Research Technical Completion Report

GROUND-WATER INVESTIGATIONS FOR THE FREMONT-MADISON IRRIGATION DISTRICT, SOUTHEASTERN IDAHO

by

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Submitted to:

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GROUND–WATER INVESTIGATIONS FOR THE FREMONT–MADISON IRRIGATION DISTRICT, SOUTHEASTERN IDAHO

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INTRODUCTION

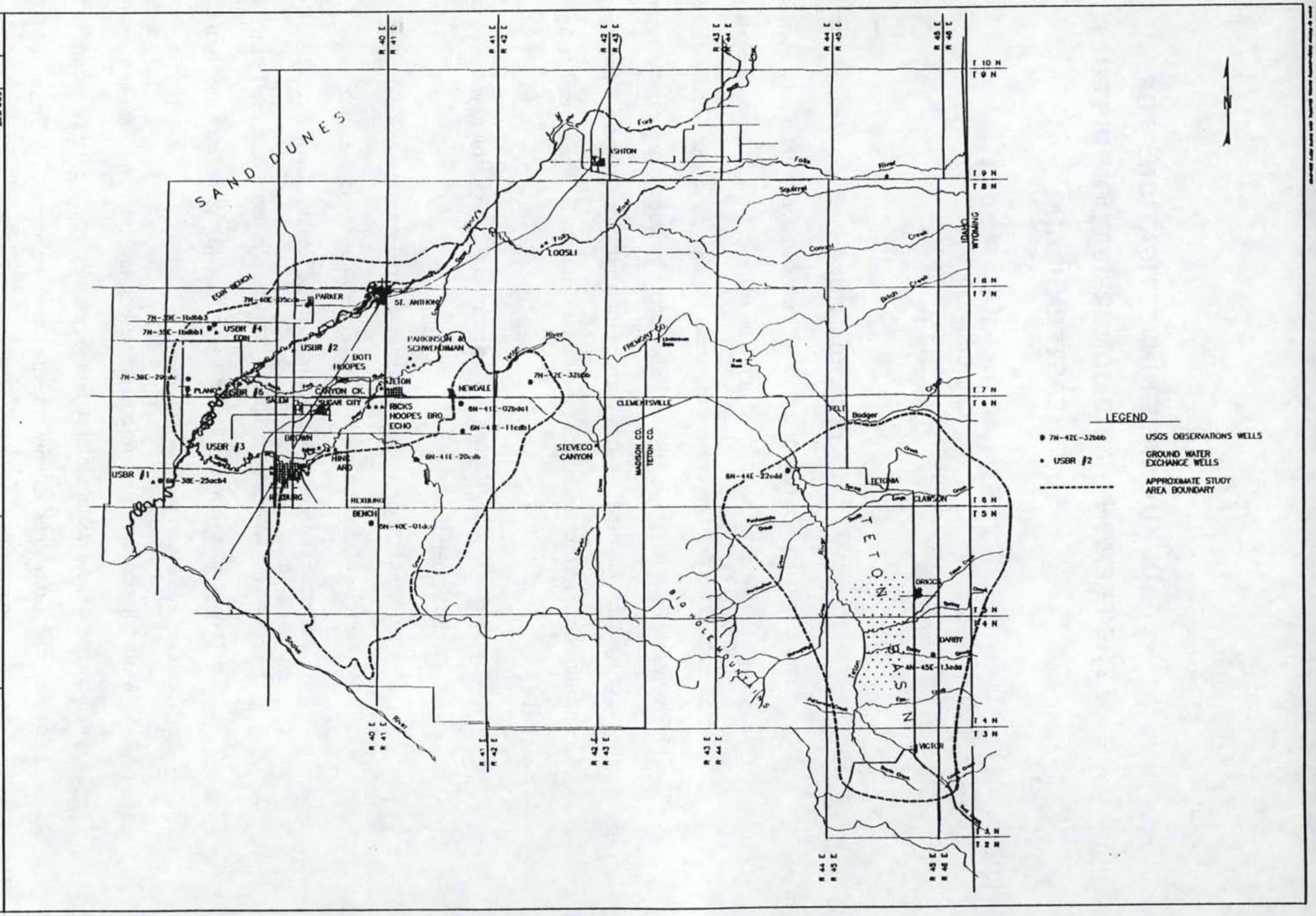
This investigation is part of a study of the operation of the Fremont-Madison Irrigation District in southeastern Idaho. The scope of work includes five particular tasks, each addressing concerns of the canal company and individual members of Fremont-Madison Irrigation District. The report includes a general description of aquifer systems followed by the purpose of study, procedure of analysis, and conclusions and recommendations for each particular task. The specific tasks are to assess:

