6/12/85	0.92	4.82
7/10/85	0.77	3.10
6/4/86	0.78	3.41
6/18/86	1.33	12.28
7/16/86	1.10	7.33
7/23/86	0.49	1.07
5/20/87	1.05	7.82
6/3/87	0.96	5.45
7/15/87	1.23	9.39

REGRESSION EQUATION: $\log(Q) = 0.777 + 2.42[\log(SG)]$

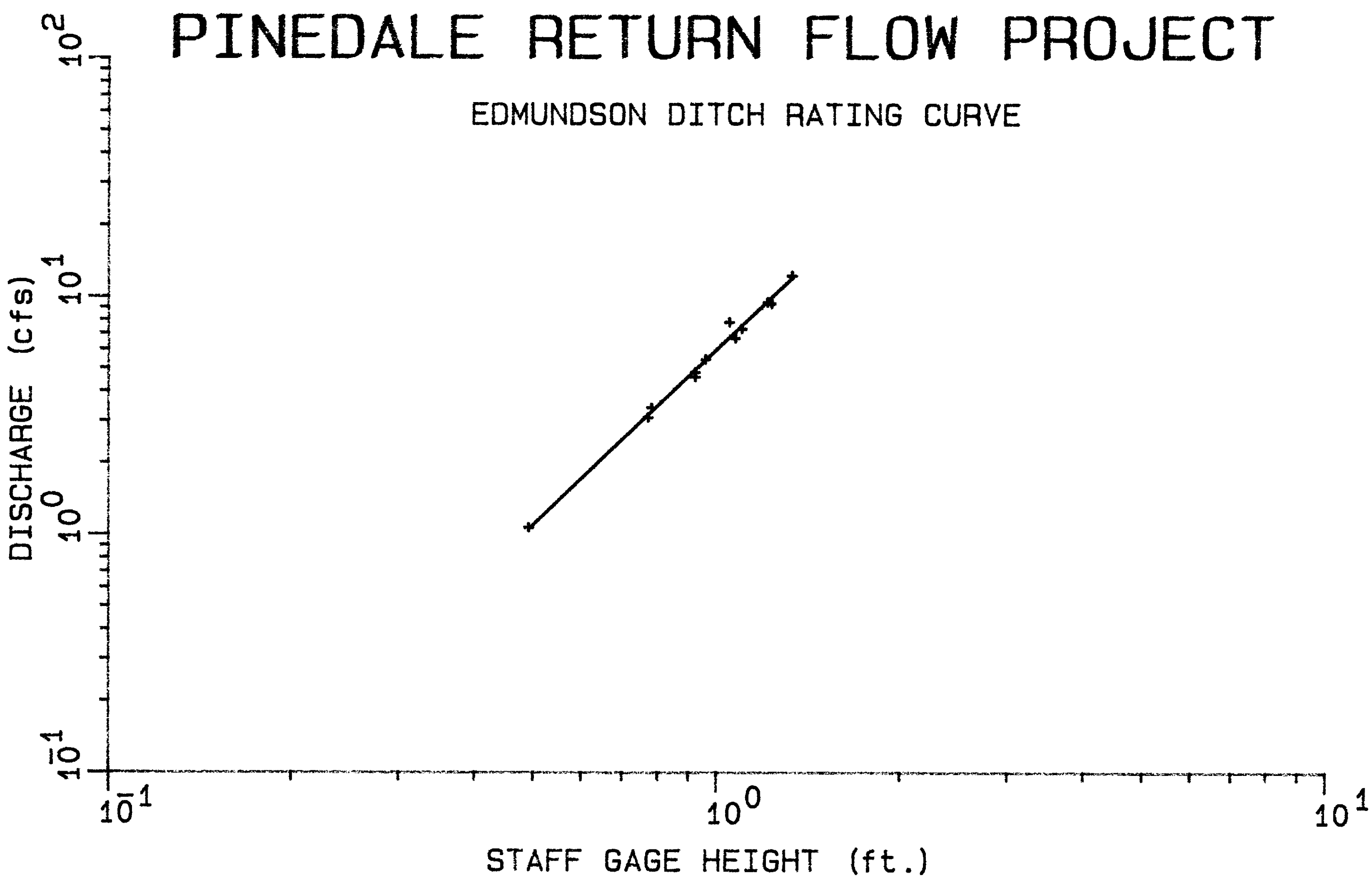


Figure 23. Edmundson Ditch Rating Curve.

RECORDER LOCATION: Harry Rahm Ditch

GAGING RECORD

DATE	**STAFF GAGE HEIGHT** (feet)	**DISCHARGE** (cfs)
5/21/84	0.59	0.54
6/15/84	1.25	11.60
7/19/84	1.02	5.45
7/19/84	0.88	3.62
6/5/85	1.33	12.43
6/19/85	0.99	6.03
7/17/85	1.14	7.45
8/14/85	0.63	0.86
8/21/85	0.73	2.51
6/4/86	1.02	6.08
6/18/86	1.44	14.63
5/20/87	1.29	11.72
6/24/87	1.15	7.89

REGRESSION EQUATION: log(Q) = 1.39 + 7.23[log(SG)]

Staff Gage Readings 0.5 to 0.71

REGRESSION EQUATION: log(Q) = 0.741 + 2.85[log(SG)]

Staff Gage Readings 0.72 to 1.50

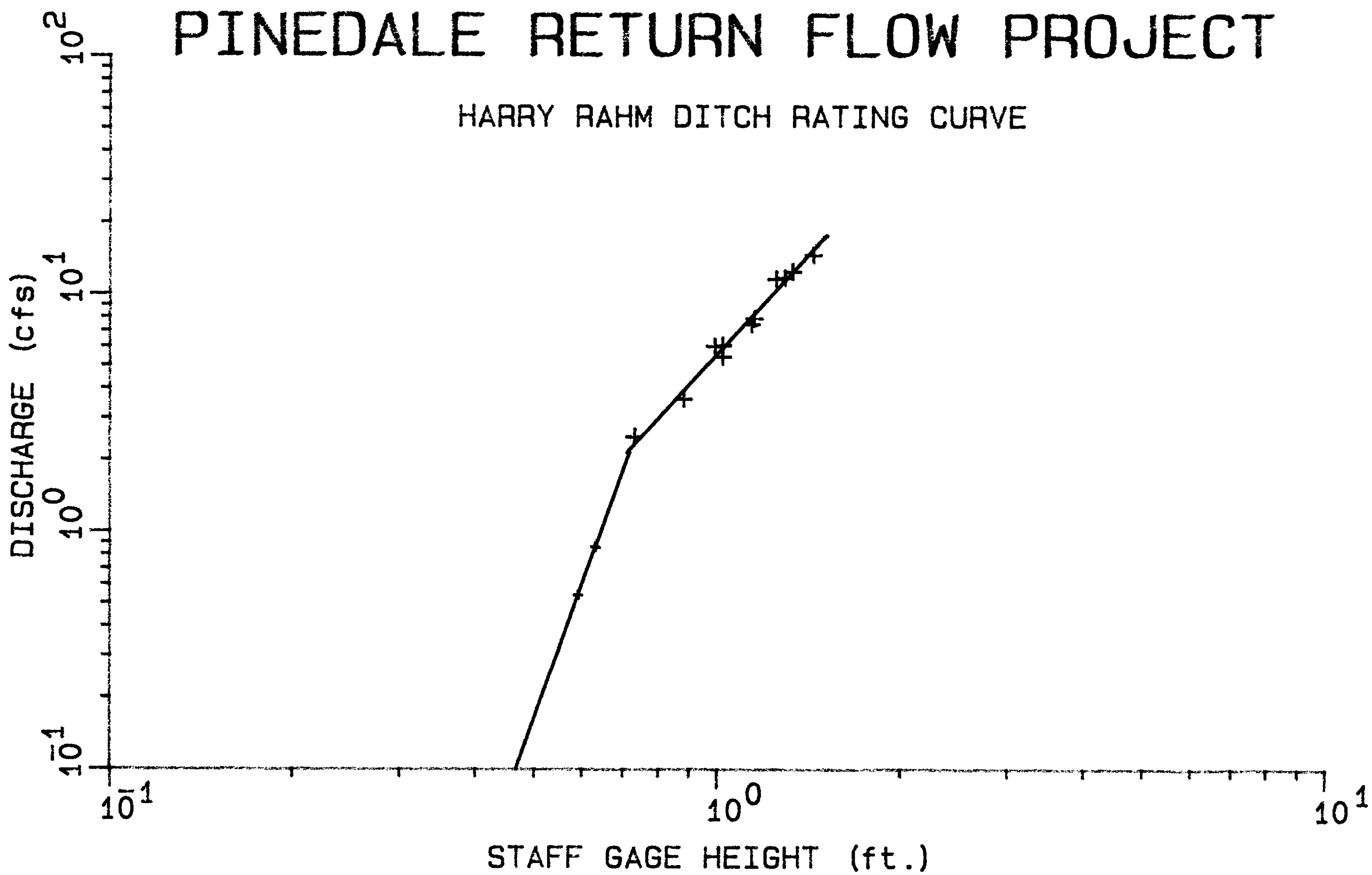


Figure 24. Harry Rahm Ditch Rating Curve.

RECORDER LOCATION: Highline Ditch (lower)

GAGING RECORD

DATE	**STAFF GAGE HEIGHT** (feet)	**DISCHARGE** (cfs)
6/14/85	1.29	27.13
6/26/85	1.31	30.57
7/11/85	1.62	43.30
7/25/85	1.25	27.67
6/2/86	0.61	7.32
6/9/86	0.89	17.37
6/16/86	1.33	33.00
6/25/86	1.53	37.69
8/19/86	0.16	0.98
6/2/87	0.80	12.87
6/23/87	1.46	38.72
7/21/87	1.00	20.57

REGRESSION EQUATION: $\log(Q) = 1.29 + 1.65[\log(SG)]$

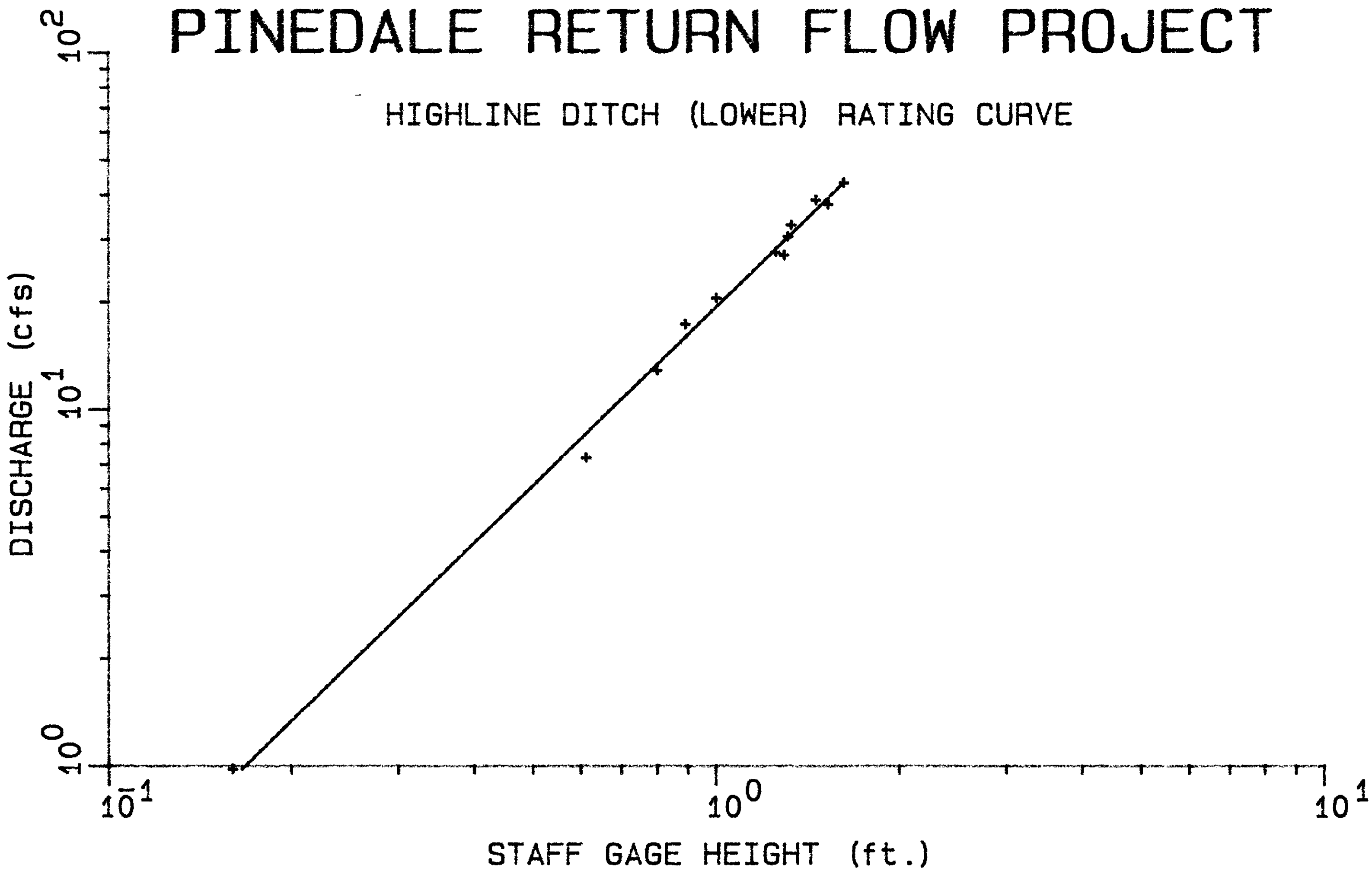


Figure 25. High Line Ditch (Lower) Rating Curve.

RECORDER LOCATION: Jenkins Ditch (Lower)

GAGING RECORD

DATE	**STAFF GAGE HEIGHT** (feet)	**DISCHARGE** (cfs)
6/13/84	1.67	25.60
6/27/84	1.75	25.40
7/6/84	1.98	31.80
7/24/84	1.41	17.80
7/25/84	0.64	2.45
5/21/85	0.71	2.78
6/24/85	1.79	27.15
7/8/85	1.68	25.20
7/22/85	0.35	0.26
7/31/85	0.55	1.39
8/12/85	0.58	1.56
6/2/86	1.19	13.60
6/16/86	1.68	24.80
7/14/86	1.44	17.31
7/21/86	0.80	4.85
5/18/87	0.83	5.86
6/15/87	1.45	18.14
7/20/87	0.45	0.64

REGRESSION EQUATION: $\log(Q) = 1.03 + 3.53[\log(SG)]$

Staff Gage Readings 0.3 to 0.94

REGRESSION EQUATION: $\log(Q) = 0.987 + 1.77[\log(SG)]$

Staff Gage Readings 0.95 to 2.50

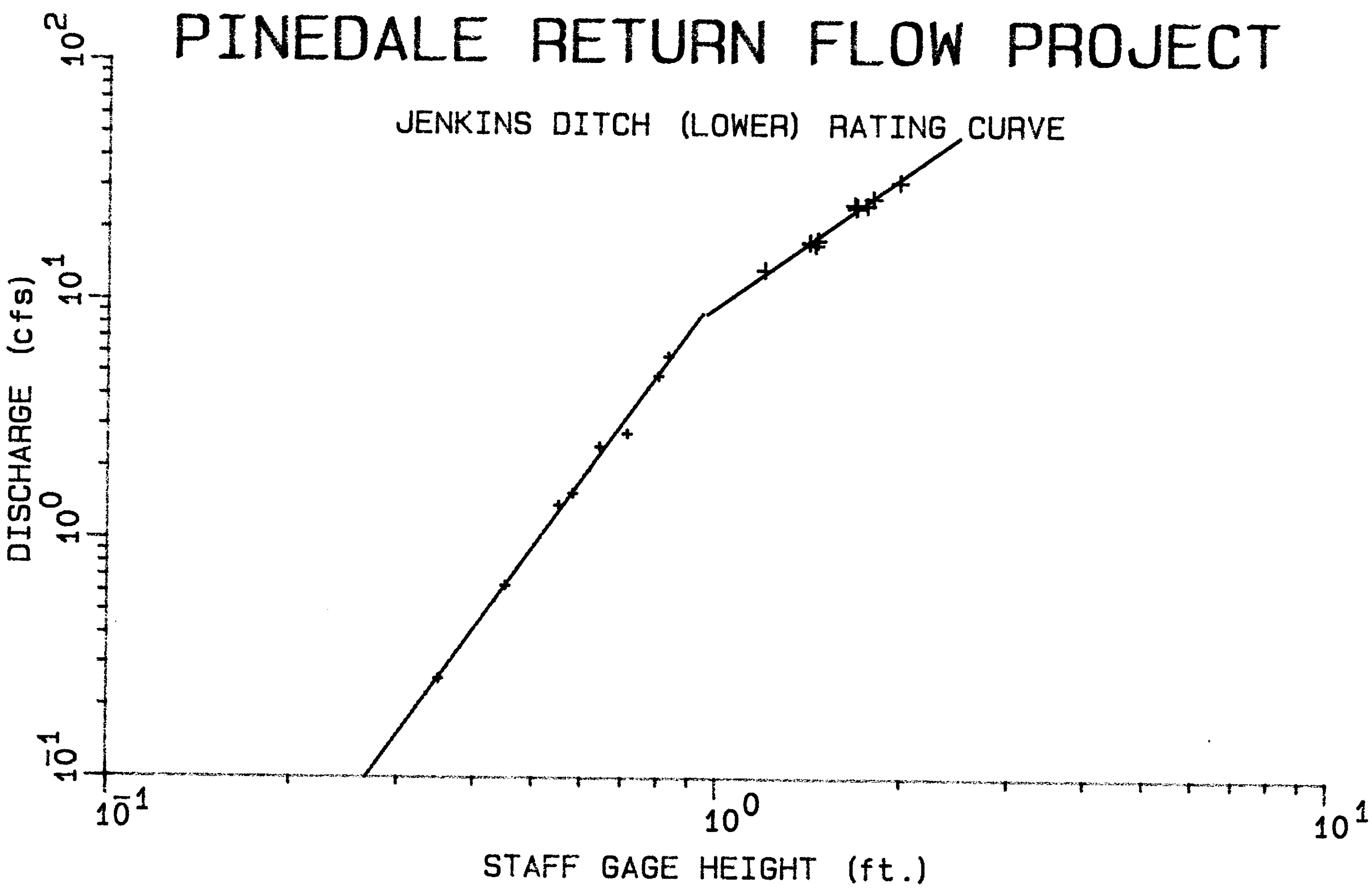


Figure 26. Jenkins Ditch (Lower) Rating Curve.

RECORDER LOCATION: Jenkins Ditch (Upper)

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
6/13/84	2.37	43.40
7/6/84	2.57	51.00
7/19/84	1.60	24.60
7/24/84	1.17	14.70
7/25/84	0.71	3.13
5/21/85	0.95	10.14
6/10/85	2.62	53.04
7/8/85	2.07	40.61
7/22/85	0.64	2.04
8/7/85	0.61	1.49
6/2/86	1.58	24.24
6/6/86	2.32	48.98
7/21/86	0.67	2.72
8/4/86	0.60	1.45
6/1/87	2.05	36.77
6/29/87	1.79	29.15
7/20/87	0.66	2.34

REGRESSION EQUATION: $\log(Q) = 1.26 + 4.95[\log(SG)]$

Staff Gage Readings 0.4 to 0.86

REGRESSION EQUATION: $\log(Q) = 1.05 + 1.64[\log(SG)]$

Staff Gage Readings 0.87 to 3.0

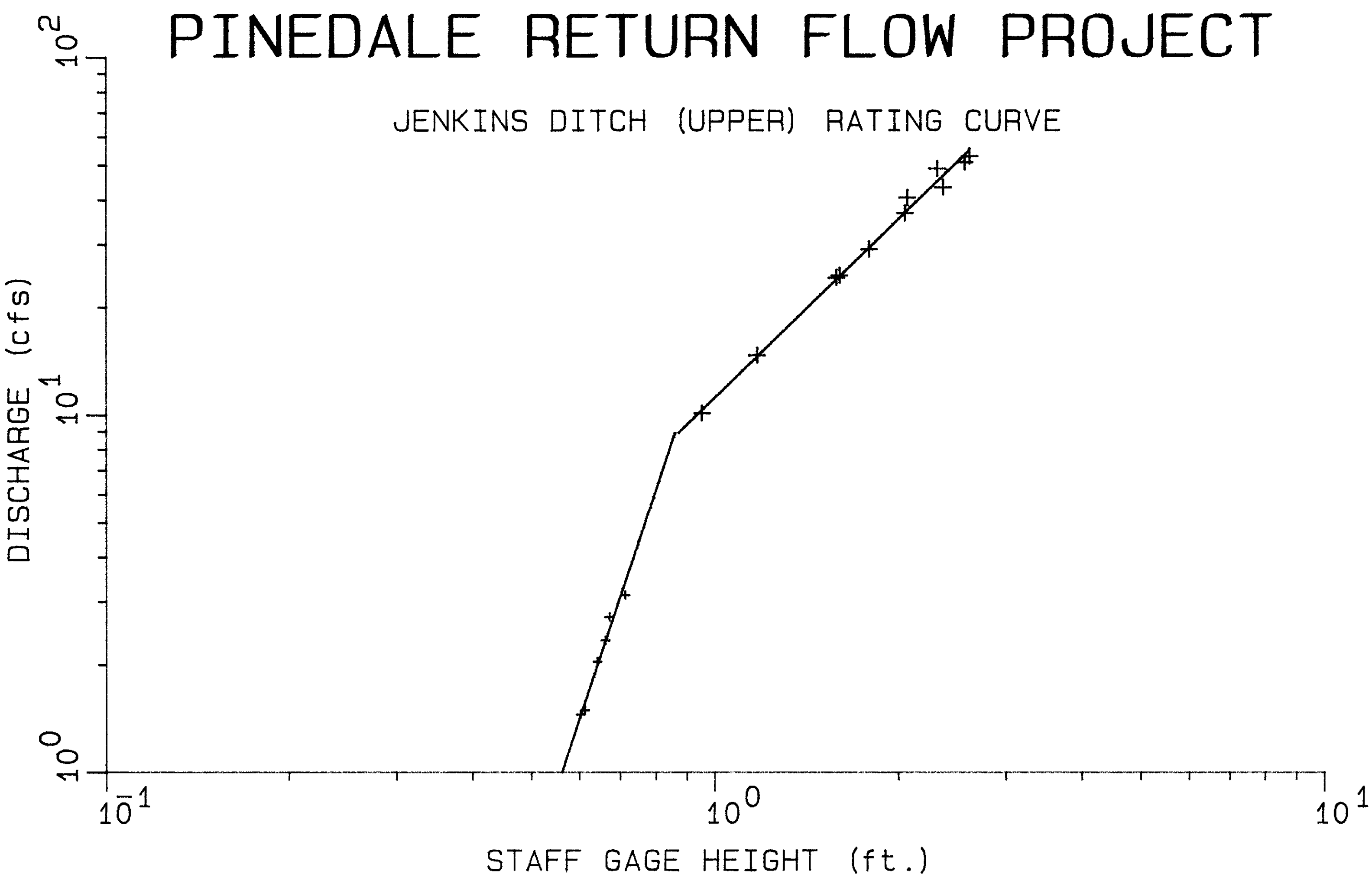


Figure 27. Jenkins Ditch (Upper) Rating Curve.

RECORDER LOCATION: Lake Creek

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
5/18/84	1.46	6.13
6/5/84	1.24	2.07
6/26/84	2.48	55.50
8/6/84	1.89	19.21
4/18/85	1.53	5.34
6/6/85	1.05	0.65
7/11/85	1.40	3.68
7/25/85	1.53	6.63
8/9/85	1.27	2.69
8/29/85	1.16	0.81
6/11/86	3.43	261.00
7/29/86	1.69	11.56
6/23/87	1.33	2.07
7/7/87	1.37	3.43
10/3/87	1.42	3.01

REGRESSION EQUATION: $\log(Q) = -0.348 + 6.18[\log(SG)]$

Staff Gage Readings 1.0 to 1.69

REGRESSION EQUATION: $\log(Q) = 0.0691 + 4.35[\log(SG)]$

Staff Gage Readings 1.70 to 4.0

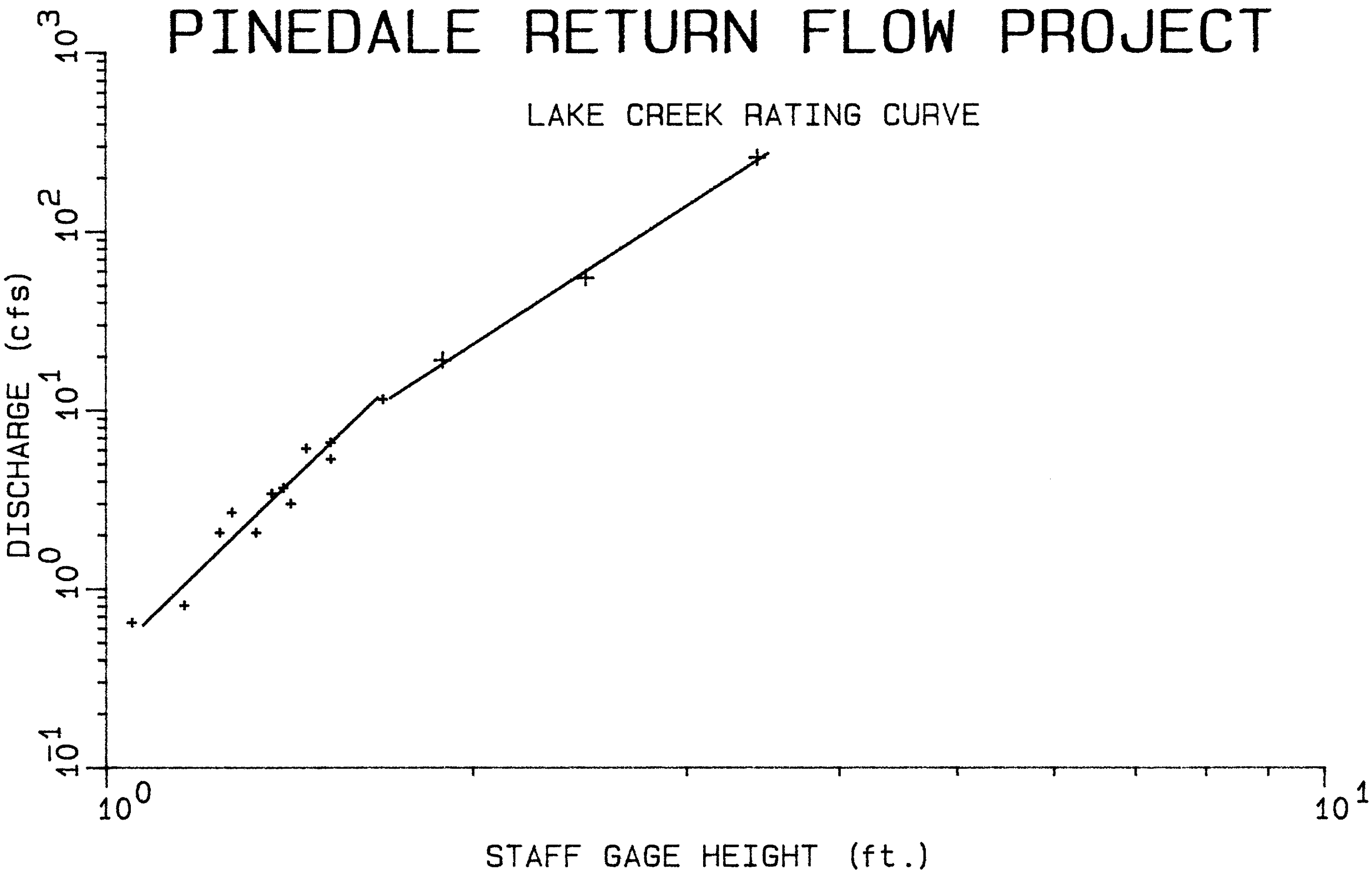


Figure 28. Lake Creek Rating Curve.

RECORDER LOCATION: Lane Ditch

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
5/27/84	1.53	3.65
6/13/84	2.30	20.40
7/14/84	1.93	9.10
6/10/85	2.14	15.61
6/24/85	2.05	11.66
7/8/85	1.99	9.70
7/15/85	1.93	8.01
6/2/86	2.36	22.93
6/20/86	1.61	4.46
5/18/87	2.02	12.57
7/13/87	2.06	12.67

REGRESSION EQUATION: $\log(Q) = -0.252 + 4.29[\log(SG)]$

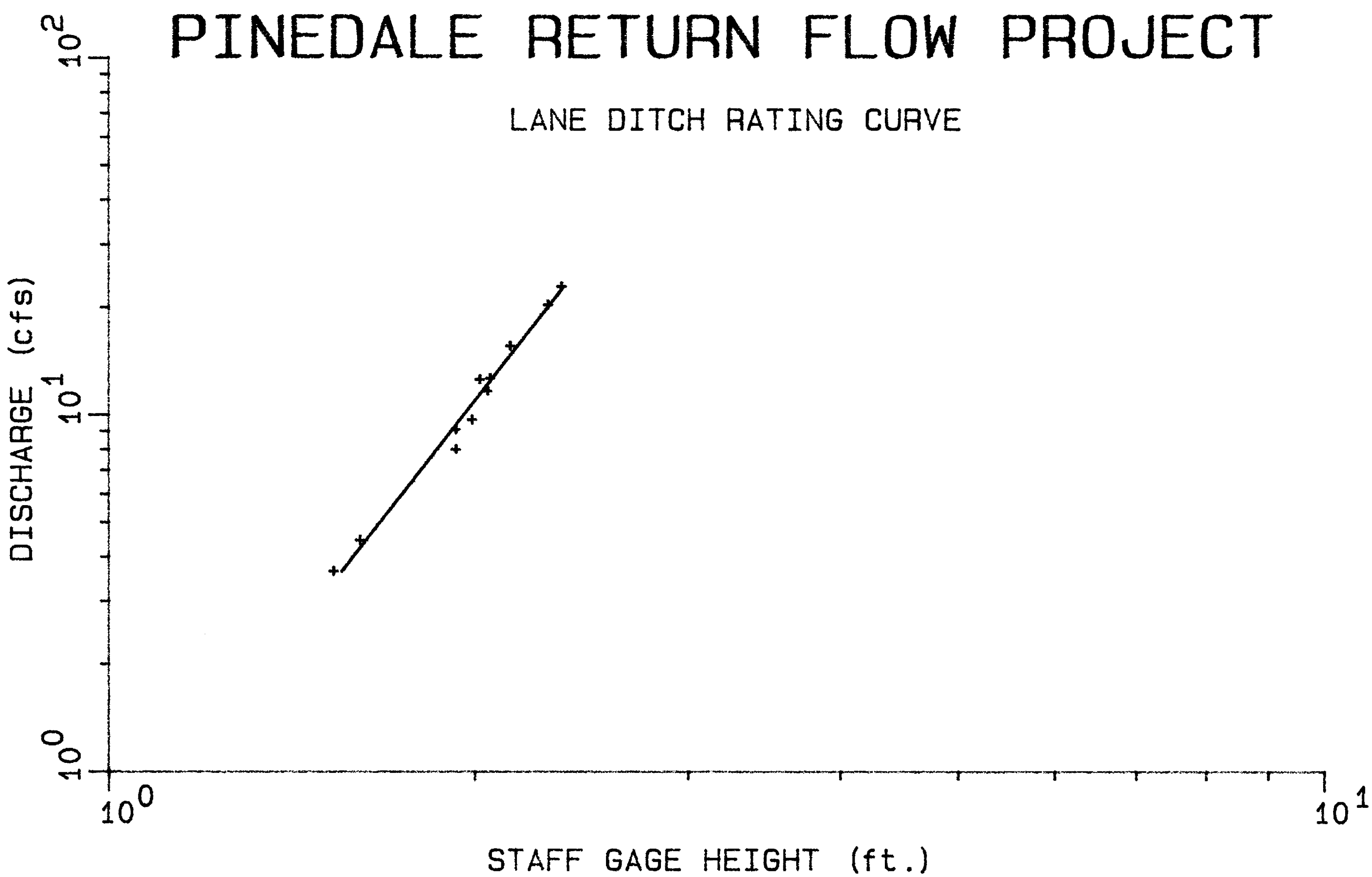


Figure 29. Lane Ditch Rating Curve.