1) effects of U. S. Bureau of Reclamation (USBR) ground-water exchange wells operation;
2) effects of privately owned ground-water exchange wells operation;
3) effects of changes in water management on the Egin Bench;
4) effects of ground-water pumping on the Rexburg Bench;
5) effects of changes in irrigation practices and land use in the Teton Basin.

The project area shown in Figure 1 identifies task areas, exchange well names and locations, and observation well locations.

Most project time and resources were spent on compiling and analyzing published data and available information. Generally, specific field data are lacking; however, the study does identify potential areas of impact on Fremont-Madison

Figure 1. Location Map



PROJECT FREMONT–MADISON IRRIGATION DISTRICT

TITLE GROUND–WATER INVESTIGATIONS

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member water supplies and trends along with associated data needs and recommendations for further study.

GROUND—WATER

There are six significant ground-water bodies found within the Fremont-Madison service area. The most widely known is the Eastern Snake Plain Aquifer, which underlies most of the Snake River Plain from Hagerman eastward. The Rexburg Bench aquifer system is closely related hydrologically to the Eastern Snake Plain Aquifer. An alluvial valley-fill aquifer underlies the Teton Basin. The other three are local systems recharged primarily by stream seepage and deep percolation of irrigation water. The largest is found in the Rexburg-St. Anthony-Newdale area where the South and North Forks of the Teton River are located. This shallow body is often called the lower Henry's Fork perched aquifer or the Teton Island area aquifer. The next most extensive local system, often considered part of the lower Henry's Fork system, underlies the Egin Bench. A perched system in the Ashton area lies between the Falls River and the Henry's Fork.

The discussions that follow are based largely on previously reported conditions. Most data gathered in this investigation were used specifically for the identified tasks and were not intended to produce comprehensive ground-water studies of the areas of concern.

SNAKE PLAIN AQUIFER

The deeper regional ground-water body which underlays the Fremont-Madison Irrigation District is part of the Snake Plain Aquifer. The portion of the extensive basalt aquifer that lies under the Fremont-Madison service area is one of the more significant recharge zones. Extent of the aquifer in the district is generally considered to run from the Rexburg Bench north to the Ashton area and then west northwest from Ashton towards the Camas Creek drainage. Numerous studies have been conducted on the Snake Plain Aquifer (Bassick).

Subsurface geology of the entire area is composed of valley alluvium on top of extensive basalt flows which in turn overlay silicic volcanic rock (rhyolite). The relatively impermeable rhyolite forms the base of the regional aquifer. Basalt thickness varies greatly, from about 500 feet in the valley floor west of Rexburg to basically nothing, as it wedges out to the east and northeast (Wytzes, p. 44). Thickness increases to the west of Egin Bench. Depth to basalt is generally greater in the lower elevations (near the rivers) and increases towards the mouth of the Henry's Fork, reaching about 250 feet at the confluence of the Henry's Fork and South Fork of the Teton River.