RECORDER LOCATION: Marsh Creek

GAGING RECORD

DATE	**STAFF GAGE HEIGHT** (feet)	**DISCHARGE** (cfs)
5/17/84	6.04	19.40
5/27/84	5.83	8.61
7/12/84	5.51	1.90
6/10/85	6.05	15.25
6/21/85	5.73	6.89
6/24/85	5.60	3.67
7/8/85	5.43	1.43
6/5/86	5.90	14.38
6/7/86	6.03	18.82
6/23/86	5.76	8.26
5/18/87	5.77	7.81
6/15/87	5.45	1.20
6/29/87	5.67	6.60
7/13/87	5.36	1.23

REGRESSION EQUATION: $\log(Q) = -17.6 + 24.3[\log(SG)]$

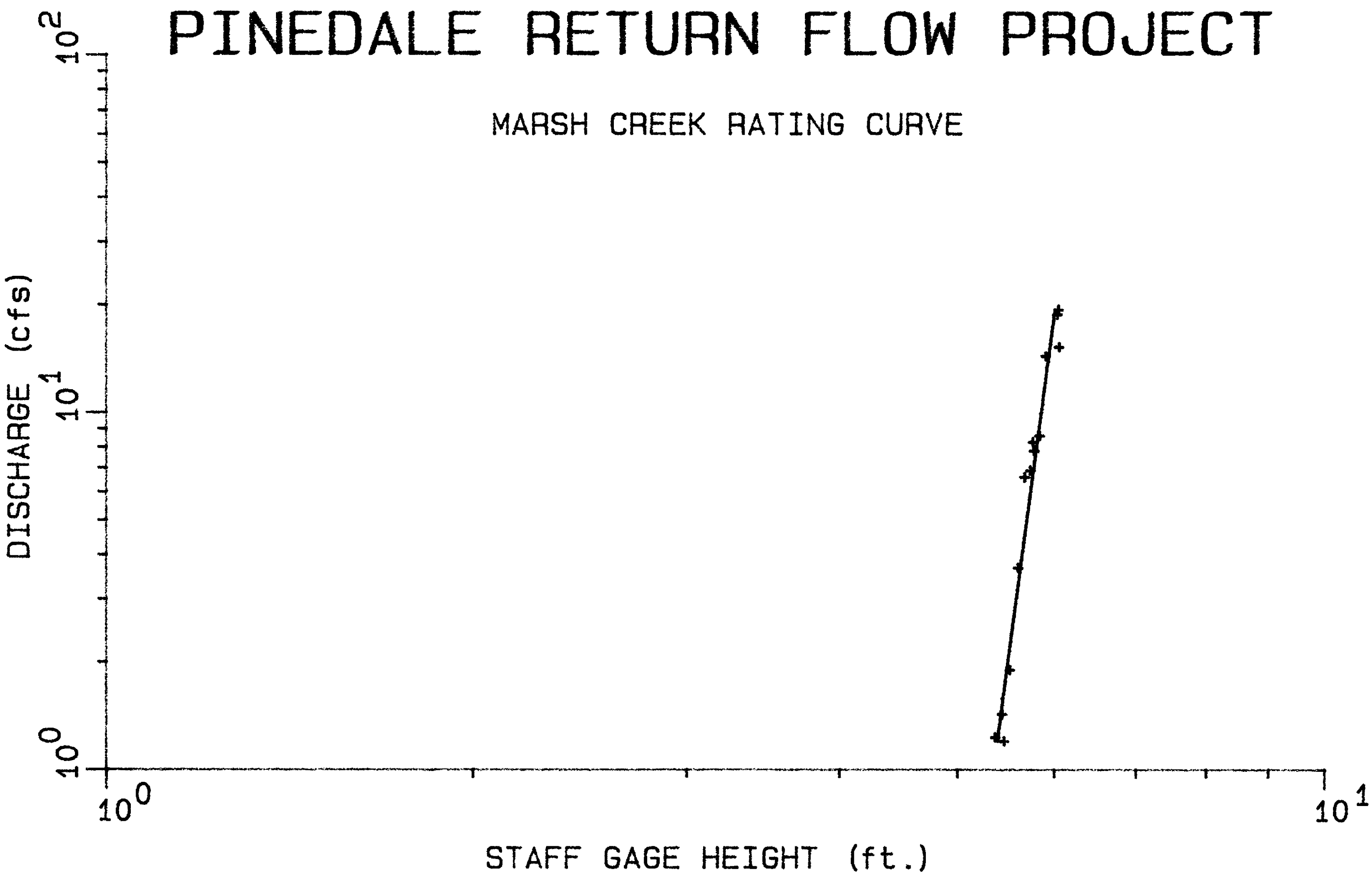


Figure 30. Marsh Creek Rating Curve.

RECORDER LOCATION: McDonough Ditch

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
6/11/85	1.75	27.09
7/3/85	0.87	0.64
7/9/85	1.61	22.48
7/16/85	1.54	19.39
7/31/85	0.84	0.44
8/27/85	1.06	2.30
6/3/86	1.90	30.19
7/22/86	0.89	0.90
8/12/86	0.81	0.17
5/20/87	2.02	38.27
6/3/87	1.42	15.42
6/24/87	1.78	31.82
10/4/87	0.90	1.35

REGRESSION EQUATION: $\log(Q) = 0.917 + 18.0[\log(SG)]$

Staff Gage Readings 0.7 to 0.98

REGRESSION EQUATION: $\log(Q) = 0.823 + 2.50[\log(SG)]$

Staff Gage Readings 0.99 to 2.5

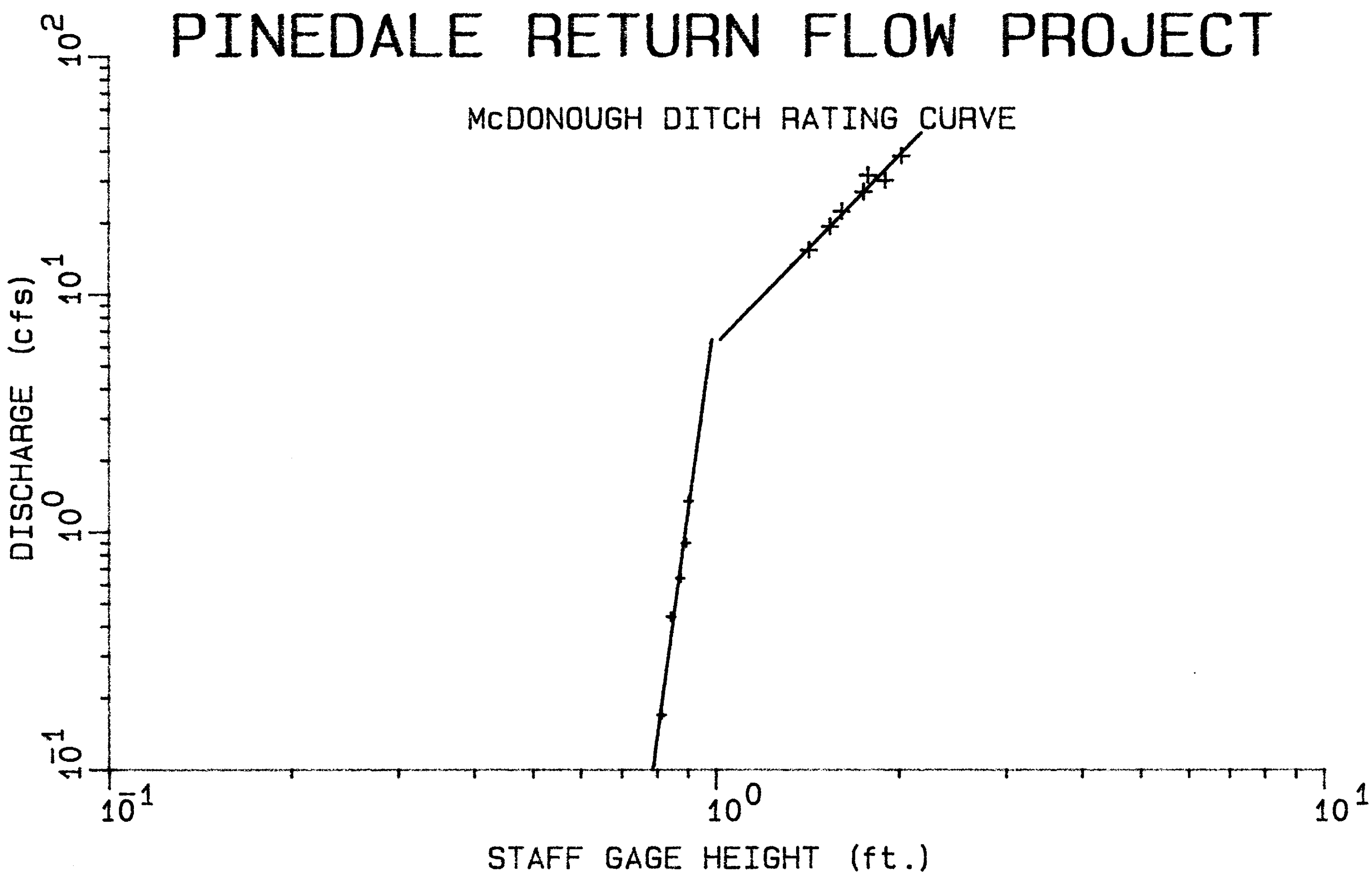


Figure 31. McDonough Ditch Rating Curve.

RECORDER LOCATION: New Fork River Below Barlow's Bridge

GAGING RECORD

DATE	**STAFF GAGE HEIGHT** (feet)	**DISCHARGE** (cfs)
5/20/84	1.49	26.10
5/27/84	1.82	68.10
5/31/84	2.54	227.40
6/7/84	2.70	264.50
8/22/84	1.55	31.56
4/18/85	1.74	51.07
6/24/85	2.34	180.87
7/3/85	1.38	15.00
7/17/85	1.39	19.74
8/12/85	1.33	14.81
8/19/85	1.42	19.67
6/11/86	3.30	462.21
7/21/86	1.72	52.78
7/29/86	1.52	28.45
8/4/86	1.46	22.31
8/18/86	1.58	35.12
5/29/87	2.42	188.46
6/22/87	2.55	227.40
7/20/87	1.56	33.34
10/3/87	1.51	25.29

RECORDER LOCATION: New Fork River Below Barlow's Bridge

REGRESSION EQUATION: $\log(Q) = 0.546 + 4.95[\log(SG)]$

Staff Gage Readings 0.7 to 2.05

REGRESSION EQUATION: $\log(Q) = 1.22 + 2.79[\log(SG)]$

Staff Gage Readings 2.06 to 3.5

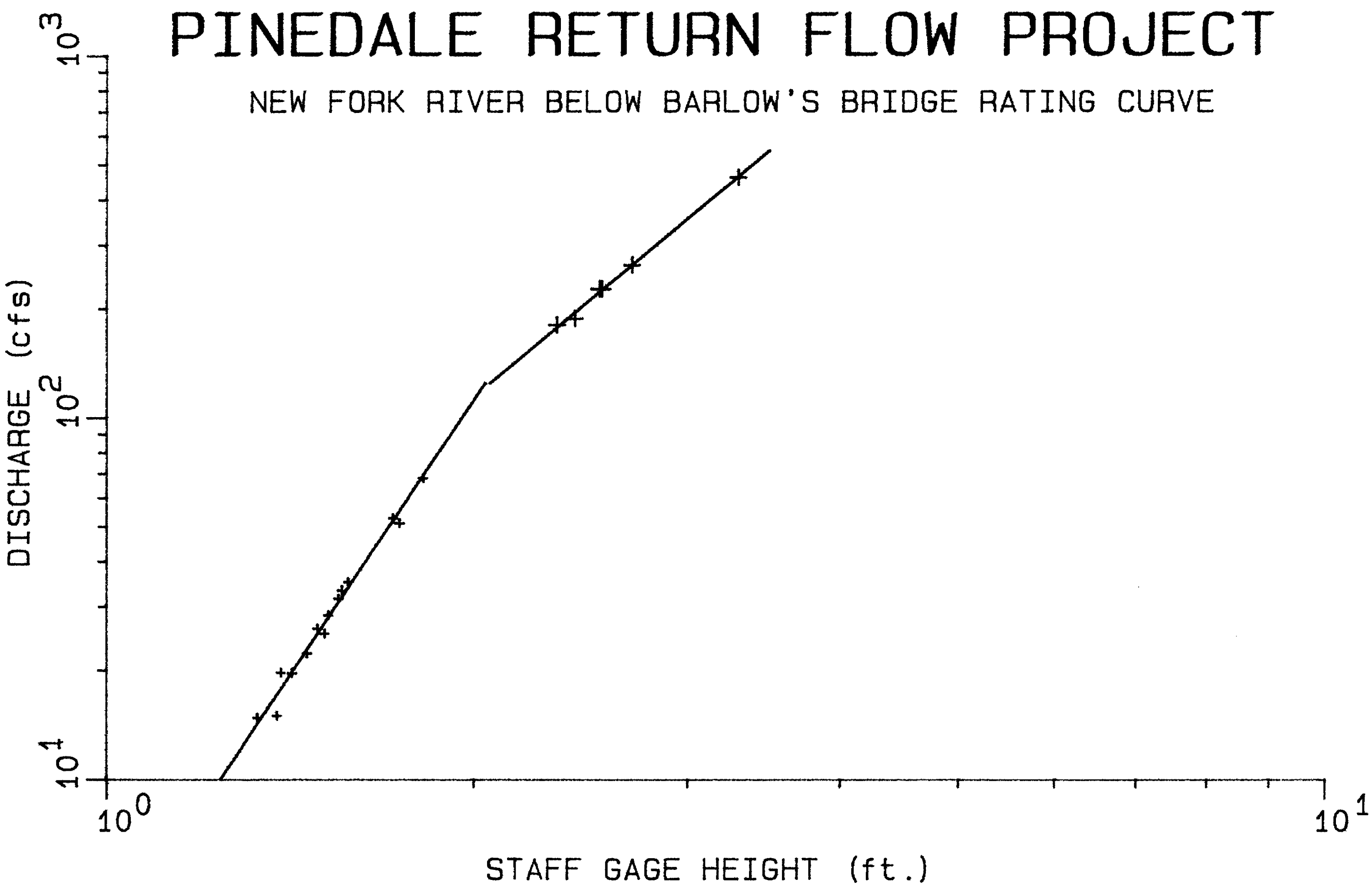


Figure 32. New Fork River Below Barlow's Bridge Rating Curve.

RECORDER LOCATION: New Fork River at the County Road

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
5/23/84	4.70	15.10
6/1/84	5.08	45.40
6/7/84	5.30	77.00
6/21/84	5.21	59.80
8/17/84	5.10	38.24
8/22/84	5.00	31.60
4/17/85	5.21	70.81
5/23/85	4.44	8.41
6/13/85	4.90	34.34
7/25/85	4.84	27.48
8/8/85	4.70	16.75
8/15/85	4.54	7.99
8/22/85	4.52	7.19
6/20/86	5.45	116.82
7/23/86	5.19	62.56
8/6/86	5.04	44.75
6/4/87	4.85	35.38
10/4/87	4.55	8.45

REGRESSION EQUATION: $\log(Q) = -8.15 + 13.9[\log(SG)]$

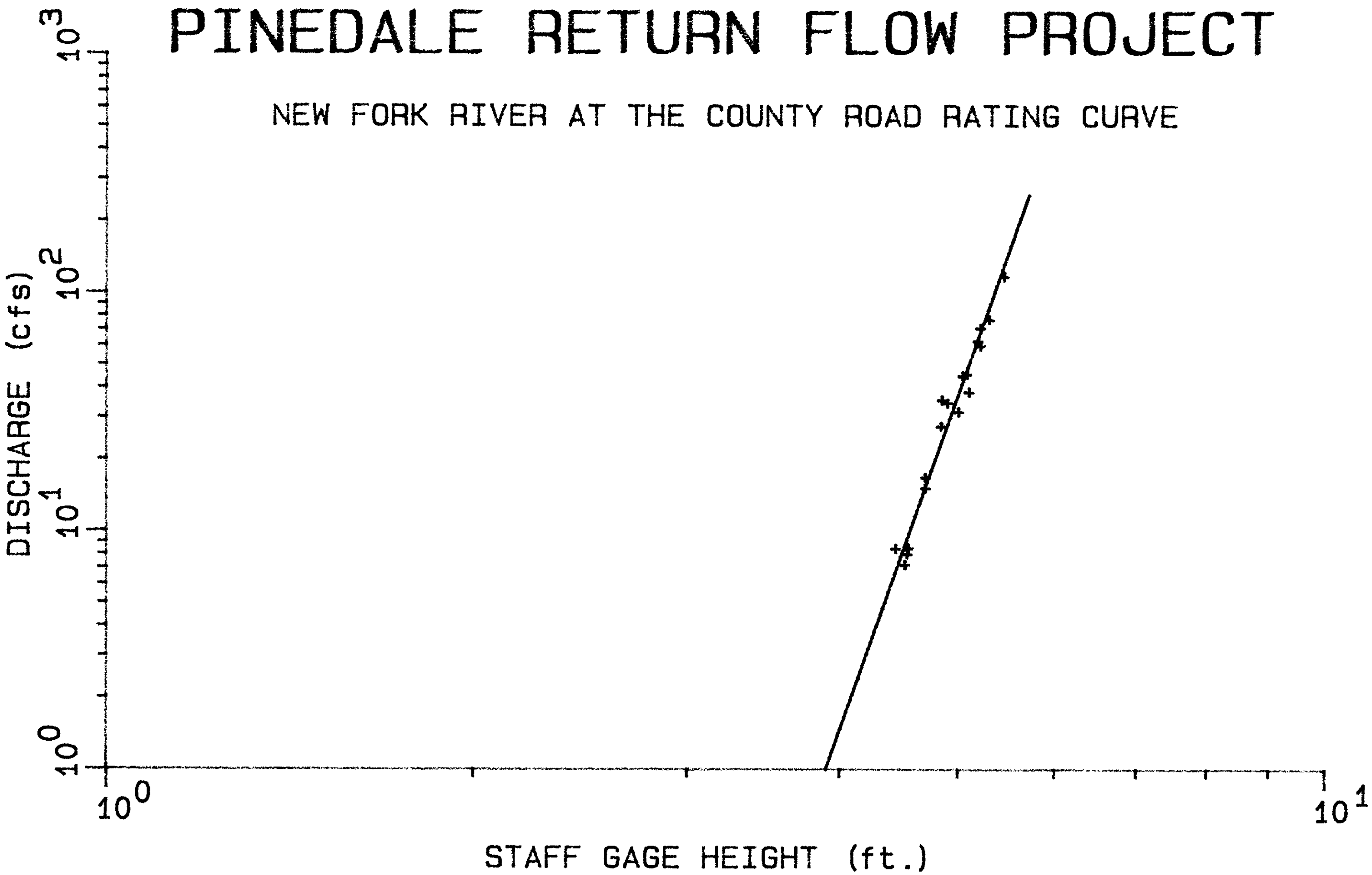


Figure 33. New Fork River At The County Road Rating Curve.

RECORDER LOCATION: New Fork River At Dick Noble's

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
5/22/84	4.45	5.93
6/1/84	5.07	30.30
6/7/84	4.72	15.40
6/21/84	4.64	12.20
7/5/84	5.30	38.60
8/21/84	5.05	25.43
4/18/85	5.67	55.12
5/22/85	4.39	4.27
7/10/85	4.66	13.76
7/24/85	4.82	20.81
8/7/85	4.71	15.64
8/14/85	4.52	8.22
6/4/86	4.63	10.57
6/25/86	5.23	33.51
7/2/86	5.69	55.82
5/15/87	4.61	10.23
6/18/87	4.41	6.29
7/16/87	4.77	16.16

REGRESSION EQUATION: $\log(Q) = -9.15 + 15.3[\log(SG)]$

Staff Gage Readings 4.0 to 4.83

REGRESSION EQUATION: $\log(Q) = -2.79 + 6.01[\log(SG)]$

Staff Gage Readings 4.84 to 6.0

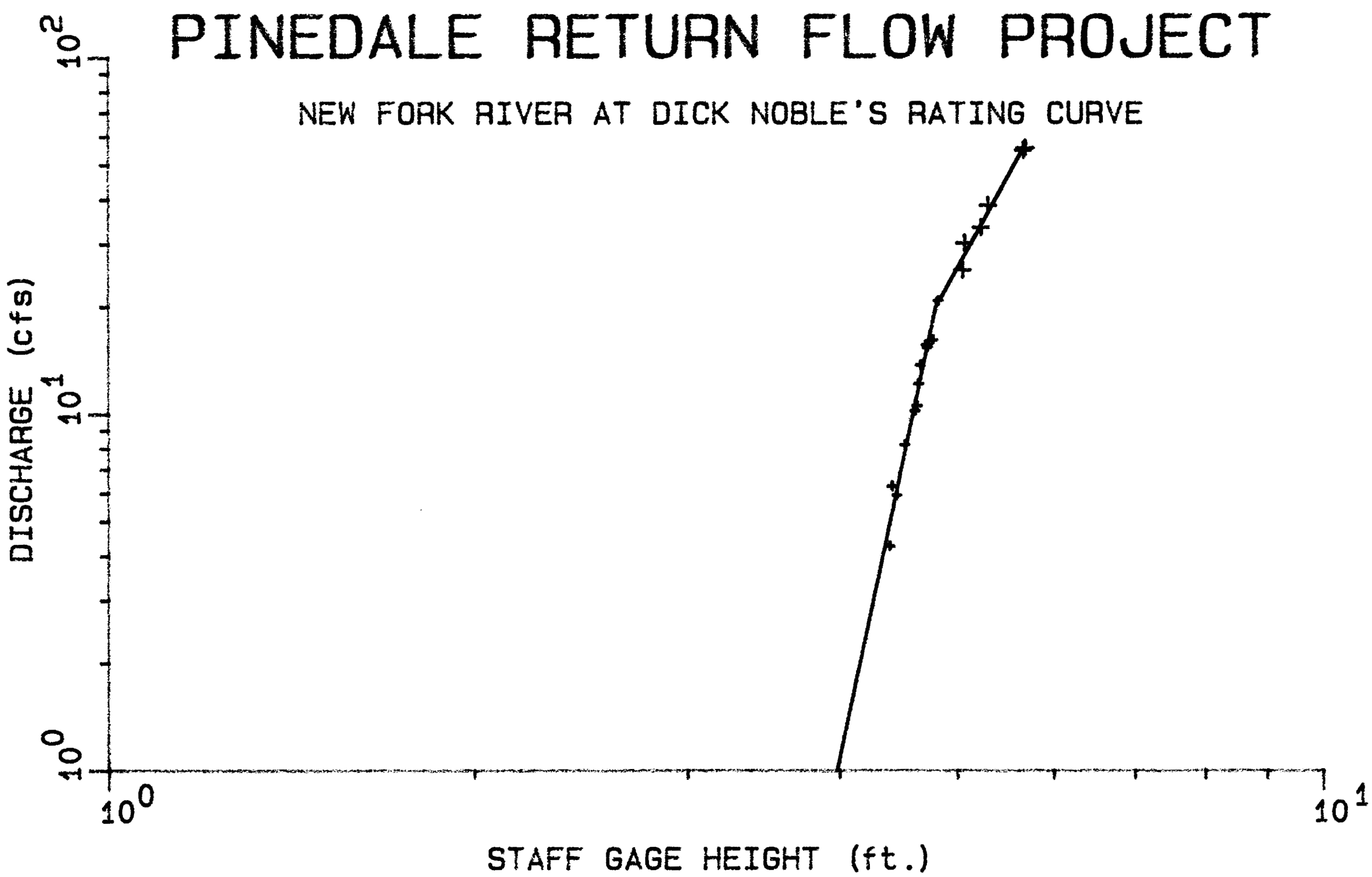


Figure 34. New Fork River At Dick Noble's Place Rating Curve.

RECORDER LOCATION: New Fork River Below Duck Creek

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
5/17/84	1.57	136.90
5/26/84	1.34	91.10
6/6/84	1.79	171.00
6/7/84	2.31	274.00
8/17/84	1.64	109.93
8/21/84	1.51	99.16
9/13/84	1.40	83.94
10/28/84	1.51	106.20
11/17/84	1.44	74.00
5/10/85	1.41	97.30
5/23/85	1.14	52.57
6/13/85	1.84	180.08
7/25/85	1.47	93.08
8/16/85	1.10	38.86
11/3/85	1.16	50.56
5/29/86	1.33	83.17
8/4/86	1.74	148.60
8/11/86	1.19	65.30
8/18/86	1.65	120.21
5/14/87	1.05	50.85
6/1/87	2.10	213.24
8/3/87	1.35	84.57

RECORDER LOCATION: New Fork River Below Duck Creek

GAGING RECORD (cont.)

DATE	**STAFF GAGE HEIGHT** (feet)	**DISCHARGE** (cfs)
10/3/87	0.95	36.25

REGRESSION EQUATION: $\log(Q) = 1.64 + 2.15[\log(SG)]$

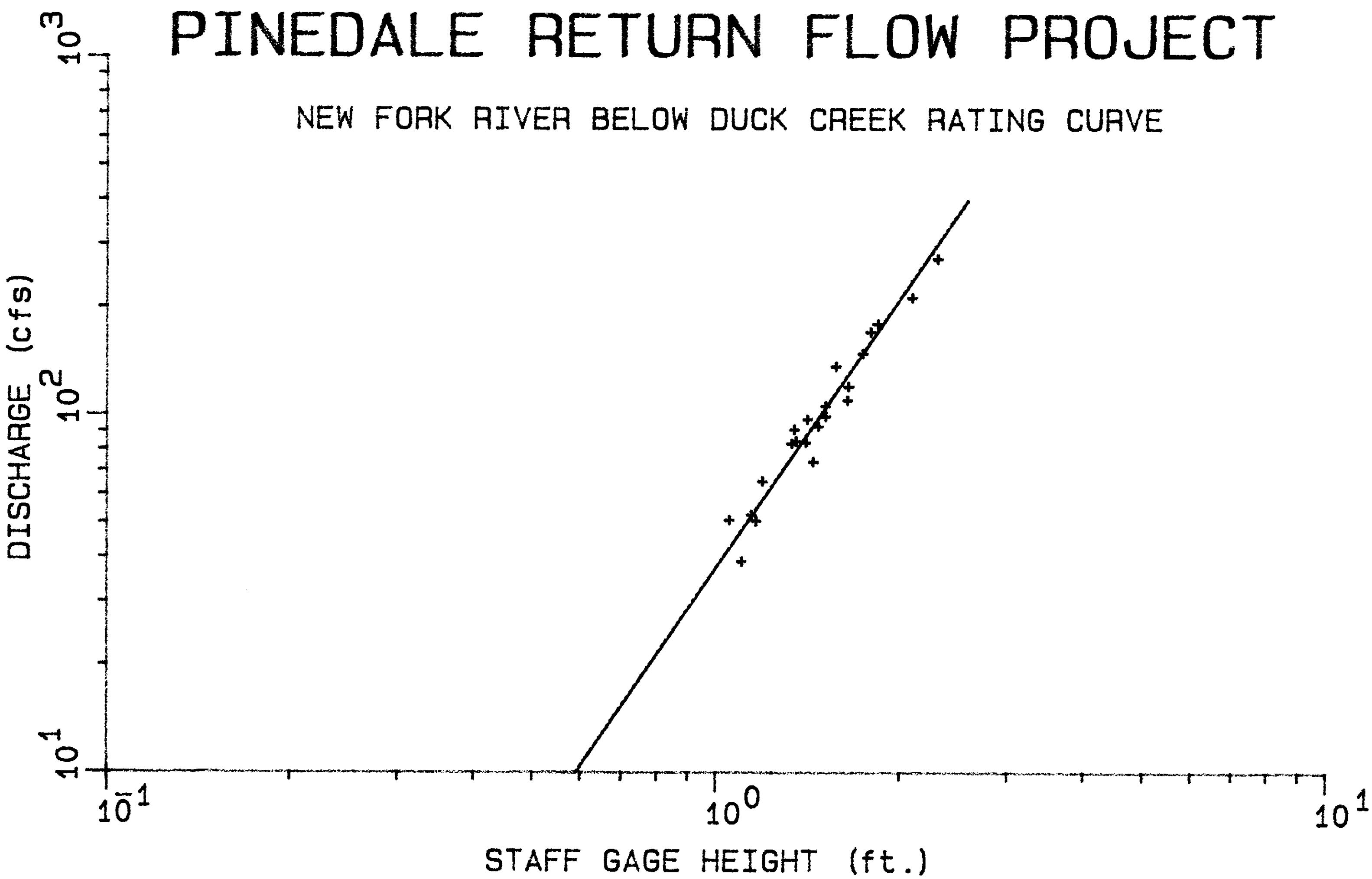


Figure 35. New Fork River Below Duck Creek Rating Curve.

RECORDER LOCATION: New Fork River At Jim Noble's

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
5/21/84	4.39	28.20
5/28/84	4.70	56.70
6/1/84	5.52	206.80
6/14/84	5.28	152.50
8/28/84	4.40	30.52
4/18/85	4.75	65.34
5/21/85	4.68	58.05
6/7/85	5.17	128.34
7/3/85	4.12	18.48
7/30/85	4.25	24.28
8/20/85	4.09	11.92
6/3/86	5.23	115.55
7/22/86	4.75	60.79
8/5/86	4.30	28.31
5/29/87	5.18	116.71
6/17/87	4.26	24.88
7/22/87	4.46	39.19

REGRESSION EQUATION: $\log(Q) = -3.75 + 8.17[\log(SG)]$

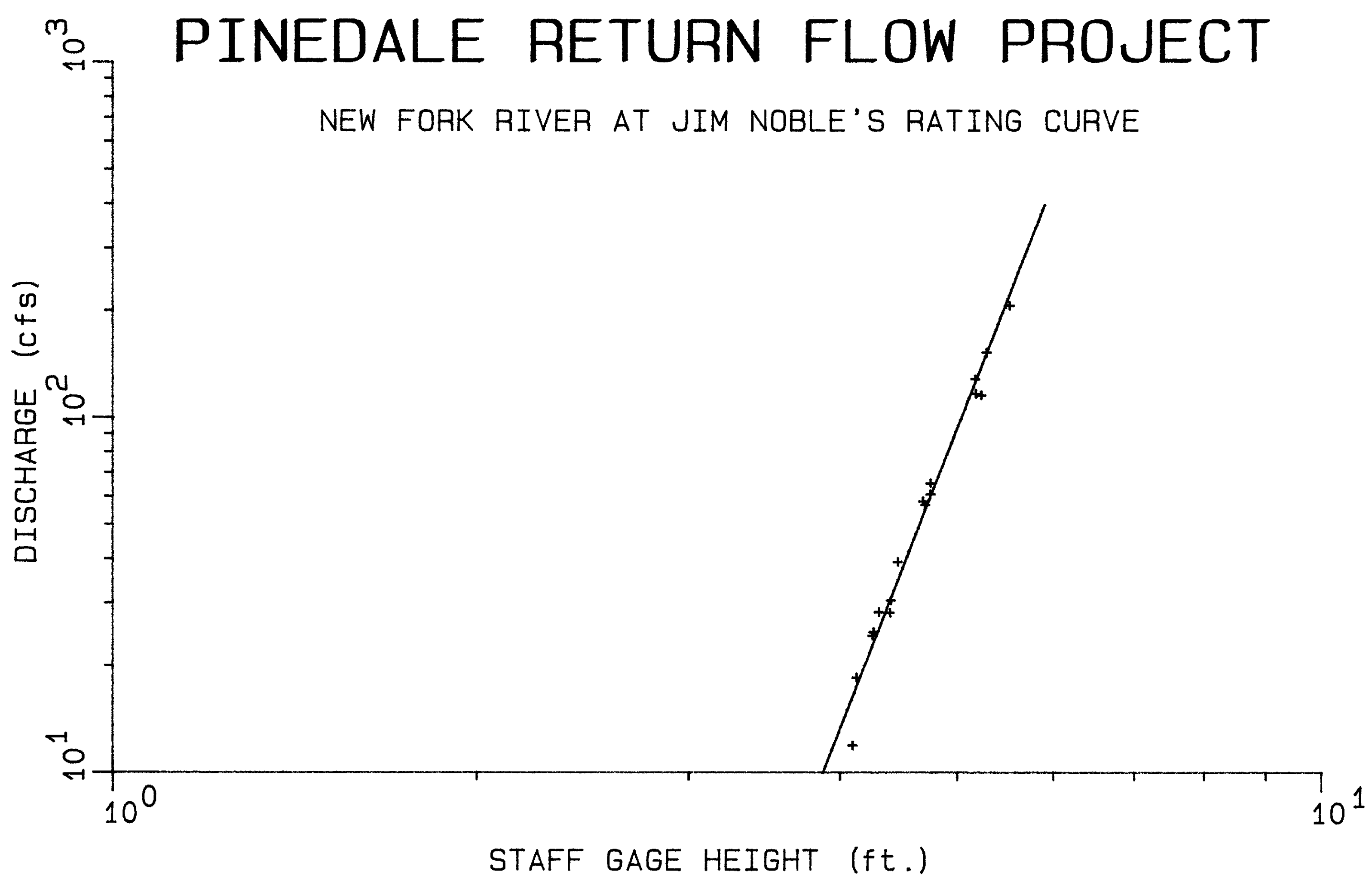


Figure 36. New Fork River At Jim Noble's Place Rating Curve.

RECORDER LOCATION: New Fork River At Leopold's

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
6/28/84	1.63	18.60
7/5/84	1.90	35.40
10/28/84	1.79	25.20
5/22/85	1.35	6.00
6/13/85	1.46	11.34
7/24/85	1.43	9.00
7/31/85	1.60	20.46
8/7/85	1.52	13.59
8/14/85	1.42	7.65
6/4/86	1.48	11.47
7/23/86	1.90	42.89
8/6/86	1.72	26.08
5/14/87	1.54	15.26
6/18/87	1.31	5.44
7/23/87	1.75	32.39

REGRESSION EQUATION: $\log(Q) = -0.0748 + 6.66[\log(SG)]$

Staff Gage Readings 1.0 to 1.60

REGRESSION EQUATION: $\log(Q) = 0.302 + 4.82[\log(SG)]$

Staff Gage Readings 1.61 to 2.50

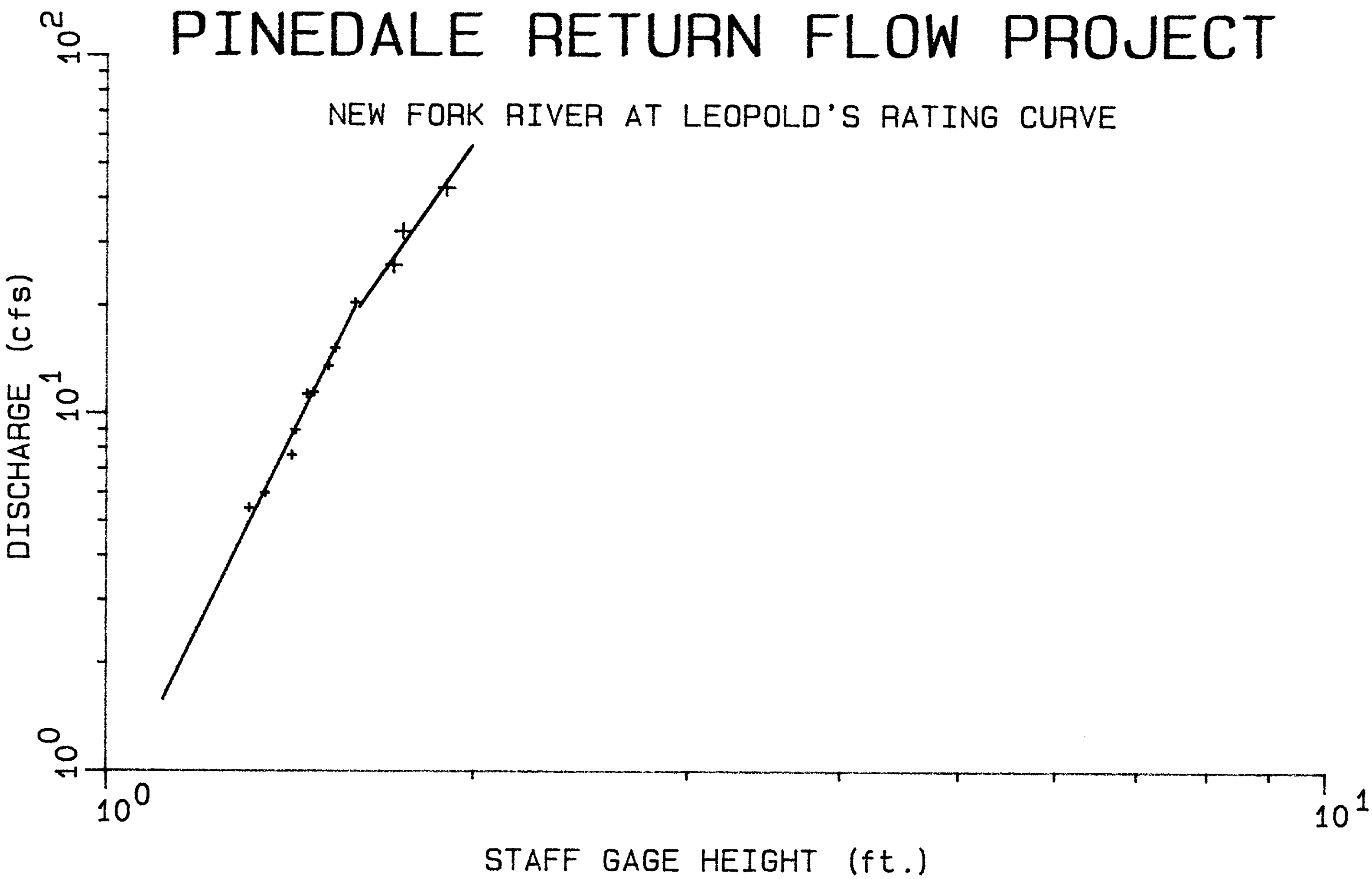


Figure 37. New Fork River At Leopold's Place Rating Curve.

RECORDER LOCATION: New Fork River Below New Fork Lakes

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
5/17/84	2.78	8.80
5/27/84	3.59	75.00
5/31/84	4.48	254.30
6/6/84	4.87	382.20
8/8/84	3.06	23.49
11/15/84	2.94	14.05
5/21/85	3.71	89.90
6/25/85	4.56	280.40
7/2/85	2.84	10.42
7/22/85	2.78	8.21
8/19/85	2.97	15.19
11/3/85	3.00	16.18
6/10/86	4.79	314.28
6/11/86	5.49	580.28
7/21/86	3.24	40.58
8/4/86	2.90	11.66
5/28/87	4.58	237.50
6/17/87	3.34	37.21
7/20/87	3.00	16.35

REGRESSION EQUATION: $\log(Q) = -2.92 + 8.68[\log(SG)]$

Staff Gage Readings 2.50 to 3.04

RECORDER LOCATION: New Fork River Below New Fork Lakes

REGRESSION EQUATION: $\log(Q) = -1.25 + 5.54[\log(SG)]$

Staff Gage Readings 3.05 to 6.00

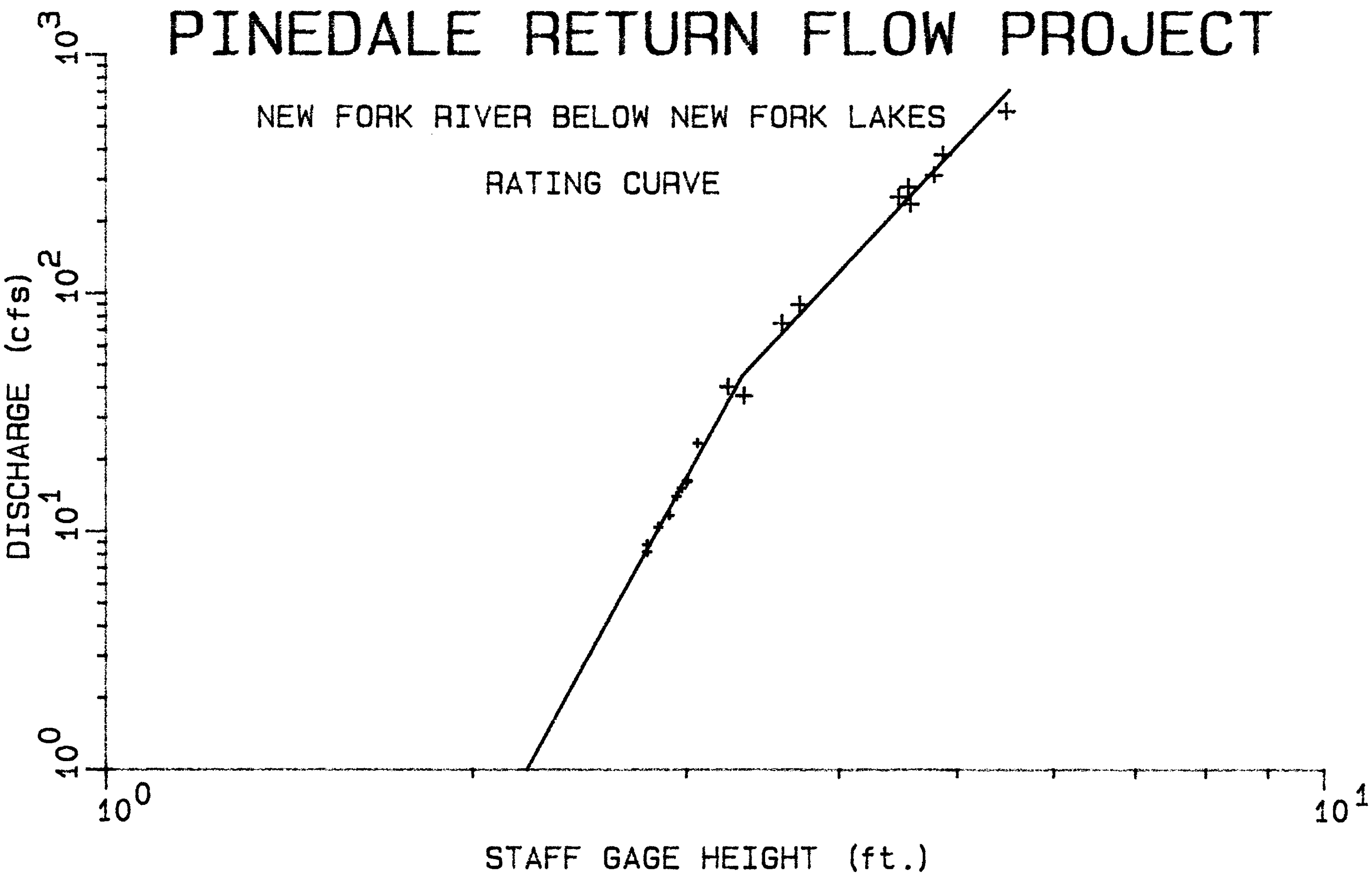


Figure 38. New Fork River Below The New Fork Lakes Rating Curve.

RECORDER LOCATION: Rahm Ditch

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
6/13/84	2.80	43.40
7/13/84	2.45	31.60
7/13/84	2.12	22.60
7/13/84	1.59	10.80
6/10/85	2.61	39.74
6/24/85	2.76	43.80
7/2/85	1.25	5.42
5/26/86	1.81	15.00
6/23/86	2.38	33.85
7/21/86	0.84	1.71
6/1/87	2.32	27.64
6/15/87	2.76	43.77

REGRESSION EQUATION: $\log(Q) = 0.465 + 2.70[\log(SG)]$

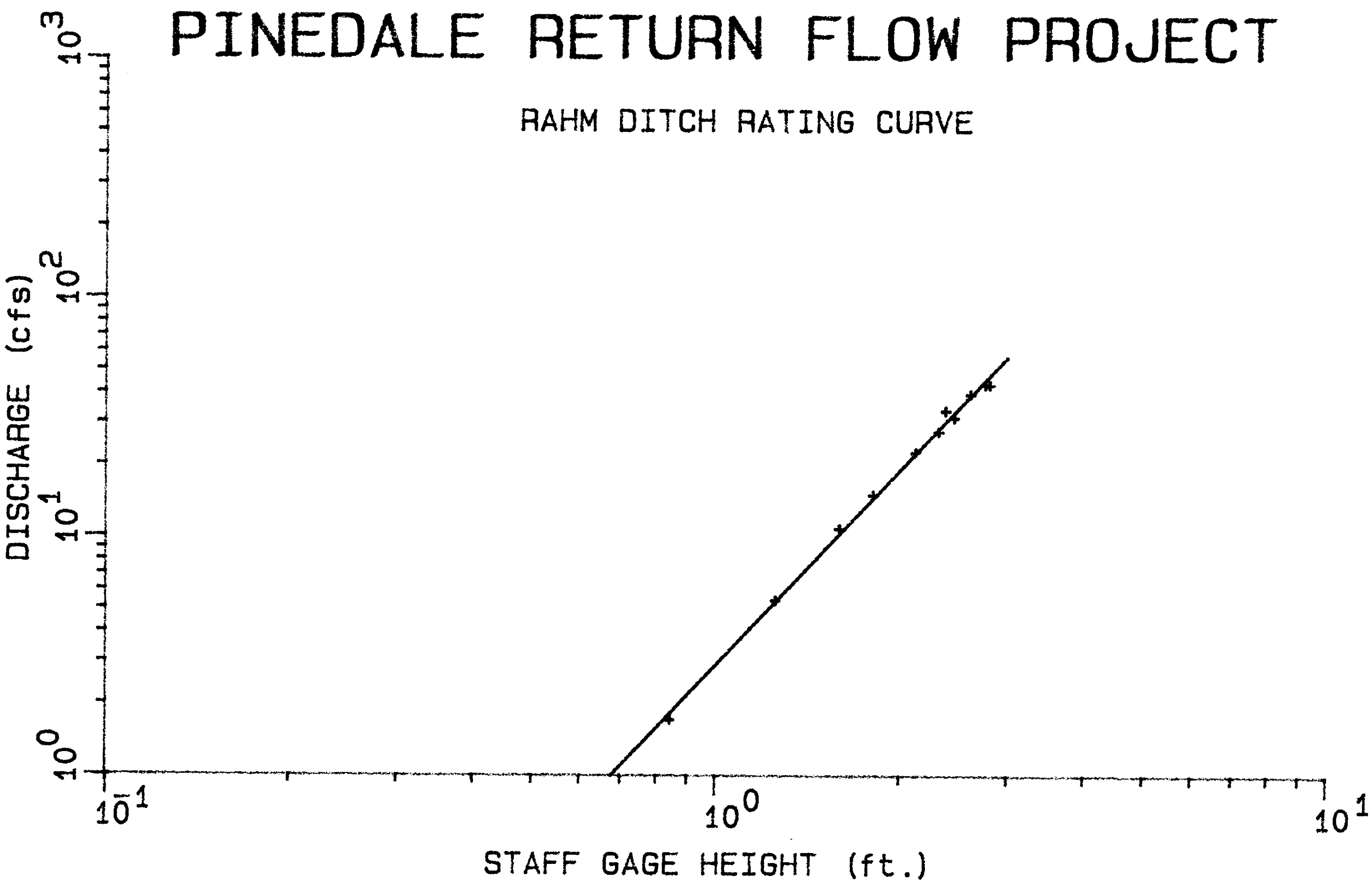


Figure 39. Rahm Ditch Rating Curve.

RECORDER LOCATION: Ulrica Ditch

GAGING RECORD

DATE	**STAFF GAGE HEIGHT** (feet)	**DISCHARGE** (cfs)
6/14/84	2.40	26.00
7/17/84	1.88	9.70
7/17/84	1.52	2.60
7/17/84	1.70	6.20
7/24/87	1.55	3.14
5/21/85	1.67	7.25
6/18/85	2.58	30.83
7/3/85	1.38	1.02
7/16/85	2.21	18.84
5/26/86	1.55	6.69
6/17/86	2.75	37.14
7/22/86	2.10	16.10
6/3/87	2.34	25.38
6/10/87	2.63	32.07
6/17/87	1.60	6.39

REGRESSION EQUATION: log(Q) = -1.18 + 8.67[log(SG)]

Staff Gage Readings 1.0 to 1.76

REGRESSION EQUATION: log(Q) = 0.156 + 3.25[log(SG)]

Staff Gage Readings 1.77 to 3.0

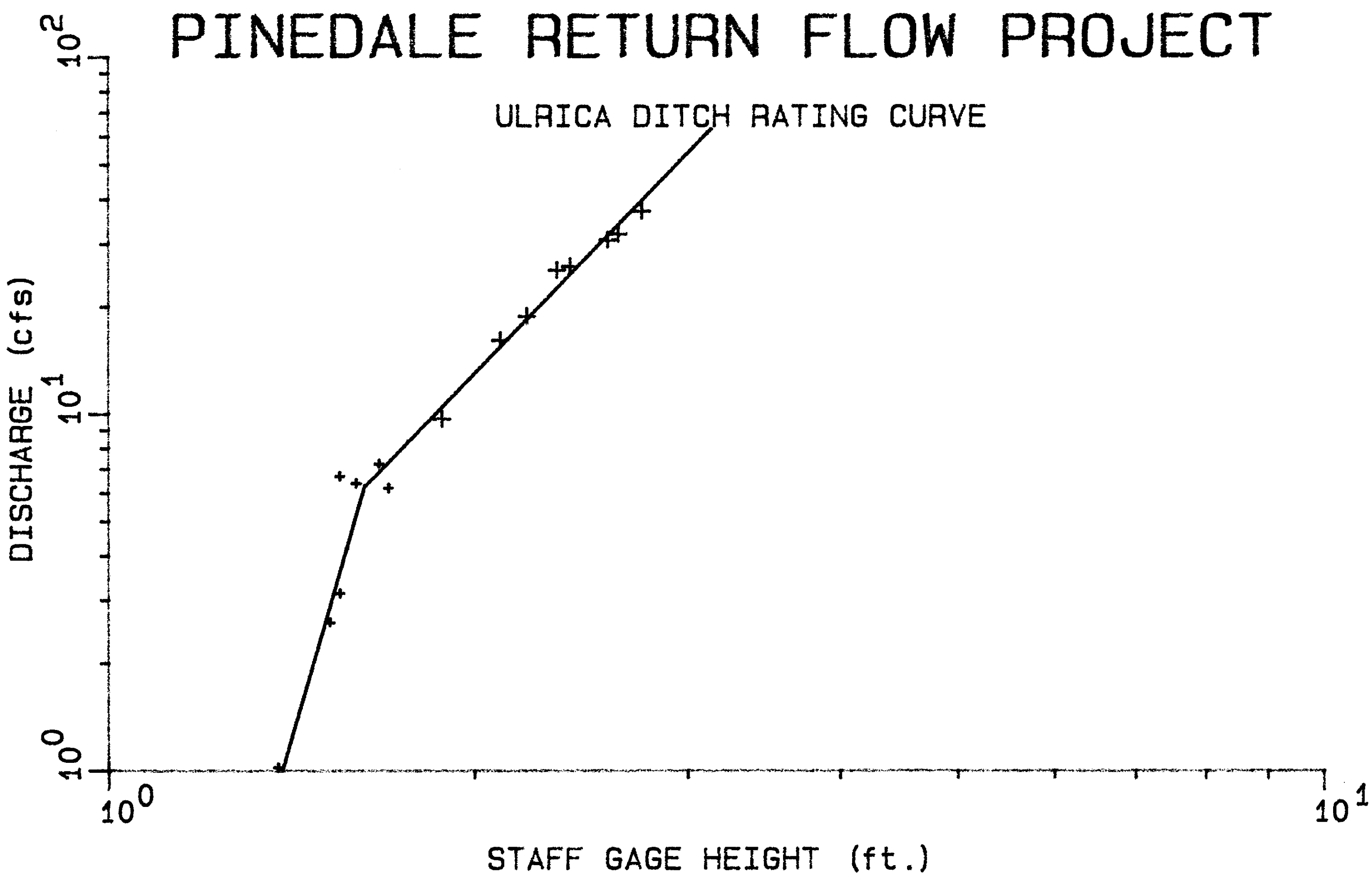


Figure 40. Ulrica Ditch Rating Curve.

RECORDER LOCATION: West Fork Ditch

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
5/20/84	0.98	1.27
6/14/84	2.70	33.60
6/29/84	2.87	36.00
7/17/84	2.42	22.90
7/17/84	2.11	17.00
7/24/84	1.75	11.50
6/18/85	2.65	30.44
7/3/85	1.22	4.82
7/16/85	2.41	23.92
7/23/85	1.06	2.09
7/30/85	1.07	1.91
8/20/85	1.13	2.52
5/27/86	1.72	10.04
6/17/86	2.91	39.34
7/22/86	2.40	27.50
5/20/87	2.56	27.80
6/7/87	1.60	10.03
7/8/87	2.71	32.74

REGRESSION EQUATION: $\log(Q) = 0.139 + 5.90[\log(SG)]$

Staff Gage Readings 0.70 to 1.24

RECORDER LOCATION: West Fork Ditch

REGRESSION EQUATION: $\log(Q) = 0.477 + 2.39[\log(SG)]$

Staff Gage Readings 1.25 to 4.0

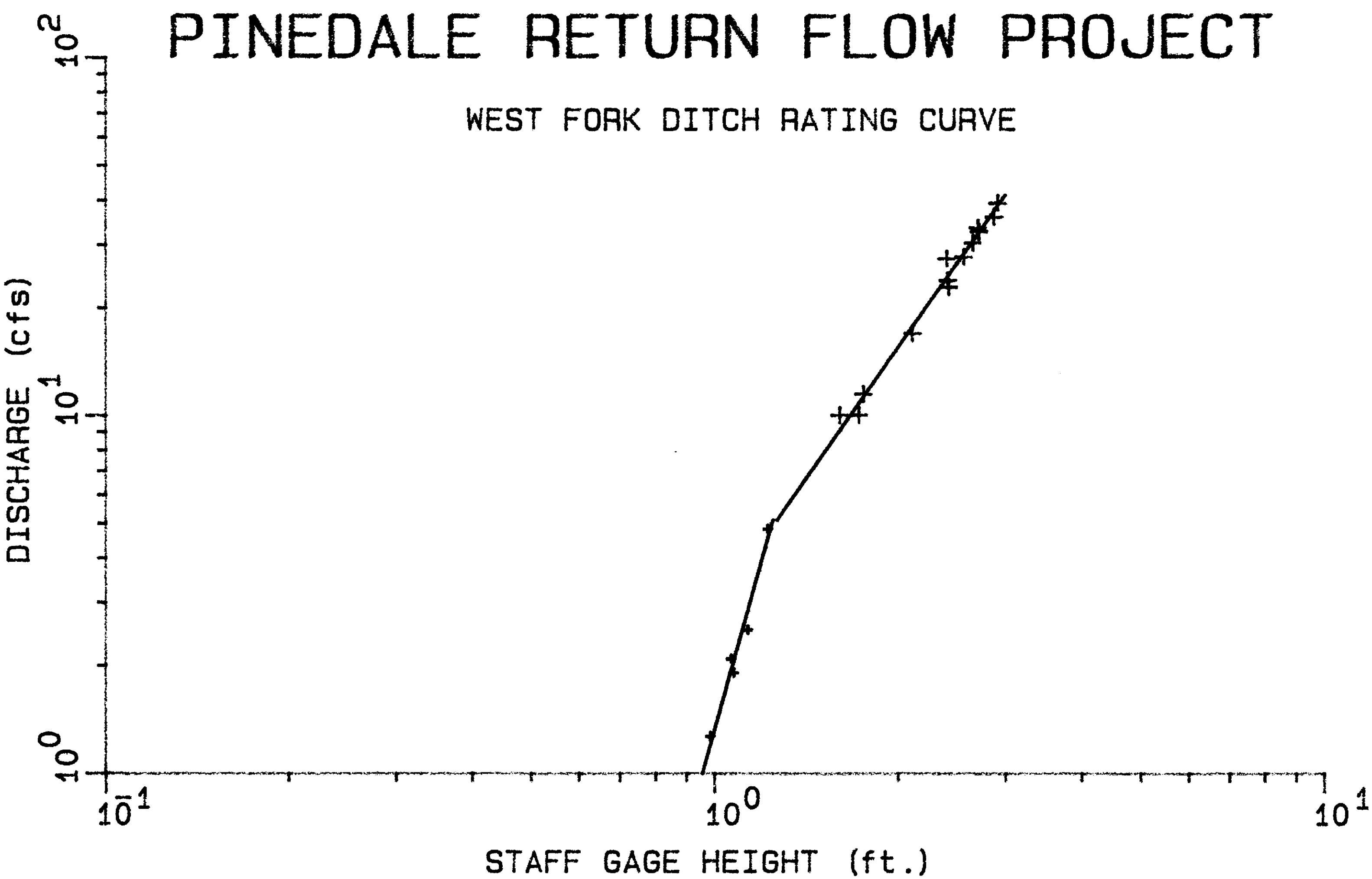


Figure 41. West Fork Ditch Rating Curve.

RECORDER LOCATION: Willow Creek At The County Road

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
5/23/84	4.68	53.40
6/2/84	5.03	99.50
6/8/84	5.20	114.40
6/21/84	5.41	155.30
8/17/84	4.60	38.80
4/19/85	4.63	47.00
5/23/85	4.51	32.06
6/6/85	4.77	62.51
7/25/85	4.57	36.36
8/8/85	4.34	15.41
9/22/85	4.26	9.56
5/29/86	4.76	60.71
6/1/86	6.30	431.66
8/6/86	4.61	51.09
5/14/87	4.47	25.81
6/17/87	5.13	103.29
7/15/87	4.90	67.71

REGRESSION EQUATION: $\log(Q) = -10.5 + 18.2[\log(SG)]$

Staff Gage Readings 3.0 to 4.71

REGRESSION EQUATION: $\log(Q) = -3.01 + 7.08[\log(SG)]$

Staff Gage Readings 4.72 to 7.00

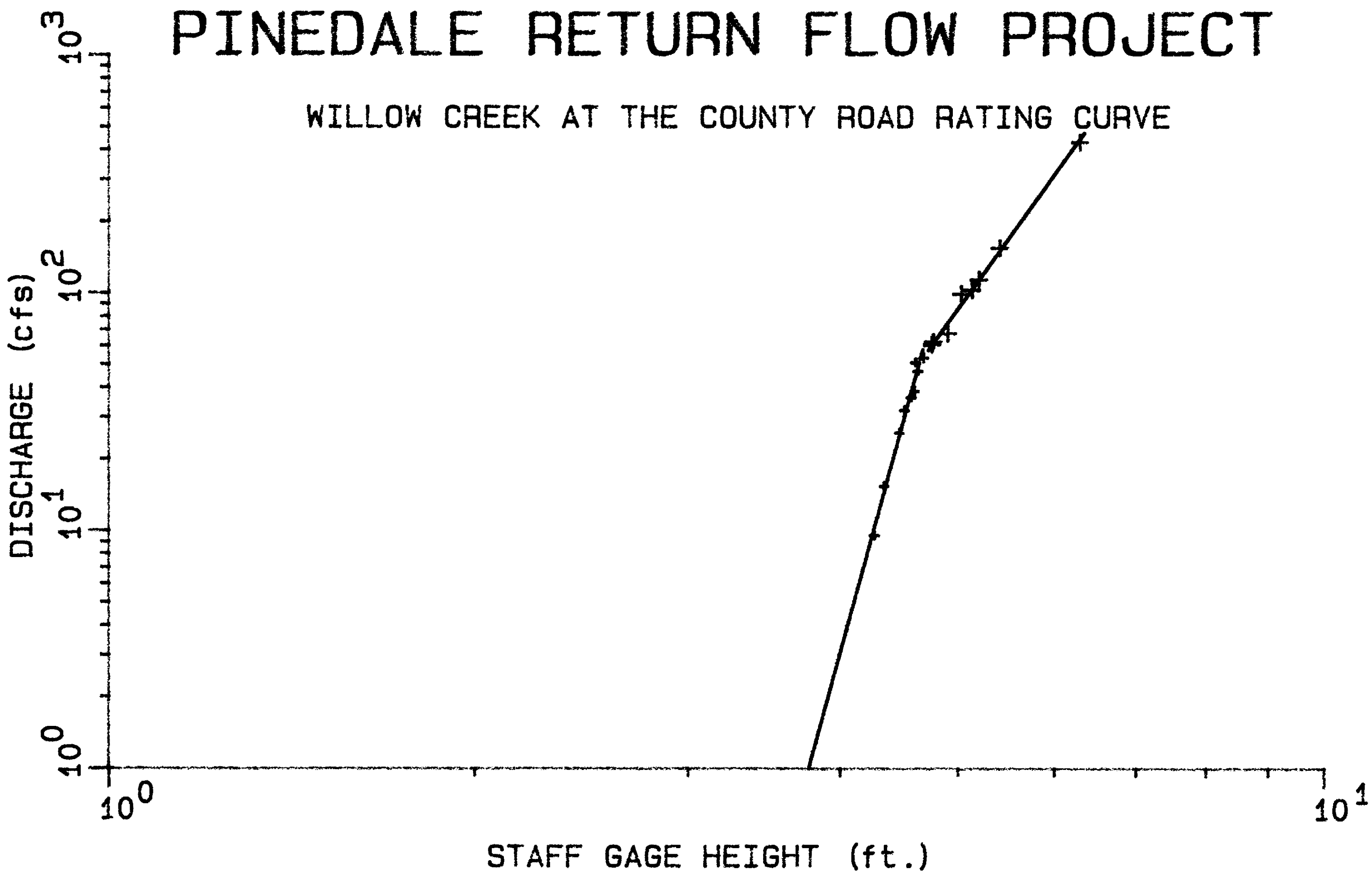


Figure 42. Willow Creek At The County Road Rating Curve.