Transmissivities of the basalt have been reported by numerous authors. Mundorff and others indicated values in excess of 20 million gpd/ft (Crosthwaite et al, 1970, p. C17), Ham (p. 17) reported values from 5.7 to 24 million gpd/ft, and Wytzes (p. 45) reported a range of 3.3 to 17 million gpd/ft. Coefficients of storage indicate that the regional system is confined under much of the Fremont-Madison service area. Values reported by Ham (p. 17) range from 1.6×10^{-13} to 6.5×10^{-3} and Wytzes (p. 45) presented values of 6.0×10^{-8} to 3.9×10^{-5}. Unconfined aquifers normally exhibit coefficients of storage of .05 or greater, approximating their specific yield. The Snake Plain Aquifer as a whole is considered an unconfined aquifer.

In general, ground-water of the regional Snake Plain Aquifer moves west-southwesterly in the area of study. However, Wytzes (p. 52) indicated a northwesterly direction in the St. Anthony area and a northerly component under the Egin Bench. He showed the slope of the water table as ranging from about 10 ft/mile in the Teton-Newdale area to about 3 ft/mile in the lower half of the Teton Island, between the North and South Forks of the Teton River. Crosthwaite et al (1970, p. C15) presented more conservative values based on earlier data in which the gradient was said to range from 5 ft/mile in the area east of Newdale and St. Anthony to about 1.5 ft/mile west of Egin Bench.

Depth to the static water level decreases from northeast to southwest. Near St. Anthony the Henry's Fork river is 100 to 150 feet above the piezometric head of the aquifer but near its confluence with the Snake River the difference is only a few feet. Seasonal fluctuations generally range from 8 to 10 feet in the lower Henry's Fork region (Brockway and Grover, p. 20).

Recharge to the regional Snake Plain Aquifer in the Fremont-Madison area originates from precipitation in the Henry's Fork, Falls River, and Teton River drainages. Crosthwaite et al (1967, p. 28) estimated that 550,000 acre-ft of water from those rivers eventually reaches the Snake Plain Aquifer annually. Most travels via leakage from the shallower local systems described subsequently. About 175,000 more acre-ft per year of precipitation is presumed infiltrated directly to the system (Ham, p. 9). Discharge consists of underflow through the lower Henry's Fork area and pumping.

REXBURG BENCH AQUIFER

Most ground-water beneath the Rexburg Bench is actually part of the regional Snake Plain Aquifer. It has commonly been omitted from studies of the Snake Plain Aquifer since over half of the water-bearing formations are silicic volcanics (rhyolite) rather than the basalt of the plain. Basalts of various age do exist under the bench, however, along with old lake and stream deposits and alluvium. Very old (pre-Tertiary) marine sediments reside at great depth. Subsurface geology of the bench is composed of those elements intermingled and is described by Haskett (1972, p. 4) as "unusually complex."

Aquifer parameters and well yields vary widely in the Rexburg Bench. The most productive wells are those that penetrate basalt. An approximate transmissivity value for the basalt is 800,000 gpd/ft (Haskett, 1972, p. 7). Most of the basalt is found near Rexburg and wedges out towards the middle of the bench. A tongue of basalt also exists in sections 23, 24, and 26 of Township 6 North Range 40 East. The most productive ground-water zone was reported by Crosthwaite et al (1970, p. C18) as the southeast quarter of that township and range. They measured the specific capacity of one well at 2000 gpd per foot of drawdown and submitted a transmissivity value of 4 million gpd/ft. Haskett (1972, p. 11) tested three wells near Newdale that indicated a very good water bearing zone, but that area is generally poor. Faults are the probable cause of the inconsistency, since wells produce warm water indicating local faulting and associated fracturing. Faulting is evident on the bench's surface and edge in several areas. The southernmost part of the bench has proven inadequate for well development, while the northeastern and middle sections are marginal. Rhyolite transmissivity is generally much lower than basalt under the bench. However, it is relatively large in comparison to common values for rhyolite. Haskett (1972, p. 7) presented a typical value of transmissivity for the rhyolite on the bench as 51,000 gpd/ft. Coefficients of storage have not been published for the bench, probably because of its geologic complexity.