RECORDER LOCATION: Willow Creek Diversion

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
5/22/84	3.81	3.67
6/2/84	4.10	10.80
6/14/84	4.64	56.70
6/19/84	4.77	67.30
6/28/84	4.92	64.00
7/26/84	4.29	17.10
6/20/85	4.46	36.33
5/28/86	4.31	19.70
6/20/86	5.28	102.93
7/2/86	5.68	120.06
7/23/86	4.38	19.16
8/6/86	4.20	17.01
8/20/86	4.14	12.54
5/14/87	4.08	11.11
6/4/87	4.39	32.03
7/23/87	4.20	15.23
10/4/87	3.92	5.64

REGRESSION EQUATION: $\log(Q) = -7.28 + 13.6[\log(SG)]$

Staff Gage Readings 3.5 to 4.60

REGRESSION EQUATION: $\log(Q) = -0.791 + 3.82[\log(SG)]$

Staff Gage Readings 4.61 to 6.50

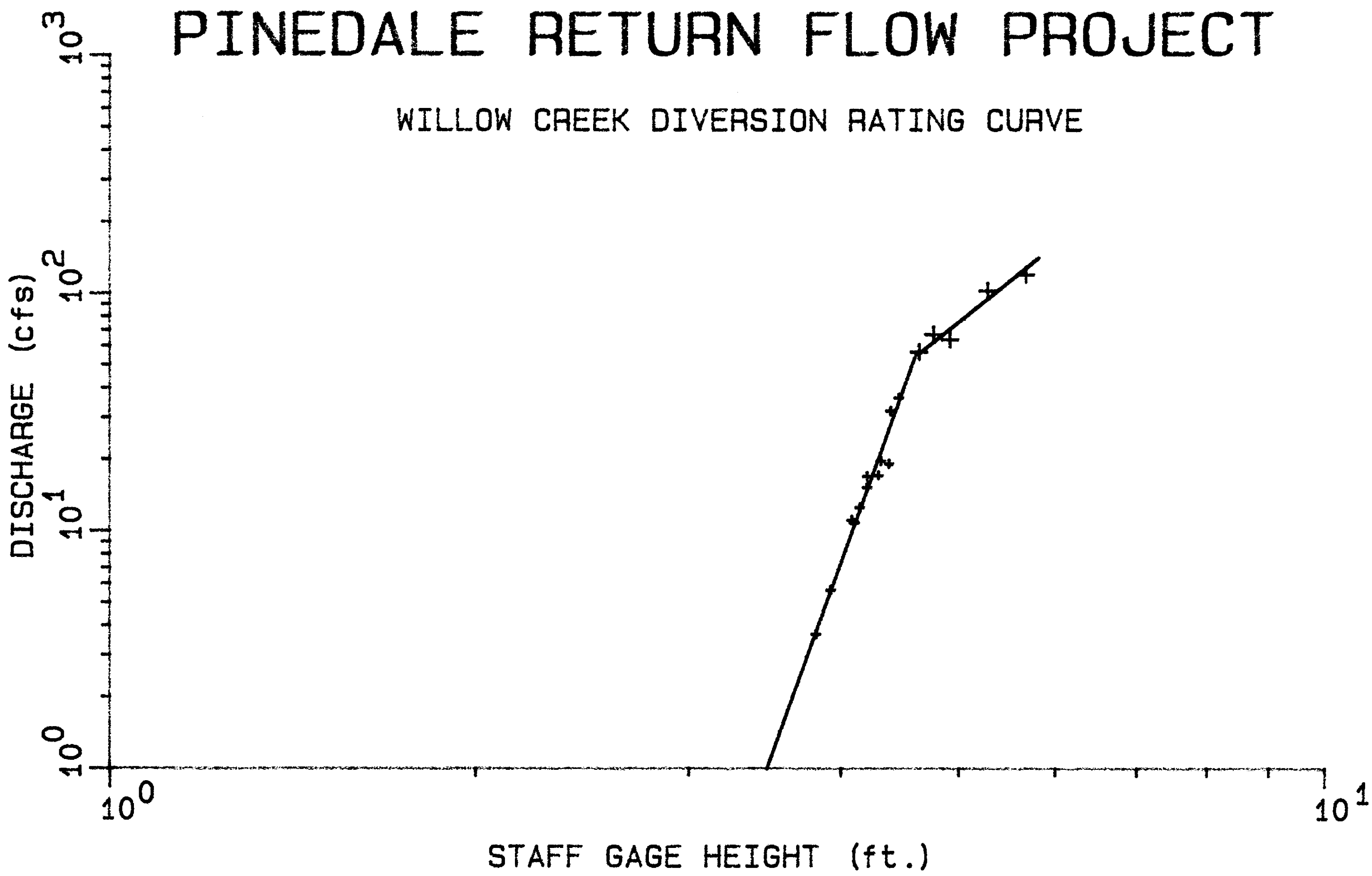


Figure 43. Willow Creek Diversion Rating Curve.

RECORDER LOCATION: Willow Creek At Willard Binning's

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
5/18/84	2.02	37.70
5/25/84	2.39	46.70
6/5/84	2.63	64.70
6/12/84	2.24	41.0
6/26/84	2.81	60.90
7/10/84	0.50	9.00
7/20/84	0.79	14.10
4/18/85	1.45	21.81
5/23/85	1.07	16.70
6/6/85	0.72	17.63
6/13/85	0.26	7.63
7/11/85	0.37	12.76
11/3/85	0.43	8.38
5/27/86	2.83	57.01
7/8/86	1.24	26.06
7/22/86	0.68	14.58
8/5/86	0.37	10.30
7/7/87	0.25	8.95
7/14/87	0.56	14.84
8/4/87	0.18	8.61
10/3/87	0.20	6.56

RECORDER LOCATION: Willow Creek At Willard Binning's

REGRESSION EQUATION: $\log(Q) = 1.36 + 0.786[\log(SG)]$

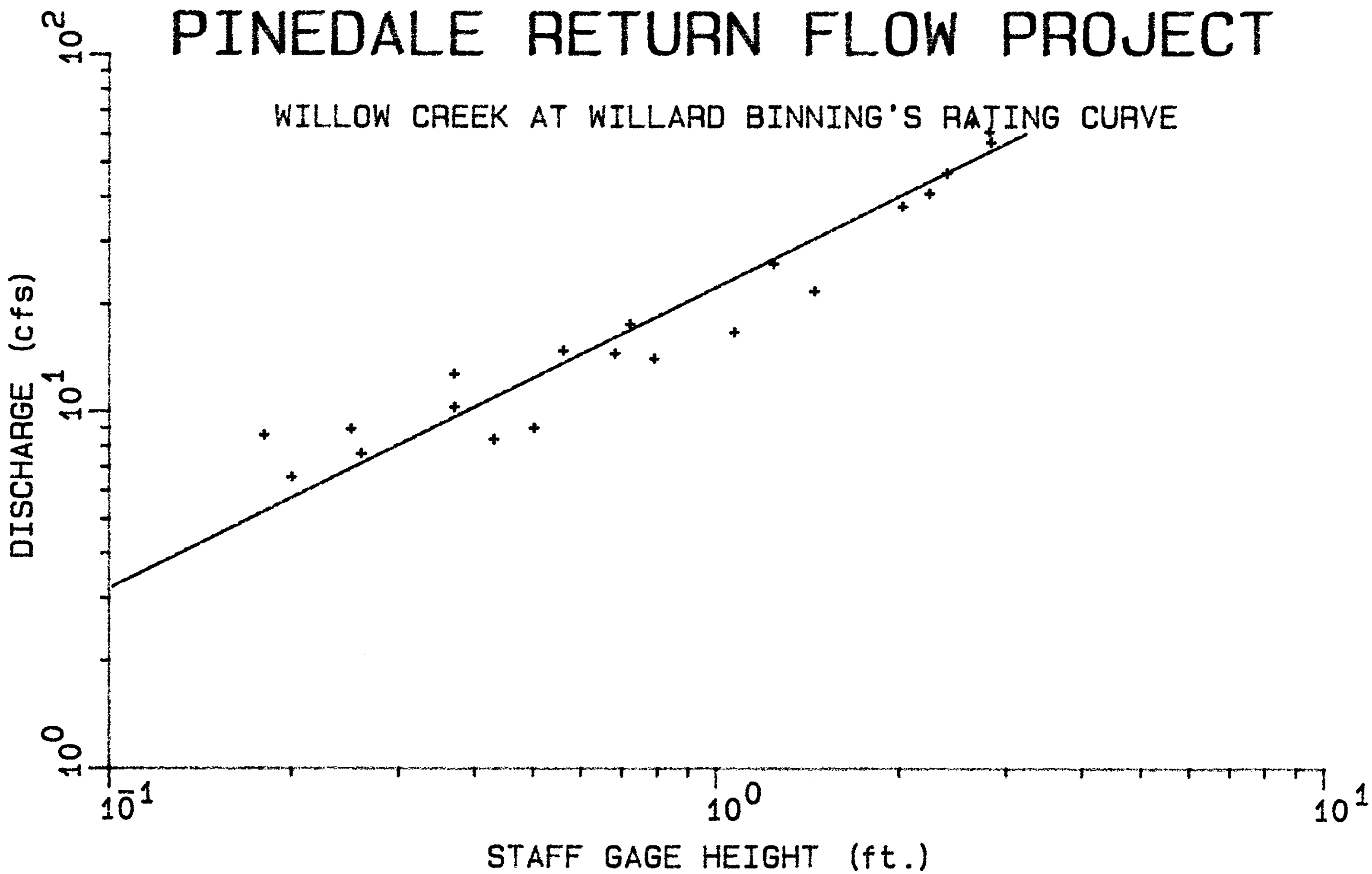


Figure 44. Willow Creek At Willard Binning's Place Rating Curve.

RECORDER LOCATION: Wright Ditch

GAGING RECORD

DATE	STAFF GAGE HEIGHT (feet)	DISCHARGE (cfs)
5/19/84	3.74	6.70
6/13/84	5.30	38.20
6/20/84	5.18	34.40
7/6/84	4.04	8.30
7/13/84	4.61	19.20
6/21/84	5.25	35.70
7/2/85	3.62	2.57
7/8/85	4.94	28.04
8/12/85	3.48	0.63
6/2/86	5.20	37.80
6/23/86	5.02	30.46
7/14/86	4.45	15.42
7/21/86	3.42	0.29
8/4/86	3.59	1.48
5/18/87	5.24	38.32
6/29/87	5.06	31.96

REGRESSION EQUATION: log(Q) = -18.2 + 33.3[log(SG)]

Staff Gage Readings 3.0 to 3.71

REGRESSION EQUATION: log(Q) = -2.26 + 5.33[log(SG)]

Staff Gage Readings 3.72 to 6.00

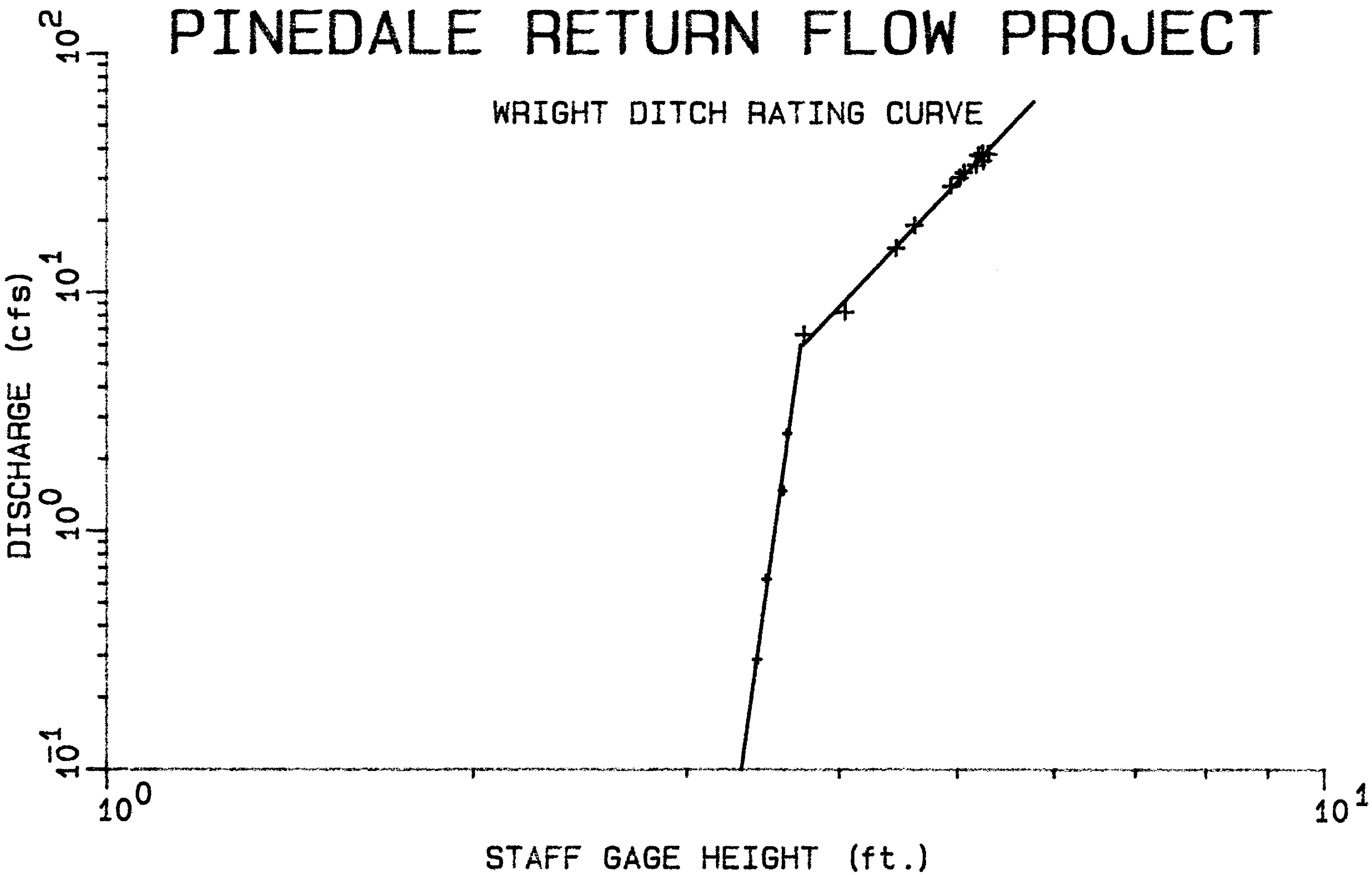


Figure 45. Wright Ditch Rating Curve.

RECORDER LOCATION: Yampa Ditch

GAGING RECORD

DATE	**STAFF GAGE HEIGHT** (feet)	**DISCHARGE** (cfs)
5/22/84	0.38	0.84
6/15/84	1.16	8.64
7/14/84	1.25	12.00
7/14/84	0.75	5.30
5/29/85	0.88	6.66
7/3/85	0.45	1.65
7/10/85	1.02	9.65
7/24/85	0.43	1.81
8/14/85	0.55	3.23
8/21/85	0.34	0.80
6/4/86	0.65	4.32
6/18/86	1.31	12.91
6/18/87	0.56	3.01
7/2/87	0.78	5.62
7/9/87	0.96	7.39

REGRESSION EQUATION: $\log(Q) = 1.25 + 2.95[\log(SG)]$

Staff Gage Readings 0.1 to 0.56

REGRESSION EQUATION: $\log(Q) = 0.912 + 1.58[\log(SG)]$

Staff Gage Readings 0.57 to 2.0

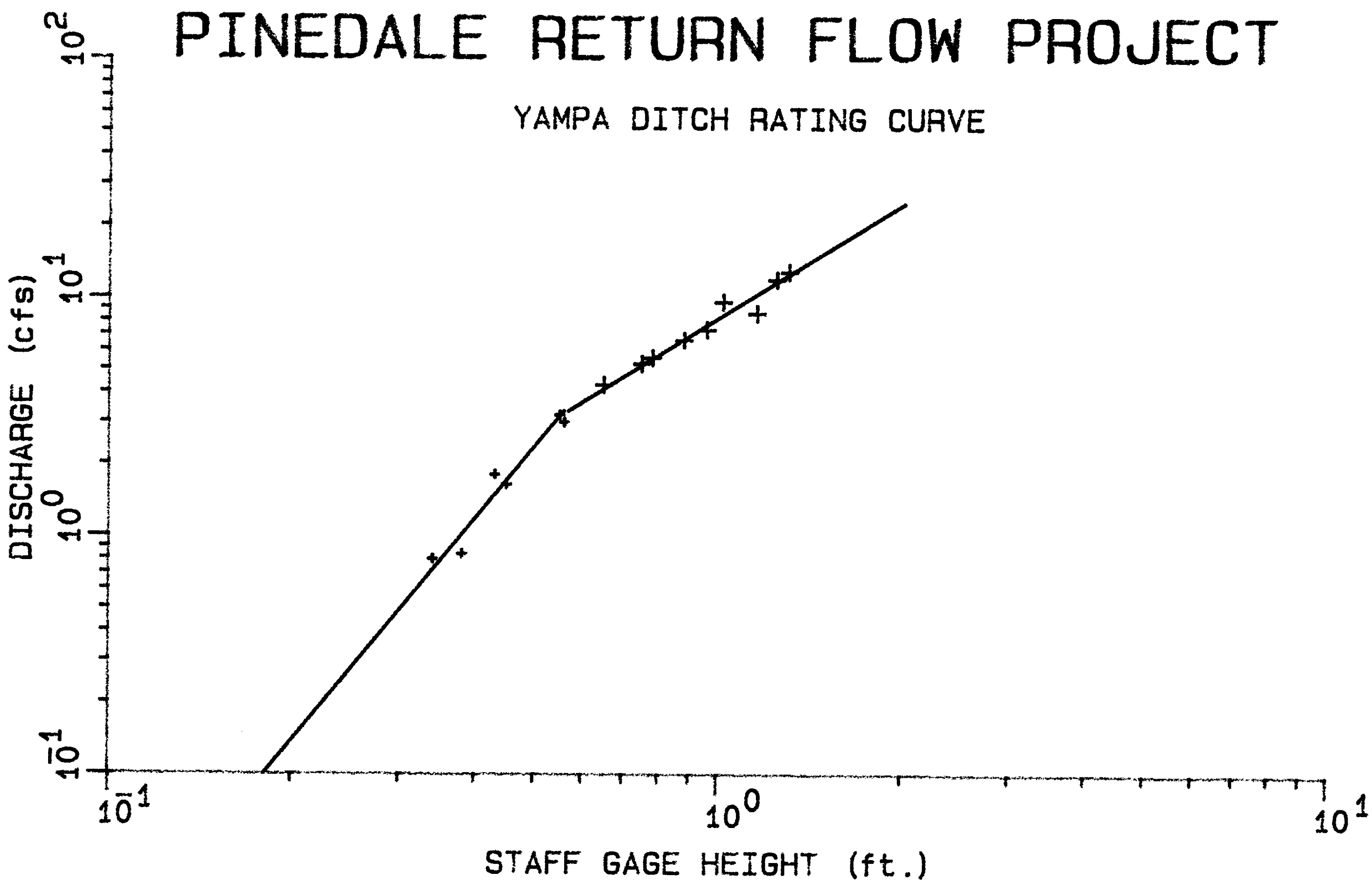


Figure 46. Yampa Ditch Rating Curve.

APPENDIX D

GROUNDWATER MONITORING WELLS
MEASURED WATER TABLE ELEVATIONS

1984 WELL ELEVATION DATA

Date	Well Number 1	2	3	4	5
June 4	7166.6	7160.2	7190.6	7180.4	7176.5
June 11	7168.3	7160.9	7192.8	7183.8	7179.7
June 18	7169.3	7160.9	7193.0	7184.0	7179.7
June 25	7169.8	7160.8	7193.0	7183.2	7179.6
July 2	7170.2	7160.9	7193.0	7183.0	7179.7
July 9	7170.4	7160.9	7193.0	7182.9	7179.8
July 16	7170.1	7160.8	7192.8	7183.1	7179.6
July 23	7170.8	7161.2	7192.8	7183.3	7180.1
July 30	7169.9	7160.5	7192.0	7180.9	7178.9
Aug. 6	7169.5	7160.4	7191.3	7180.0	7178.2
Aug. 13	7168.3	7160.1	7190.2	7179.0	7177.2
Aug. 20	7167.5	7160.0	7189.9	7178.6	7176.4
Aug. 27	7167.2	7159.9	7189.4	7178.3	7176.0
Sept. 3	7166.8	7159.8	7188.8	7178.0	7175.5
Sept. 14	7166.3	7159.8	7187.0	7177.8	7175.2
Sept. 29	7165.9	7160.1	7187.1	7177.6	7175.2
Oct. 27	7165.4	7159.7	7186.0	7177.7	7175.6
Nov. 15	7165.1	7159.6	7185.5	7177.5	7175.5

Elevation in feet

Date	Well Number 7	8	9	10	10A
June 4	7230.3	7237.0	7252.2	7247.6	*7260.5
June 11	7230.7	7238.9	7252.2	7248.3	*7260.5
June 18	7230.8	7239.2	7252.1	7250.0	7260.8
June 25	7231.4	7239.0	7252.2	7249.3	7260.8
July 2	7231.5	7239.3	7252.3	7250.0	7260.5
July 9	7230.8	7239.0	7251.9	7248.2	7260.8
July 16	7231.1	7238.7	7252.3	7247.4	7260.5
July 23	7231.5	7238.2	7252.3	7246.9	7260.8
July 30	7230.6	7237.6	7251.2	7246.4	7259.4
Aug. 6	7230.2	7237.0	7250.2	7246.0	7258.5
Aug. 13	7229.8	7236.6	7249.1	7245.6	7257.5
Aug. 20	7229.7	7236.3	7248.4	7245.4	7257.1
Aug. 27	7229.6	7236.3	7247.7	7245.1	7256.6
Sept. 3	7229.5	7236.1	7247.0	7244.7	7256.2
Sept. 14	7229.6	7236.0	7246.1	7244.6	*7256.5
Sept. 29	7229.7	7236.1	7245.6	7244.5	*7256.5
Oct. 27	7229.7	7236.7	7247.9	7244.4	*7256.5
Nov. 15	7229.7	7236.4	7246.0	7244.4	7257.0

* Indicates the elevation is estimated

	Well Number				
Date	12	13	14	18	19
June 4	7303.5	7312.9	7326.8	7351.9	7324.7
June 11	7303.7	7312.9	7327.1	7352.1	7329.3
June 18	7303.7	7312.7	7327.0	7352.1	7329.4
June 25	7303.6	7312.9	7326.7	7352.1	7329.4
July 2	7303.7	7312.5	7326.8	7351.7	7329.4
July 9	7303.7	7312.8	7326.9	7351.9	7329.0
July 16	7303.6	7312.5	7326.8	7351.9	7329.2
July 23	7303.5	7312.6	7326.5	7351.0	7329.2
July 30	7302.8	7311.8	7325.9	7350.0	7326.8
Aug. 6	7302.6	7311.5	7325.7	7349.6	7325.5
Aug. 13	7301.4	7311.2	7325.5	7349.2	7324.0
Aug. 20	7301.5	7311.0	7325.8	7349.0	7323.0
Aug. 27	7301.3	7310.9	7325.8	7348.8	7322.3
Sept. 3	7300.8	7310.7	7325.5	7348.6	7321.9
Sept. 14	7301.2	7310.8	7325.8	7349.6	7321.4
Sept. 29	7302.1	7311.5	7326.3	7349.9	7322.8
Oct. 27	7302.0	7311.8	7326.3	7349.1	7322.5
Nov. 15	7301.9	7311.3	7326.2	7348.6	7321.7

Date	Well Number 20	21	22	23	24
June 4	7395.7	7375.5	7422.5	7418.8	7427.1
June 11	7395.8	7383.5	7424.9	7419.4	7429.0
June 18	7395.9	7383.5	7426.1	7419.4	7429.0
June 25	7395.8	7383.5	7426.3	7419.4	7428.8
July 2	7395.8	7383.6	7426.3	7419.4	7428.8
July 9	7395.8	7383.3	7426.3	7419.4	7428.8
July 16	7395.8	7383.5	7426.3	7419.4	7428.6
July 23	7395.8	7383.3	7425.9	7419.4	7428.6
July 30	7395.6	7381.3	7425.8	7418.6	7425.9
Aug. 6	7395.7	7380.1	7425.4	7417.6	7424.6
Aug. 13	7395.9	7378.8	7425.1	7416.5	7423.0
Aug. 20	7396.4	7377.9	744.8	7415.7	7421.7
Aug. 27	7396.7	7377.2	7424.3	7415.0	7420.8
Sept. 3	7396.9	7376.6	7424.2	7414.4	7420.0
Sept. 14	7397.3	7375.8	7423.8	7413.5	7419.2
Sept. 29	7397.5	7375.2	7423.7	7412.4	*7418.1
Oct. 27	7397.0	7374.2	7423.0	7410.5	*7416.2
Nov. 15	7396.9	7373.1	7422.5	7409.4	*7415.1

	Well Number	
Date	25	26
June 4	7333.6	7343.2
June 11	7333.3	7343.8
June 18	7333.4	7343.9
June 25	7333.6	7344.0
July 2	7333.4	7344.1
July 9	7333.0	7344.0
July 16	7332.7	7344.1
July 23	7333.1	7343.1
July 30	7332.5	7341.3
Aug. 6	7332.1	7340.1
Aug. 13	7331.7	7339.0
Aug. 20	7331.7	7338.3
Aug. 27	7331.7	7337.7
Sept. 3	7331.2	7337.2
Sept. 14	7331.4	7336.7
Sept. 29	7331.8	7336.4
Oct. 27	7331.5	7335.6
Nov. 15	7331.5	7335.3

1985 WELL ELEVATION DATA

Date	Well Number 1	2	3	4	5
Jan. 3	7164.8	7159.5	7184.1	7177.2	7174.8
Feb. 18	7165.0	7159.4	7183.5	7177.1	7174.6
March 24	7165.1	7159.7	7183.2	7177.1	7174.9
April 18	7166.2	7160.0	7188.2	7178.9	7178.0
May 9	7165.4	7159.7	7187.8	7177.8	7177.1
May 20	7165.4	7160.0	7187.5	7176.7	7176.7
May 28	7165.3	7159.6	7187.0	7177.6	7176.2
June 4	7165.3	7159.6	7191.0	7178.4	7175.9
June 11	7165.6	7160.0	7192.8	7183.9	7179.2
June 18	7169.1	7160.8	7192.9	7183.1	7179.6
June 25	7170.1	7161.1	7193.0	7183.4	7179.9
July 2	7170.3	7160.8	7193.0	7183.0	7179.7
July 9	7170.2	7160.9	7193.0	7182.8	7179.2
July 16	7170.3	7160.9	7193.0	7183.2	7179.7
July 23	7170.1	7160.8	7192.9	7182.5	7179.5
July 30	7169.1	7160.7	7192.2	7180.8	7179.8
Aug. 6	7168.3	7160.2	7191.2	7179.7	7178.4
Aug. 13	7167.6	7160.0	7190.1	7178.8	7177.3
Aug. 20	7167.0	7159.8	7189.2	7178.2	7176.4
Aug. 27	7166.6	7159.8	7188.4	7177.9	7175.9
Sept. 2	7166.5	7159.7	7188.1	7177.8	7175.8
Sept. 11	7166.0	7159.9	7187.5	7177.7	7175.2
Sept. 18	7165.7	7159.7	7187.0	7177.6	7175.1

	Well Number				
Date	1	2	3	4	5
Sept. 25	7165.7	7159.7	7186.7	7177.6	7175.3
Oct. 8	7165.5	7159.7	7186.4	7177.8	7175.3
Nov. 3	7165.1	7159.6	7186.1	7177.5	7175.2
Dec. 7	7165.2	7159.6	7185.1	7177.5	7175.3

Date	Well Number 7	8	9	10	10A
Jan. 3	7230.2	7236.2	7243.9	7243.9	7253.7
Feb. 18	7231.5	7235.8	7242.6	7243.6	*7255.8
March 24	7231.6	7235.7	7242.0	7243.5	*7257.3
April 18	7231.0	7236.7	7242.9	7244.3	*7258.4
May 9	7230.2	7236.3	7244.7	7244.0	*7259.3
May 20	7230.0	7236.4	7245.8	7244.0	7259.8
May 28	7229.8	7236.3	7249.6	7246.9	7260.2
June 4	7229.8	7239.0	7252.0	7249.6	7260.6
June 11	7229.8	7238.1	7252.2	7249.6	7260.7
June 18	7229.7	7238.9	7252.0	7250.3	7260.8
June 25	7229.7	7239.1	7252.1	7249.8	7260.6
July 2	7230.1	7238.5	7251.9	7249.3	7260.0
July 9	7229.8	7238.5	7252.0	7248.8	7260.3
July 16	7230.6	7238.8	7252.0	7247.8	7260.5
July 23	7230.2	7238.5	7251.6	7247.1	7259.8
July 30	7229.6	7238.0	7250.4	7246.9	7258.4
Aug. 6	7229.3	7236.9	7249.3	7246.2	7257.6
Aug. 13	7229.2	7236.4	7248.6	7245.8	7256.9
Aug. 20	7229.0	7236.2	7248.0	7245.4	7256.4
Aug. 27	7229.3	7236.0	7247.4	7245.0	7256.1
Sept. 2	7229.1	7236.0	7247.0	7244.8	*7256.1
Sept. 11	7228.9	7236.0	7246.4	7244.6	7256.2
Sept. 18	7229.1	7236.1	7249.4	7244.6	7256.6

Date	Well Number				
	7	8	9	10	10A
Sept. 25	7229.2	7236.3	7250.7	7244.8	7257.3
Oct. 8	7229.3	7236.4	7250.4	7244.7	7259.2
Nov. 3	7229.4	7236.5	7250.1	7244.6	7258.1
Dec. 7	7229.7	7236.3	7247.2	7244.8	7260.2

Date	Well Number 12	13	14	15	16
Jan. 3	7300.9	7310.9	7326.4		
Feb. 18	7300.8	7310.4	7325.5	7320.0	7316.9
March 24	7301.2	7310.4	7325.0	7319.4	7317.5
April 18	7303.2	7312.1	7326.5	7323.1	7318.0
May 9	7302.7	7311.6	7326.3	7323.3	7317.9
May 20	7302.1	7311.7	7326.3	7322.8	7317.8
May 28	7303.0	7313.1	7326.4	7323.2	7317.8
June 4	7303.3	7313.4	7326.5	7322.8	7317.7
June 11	7303.3	7312.6	7326.3	7323.0	7317.4
June 18	7303.2	7313.3	7326.2	7322.9	7316.5
June 25	7303.4	7313.4	7326.5	7323.0	7316.2
July 2	7302.8	7311.6	7325.8	7322.5	7316.2
July 9	7303.2	7313.1	7326.4	7322.5	7315.6
July 16	7303.2	7313.2	7326.5	7322.3	7315.5
July 23	7302.8	7311.6	7325.8	7322.3	7315.6
July 30	7302.0	7311.3	7325.6	7322.5	7315.4
Aug. 6	7300.8	7311.0	7325.4	7322.1	7315.3
Aug. 13	7300.5	7310.9	7325.2	7322.3	7315.1
Aug. 20	7300.3	7310.8	7325.1	7322.4	7314.9
Aug. 27	7300.2	7310.9	7325.1	7322.1	7314.8
Sept. 2	7300.4	7311.0	7325.2	7322.2	7314.8
Sept. 11	7301.8	7311.1	7325.5	7322.1	7314.8
Sept. 18	7302.0	7311.2	7325.8	7322.0	7315.0

Date	Well Number				
	12	13	14	15	16
Sept. 25	7301.9	7311.4	7326.0	7322.1	7316.2
Oct. 8	7302.2	7311.5	7326.1	7321.4	7316.7
Nov. 3	7302.0	7311.3	7326.0	7321.1	7316.7
Dec. 7	7301.5	7311.4		7320.1	

	Well Number				
Date	18	19	20	21	22
Jan. 3	7348.4	*7320.7	7395.9	7370.5	7421.3
Feb. 18	7348.6	7319.7	7395.0	7367.5	7420.7
March 24	7348.3	7318.7	7394.6	*7367.0	7420.4
April 18	7348.5	7324.7	7395.5	7368.6	7422.8
May 9	7348.2	7323.4	7395.0	7370.8	7421.0
May 20	7347.8	*7325.0	7395.0	7374.8	7420.9
May 28	7347.8	*7326.6	7394.9	7380.6	7421.9
June 4	*7349.0	*7327.9	7395.4	7383.4	7423.7
June 11	*7350.2	7329.5	7395.4	7383.5	7425.2
June 18	7351.4	7329.4	7395.3	7383.5	7426.2
June 25	7352.0	7329.6	7395.4	7383.5	7426.3
July 2	7350.0	7329.2	7394.7	7381.6	7425.7
July 9	7351.4	7329.2	7394.8	7383.3	7426.2
July 16	7351.8	7329.6	7394.8	7383.4	7426.3
July 23	7349.8	7329.3	7394.4	7381.3	7426.0
July 30	7349.3	*7329.2	7394.2	7379.8	7425.5
Aug. 6	7348.9	7323.9	7394.0	7378.8	7425.0
Aug. 13	7348.7	7322.8	7394.1	7378.0	7424.7
Aug. 20	7348.8	7322.0	7394.2	7377.2	7424.4
Aug. 27	7349.1	*7321.3	7394.4	7376.8	7424.1
Sept. 2	7349.3	7320.9	7394.8	7376.6	7424.0
Sept. 11	7349.5	7320.8	7395.7	7377.2	7423.8
Sept. 18	7349.7	7320.8	7396.0	7378.0	7423.6

Date	Well Number				
	18	19	20	21	22
Sept. 25	7350.0	7321.6	7396.2	7378.4	7423.4
Oct. 8	7649.9	7322.7	7396.3	7377.5	7423.2
Nov. 3	7349.6	7322.4	7396.2	*7376.0	7422.5
Dec. 7	7348.6	7321.0	7396.1	*7374.1	7421.8

Date	Well Number 23	24	25	26
Jan. 3	7407.6	*7415.1	7331.0	7334.3
Feb. 18	7407.2	*7415.1	7330.6	7333.8
March 24	7407.3	*7416.3	7331.3	7333.7
April 18	7407.8	*7417.5	7332.9	7335.6
May 9	7409.0	*7418.0	7332.9	7342.9
May 20	7411.2	*7418.0	7332.7	7343.0
May 28	7414.4	7421.1	7332.5	7343.2
June 4	7419.1	7428.2	7332.5	7343.6
June 11	7419.2	7428.8	*7332.3	*7343.5
June 18	7419.3	7428.9	7332.3	7343.6
June 25	7419.4	7428.8	7332.3	7343.8
July 2	7419.0	7427.0	7332.6	7343.7
July 9	7419.3	7428.5	7332.9	7344.2
July 16	7419.3	7428.6	7332.6	7344.0
July 23	7418.6	7426.1	7332.4	7342.8
July 30	7417.6	7424.6	7331.9	7341.1
Aug. 6	7416.5	7423.1	7331.4	7339.9
Aug. 13	7415.7	7422.0	7331.1	7338.9
Aug. 20	7415.1	7421.1	7330.9	7337.8
Aug. 27	7413.5	7420.4	7330.7	7336.9
Sept. 2	7414.1	7419.9	7330.8	7336.3
Sept. 11	7413.7	7419.3	7330.6	7335.9
Sept. 18	7412.3	7419.0	7330.9	7335.6

Date	Well Number			
	23	24	25	26
Sept. 25	7413.0	*7418.0	7331.3	7335.6
Oct. 8	7412.2	*7417.5	7331.4	7335.3
Nov. 3	7410.7	*7417.3	7331.2	7334.8
Dec. 7	7409.8	*7415.9	7331.4	7335.3

1986 WELL ELEVATION DATA

Date	Well Number 1	2	3	4	5
Jan. 10		7159.9	7184.3	7177.4	*7175.1
Feb. 8		7159.5	7183.9	7177.4	7174.9
March 22		7159.4	7183.5	7181.8	*7177.2
April 13	7170.5	7160.8	7189.9	7179.3	7178.3
May 27	7168.3	7159.8	7189.4	7178.2	7176.7
June 3	7168.2	7159.9	7191.5	7181.6	7176.2
June 10	7171.4	7159.3	7192.9	7184.1	7179.8
June 17	7171.4	7161.2	7192.9	7183.2	7179.9
June 24	7171.9	7161.1	7192.9	7183.3	7179.8
July 1	7172.3	7161.1	7192.9	7183.2	7179.8
July 8	7172.5	7161.3	7192.9	7183.2	7180.1
July 15	7172.6	7161.2	7192.1	7183.1	7180.9
July 22	7172.3	7162.9	7193.0	7181.7	7179.8
July 29	7171.5	7158.6	7192.2	7180.4	7179.0
Aug. 5	7170.9	7160.4	7191.5	7179.6	7178.1
Aug. 12	7170.7	7160.3	7191.3	7179.0	7177.3
Aug. 19	7170.5	7160.2	7189.1	7178.7	7176.4
Aug. 30	7170.1	7160.1	7188.5	7178.3	7175.6
Sept. 13	7171.6	7158.6	7188.1	7178.4	7175.3
Sept. 27	7169.2	7160.1	7187.6	7179.6	7175.2
Oct. 9	7169.2	7160.0	7187.4	7177.9	7175.2
Nov. 5	7165.9	7159.8	7186.4	7177.9	7175.5
Dec. 6	7165.2	7159.8	7185.3	7177.5	7175.2

Date	Well Number 7	8	9	10	10A
Jan. 10	7230.4	7236.1	7245.2	7244.6	*7258.1
Feb. 8	7230.2	7236.0	7245.9	7244.1	*7256.4
March 22	7230.9	7236.0	*7242.9	7244.0	7254.0
April 13	7231.7	7237.8	7244.8	7245.1	7257.7
May 27	7230.0	7237.4	7249.9	7248.6	7259.8
June 3	7230.1	7238.6	7250.9	7247.7	7259.8
June 10	7232.4	7240.2	7252.2	7249.9	7261.6
June 17	7232.2	7239.4	7252.3	7250.2	7260.4
June 24	7231.9	7240.0	7252.3	7250.2	7260.8
July 1	7231.5	7239.5	7252.2	7249.9	7260.8
July 8	7231.7	7239.8	7252.3	7248.1	7260.5
July 15	7231.3	7239.2	7252.4	7247.7	7260.0
July 22	7230.9	7238.3	7252.0	7246.9	7259.2
July 29	7230.4	7237.7	7251.4	7246.5	7259.0
Aug. 5	7229.8	7237.2	7249.9	7246.0	7258.8
Aug. 12	7229.7	7236.8	7249.0	7245.6	7256.7
Aug. 19	7229.5	7236.9	7248.1	7245.3	7257.0
Aug. 30	7229.4	7236.8	7247.2	7244.9	7256.1
Sept. 13	7229.4	7236.7	7246.6	*7244.9	7255.9
Sept. 27	7228.5	7236.7	7245.5	7244.8	7255.7
Oct. 9	7229.5	7236.9	7245.7	7244.4	7256.6
Nov. 5	7229.5	7237.1	7246.4	7244.5	7257.6
Dec. 6	7229.8	7236.3	7245.2	*7245.2	*7255.7

Date	Well Number 12	13	15	16	18
Jan. 10	7301.2	7311.1	7320.0	7316.2	7348.9
Feb. 8	7301.3	7311.2	7320.2	7316.9	7348.9
March 22	7301.8	7311.1		7317.0	7348.9
April 13	*7303.2	7312.5		7319.2	7349.6
May 27	7301.3	7311.4	7324.7	7318.6	7349.9
June 3	7301.1	7311.9	7324.9	7318.2	7351.5
June 10	7303.5	7313.5	7324.9	7318.1	7351.7
June 17	7303.3	7313.5	7324.5	7317.6	7351.9
June 24	7304.6	7313.5	7324.8	7316.1	7352.0
July 1	7303.3	7313.5	7324.7	7316.8	7352.1
July 8	7303.4	7313.5	7324.6	7316.8	7351.9
July 15	7303.1	7313.3	7323.7	7316.9	7351.5
July 22	7303.0	7312.1	7324.6	7317.2	7350.2
July 29	7302.0	7311.6	7324.6	7317.5	7349.6
Aug. 5	7301.1	7311.0	7323.2	7316.9	7349.1
Aug. 12	7300.6	7310.7	7324.8	7316.4	7348.1
Aug. 19	7300.3	7310.5	7323.9	7316.1	7348.9
Aug. 30	7300.4	7310.4		7316.4	7349.1
Sept. 13	7300.6	7310.3		7316.8	7349.6
Sept. 27	7300.9	7313.0		7317.4	7351.0
Oct. 9	7301.2	7313.2		7317.5	7351.0
Nov. 5	7301.5	7313.4		7317.3	7349.0
Dec. 6	7301.3	7312.1		7317.1	7349.2

Date	Well Number 19	20	21	22	23
Jan. 10	7320.7	7395.5	*7372.1	7421.3	7409.0
Feb. 8	*7322.1	7395.3	7370.5	7421.1	7408.6
March 22	7320.8	7394.8	7368.9	7420.6	7408.1
April 13	7325.4	7395.6	7370.2	7423.0	7409.6
May 27	7323.4	7395.6	7375.5	7422.9	7417.3
June 3	7329.4	7395.9	7382.6	7423.1	7419.0
June 10	7329.4	7396.2	7383.5	7424.5	7419.3
June 17	7329.5	7396.3	7383.5	7425.6	7419.3
June 24	7329.3	7396.4	7383.7	7426.1	7419.4
July 1	7329.4	7396.4	7383.6	7426.1	7419.4
July 8	7329.2	7396.5	7383.5	7426.3	7419.4
July 15	7329.0	7396.6	7383.2	7426.1	7419.4
July 22	7328.8	7396.6	7382.7	7425.9	7418.7
July 29	7325.9	7396.9	7380.5	7425.4	7417.8
Aug. 5	7324.4	7397.0	7379.1	7425.1	7416.7
Aug. 12	7323.2	7397.1	7375.9	7424.8	7416.1
Aug. 19	7322.5	7397.2	7377.1	7424.5	7416.5
Aug. 30	7321.8	7397.3	7376.1	7424.2	7416.5
Sept. 13	7321.0	7397.3	7379.2	7424.0	7415.0
Sept. 27	7320.8	7397.4	7380.6	7425.2	7413.6
Oct. 9	7323.0	7397.3	7380.8	7424.0	7412.9
Nov. 5	7324.5	7398.0	7378.8	7423.2	7411.1
Dec. 6	7322.0	7396.8	7374.7	7422.4	7409.9

	Well Number		
Date	24	25	26
Jan. 10	*7415.6	7331.2	7334.9
Feb. 8	*7416.9	7331.5	7336.3
March 22	*7418.7	7332.7	7335.8
April 13	7419.6	7333.4	7342.1
May 27	7427.2	7332.9	7342.5
June 3	7428.6	7334.9	7343.1
June 10	7428.7	7334.5	7343.8
June 17	7428.9	7334.4	7343.8
June 24	7428.6	7333.5	7343.9
July 1	7428.5	7332.9	7343.9
July 8	7428.5	7333.1	7343.8
July 15	7427.9	7332.7	7342.8
July 22	7425.8	7332.5	7341.9
July 29	7424.5	7332.4	7340.8
Aug. 5	7423.0	7331.7	7339.9
Aug. 12	7420.1	7331.5	7339.2
Aug. 19	7421.2	7331.2	7340.2
Aug. 30	7422.8	7331.2	7338.2
Sept. 13	7418.9	7331.3	7337.4
Sept. 27	7419.5	7331.7	7337.7
Oct. 9	*7419.0	7331.7	7336.6
Nov. 5	*7417.5	7331.5	7336.2
Dec. 6	*7416.0	7331.7	7334.5

1987 WELL ELEVATION DATA

Date	Well Number				
	1	2	3	4	5
Jan. 5	7163.0	7159.6	7183.4	7176.9	7174.8
Feb. 7	7162.8	7159.6	7183.8	7177.3	7174.8
March 5	7164.8	7159.6	7184.4	*7177.3	7174.8
April 4	7164.9	7159.6	7183.3	7177.3	7171.5
April 25	7170.3	7156.7	7189.8	7179.4	7177.9
May 19	7168.9	7160.3	7190.0	7178.5	7176.5
May 27	7171.0	7161.3	7192.9	7183.7	7180.1
June 2	7170.8	7160.7	7192.8	7182.7	7179.5
June 9	7170.8	7161.0	7193.0	7183.5	7179.8
June 16	7170.8	7160.8	7192.8	7183.1	7179.6
June 23	7170.4	7160.8	7193.9	7183.4	7179.5
June 30	7170.4	7160.7	7192.8	7183.0	7179.8
July 7	7170.1	7160.6	7192.6	7182.7	7179.0
July 14	7170.4	7160.9	7192.6	7182.9	7179.6
July 21	7170.0	7160.5	7192.3	7182.4	7179.6
July 28	7169.2	7160.3	7191.8	7180.2	7178.4
Aug. 4	7168.8	7160.2	7191.5	7179.6	7177.5
Aug. 11	7168.2	7160.1	7191.5	7179.25	7176.6
Aug. 19	7168.4	7160.3	7190.4	7179.8	7176.1
Sept. 6	7167.8	7160.0	7189.4	7178.4	*7175.6
Oct. 3	7166.9	7159.8	7187.3	7177.7	7174.8
Oct. 31	7165.8	7159.6	7186.2	7177.5	7174.9
Dec. 12	7165.2	7160.0	7184.6	7177.3	7174.9

Date	Well Number 7	8	9	10	10A
Jan. 5	7230.5	7236.1	7243.8	7245.8	7253.9
Feb. 7	7231.4	7236.1	7243.2	7245.0	7253.9
March 5	7230.1	*7237.2	7242.6	*7244.4	*7255.3
April 4	7230.1	*7237.2	7242.4	7243.7	*7256.8
April 25	7230.9	7237.3	7247.4	7246.2	7257.9
May 19	7229.8	7237.3	7248.5	7244.4	7260.5
May 27	7230.7	7239.2	7252.1	7250.1	7260.6
June 2	7230.7	7238.3	7252.0	7249.8	7260.2
June 9	7230.4	7239.7	7252.0	7250.4	7260.4
June 16	7230.2	7238.8	7252.2	7250.3	7260.5
June 23	7229.9	7239.4	7252.2	7248.7	7260.3
June 30	7229.8	7238.6	7252.2	7247.7	7260.5
July 7	7229.6	7238.0	7251.8	7247.7	7259.7
July 14	7230.8	7238.6	7252.2	7249.5	7260.3
July 21	7230.1	7239.4	7252.2	7249.6	7260.2
July 28	7229.7	7237.3	7251.1	7249.6	7258.8
Aug. 4	7229.4	7236.8	7249.8	7248.6	7257.7
Aug. 11	7229.2	7236.6	7249.1	7247.5	7257.1
Aug. 19	7229.3	7236.7	7248.5	7246.8	7256.8
Sept. 6	7229.2	7236.2	7246.8	7245.8	7256.2
Oct. 3	7229.1	7236.3	7245.1	7245.3	7256.9
Oct. 31	7229.2	7236.5	7247.8	7244.5	7259.7
Dec. 12	7231.1	7236.0	7245.5	7244.2	7256.5

Date	Well Number				
	12	13	15	16	18
Jan. 5	7300.6	7312.8		7316.7	7348.7
Feb. 7	7301.4	7314.0		7317.4	7348.6
March 5	*7301.9	7312.2			7349.1
April 4	*7302.4	7312.2			7348.2
April 25	7302.8	7313.8	7324.1	7318.3	7349.1
May 19	7302.6	7313.1	7325.0	7318.1	7350.9
May 27	7302.9	7313.3	7339.8	7318.8	7351.5
June 2	7302.7	7312.7	7325.6	7318.3	7351.2
June 9	7302.9	7313.1	7325.2	7318.2	7351.5
June 16	7302.9	7313.0	7325.2	7317.9	7350.6
June 23	7302.9	7313.2	7325.3	7317.3	7351.6
June 30	7302.9	7313.1	7325.4	7316.9	7351.2
July 7	7302.4	7311.6	7325.5	7316.4	7350.6
July 14	7303.0	7313.1	7326.2	7317.1	7351.4
July 21	7302.6	7311.8	7325.6	7317.2	7350.1
July 28	7301.4	7311.2	7325.5	7316.9	7349.2
Aug. 4	7300.6	7311.0	7324.8	7316.5	7348.8
Aug. 11	7300.3	7310.8	7325.3	7316.2	7348.5
Aug. 19	7300.7	7310.8	7325.6	7316.6	7348.4
Sept. 6	7300.4	7310.9	7325.2	7316.8	7349.2
Oct. 3	7300.2	7311.0	7324.8	7315.8	7349.0
Oct. 31	7301.1	7311.2	7325.2	7316.6	7349.8
Dec. 12	7300.4	7311.0	7324.7	7316.1	7348.3

Date	Well Number				
	19	20	21	22	23
Jan. 5	7320.6	7396.8	7372.5	7421.8	7408.6
Feb. 7	7320.2	7397.7	7372.0	7421.2	7407.6
March 5	7320.2	7398.2	7369.7	7420.6	7407.4
April 4	7320.3	7397.1	7368.4	7420.4	7406.5
April 25	7325.0	7397.4	7380.3	7423.4	7409.8
May 19	*7327.8	7396.0	7383.2	7422.4	7419.2
May 27	*7328.8	7397.0	7383.5	7423.8	7419.7
June 2	7329.4	7396.0	7383.4	7425.4	7419.2
June 9	7329.5	7396.5	7383.5	7426.0	7419.4
June 16	7329.5	7396.4	7383.3	7426.2	7419.2
June 23	7329.4	7396.0	7383.6	7426.1	7419.3
June 30	7329.4	7395.7	7383.4	7426.3	7419.5
July 7	7328.2	7395.8	7383.3	7426.1	7419.1
July 14	7329.2	7395.9	7383.4	7426.1	7419.2
July 21	*7327.6	7395.6	7382.8	7426.3	7419.0
July 28	7325.7	7395.4	7380.5	7425.7	7418.1
Aug. 4	*7324.7	7395.2	7379.1	7425.2	7416.8
Aug. 11	*7323.6	7395.3	7377.9	7424.9	7415.9
Aug. 19	7322.4	7396.2	7377.0	7424.7	7415.0
Sept. 6	7321.4	7396.6	7377.8	7424.0	7413.2
Oct. 3	7320.7	7396.6	7378.2	7423.1	7411.3
Oct. 31	7321.9	7396.9	7378.3	7422.5	7411.4
Dec. 12	7321.2	7396.2	7374.6	7421.8	7409.1

Date	Well Number 24	25	26
Jan. 5	*7415.0	7331.5	7335.4
Feb. 7	*7415.3	7329.4	*7338.6
March 5	*7415.6	*7333.0	7336.1
April 4	*7416.0	7332.3	7335.7
April 25	7419.4	7332.8	7338.0
May 19	7428.5	7333.3	7342.1
May 27	7428.8	7333.7	7343.0
June 2	7428.8	7333.0	7343.2
June 9	7428.8	7333.4	7343.7
June 16	7428.4	7333.4	7343.8
June 23	7428.6	7333.3	7343.7
June 30	7428.6	7333.1	7343.6
July 7	7427.8	7333.5	7343.9
July 14	7428.1	7333.0	7341.9
July 21	7426.7	7332.8	7340.6
July 28	7425.0	7332.5	7339.5
Aug. 4	7423.3	7332.4	7338.7
Aug. 11	7421.9	7332.2	7338.0
Aug. 19	7420.1	7332.4	7337.6
Sept. 6	*7419.0	7332.4	7336.8
Oct. 3	*7417.5	7332.0	7335.8
Oct. 31	*7416.0	7332.4	7335.4
Dec. 12	*7415.5	7331.3	7334.6

1988 WELL ELEVATION DATA

Date	Well Number 1	2	3	4	5
Jan. 23	7164.6	7159.1	7183.6	7176.9	7174.4
Feb. 27	7164.4	7159.4	7183.2	7176.8	7174.4

Date	Well Number				
	7	8	9	10	10A
Jan. 23	*7231.0	7236.0	7243.6	7243.9	7254.5
Feb. 27	7230.3	7235.7	7242.5	7243.6	7253.4

Date	Well Number 12	13	15	16	18
Jan. 23	7300.0	7310.5	7324.0	7318.1	7347.9
Feb. 27	7300.0	7310.0	7323.5	*7318.2	*7348.6

Date	Well Number				
	19	20	21	22	23
Jan. 23	*7320.3	7395.5	7371.4	7421.4	7408.1
Feb. 27	7319.5	7395.0	7369.6	7420.8	7406.8

	Well Number		
Date	24	25	26
Jan. 23	*7415.0	*7331.4	*7334.0
Feb. 27	*7415.5	7331.5	7333.6

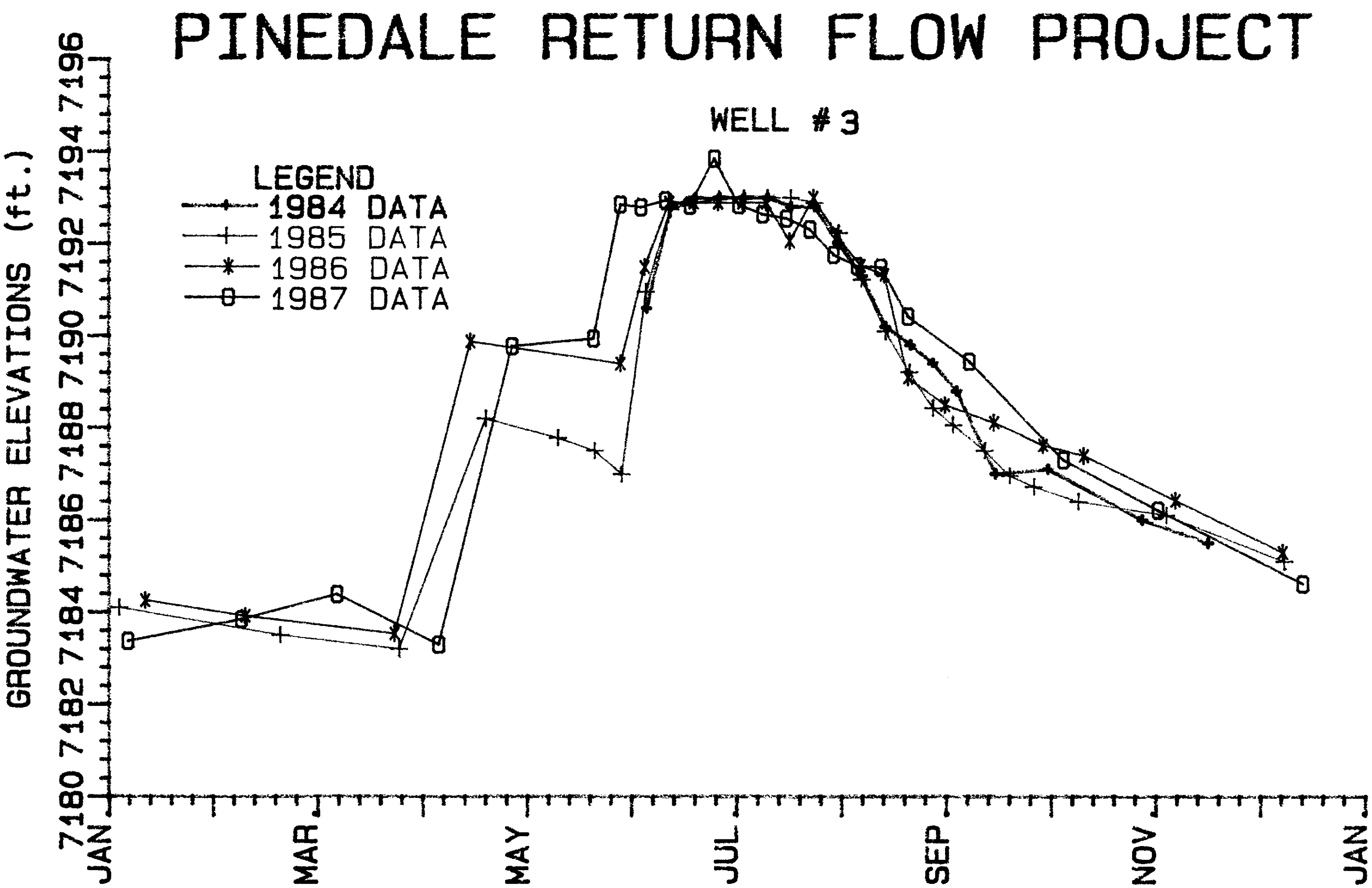


Figure 47. 1984 through 1987 Groundwater Elevations in Monitoring Well #3.

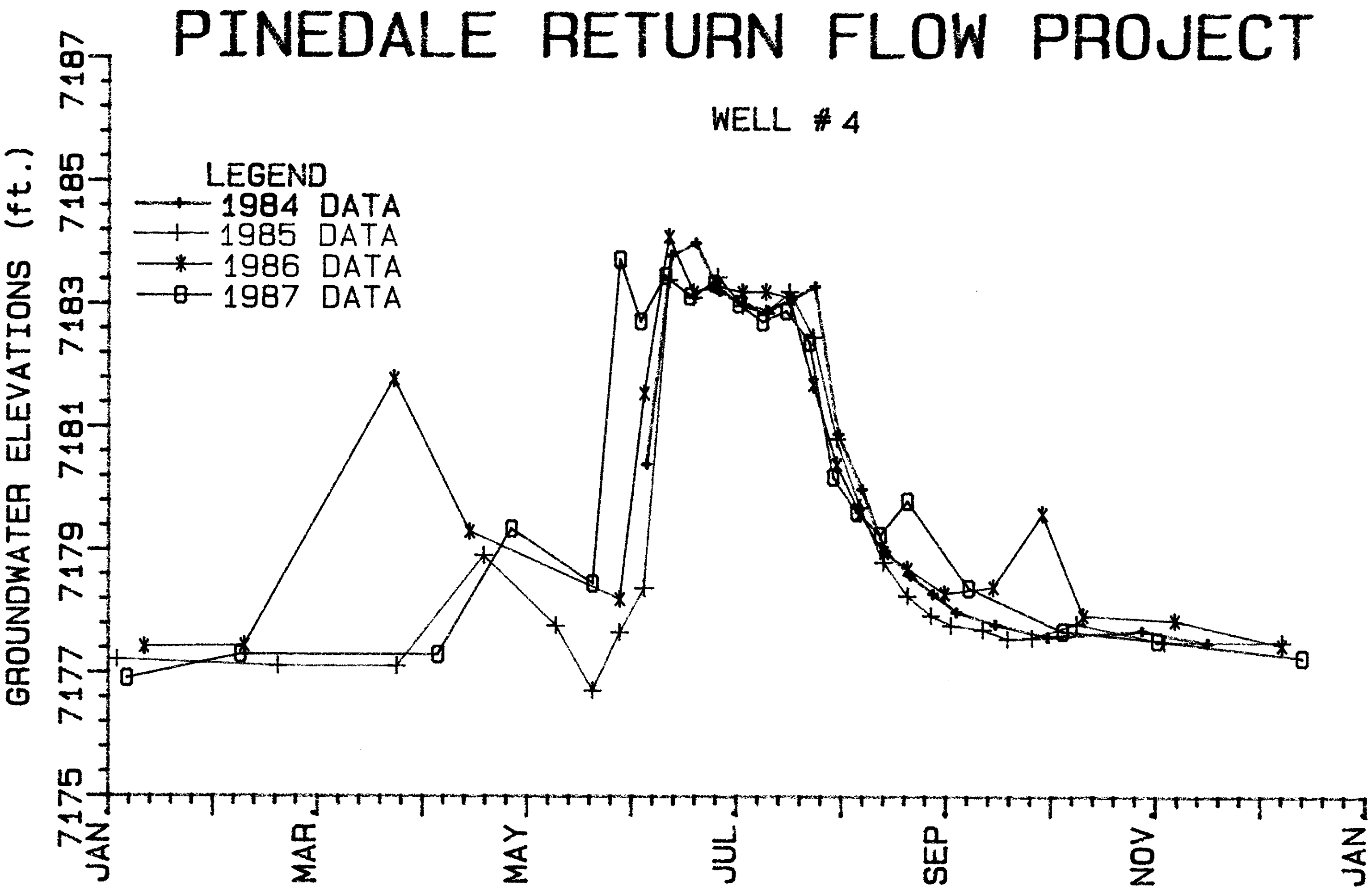


Figure 48. 1984 through 1987 Groundwater Elevations in Monitoring Well #4.

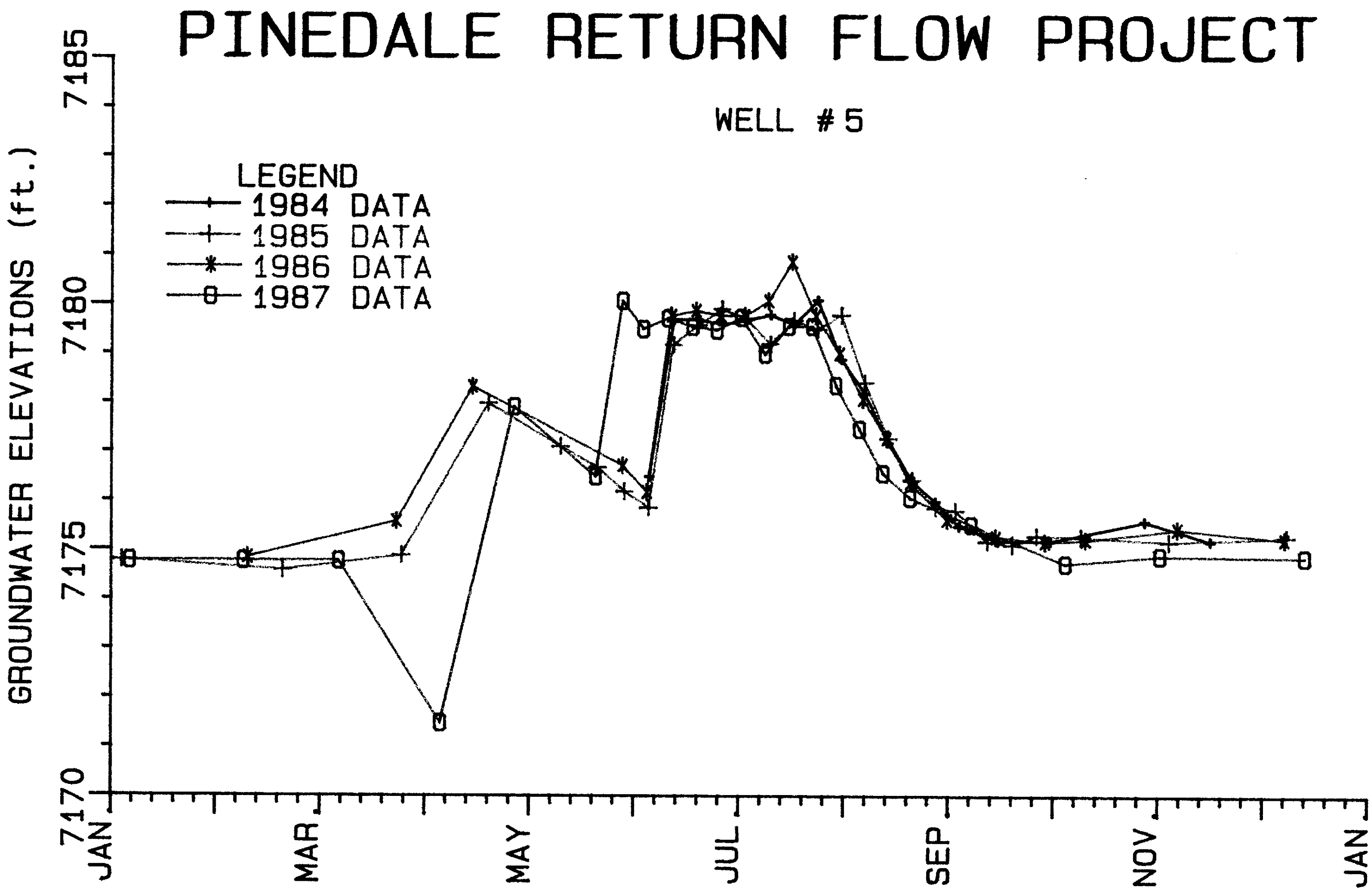


Figure 49. 1984 through 1987 Groundwater Elevations in Monitoring Well #5.