Regional Snake Plain Aquifer ground-water travels generally northwesterly under the bench. The gradient was about 5.5 ft/mile in the fall of 1970 (Haskett, 1972, p. 12).

Depth to static water level of the regional Snake Plain Aquifer water table varies greatly with land topography, but in most cases is more than 500 feet. Seasonal fluctuation of the Snake Plain Aquifer is generally less than 10 feet.

Haskett (1972) was the first to map perched ground-water under the bench. Perched water systems are supported by the stream and lake deposits which contain low permeability clays. There are three major perched aquifers: a system near the Teton River in the vicinity of the Teton Dam site, one in the center of the southern part of the bench, and one in the southernmost section. The piezometric water level of the perched systems are each at least 100 feet above that of the regional system. Deep irrigation wells that are completed open-hole and shallow domestic wells both draw supplies from these formations. In general, productivity of these perched zones is very poor. Well depths required for irrigation uses in the middle of the bench are greater than 1000 feet due to the extensive clay area that must be penetrated to reach the regional Snake Plain Aquifer ground-water.

Annual recharge to the Rexburg Bench ground-water system was estimated by Crosthwaite et al (1970, p. C19) as 25,000 to 35,000 acre-ft. They indicated components of recharge to be seepage to outcrop in the Big Hole Mountains and seepage from Moody and Canyon Creeks. Deep percolation of precipitation falling directly on the bench is also a minor source. Discharge from ground-water under the bench includes underflow to the Snake Plain Aquifer, spring discharge from the northern and southern perched systems, and pumping.

TETON ISLAND AREA AQUIFER

Recharge to the shallow aquifer system found between St. Anthony and the Snake River is due in large part to irrigation, especially sub and surface irrigation. For purposes of this investigation, the "Teton Island Area Aquifer" will mean the shallow aquifer on the east side of the Henry's Fork stretching from above St. Anthony south to the Snake River. Ground-water found above the regional aquifer is generally held in the valley alluvium - Henry's Fork and Teton River deposited sediments that form a trough-like formation. The alluvium overlays the basalts that constitute the Snake Plain Aquifer. Particles range in size from clays to boulders with larger and more extensive gravels on the east side of Henry's Fork than on the west side (Wytzes, p. 48). Alluvium thickness, essentially depth to basalt, was shown by Wytzes (p. 47) to increase from about 60 feet near St. Anthony and Newdale to over 300 feet above the confluence of the Henry's Fork and the Snake River.

Crosthwaite et al (1970, p. C13) labeled the Henry's Fork alluvium an "excellent aquifer." They noted, however, that the aquifer transmissivity was ordinarily lower than that of the deeper basalts. Wytzes (p. 156) used transmissivity values for a shallow system model ranging from 7,480 to about 135,000 gpd/ft, with about 22,500 gpd/ft being representative. Generally, the southwestern part of the system was modeled as having higher transmissivities than the northern regions. He used coefficients of storage that ranged from .04 to .35, but a value of .15 is representative (p. 157). Haskett (1977, p. 8) used a value of .20 for ground-water volumetric calculations.

The shallow ground-water generally flows west to southwest towards the Henry's Fork river. Haskett et al (1977, following p. G2) showed water table contour lines for August 1977 that indicated southwesterly flow in the area east of the Yellowstone Highway from Rexburg to St. Anthony. Wytzes (p. 62) showed contour lines from June of 1977 that, in general, indicate a more westerly direction. The differences may be the result of seasonal dynamics of the shallow system. The shallow ground-water system is highly dependent on irrigation diversions and river flows, changing seasonally and from year to year.

The water table gradient generally decreases from east to west. Wytzes (p. 62) showed slopes of about 25 ft/mile south of St. Anthony and values of about 7 ft/mile in the lower half and south of the "island" between the North and South Forks of the Teton River. Haskett et al (1977, following p. G2) showed a similar pattern and magnitudes, except for steeper slopes perpendicular to and near the Henry's Fork. He showed gradients near the river that ranged up to 100 ft/mile just downstream of St. Anthony.