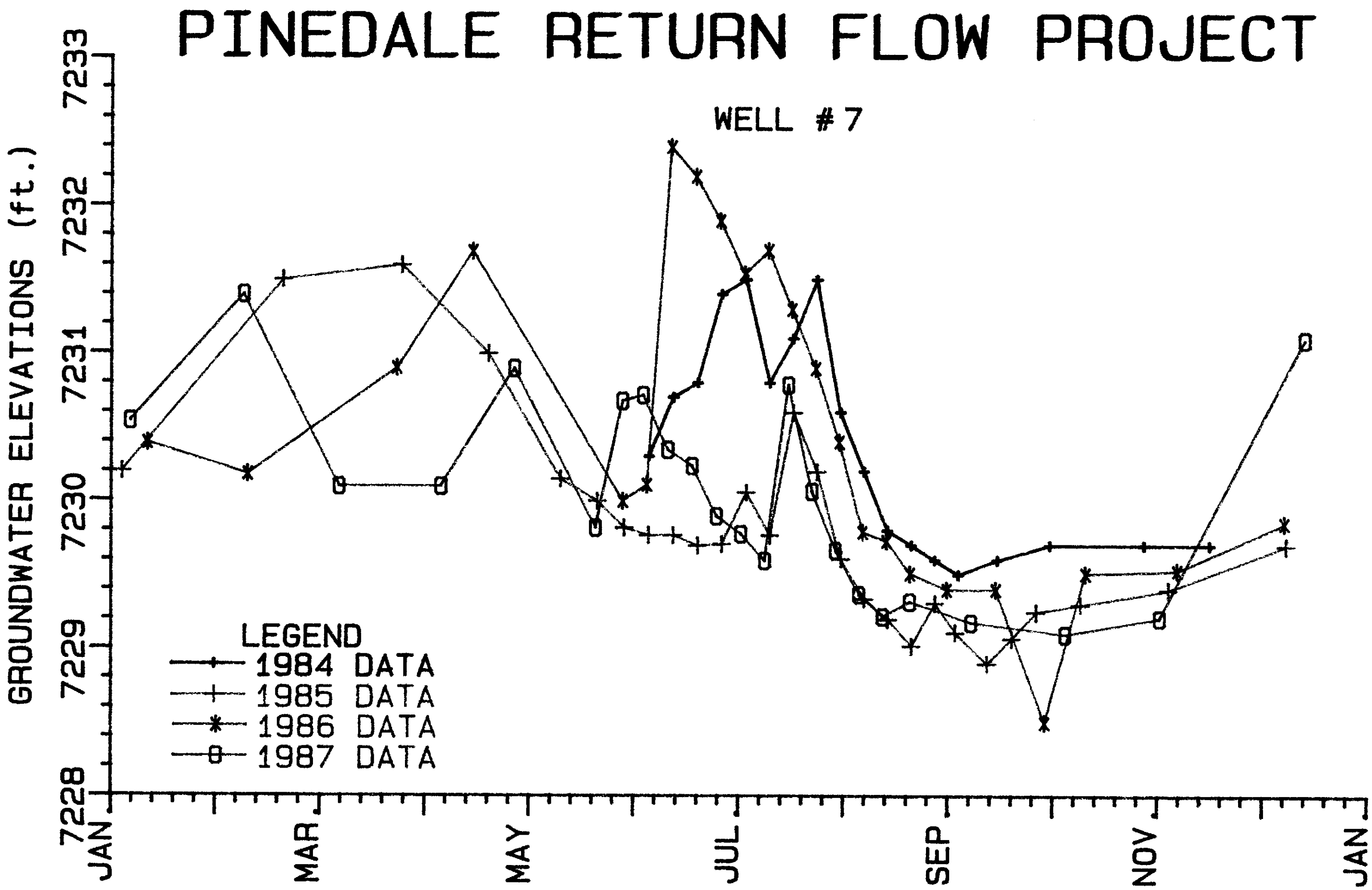


Figure 50. 1984 through 1987 Groundwater Elevations in Monitoring Well #7.

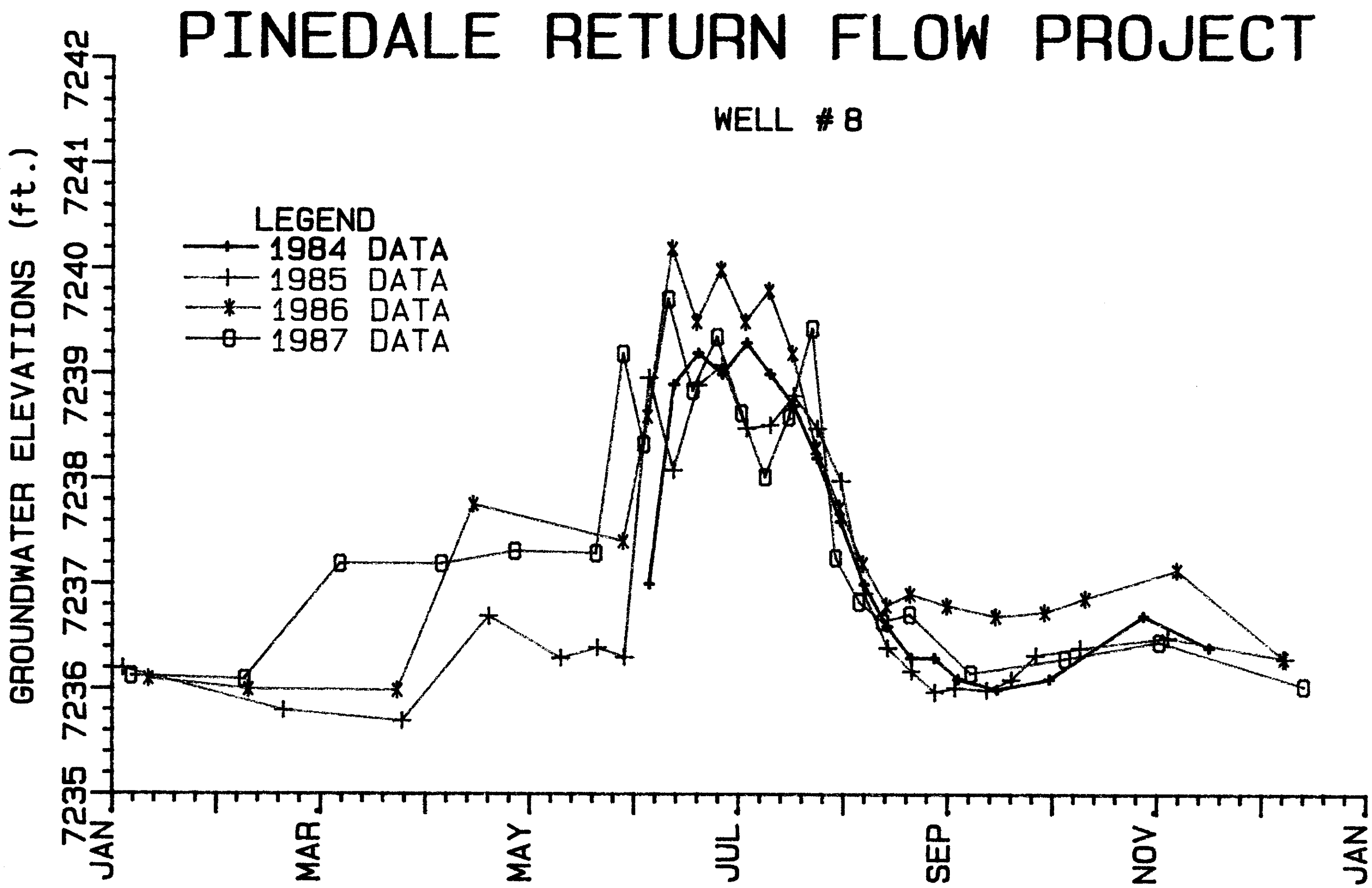


Figure 51. 1984 through 1987 Groundwater Elevations in Monitoring Well #8.

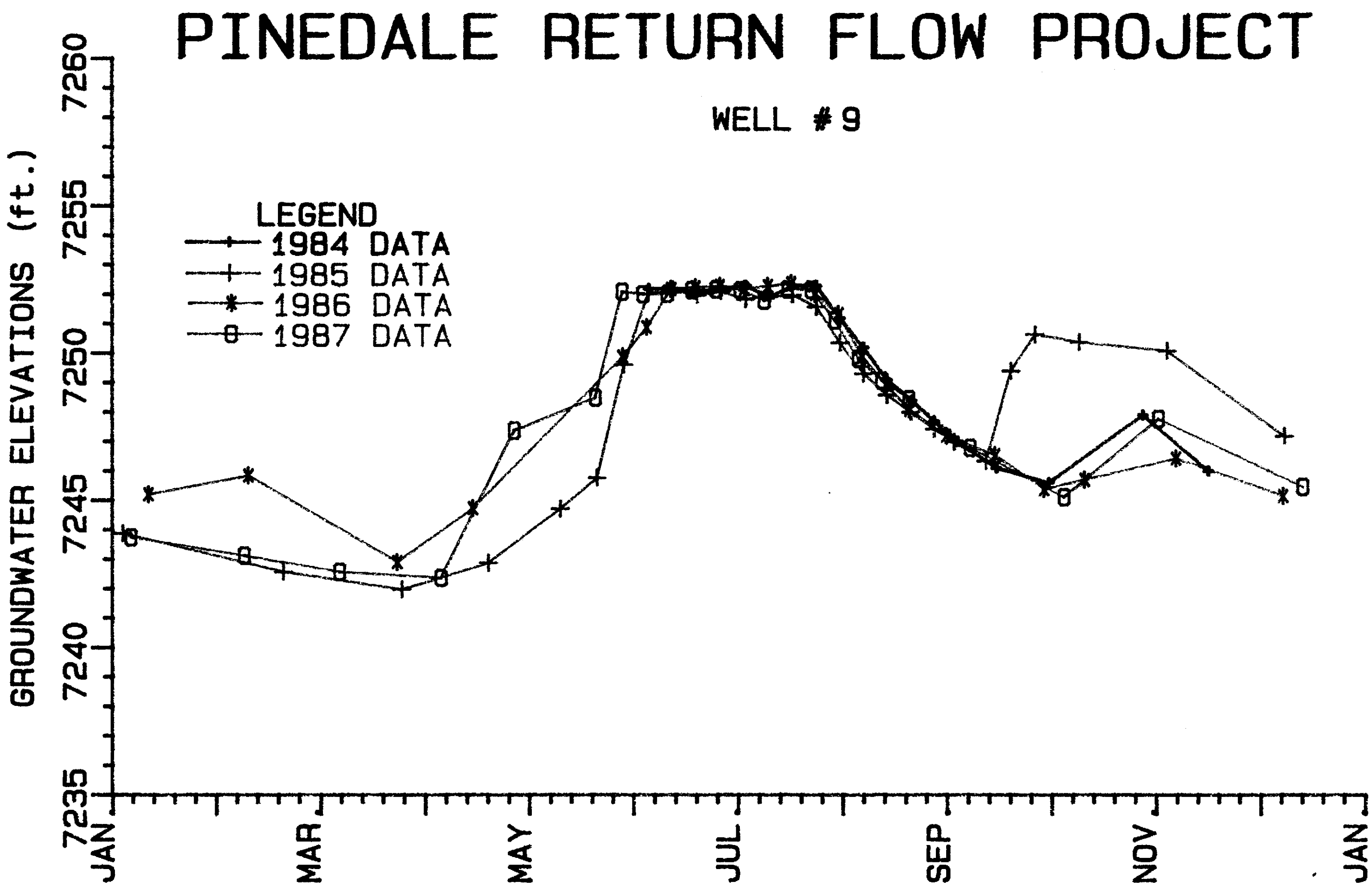


Figure 52. 1984 through 1987 Groundwater Elevations in Monitoring Well #9.

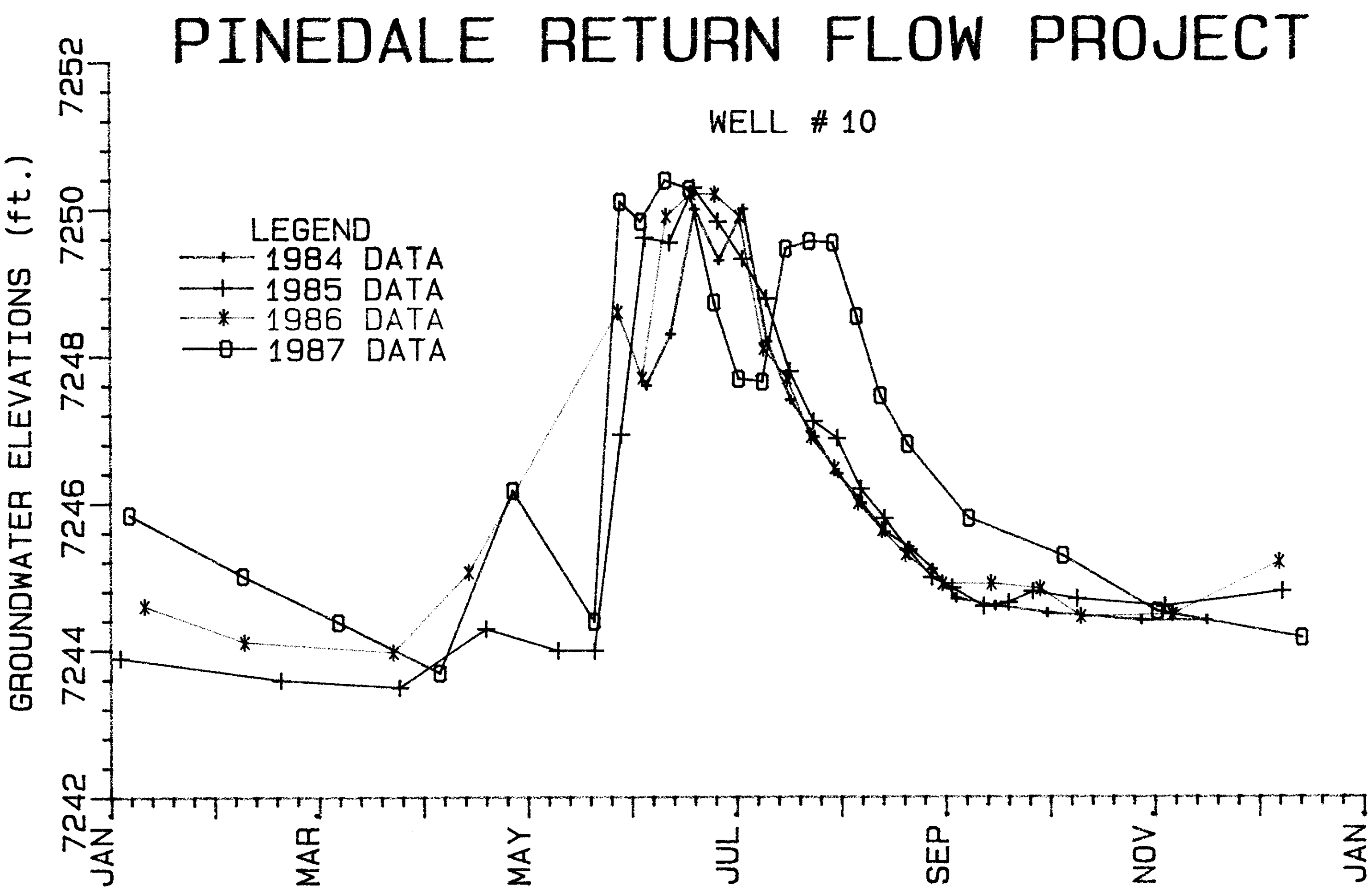


Figure 53. 1984 through 1987 Groundwater Elevations in Monitoring Well #10.

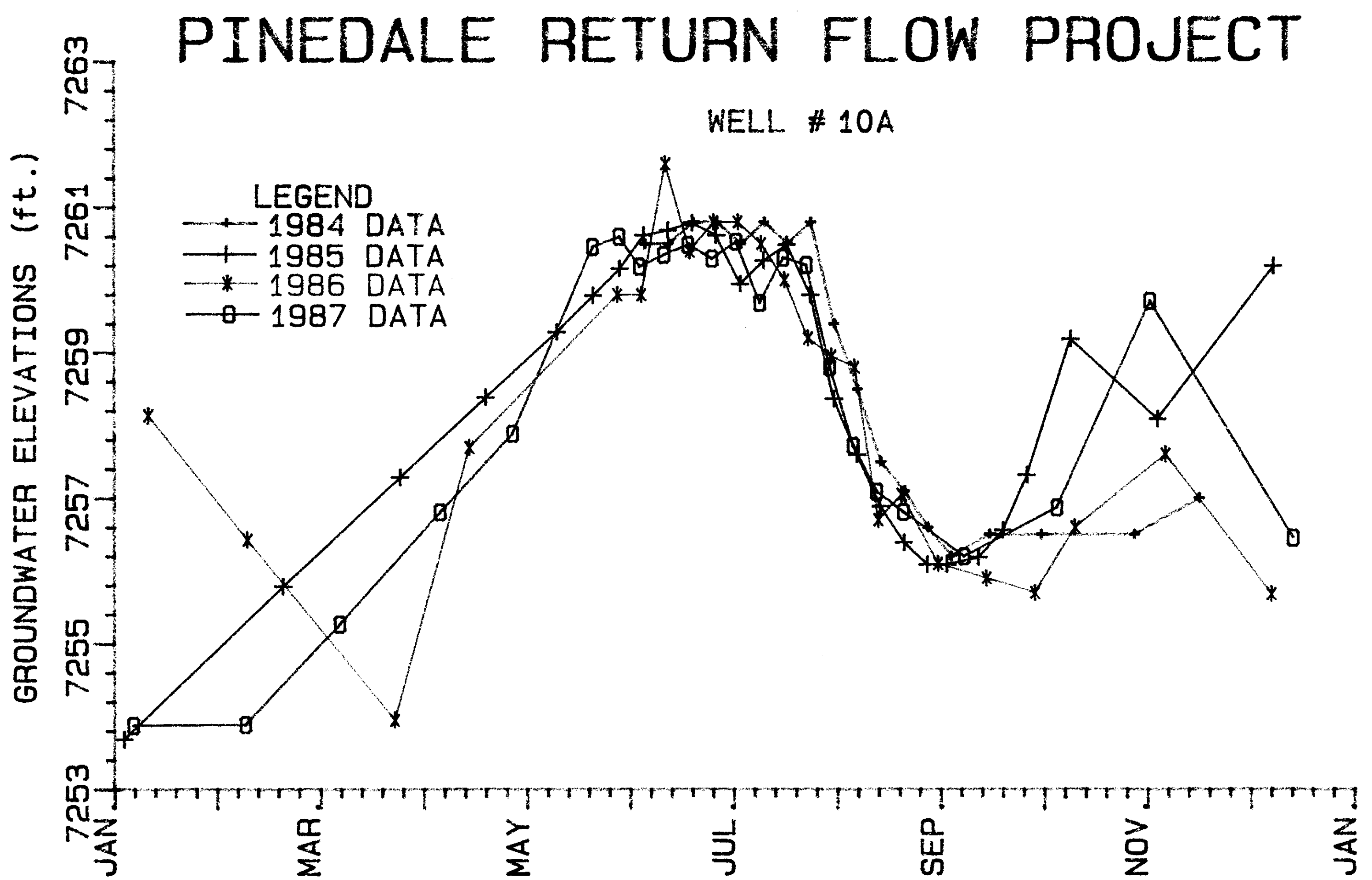


Figure 54. 1984 through 1987 Groundwater Elevations in Monitoring Well #10A.

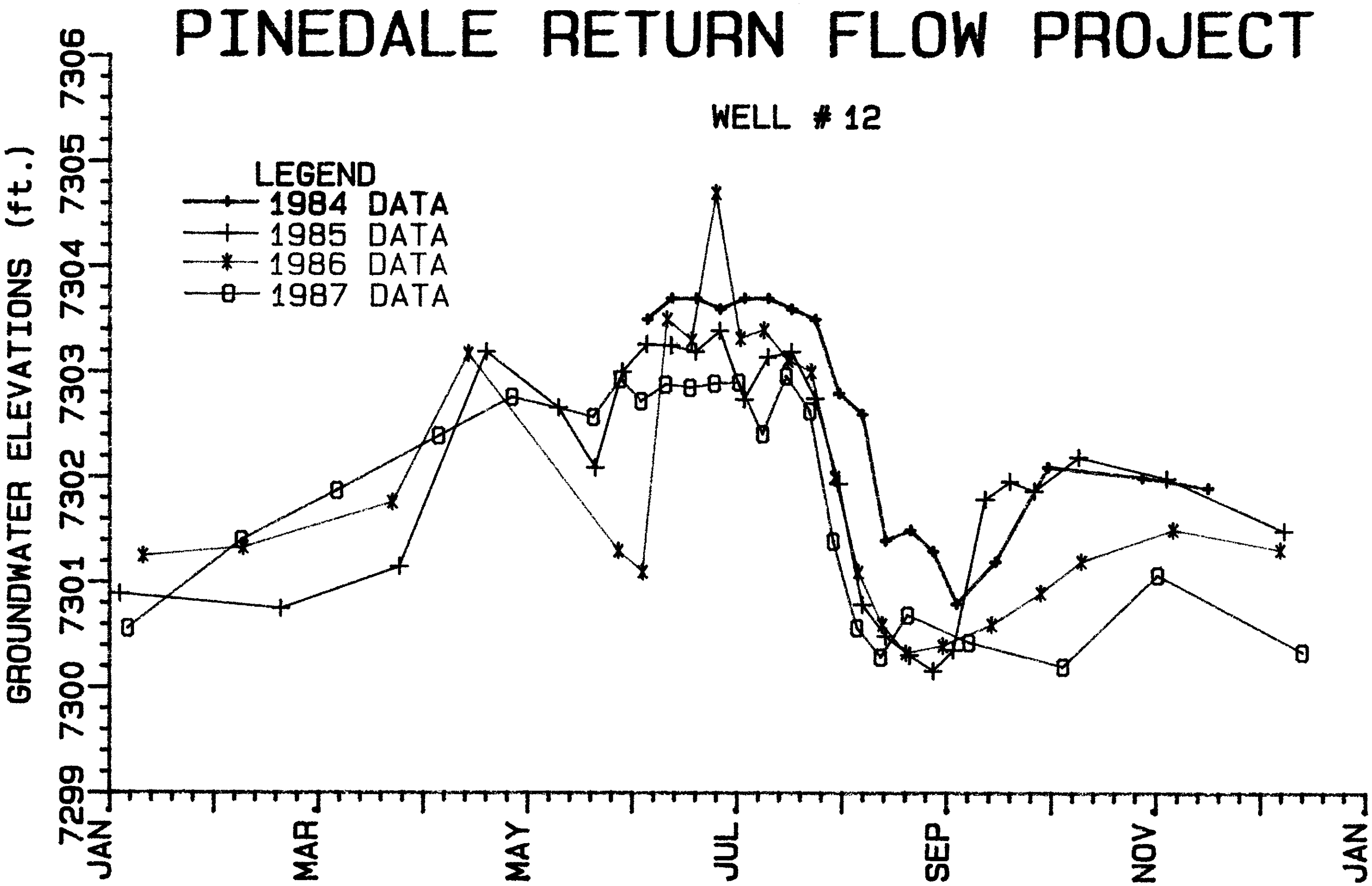


Figure 55. 1984 through 1987 Groundwater Elevations in Monitoring Well #12.

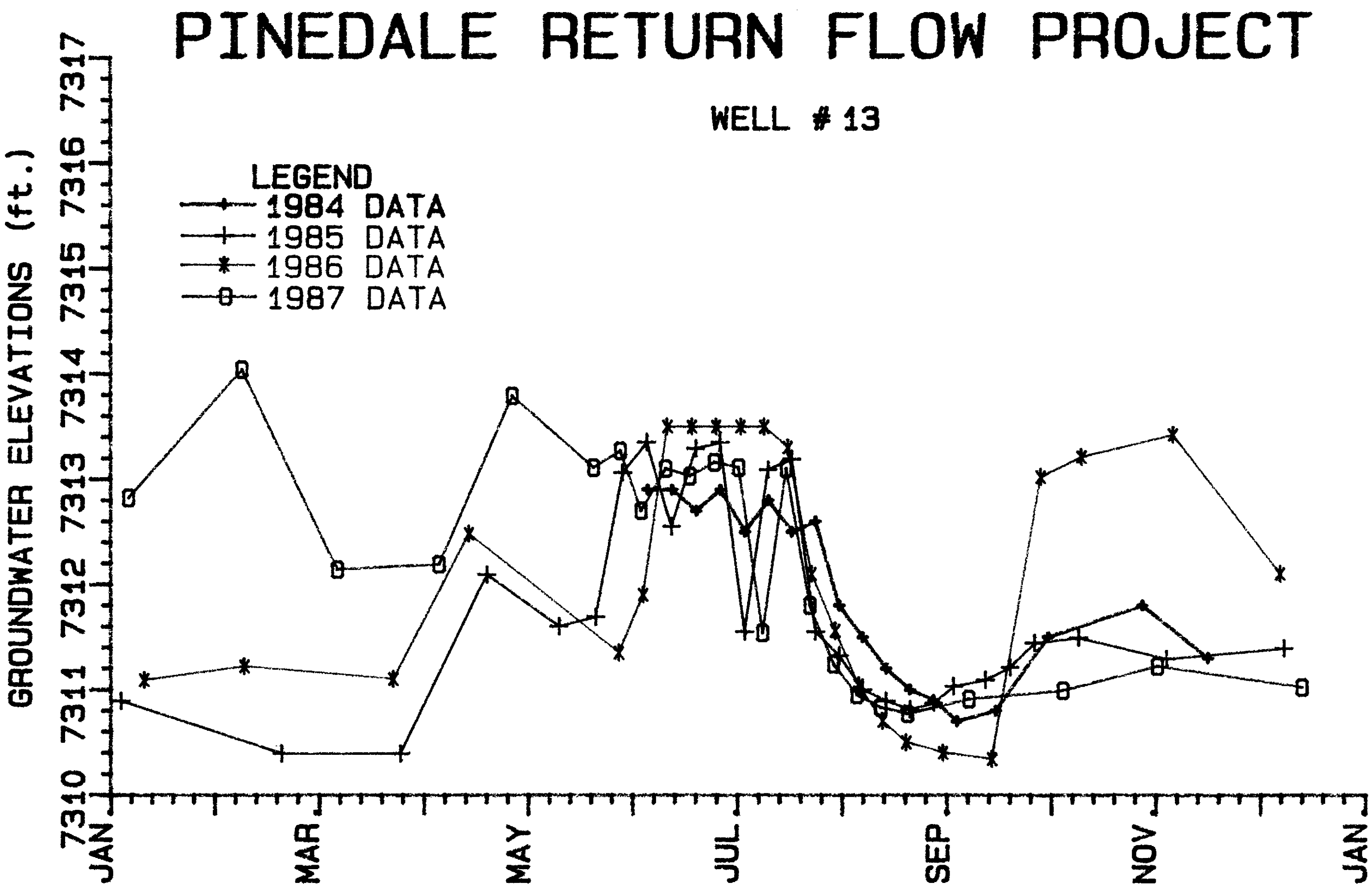


Figure 56. 1984 through 1987 Groundwater Elevations in Monitoring Well #13.

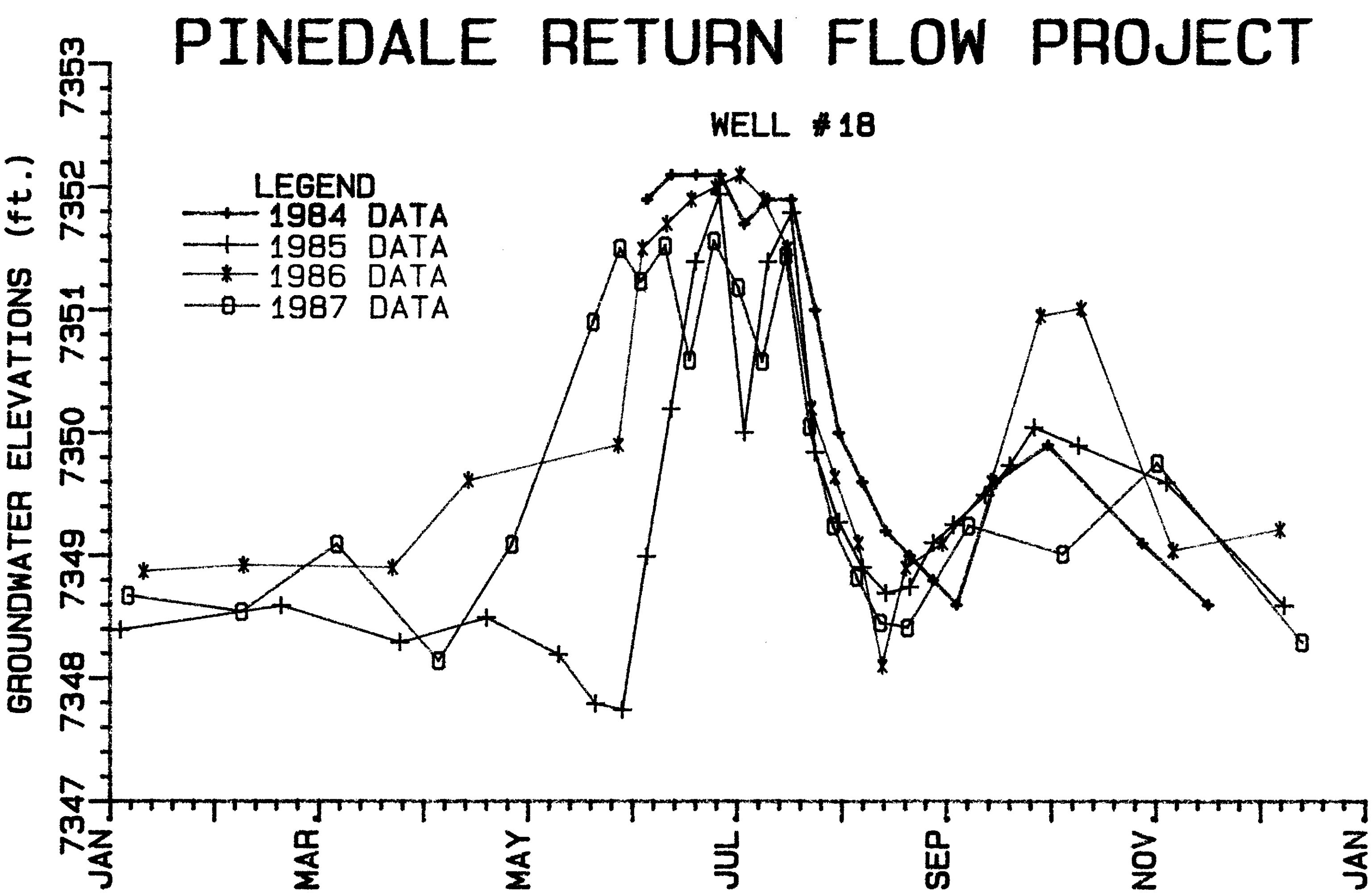


Figure 57. 1984 through 1987 Groundwater Elevations in Monitoring Well #18.

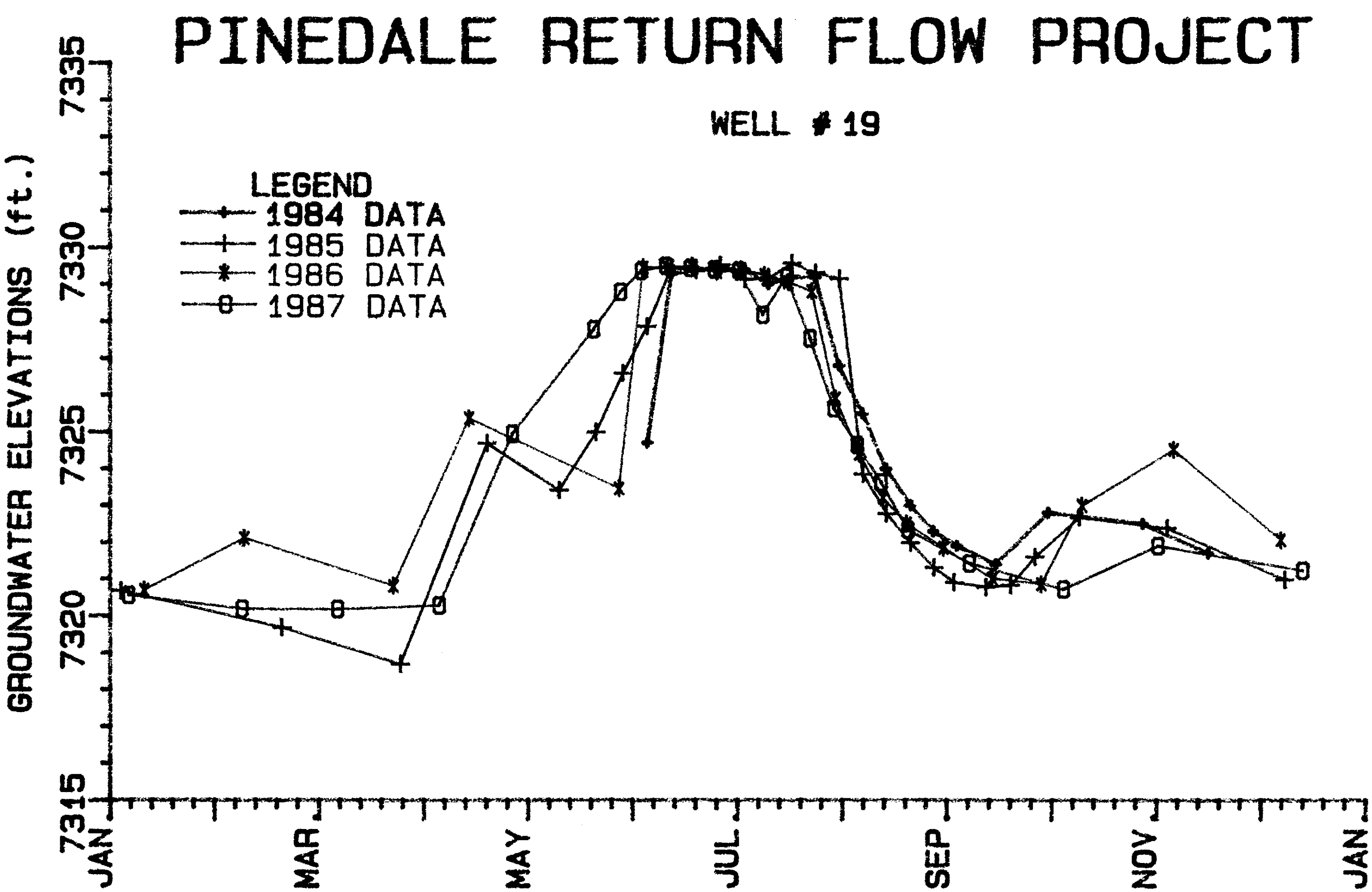


Figure 58. 1984 through 1987 Groundwater Elevations in Monitoring Well #19.

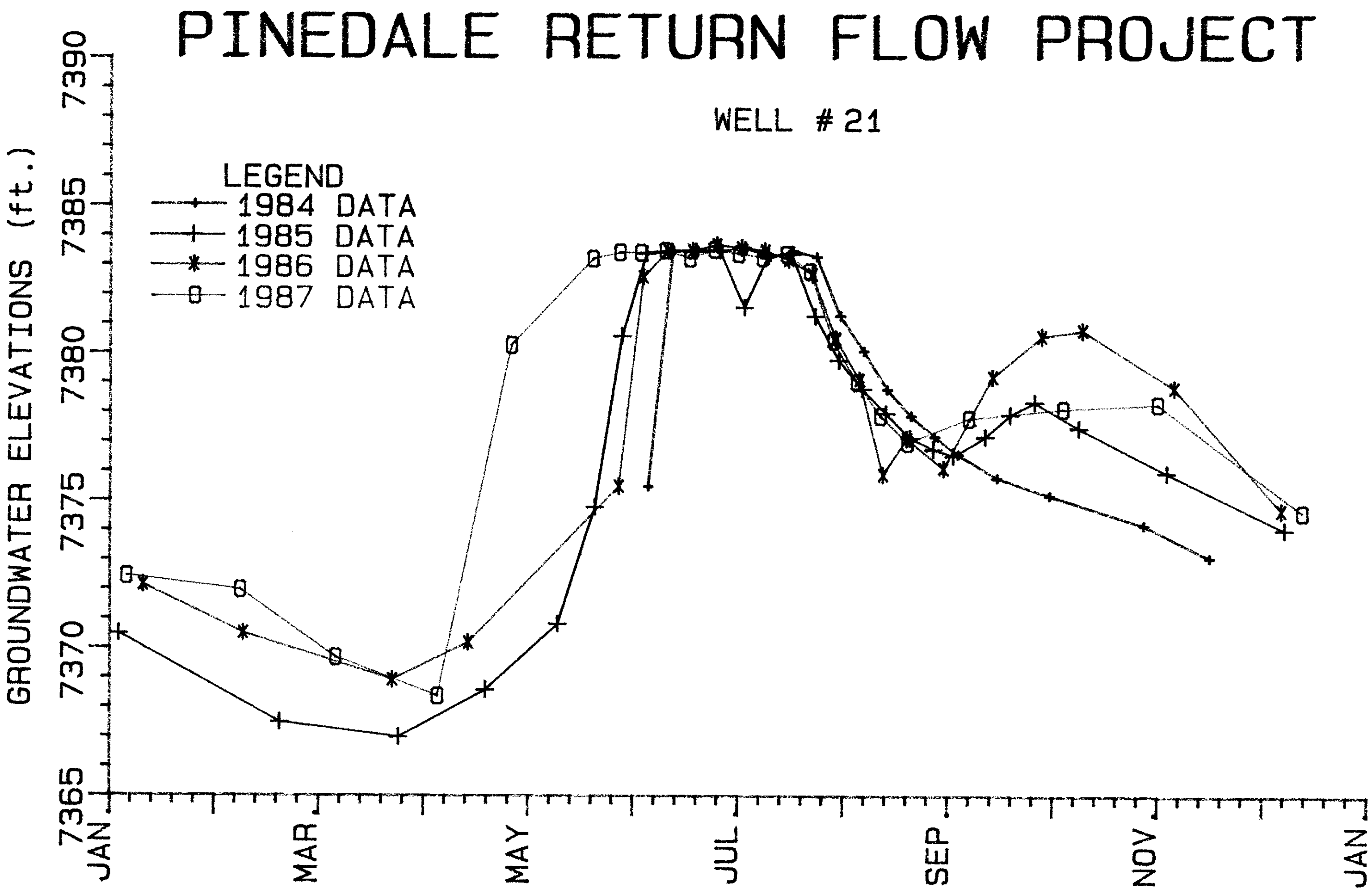


Figure 59. 1984 through 1987 Groundwater Elevations in Monitoring Well #21.

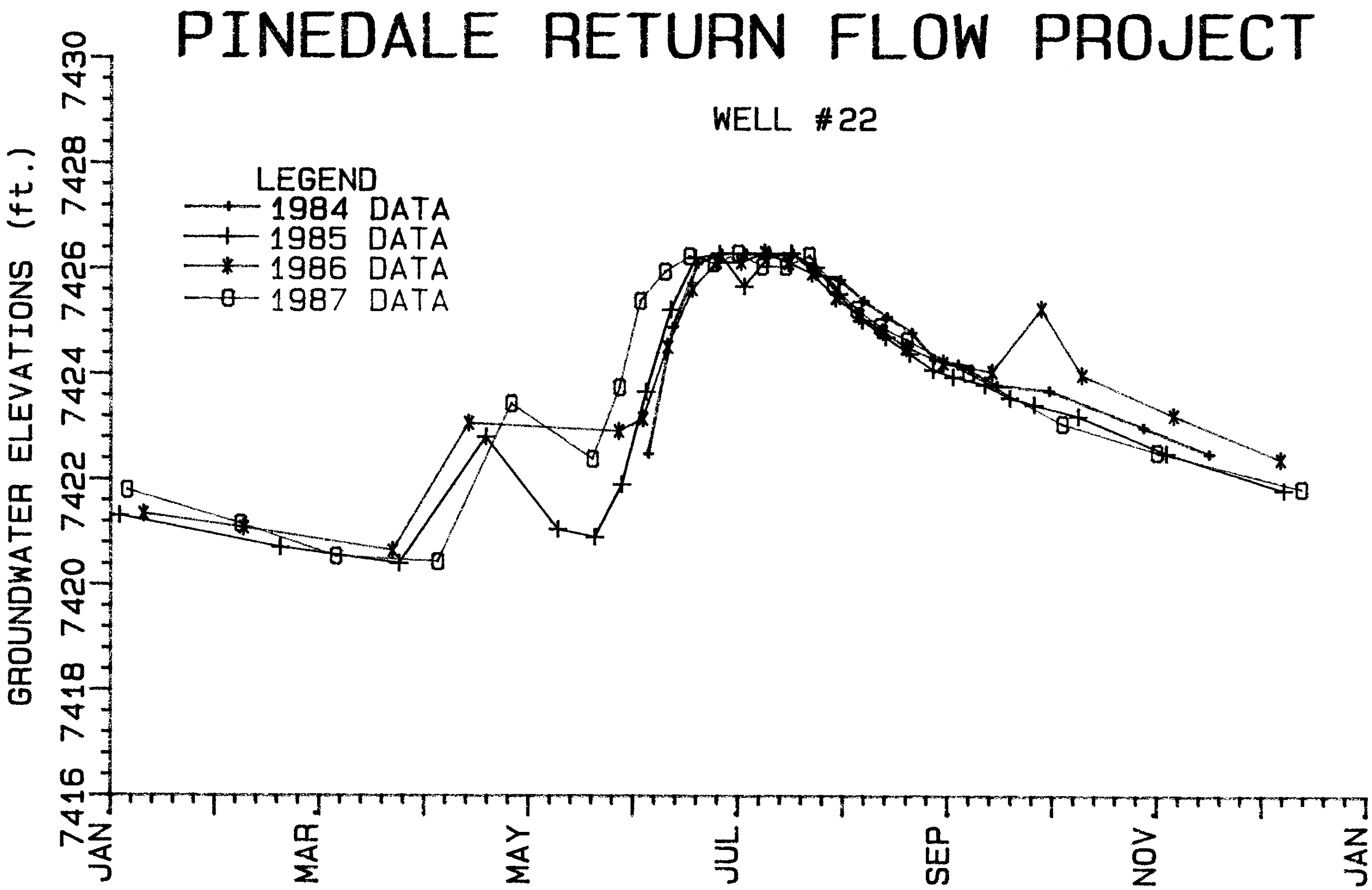


Figure 60. 1984 through 1987 Groundwater Elevations in Monitoring Well #22.

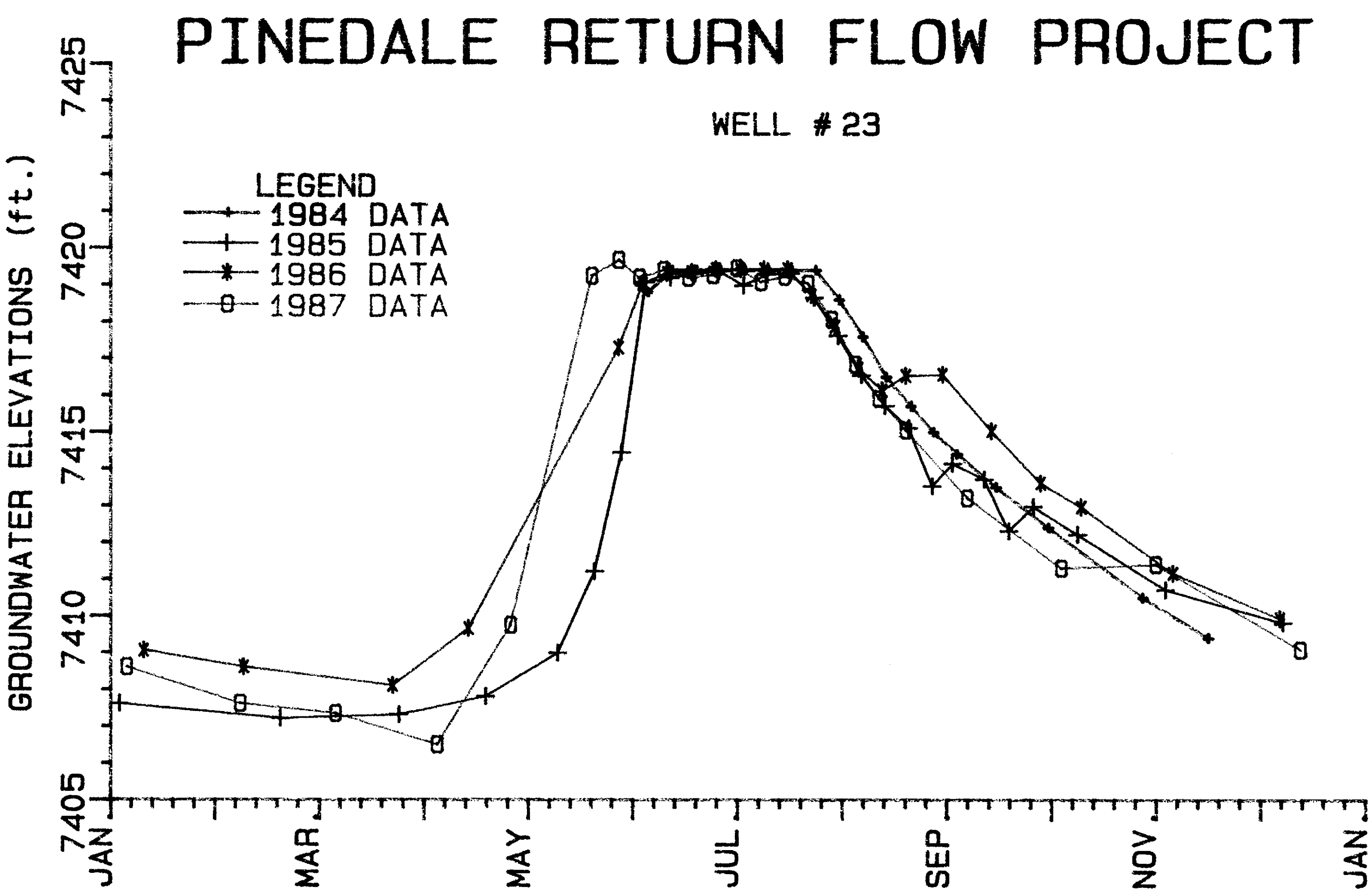


Figure 61. 1984 through 1987 Groundwater Elevations in Monitoring Well #23.

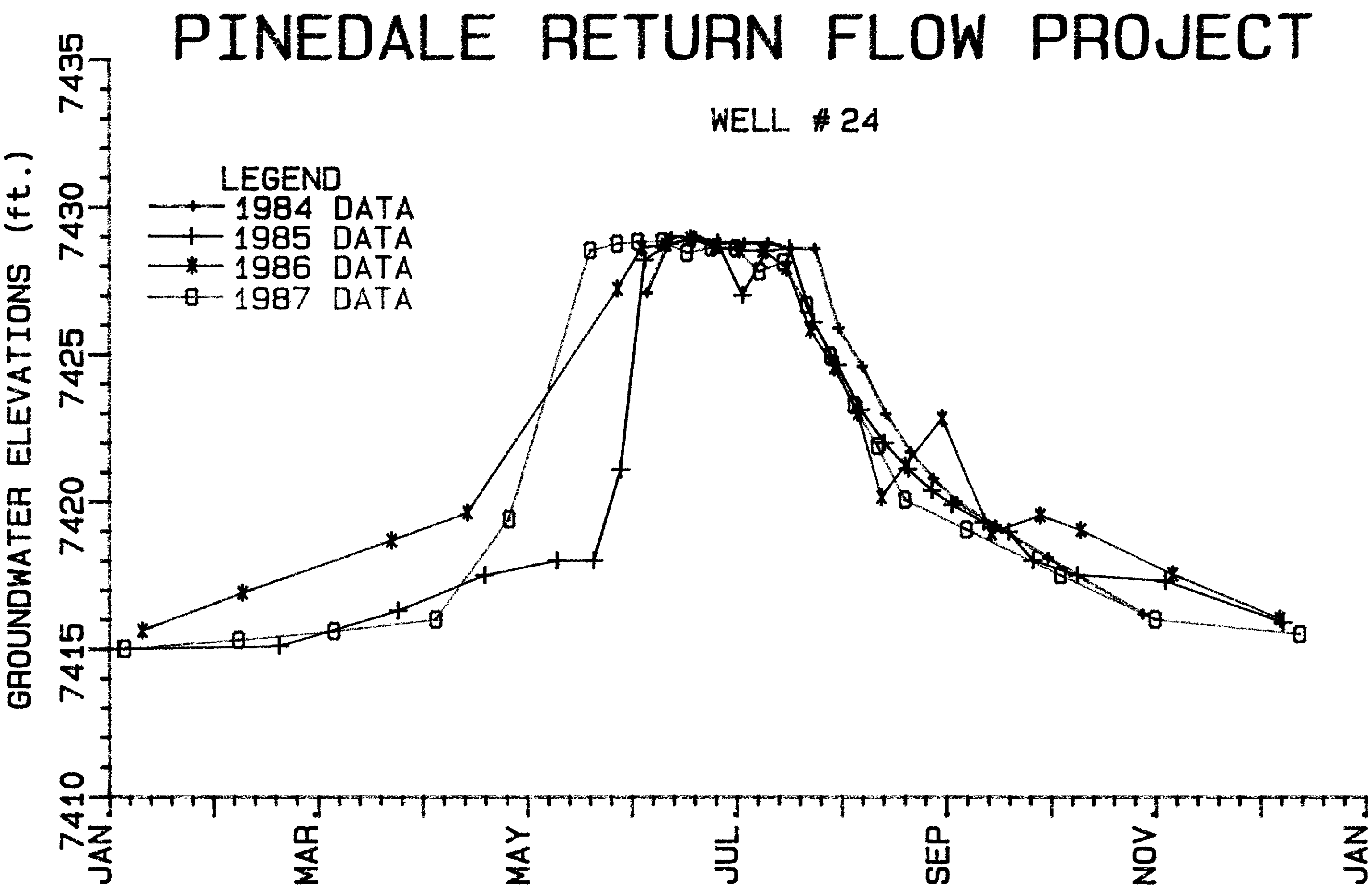


Figure 62. 1984 through 1987 Groundwater Elevations in Monitoring Well #24.

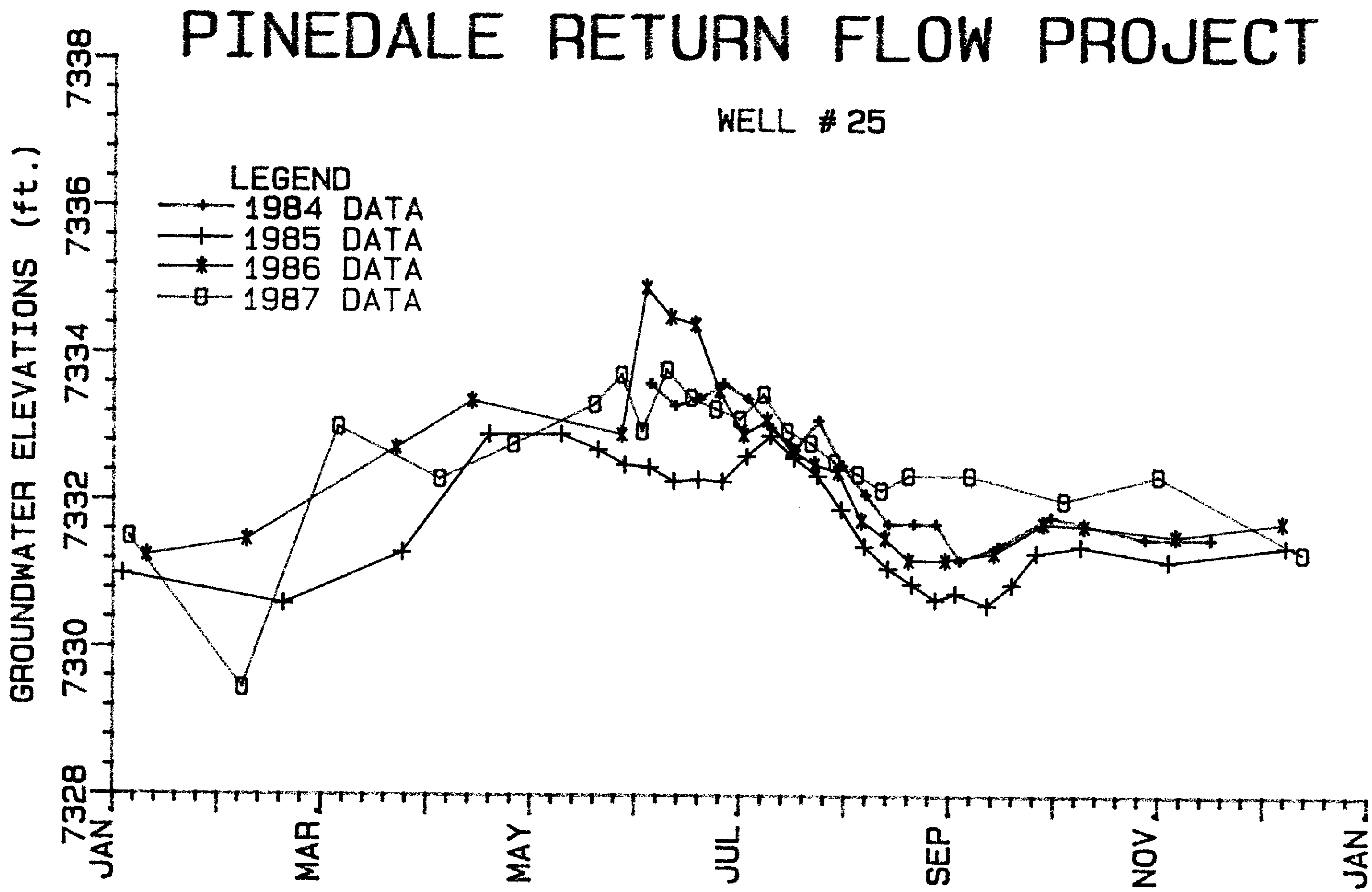


Figure 63. 1984 through 1987 Groundwater Elevations in Monitoring Well #25.

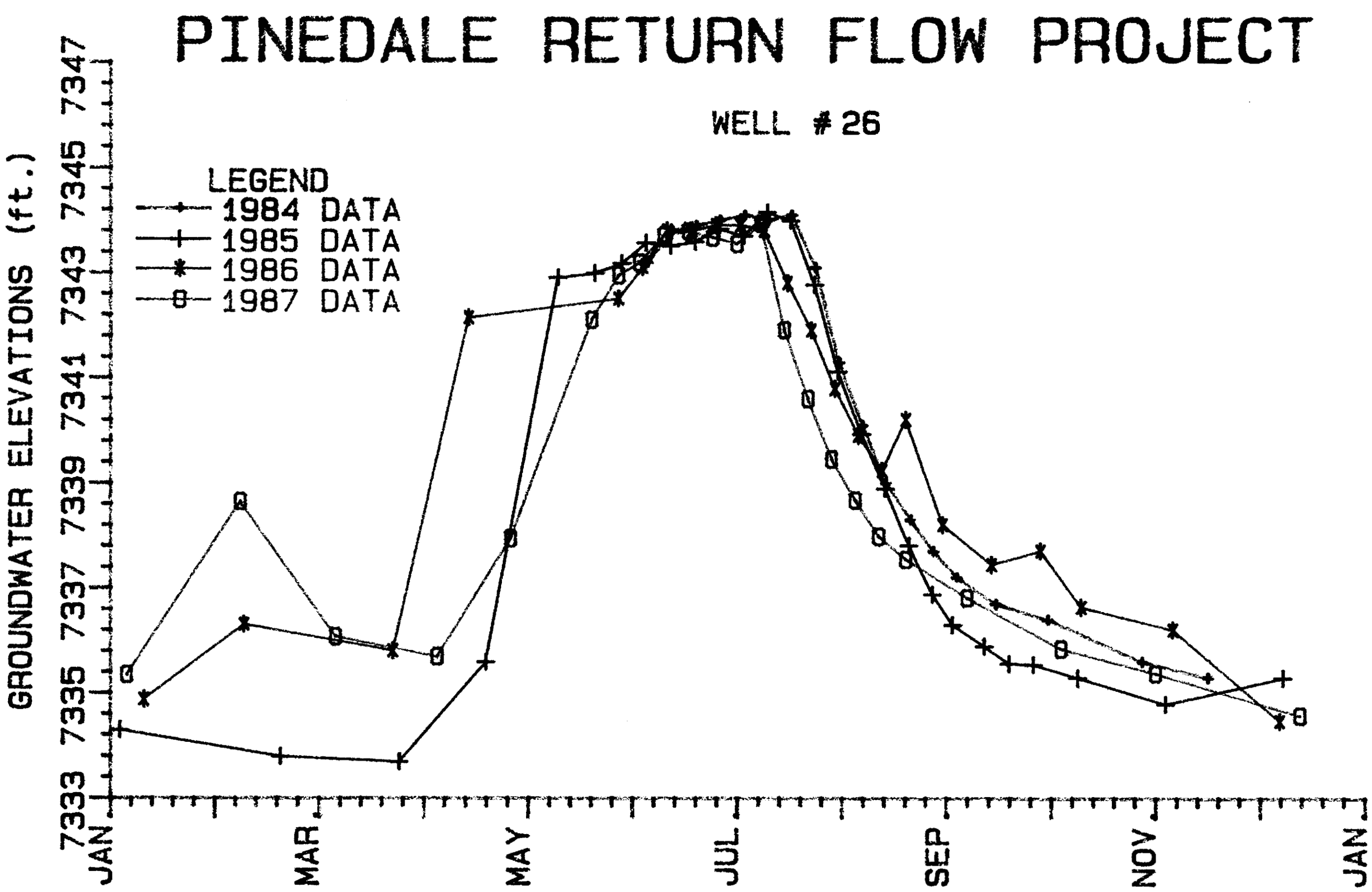


Figure 64. 1984 through 1987 Groundwater Elevations in Monitoring Well #26.

APPENDIX E

USGS GROUNDWATER MODEL CALCULATED HEAD ELEVATIONS COMPARED WITH THE FIELD MEASURED WATER TABLE ELEVATIONS

SIMULATION PERIOD: 1984 Recharge

DATES: 6/4/84 - 6/25/84

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7193.0	7193.2	+0.2
4	7183.2	7183.6	+0.4
5	7179.6	7179.9	+0.3
7	7231.4	7231.2	-0.2
8	7239.0	7239.2	+0.2
9	7252.2	7252.2	0.0
10	7249.3	7249.3	0.0
10A	7260.8	7260.6	-0.2
12	7303.6	7304.1	+0.5
13	7312.9	7312.7	-0.2
18	7352.1	7352.4	+0.3
19	7329.4	7329.1	-0.3
21	7383.5	7383.5	0.0
22	7426.3	7426.3	0.0
23	7419.4	7419.6	+0.2
24	7428.4	7428.2	-0.2
25	7333.6	7333.6	0.0
26	7344.0	7344.1	+0.1

SIMULATION PERIOD: 1984 Saturation

DATES: 6/26/84 - 7/23/84

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7192.8	7192.5	-0.3
4	7183.3	7183.7	+0.4
5	7180.1	7179.9	-0.2
7	7231.5	7231.6	+0.1
8	7238.2	7238.3	+0.1
9	7252.3	7252.3	0.0
10	7246.9	7246.6	-0.3
10A	7260.8	7260.5	-0.3
12	7303.5	7304.0	+0.5
13	7312.6	7312.5	-0.1
18	7351.0	7350.8	-0.2
19	7329.2	7329.1	-0.1
21	7383.3	7383.5	+0.2
22	7425.9	7425.9	0.0
23	7419.4	7419.9	+0.5
24	7428.6	7428.3	-0.3
25	7333.1	7333.1	0.0
26	7343.1	7343.1	0.0

SIMULATION PERIOD: 1984 Haying

DATES: 7/24/84 - 9/14/84

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7187.0	7187.1	+0.1
4	7177.8	7177.6	-0.2
5	7175.2	7175.5	+0.3
7	7229.6	7230.4	+0.8
8	7236.0	7235.4	-0.6
9	7246.1	7246.5	+0.4
10	7244.6	7244.8	+0.2
10A	*7256.5	7255.3	-1.2
12	7301.2	7299.5	-1.7
13	7310.8	7311.5	+0.7
18	7349.6	7349.4	-0.2
19	7321.4	7319.8	-1.6
21	7375.8	7375.1	-0.7
22	7423.8	7423.8	0.0
23	7413.5	7413.7	+0.2
24	7419.2	7419.7	+0.5
25	7331.4	7331.4	0.0
26	7336.7	7335.0	-1.7

* Estimated Data

SIMULATION PERIOD: 1984 Fall Recharge

DATES: 9/15/84 - 9/29/84

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7187.1	7187.2	+0.1
4	7177.6	7177.5	-0.1
5	7175.2	7175.1	-0.1
7	7229.7	7229.6	-0.1
8	7236.1	7236.1	0.0
9	7245.6	7245.8	+0.2
10	7244.5	7244.6	+0.1
10A	*7256.5	7256.6	+0.1
12	7302.1	7302.3	+0.2
13	7311.5	7311.4	-0.1
18	7349.9	7349.8	-0.1
19	7322.8	7322.6	-0.2
21	7375.2	7375.2	0.0
22	7423.7	7423.7	0.0
23	7412.4	7412.6	+0.2
24	*7418.1	7419.0	+0.9
25	7331.8	7331.8	0.0
26	7336.4	7336.2	-0.2

SIMULATION PERIOD: 1984-1985 Winter

DATES: 9/30/84 - 3/24/85

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7183.2	7183.4	+0.2
4	7177.1	7177.2	+0.1
5	7174.9	7174.7	-0.2
7	7231.6	7231.4	-0.2
8	7235.7	7235.0	-0.7
9	7242.0	7243.2	+1.2
10	7243.5	7245.5	+2.0
10A	*7258.5	7252.0	-6.5
12	7301.2	7301.4	+0.2
13	7310.4	7311.4	+1.0
18	7348.3	7349.3	+1.0
19	7318.7	7319.1	+0.4
21	*7367.0	7366.9	-0.1
22	7420.4	7420.4	0.0
23	7407.3	7410.7	+3.4
24	*7418.2	7419.0	+0.8
25	7331.3	7331.3	0.0
26	7333.7	7333.5	-0.2

SIMULATION PERIOD: 1985 Spring Runoff

DATES: 3/25/85 - 4/18/85

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7188.2	7188.2	0.0
4	7178.9	7178.9	0.0
5	7178.0	7180.8	+2.8
7	7231.0	7231.6	+0.6
8	7236.7	7237.0	+0.3
9	7242.9	7244.1	+1.2
10	7244.3	7245.1	+0.8
10A	*7259.2	7259.7	+0.5
12	7303.2	7303.1	-0.1
13	7312.1	7312.0	-0.1
18	7348.5	7349.4	+0.9
19	7324.7	7324.4	-0.3
21	7368.6	7368.5	-0.1
22	7422.8	7422.8	0.0
23	7407.8	7409.9	+2.1
24	*7418.8	7419.1	+0.3
25	7332.9	7332.9	0.0
26	7335.6	7336.1	+0.5

SIMULATION PERIOD: 1985 End of Runoff

DATES: 4/19/85 - 5/9/85

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7187.8	7187.6	-0.2
4	7177.8	7177.5	-0.3
5	7177.1	7176.8	-0.3
7	7230.1	7231.0	+0.9
8	7236.3	7236.4	+0.1
9	7244.7	7245.1	+0.4
10	7244.0	7245.2	+1.2
10A	*7259.9	7259.2	-0.3
12	7302.7	7302.5	-0.2
13	7311.6	7311.4	-0.2
18	7348.2	7349.1	+0.9
19	7323.4	7323.7	+0.3
21	7370.8	7370.6	-0.2
22	7421.0	7421.0	0.0
23	7409.0	7409.8	+0.8
24	*7417.9	7419.2	+1.3
25	7332.9	7332.9	0.0
26	7342.9	7342.5	-0.4