Seasonal water level fluctuations and depth to water normally decrease from northeast to southwest. Consistent with other authors, Wytzes (p. 65) shows the depth to water table as decreasing from about 50 feet in the Newdale area to near land surface along the Henry's Fork from just south of St. Anthony to its confluence with the Snake River. Wytzes (p. 63) found mean seasonal fluctuations of the water table in the lower reaches of the North and South Forks of the Teton River to be about 5 feet. For the entire system Crosthwaite et al (1970, p. C14) reported a range of 2 to 40 feet in fluctuation.

Recharge to the Teton Island area shallow system is composed of deep percolation of irrigation water, seepage losses from the Teton River and North and South Forks of the Teton River, deep percolation of precipitation, and possibly some inflow from the perched water on the Rexburg Bench. Discharge consists of leakage to the regional system, pumping, crop and other plant evapotranspiration, seepage and underflow southward and to the Snake River, and seepage to the Henry's Fork. Discharge to the Henry's Fork can occur directly or by overland flow after reaching the North or South Forks of the Teton River or other natural drainages.

EGIN BENCH AQUIFER

The shallow aquifer found beneath the Egin Bench is primarily a result of irrigation, especially sub irrigation techniques. It is normally considered part of a lower Henry's Fork Aquifer system that includes ground-water east of the river, but the Henry's Fork provides an hydraulic barrier that essentially separates the two bodies. In fact, consistent with other authors Wytzes (p. 61) stated "No definite connection seems to exist with the lands east of the river."

Shallow ground-water under the bench is contained in the sandy alluvium which overlays black volcanic sands which in turn overlay basalt of the Snake River Group. Alluvium thickness, or depth to basalt, ranges from nearly zero to about 100 feet, generally being less in the north and northwest fringes of the bench (King, p.1). Thin layers of clays and silts produce a vertical hydraulic conductivity in the alluvium that is less than that of the basalt, thus producing the shallow system (Wytzes, pp. 48-49). The alluvium is otherwise a very permeable aquifer. In fact, King (p. 6) assumes a perched condition is created by the lesser vertical permeability of the underlying basalt, which has a much greater horizontal conductivity than vertical conductivity due to the highly permeable layered interflow zones. It is likely a combination of the two effects that create the apparently perched system.

Wytzes (p. 156) employed transmissivity values for his shallow system modeling effort that ranged from 7,480 to 112,000 gpd/ft, with about 19,000 gpd/ft being representative. A value of .15 is representative of the storage coefficients he used (p. 157) on Egin Bench.

The water table is generally in the shape of a ridge that extends throughout the bench, with a general slope to the southwest in conjunction with the land surface. It also slopes to the northwest and southeast, an indication of movement to the regional Snake Plain Aquifer and the Henry's Fork, respectively. The crest of the ridge is generally found under the main canals (Wytzes, p. 61). Wytzes reported the slope of the water table in 1977 to be about 10 ft/mile in a southwesterly direction. Slopes to the north side of the bench were about 30 ft/mile while those to the Henry's Fork were about 20 ft/mile. King (p. 7) showed similar perched water table contours.

Depth to the water table varies greatly throughout the year since irrigation water is the primary recharge component. When sub irrigation was practiced extensively on the bench the water table was raised everywhere to within 6 to 18 inches of the surface in the summer and enough water infiltrated during the non-freezing season to keep it within about 20 feet of the surface (King, p. 6). Wytzes (p. 61) reported that areas on the fringe of the bench fluctuate more than those in the middle.