SIMULATION PERIOD: 1985 Recharge

DATES: 5/10/85 - 6/11/85

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7192.8	7192.8	0.0
4	7183.9	7183.6	-0.3
5	7179.2	7179.4	+0.2
7	7229.8	7230.1	+0.3
8	7238.1	7238.5	+0.4
9	7252.2	7251.8	-0.4
10	7249.6	7249.6	0.0
10A	7260.7	7260.7	0.0
12	7303.3	7303.0	-0.3
13	7312.6	7312.5	-0.1
18	*7350.2	7350.3	+0.1
19	7329.5	7329.4	-0.1
21	7383.5	7383.1	-0.4
22	7425.2	7425.2	0.0
23	7419.2	7418.8	-0.4
24	7428.8	7429.2	+0.4
25	7332.3	7332.3	0.0
26	*7343.5	7343.5	0.0

SIMULATION PERIOD: 1985 Saturation

DATES: 6/12/85 - 7/23/85

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7192.9	7192.8	-0.1
4	7182.5	7182.6	+0.1
5	7179.5	7179.5	0.0
7	7230.2	7230.2	0.0
8	7238.5	7238.5	0.0
9	7251.6	7251.7	+0.1
10	7247.1	7246.9	-0.2
10A	7259.8	7259.8	0.0
12	7302.8	7303.0	+0.2
13	7311.6	7311.6	0.0
18	7349.8	7349.9	+0.1
19	7329.3	7329.4	+0.1
21	7381.3	7381.6	+0.3
22	7426.0	7426.0	0.0
23	7418.6	7418.8	+0.2
24	7426.1	7425.8	-0.3
25	7332.4	7332.4	0.0
26	7342.8	7343.0	+0.2

SIMULATION PERIOD: 1985 Haying

DATES: 7/23/85 - 9/2/85

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7188.1	7188.2	+0.1
4	7177.8	7177.5	-0.3
5	7175.8	7176.0	+0.2
7	7229.1	7229.4	+0.3
8	7236.0	7236.1	+0.1
9	7247.0	7247.3	+0.3
10	7244.8	7244.9	+0.1
10A	7256.1	7256.1	0.0
12	7300.4	7300.5	+0.1
13	7311.0	7311.3	+0.3
18	7349.3	7349.2	-0.1
19	7320.9	7320.8	-0.1
21	7376.6	7376.5	-0.1
22	7424.0	7424.0	0.0
23	7414.0	7414.3	+0.3
24	7419.9	7420.1	+0.2
25	7330.8	7330.8	0.0
26	7336.3	7336.6	+0.3

SIMULATION PERIOD: 1985 Fall Recharge

DATES: 9/3/85 - 10/8/85

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7186.8	7186.8	0.0
4	7177.8	7177.4	-0.4
5	7175.3	7175.9	+0.6
7	7229.3	7229.1	-0.2
8	7236.4	7236.6	+0.2
9	7250.4	7250.1	-0.3
10	7244.7	7245.0	+0.3
10A	7259.2	7259.0	-0.2
12	7302.2	7302.2	0.0
13	7311.5	7311.4	-0.1
18	7349.9	7349.7	-0.2
19	7322.7	7322.7	0.0
21	7377.5	7377.7	+0.2
22	7423.2	7423.2	0.0
23	7412.2	7411.7	-0.5
24	*7417.5	7418.9	+1.4
25	7331.4	7331.4	0.0
26	7335.3	7335.5	+0.2

SIMULATION PERIOD: 1985-1986 Winter

DATES: 10/9/85 - 3/22/86

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7183.5	7183.5	0.0
4	7181.8	7176.1	-5.7
5	*7177.2	7175.3	-1.9
7	7230.4	7230.7	+0.3
8	7236.1	7235.6	-0.5
9	7245.2	7245.5	+0.3
10	7244.6	7245.0	+0.4
10A	7254.0	7254.2	+0.2
12	7301.2	7301.0	-0.2
13	7311.1	7311.2	+0.1
18	7348.9	7349.1	+0.2
19	7320.7	7320.8	+0.1
21	7375.6	7375.5	-0.1
22	7421.3	7421.3	0.0
23	7409.0	7409.4	+0.4
24	*7418.7	7419.2	+0.5
25	7331.2	7331.2	0.0
26	7334.9	7334.9	0.0

SIMULATION PERIOD: 1986 Spring Runoff

DATES: 3/23/86 - 4/13/86

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7189.9	7189.9	0.0
4	7179.3	7179.4	+0.1
5	7178.3	7178.3	0.0
7	*7231.7	7230.9	-0.8
8	7237.8	7237.4	-0.4
9	7244.8	7245.1	+0.3
10	7245.1	7245.4	+0.3
10A	7257.7	7257.6	-0.1
12	7303.2	7303.1	-0.1
13	7312.5	7312.4	-0.1
18	7349.6	7349.7	+0.1
19	7325.4	7325.4	0.0
21	7370.2	7370.2	0.0
22	7423.0	7423.0	0.0
23	7409.6	7410.1	+0.5
24	7419.6	7419.6	0.0
25	7333.4	7333.4	0.0
26	7342.1	7341.9	-0.2

SIMULATION PERIOD: 1986 End of Runoff

DATES: 4/14/86 - 5/27/86

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7189.4	7189.2	-0.2
4	7178.2	7178.4	+0.2
5	7176.7	7176.3	-0.4
7	*7230.0	7230.9	+0.9
8	7237.4	7237.0	-0.4
9	7249.9	7249.7	-0.2
10	7248.6	7248.6	0.0
10A	7259.8	7260.0	+0.2
12	7301.3	7301.4	+0.1
13	7311.4	7311.4	0.0
18	7349.9	7349.7	-0.2
19	7323.4	7323.6	+0.2
21	7375.5	7375.3	-0.2
22	7422.9	7422.9	0.0
23	7417.3	7417.0	-0.3
24	7427.2	7427.5	+0.3
25	7331.1	7331.1	0.0
26	7342.5	7342.5	0.0

SIMULATION PERIOD: 1986 Recharge

DATES: 5/28/86 - 6/10/86

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7192.9	7193.2	+0.3
4	7184.1	7184.1	0.0
5	7179.8	7179.7	-0.1
7	7232.4	7232.4	0.0
8	7240.2	7240.0	-0.2
9	7252.2	7252.1	-0.1
10	7249.9	7249.9	0.0
10A	7261.6	7261.4	-0.2
12	7303.5	7303.1	-0.4
13	7313.5	7313.7	+0.2
18	7351.7	7351.4	-0.3
19	7329.4	7329.3	-0.1
21	7383.5	7383.2	-0.3
22	7423.7	7423.7	0.0
23	7419.3	7419.4	+0.1
24	7428.7	7429.2	+0.5
25	7333.7	7333.7	0.0
26	7343.8	7343.7	-0.1

SIMULATION PERIOD: 1986 Saturation

DATES: 6/11/86 - 7/22/86

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7193.0	7192.7	-0.3
4	7187.7	7187.4	-0.3
5	7179.8	7180.0	+0.2
7	7230.9	7230.8	-0.1
8	7238.3	7238.8	+0.5
9	7252.0	7251.7	-0.3
10	7246.9	7246.7	-0.2
10A	7259.2	7258.9	-0.3
12	7303.0	7303.2	+0.2
13	7312.1	7312.0	-0.1
18	7350.2	7350.6	+0.4
19	7328.8	7328.8	0.0
21	7382.7	7383.1	+0.4
22	7425.9	7425.9	0.0
23	7418.7	7419.0	+0.3
24	7425.4	7425.0	-0.4
25	7332.5	7332.5	0.0
26	7341.9	7342.0	+0.1

SIMULATION PERIOD: 1986 Haying

DATES: 7/23/86 - 9/13/86

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7188.1	7188.1	0.0
4	7178.4	7178.2	-0.2
5	7175.3	7175.4	+0.1
7	7229.4	7229.4	0.0
8	7236.7	7236.2	-0.5
9	7246.6	7246.5	-0.1
10	*7244.9	7244.9	0.0
10A	*7255.9	7255.8	-0.1
12	7300.6	7300.2	-0.4
13	7310.3	7311.6	+1.3
18	7349.6	7349.4	-0.2
19	7321.0	7321.0	0.0
21	7379.2	7379.6	+0.4
22	7424.0	7424.0	0.0
23	7415.0	7414.9	-0.1
24	7418.9	7419.5	+0.6
25	7331.3	7331.3	0.0
26	7337.4	7337.4	0.0

SIMULATION PERIOD: 1986 Fall Recharge

DATES: 9/14/86 - 11/4/86

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7186.4	7186.5	+0.1
4	7177.9	7178.2	+0.3
5	7175.5	7175.4	+0.1
7	7229.5	7229.4	-0.1
8	7237.1	7236.6	-0.5
9	7246.4	7246.3	-0.1
10	7244.5	7244.7	+0.2
10A	7257.6	7257.7	+0.1
12	7301.5	7301.8	+0.3
13	7313.4	7313.5	+0.1
18	7349.0	7349.3	+0.3
19	*7324.5	7324.3	-0.2
21	7378.9	7378.8	-0.1
22	7423.0	7423.0	0.0
23	7411.1	7411.2	+0.1
24	*7417.5	7418.7	+1.2
25	7331.5	7331.5	0.0
26	7336.2	7336.3	+0.1

SIMULATION PERIOD: 1986-1987 Winter

DATES: 11/5/86 3/5/87

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7184.4	7184.5	+0.1
4	*7177.3	7176.9	-0.4
5	7174.8	7174.6	-0.2
7	7230.1	7230.1	0.0
8	*7237.2	7234.2	-3.0
9	7242.6	7243.0	+0.4
10	*7243.9	7245.4	+1.5
10A	*7253.9	7253.1	+0.8
12	*7301.5	7301.7	+0.2
13	7312.2	7312.3	+0.1
18	7349.1	7349.3	+0.2
19	7320.2	7320.1	-0.1
21	7369.7	7369.8	+0.1
22	7420.6	7420.6	0.0
23	7407.4	7410.5	+3.1
24	*7415.6	7419.0	+3.4
25	7333.0	7333.0	0.0
26	7336.1	7336.1	0.0

SIMULATION PERIOD: 1987 Spring Runoff

DATES: 3/6/87 - 4/25/87

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7189.8	7189.6	-0.2
4	7179.4	7179.9	+0.5
5	7177.9	7177.7	-0.2
7	7230.9	7230.8	-0.1
8	7237.3	7237.1	-0.2
9	7247.4	7247.6	+0.2
10	7246.2	7245.9	-0.3
10A	7257.9	7257.8	-0.1
12	7302.8	7302.6	-0.2
13	7313.8	7313.7	-0.1
18	7349.1	7349.3	+0.2
19	7325.0	7324.7	-0.3
21	7380.3	7380.2	-0.1
22	7423.5	7423.5	0.0
23	7409.8	7410.4	+0.6
24	7419.4	7419.4	0.0
25	7332.8	7332.8	0.0
26	7338.0	7338.0	0.0

SIMULATION PERIOD: 1987 End of Runoff

DATES: 4/26/87 - 5/19/87

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7190.0	7190.1	+0.1
4	7178.5	7178.3	-0.2
5	7176.5	7176.9	+0.4
7	7229.8	7230.9	+1.1
8	7237.3	7237.5	+0.2
9	7248.5	7248.2	-0.3
10	7244.4	7244.9	+0.5
10A	7260.5	7260.5	0.0
12	7302.6	7303.1	+0.5
13	7313.1	7313.0	-0.1
18	7350.9	7351.0	+0.1
19	*7323.5	7323.9	+0.4
21	7383.2	7383.2	0.0
22	7422.4	7422.4	0.0
23	7419.3	7419.2	-0.1
24	7428.5	7428.0	-0.5
25	7333.3	7333.3	0.0
26	7342.1	7341.8	-0.3

SIMULATION PERIOD: 1987 Recharge

DATES: 5/20/87 - 6/2/87

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7192.8	7193.1	+0.3
4	7182.7	7182.9	+0.2
5	7179.5	7179.4	-0.1
7	7230.7	7230.8	+0.1
8	7238.3	7238.4	+0.1
9	7252.0	7252.2	+0.2
10	7249.8	7249.7	-0.1
10A	7260.2	7260.5	+0.3
12	7302.7	7303.1	+0.4
13	7312.7	7312.8	+0.1
18	7351.2	7351.4	+0.2
19	7329.4	7329.2	-0.2
21	7383.5	7383.4	-0.1
22	7425.4	7425.4	0.0
23	7419.2	7419.6	+0.4
24	7428.8	7428.6	-0.2
25	7333.0	7333.0	0.0
26	7343.2	7343.1	-0.1

SIMULATION PERIOD: 1987 Saturation

DATES: 6/3/87 - 7/21/87

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7192.3	7192.3	0.0
4	7182.4	7182.7	+0.3
5	7179.6	7179.4	-0.2
7	7230.1	7229.8	-0.3
8	7239.4	7239.4	0.0
9	7252.2	7252.1	-0.1
10	7249.6	7249.6	0.0
10A	7260.2	7260.0	-0.2
12	7302.6	7303.0	+0.4
13	7311.8	7312.2	+0.4
18	7350.1	7350.3	+0.2
19	*7329.2	7328.8	-0.4
21	7382.8	7383.0	+0.2
22	7426.3	7426.3	0.0
23	7419.0	7419.2	+0.2
24	7426.7	7426.9	+0.2
25	7332.8	7332.8	0.0
26	7340.6	7340.7	+0.1

SIMULATION PERIOD: 1987 Haying

DATES: 7/22/87 - 10/3/87

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7187.3	7187.3	0.0
4	7177.7	7177.3	-0.4
5	7174.8	7175.1	+0.3
7	7229.1	7229.2	+0.1
8	7236.3	7236.1	-0.2
9	7245.1	7245.7	+0.6
10	7245.3	7244.8	-0.5
10A	7256.9	7257.1	+0.2
12	7300.2	7299.6	-0.6
13	7311.0	7311.5	+0.5
18	7349.0	7349.4	+0.4
19	7320.7	7320.8	+0.1
21	7378.2	7378.0	-0.2
22	7423.1	7423.1	0.0
23	7411.3	7411.9	+0.6
24	7417.5	7419.0	+1.5
25	7332.0	7332.0	0.0
26	7335.9	7335.8	-0.1

SIMULATION PERIOD: 1987 Fall Recharge

DATES: 10/4/87 - 13/31/87

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7186.2	7186.4	+0.2
4	7177.5	7177.5	0.0
5	7174.9	7175.0	+0.1
7	7229.2	7229.1	-0.1
8	7236.5	7236.2	-0.3
9	7247.8	7247.7	-0.1
10	7244.5	7244.7	+0.2
10A	7259.7	7259.7	0.0
12	7301.1	7301.2	+0.1
13	7311.2	7311.4	+0.2
18	7349.8	7349.8	0.0
19	7321.9	7321.9	0.0
21	7378.3	7378.5	+0.2
22	7422.5	7422.5	+0.2
23	7411.4	7411.4	0.0
24	*7416.0	7418.9	+2.9
25	7332.4	7332.4	0.0
26	7335.4	7335.5	+0.1

SIMULATION PERIOD: 1987-1988 Winter

DATES: 11/1/87 - 2/27/88

Well #	Measured Water Table Elevation (ft.)	Model Calculated Head Elevation (ft.)	Difference (ft.)
3	7183.2	7183.6	+0.4
4	7176.8	7177.1	+0.3
5	7174.4	7174.7	+0.3
7	7230.3	7230.4	+0.1
8	7235.7	7234.9	-0.8
9	7242.5	7243.4	+0.9
10	7243.6	7245.4	+1.8
10A	7253.4	7253.6	+0.2
12	7300.1	7300.3	+0.2
13	7310.1	7311.4	+1.3
18	*7348.6	7349.3	+0.7
19	7319.5	7319.3	-0.2
21	7369.6	7369.8	+0.2
22	7420.8	7420.8	0.0
23	7406.8	7410.6	+3.8
24	*7415.5	7419.0	+3.5
25	7331.5	7331.5	0.0
26	7333.6	7333.7	+0.1

APPENDIX F

PINEDALE RETURN FLOW PROJECT
WATER BUDGET CALCULATIONS

Simulation Period	Dates	Change in Storage (ac-ft)	I_s-O_s (ac-ft)	Precip. (ac-ft)	Et (ac-ft)	I_g-O_g (ac-ft)
1984 Recharge	6/4/84 - 6/25/84	6025	8501	1004	6189	2709
1984 Saturation	6/26/84 - 7/23/84	-2823	11417	2364	6071	-10533
1984 Haying	7/24/84 - 9/14/84	-11343	-7582	3884	1406	-6239
1984 Fall Recharge	9/15/84 - 9/29/84	1329	-606	2231	1674	1378
1984-1985 Winter	9/30/84 - 3/24/85	-3020	2346	639	858	-5147
1985 End of Runoff	4/19/85 - 5/9/85	-401	-1232	599	0	232
1985 Recharge	5/10/85 - 6/11/85	9560	10941	1119	7529	5029
1985 Saturation	6/12/85 - 7/23/85	-3295	11968	2253	7498	-10018
1985 Haying	7/24/85 - 9/2/85	-10025	-1110	1403	1706	-8612
1985 Fall Recharge	9/3/85 - 10/8/85	1442	-486	4386	248	-2210
1985-1986 Winter	10/9/85 - 3/22/86	-4331	-11337	0	0	7006

Simulation Period	Dates	Change in Storage (ac-ft)	$I_s - O_s$ (ac-ft)	Precip. (ac-ft)	Et (ac-ft)	$I_g - O_g$ (ac-ft)
1986 End of Runoff	4/14/86 - 5/27/86	1803	-3431	2607	0	2627
1986 Recharge	5/28/86 - 6/10/86	7236	8475	820	3941	1882
1986 Saturation	6/11/86 - 7/22/86	-2232	12720	2066	7641	-9377
1986 Haying	7/23/86 - 9/13/86	-9854	-2396	3548	2239	-8767
1986 Fall Recharge	9/14/86 - 11/4/86	707	1608	2835	1069	-2667
1986-1987 Winter	11/5/86 - 3/5/87	-3776	-5537	0	0	1761
1987 End of Runoff	4/26/87 - 5/19/87	830	6880	1304	0	-7354
1987 Recharge	5/20/87 - 6/2/87	3379	1271	4077	2952	983
1987 Saturation	6/3/87 - 7/21/87	-2784	11986	5166	11801	-8135
1987 Haying	7/22/87 - 10/3/87	-10844	-1760	3435	2453	-10066
1987 Fall Recharge	10/4/87 - 10/31/87	1353	1401	219	1095	828
1987-1988 Winter	11/1/87 - 2/27/88	-3835	-2201	0	0	-1634

APPENDIX G

PINEDALE RETURN FLOW PROJECT
OVERLAND AND RETURN FLOW CALCULATIONS

OVERLAND FLOW CALCULATIONS

Simulation Period	Dates	Total Diversion Flow (ac-ft)	Precip. (ac-ft)	Model Calculated Recharge (ac-ft)	Et (ac-ft)	Overland Flow (ac-ft)
1984 Recharge	6/4/84 - 6/25/84	23610	1004	12434	6189	5991
1984 Saturation	6/26/84 - 7/23/84	29220	2364	11608	6071	13905
1984 Haying	7/24/84 - 9/14/84	4014	3884	0	1406	6492
1984 Fall Recharge	9/15/84 - 9/29/84	1088	2231	3889	1674	-2244
1984-1985 Winter	9/30/84 - 3/24/85	2112	639	23560	858	-21667
1985 End of Runoff	4/19/85 - 5/9/85	9	599	3305	0	-2697
1985 Recharge	5/10/85 - 6/11/85	15490	1119	19225	7529	-10145
1985 Saturation	6/12/85 - 7/23/85	31254	2253	15987	7498	10022
1985 Haying	7/24/85 - 9/2/85	1932	1403	0	1706	1629
1985 Fall Recharge	9/3/85 - 10/8/85	3080	4386	7680	248	-462
1985-1986 Winter	10/9/85 - 3/22/86	1864	0	21105	0	-19241

Simulation Period	Dates	Total Diversion Flow (ac-ft)	Precip. (ac-ft)	Model Calculated Recharge (ac-ft)	Et (ac-ft)	Overland Flow (ac-ft)
1986 End of Runoff	4/14/86 - 5/27/86	2450	2607	9616	0	-4559
1986 Recharge	5/28/86 - 6/10/86	14955	820	11752	3941	82
1986 Saturation	6/11/86 - 7/22/86	53236	2066	18332	7641	29329
1986 Haying	7/23/86 - 9/13/86	4696	3548	2134	2239	3871
1986 Fall Recharge	9/14/86 - 11/4/86	6067	2835	9703	1069	-1870
1986-1987 Winter	11/5/86 - 3/5/87	497	0	14598	0	-14101
1987 End of Runoff	4/26/87 - 5/19/87	3698	1304	6083	0	-1081
1987 Recharge	5/20/87 - 6/2/87	10377	4077	7349	2952	4153
1987 Saturation	6/3/87 - 7/21/87	37013	5166	22726	11801	7652
1987 Haying	7/22/87 - 10/3/87	4955	3435	4363	2453	1574
1987 Fall Recharge	10/4/87 - 10/31/87	2655	219	5909	1095	-4130
1987-1988 Winter	11/1/87 - 2/27/88	1638	0	13919	0	-12281

CHANNEL FLOW CALCULATIONS

1984 CHANNEL FLOW CALCULATIONS

1984 Simulation Periods	Surface Inflows A (ac-ft)	B (ac-ft)	C (ac-ft)	D (ac-ft)	Total Inflow (ac-ft)	Diversion Flow (ac-ft)	Model Calculated River Seepage (ac-ft)	Channel Flow (ac-ft)
Recharge	9606	2241	435	775	13057	13699	-176	-642
Saturation	16132	1455	1168	1150	19905	17111	-419	2794
Haying	3539	961	1491	1849	7840	2463	283	5094
Fall Recharge	558	310	396	429	1693	773	189	731
Winter	11451	3502	4690	3722	23365	1571	2371	19423

A is the inflow measured at New Fork River Below Barlow's Bridge recorder.

B is the inflow measured at Willow Creek At Willard Binning's recorder.

C is the inflow measured at Duck Creek Below Kitchen Reservoir recorder.

D is the inflow measured at Lake Creek recorder.

1985 CHANNEL FLOW CALCULATIONS

1985 Simulation Periods	Surface Inflows A (ac-ft)	Surface Inflows B (ac-ft)	Surface Inflows C (ac-ft)	Surface Inflows D (ac-ft)	Total Inflow (ac-ft)	Diversion Flow (ac-ft)	Model Calculated River Seepage (ac-ft)	Channel Flow (ac-ft)
End of Runoff	1019	674	211	10	1914	0	215	1699
Recharge	9088	1200	578	35	10901	10599	-602	302
Saturation	11799	573	798	142	13312	17171	-882	-3859
Haying	1388	307	831	195	2721	1488	128	1105
Fall Recharge	1855	558	958	102	3473	2851	431	191
Winter	7556	2951	4255	620	15382	1616	2223	11543

A is the inflow measured at New Fork River Below Barlow's Bridge recorder.

B is the inflow measured at Willow Creek At Willard Binning's recorder.

C is the inflow measured at Duck Creek Below Kitchen Reservoir recorder.

D is the inflow measured at Lake Creek recorder.

1986 CHANNEL FLOW CALCULATIONS

1986 Simulation Periods	Surface Inflows A (ac-ft)	B (ac-ft)	C (ac-ft)	D (ac-ft)	Total Inflow (ac-ft)	Diversion Flow (ac-ft)	Model Calculated River Seepage (ac-ft)	Channel Flow (ac-ft)
End of Runoff	2932	3355	862	1095	8244	1245	472	6527
Recharge	7387	1559	270	4365	13581	8657	-368	4924
Saturation	41493	2954	1068	11070	56585	37066	-343	19519
Haying	3181	734	1424	2472	7811	2776	620	4415
Fall Recharge	4325	866	1274	1327	7792	4526	301	2965
Winter	10501	1112	2804	1357	15774	0	1878	13896

A is the inflow measured at New Fork River Below Barlow's Bridge recorder.

B is the inflow measured at Willow Creek At Willard Binning's recorder.

C is the inflow measured at Duck Creek Below Kitchen Reservoir recorder.

D is the inflow measured at Lake Creek recorder.

1987 CHANNEL FLOW CALCULATIONS

1987 Simulation Periods	Surface Inflows A (ac-ft)	B (ac-ft)	C (ac-ft)	D (ac-ft)	Total Inflow (ac-ft)	Diversion Flow (ac-ft)	Model Calculated River Seepage (ac-ft)	Channel Flow (ac-ft)
End of Runoff	7808	2040	413	62	10323	2781	-125	7542
Recharge	5844	1329	318	19	7510	7475	-113	35
Saturation	16389	2768	1343	391	20891	20765	-441	126
Haying	4431	1126	2431	539	8527	3273	847	4407
Fall Recharge	2049	358	802	197	3406	2269	229	908
Winter	8710	1522	3409	837	14478	0	1733	12745

A is the inflow measured at New Fork River Below Barlow's Bridge recorder.

B is the inflow measured at Willow Creek At Willard Binning's recorder.

C is the inflow measured at Duck Creek Below Kitchen Reservoir recorder.

D is the inflow measured at Lake Creek recorder.

RETURN FLOW CALCULATIONS

1984 RETURN FLOW CALCULATIONS

Simulation Period	Dates	Measured Surface Flow (ac-ft)	I_g-O_g (ac-ft)	Channel Flow (ac-ft)	Overland Flow (ac-ft)	Return Flow (ac-ft)
1984 Recharge	6/4/84 - 6/25/84	14467	2709	0	5991	5767
1984 Saturation	6/26/84 - 7/23/84	21037	0	2794	13905	4338
1984 Haying	7/24/84 - 9/14/84	16994	0	5094	6492	5408
1984 Fall Recharge	9/15/84 - 9/29/84	2993	1378	731	*2244	0
1984-1985 Winter	9/30/84 - 3/24/85	21559	0	19423	0	2136

* The negative overland flow value that was calculated previously that was subtracted from the surface outflow value to account for spring and fall snowmelt infiltration.

1985 RETURN FLOW CALCULATIONS

Simulation Period	Dates	Measured Surface Flow (ac-ft)	$I_g - O_g$ (ac-ft)	Channel Flow (ac-ft)	Overland Flow (ac-ft)	Return Flow (ac-ft)
1985 End of Runoff	4/19/85 - 5/9/85	3155	232	1699	*2697	0
1985 Recharge	5/10/85 - 6/11/85	5174	5029	302	0	0
1985 Saturation	6/12/85 - 7/23/85	15427	0	0	10022	5405
1985 Haying	7/24/85 - 9/2/85	4785	0	1105	1629	2051
1985 Fall Recharge	9/3/85 - 10/8/85	4178	0	191	*462	3525
1985-1986 Winter	10/9/85 - 3/22/86	23564	7006	11543	0	5015

* The negative overland flow value that was calculated previously that was subtracted from the surface outflow value to account for spring and fall snowmelt infiltration.

1986 RETURN FLOW CALCULATIONS

Simulation Period	Dates	Measured Surface Flow (ac-ft)	I_g-O_g (ac-ft)	Channel Flow (ac-ft)	Overland Flow (ac-ft)	Return Flow (ac-ft)
1986 End of Runoff	4/14/86 - 5/27/86	12879	2627	6527	*4559	0
1986 Recharge	5/28/86 - 6/10/86	11404	1882	4924	82	4516
1986 Saturation	6/11/86 - 7/22/86	60034	0	19519	29329	11186
1986 Haying	7/23/86 - 9/13/86	12128	0	4415	3871	3842
1986 Fall Recharge	9/14/86 - 11/4/86	7724	0	2965	*1870	2889
1986-1987 Winter	11/5/86 - 3/5/87	21808	1761	13896	0	6151

* The negative overland flow value that was calculated previously that was subtracted from the surface outflow value to account for spring and fall snowmelt infiltration.

1987 RETURN FLOW CALCULATIONS

Simulation Period	Dates	Measured Surface Flow (ac-ft)	$I_g - O_g$ (ac-ft)	Channel Flow (ac-ft)	Overland Flow (ac-ft)	Return Flow (ac-ft)
1987 End of Runoff	4/26/87 - 5/19/87	4261	0	7542	*1081	0
1987 Recharge	5/20/87 - 6/2/87	9140	983	35	4153	3969
1987 Saturation	6/3/87 - 7/21/87	25152	0	126	7652	17374
1987 Haying	7/22/87 - 10/3/87	11968	0	4407	1574	5987
1987 Fall Recharge	10/4/87 - 10/31/87	2391	828	908	*4130	0
1987-1988 Winter	11/1/87 - 2/27/88	18317	0	12745	0	5572

* The negative overland flow value that was calculated previously that was subtracted from the surface outflow value to account for spring and fall snowmelt infiltration.

APPENDIX H

AVERAGE MONTHLY WEATHER DATA

1983 DATA

Month	Average Maximum Temperature (Fahrenheit)	Average Minimum Temperature (Fahrenheit)	Snowfall (inches)
Nov.	32.97	13.4	17
Dec.	17.23	-5.8	18.5

1984 DATA

Month	Average Maximum Temperature (Fahrenheit)	Average Minimum Temperature (Fahrenheit)	Snowfall (inches)
Jan.	24.77	0.74	1.5
Feb.	28.00	1.31	9.0
March	37.42	10.26	4.2
April	43.36	17.62	11.2
May	56.32	24.94	*
June	64.03	31.70	
July	77.09	40.10	
Aug.	73.23	36.39	
Sept.	60.52	27.75	0.8
Oct.	44.55	16.45	8.5
Nov.	33.03	7.70	15.5
Dec.	17.03	-5.48	16.8

* The precipitation for the summer months can be found in Appendix F.

1985 DATA

Month	Average Maximum Temperature (Fahrenheit)	Average Minimum Temperature (Fahrenheit)	Snowfall (inches)
Jan.	23.52	-4.44	6.2
Feb.	25.14	-6.78	8.1
March	34.82	4.00	10.6
April	52.58	21.35	3.0
May	63.26	28.97	
June	68.30	32.46	
July	75.74	40.03	
Aug.	73.03	30.22	
Sept.	58.20	27.47	7.2
Oct.	51.68	19.89	4.5
Nov.	26.89	4.93	33.6
Dec.	26.02	3.45	7.7

1986 DATA

Month	Average Maximum Temperature (Fahrenheit)	Average Minimum Temperature (Fahrenheit)	Snowfall (inches)
Jan.	28.20	2.29	10.6
Feb.	30.48	7.32	26.8
March	41.67	15.40	2.2
April	46.72	21.96	5.9
May	57.80	23.94	
June	72.20	36.20	
July	69.56	35.70	
Aug.	75.50	37.86	
Sept.	58.10	28.93	2.2
Oct.	51.15	23.88	2.5
Nov.	34.40	9.34	18.2
Dec.	23.98	-1.24	0.5

1987 DATA

Month	Average Maximum Temperature (Fahrenheit)	Average Minimum Temperature (Fahrenheit)	Snowfall (inches)
Jan.	23.02	-2.84	21.0
Feb.	29.23	4.85	13.3
March	34.78	7.09	12.4
April	55.82	19.27	2.6
May	60.70	31.90	
June	69.33	35.70	
July	70.35	40.32	
Aug.	70.48	33.27	
Sept.	68.71	25.86	0.0
Oct.	54.26	17.74	0.0
Nov.	39.77	15.83	3.5
Dec.	24.74	0.00	11.5

1988 DATA

Month	Average Maximum Temperature (Fahrenheit)	Average Minimum Temperature (Fahrenheit)	Snowfall (inches)
Jan.	21.65	-3.36	5.6
Feb.	25.79	0.32	3.8
March	32.10	11.61	7.8
April	43.45	19.50	6.0

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