Recharge to the bench aquifer consists of 1) deep percolation of applied irrigation water, 2) seepage from irrigation canals, borrow pits, and "waste ponds" (including Quayles Lake), and 3) deep percolation of precipitation. Outflows or water use on the bench consists of crop and phreatophyte evapotranspiration, free water surface evaporation, seepage to the perched system, and surface return flow to the Henry's Fork. King (p. 4) indicated that over 80 percent of the total diversion to

Egin Bench reaches the perched system and 70 percent of that reaches the regional system. Discharge from the aquifer is composed of 1) seepage to Henry's Fork, 2) horizontal movement of water off the bench which eventually reaches the regional system to the southwest, west, northwest, and north, 3) leakage to the regional system through the confining layers of the bench, and 4) very minor pumping.

ASHTON AQUIFER

A shallow ground-water body exists in the Ashton area between the Henry's Fork and Falls River. It developed primarily as a result of percolation of irrigation water from the lower Falls River. The water-bearing formation is basalt, found above the regional Snake Plain Aquifer. The perched water is supported in the basalt by the underlying silicic volcanic rocks. Basalt ranges from 20 to 100 feet in thickness (Crosthwaite, et al., 1970, p. C14).

Productivity of the perched system (and the Snake Plain Aquifer in this area) is often reported as poor or limited. The static water level of the local system is found only a few feet below land surface, as evidenced by extensive swampy areas and springs that discharge to natural channels.

Some of the perched water undoubtedly leaks through the silicic rocks and reaches the Snake Plain Aquifer, but most is thought to discharge to the Henry's Fork above St. Anthony. Very little, if any, water reaches the perched system in the lower Henry's Fork area via lateral movement.

Whitehead (1977) presents the most extensive information on ground-water found north of St. Anthony.

TETON BASIN AQUIFER

The aquifer found in the Teton Basin is composed principally of alluvium. The alluvium is composed of deposits carried out of the canyons by the streams that are intermittently tributary to the Teton River. Deposits range in size from boulders to sand and finer particles. Average particle size in the alluvial fans decreases toward the valley floor since sediment transport capacity decreases as stream slope decreases and water is lost through seepage and diversion. Thickness of the alluvium increases towards the valley floor, ranging from a few feet along the borders to several hundred feet in the middle.

The ground-water reservoir is considered to be an unconfined aquifer. However, due to the erratic nature of alluvial deposits there is probably interfingering of relatively sorted materials that lead to lenses which may produce small areas with artesian conditions (Kilburn, 1964, p. 24).

The productivity of the aquifer on the east side of the Teton River is generally good, especially where the sand and gravel are clean and well sorted. Based on a pumping test of well 4N-45E-13adl, found in the Darby Creek fan, Kilburn (1964, p. 20) reported the aquifer transmissivity as about 500,000 gpd/ft and the coefficient of storage as .03. On the west side of the river the aquifer is reported as being less permeable and less productive.

The water table configuration is generally consistent with the shape of the land surface except that it is not as spatially variable. Ground-water flow is therefore generally towards the Teton River, perpendicular to the bordering mountains. Near the river on the valley floor it turns northward, essentially following the path of the river. The gradient ranges from around 100 ft/mile in the valley margins down to about 25 ft/mile in the lower half of the tributary alluvial fans (Kilburn, 1964, p. 26). The gradient changes with seasonal variations of the water table caused by changes in recharge and discharge. Generally, depth to water and seasonal fluctuation decrease toward the river. Depth to water in April of 1959 ranged from near land surface in areas adjacent to the Teton River to over 200 feet near Darby. Seasonal fluctuations range from 85 feet or more in the uplands to less than 5 feet in the valley floor (Kilburn, 1964, p. 30).

Recharge to the aquifer occurs directly or indirectly from precipitation in the basin. Recharge components are 1) tributary underflow from the surrounding mountain bedrock and alluvium, 2) seepage losses from the tributary streams, 3) deep percolation of direct precipitation, 4) seepage from canals, and 5) deep percolation of applied irrigation water. Discharge from the aquifer consists of 1) stream seepage, 2) evapotranspiration, 3) valley underflow to the north, and 4) pumping. Eventually, all ground-water that is not evaporated or transpired by plants in the basin is tributary to the Teton River. This includes that which leaves the Teton Basin as valley underflow, since it reaches the river via either direct seepage or spring discharge and overland flow unless intercepted by deep wells in the mouth of the basin.

U. S. BUREAU OF RECLAMATION EXCHANGE WELLS

PURPOSE

One of the tasks for this project was to assess the effect of USBR exchange well operation on the Fremont-Madison water supply. Impacts on the deep regional Snake Plain Aquifer, the shallow local aquifers, and ultimately surface-waters in the Henry's Fork and Teton Rivers were of primary concern.

PROCEDURE

The first step in the analysis of the USBR exchange wells was to obtain and review well construction data in order to identify the apparent ground-water source of each well. Pumping impacts on the ground-water regime were addressed. Potential effects of pumping on nearby streams were then evaluated and, finally, stream impacts were related to Fremont-Madison water supply. Well pumping records were also obtained and reviewed in order to assess historical use patterns and thereby compare actual to potential impact.

RESULTS

Original exchange well files were obtained from the USBR. Construction data found in well logs, pumping test data, miscellaneous notes, and pertinent published information indicate that all of these wells are pumping from the Snake Plain Aquifer. They were designed to be isolated from the local aquifer systems that exist in the lower Henry's Fork area. Well locations are shown in Figure 1. Each of the five wells has been drilled to a depth that penetrates basalt of the Snake River Group. They have been cased and grouted in such a way as to seal the hole off from the alluvial overburden in which the local aquifers exist. Table 1 lists relevant information for each well.

Since direct pumping from the shallow systems by these wells does not occur, an attempt was made to estimate indirect influences on the rivers. This entailed analyzing a potential increase in leakage from the shallow systems to the regional Snake Plain Aquifer due to local drawdown in the regional system. An increase could result in lower water levels in the shallow systems which could, in turn, reduce seepage to or increase seepage from the rivers.

When saturated vertical flow exists from one aquifer to another they are said to be hydraulically connected. If so, the leakage from one system to the other can be estimated from the product of a constant leakage factor, or impedance, and the difference in static water levels, or piezometric heads. Wytzes modeled leakage from the shallow systems to the deeper Snake Plain Aquifer using this method and the inherent assumption of hydraulic connection.

Since drawdown in the regional system will increase the head difference between the two systems there will be an induced increase in leakage. For example, at USBR#3 the head difference has consistently been measured as about 23 feet and drawdown in the well itself was measured at about 5 feet (excluding well losses). Therefore, leakage at the well site would theoretically increase by about 20 or 25

TABLE 1. USBR GROUND-WATER EXCHANGE WELLS

NAME	TRIBUTARY TO	LOCATION	PUMPING CAPACITY[1] (cfs)	APPROX. DEPTH TO WATER (ft)	LOCATION OF PERFORATED OR OPEN HOLE (ft)	LOCATION OF GROUT (ft)
Number 2	Henry's Fork	SENE Sec.19 T7N R40E	17.0	30	199-394	154-160
Number 5	Henry's Fork	SWSW Sec.34 T7N R39E	19.0	11	157-410	150-157
Number 3	South Fork Teton River	NENE Sec.23 T6N R39E	9.6	26	245-426	240-245
Number 1	Henry's Fork	SWNE Sec.25 T6N R38E	19.0	18	451-685	437-451
Number 4	Independent Canal	NWSE Sec.16 T7N R39E	15.6	57	256-503	216-229

[1] Reported by Fremont-Madison Irrigation District.

percent since the leakage factor is a constant. The area of influence only extends as far from the pumping well as significant drawdown occurs, and the magnitude of that influence decreases with distance away from the well as drawdown decreases. Pumping tests of each of the USBR wells show small drawdowns in the Snake Plain Aquifer. This means that the area in which measurable drawdown occurs is rather small, on the order of a few hundred feet. Furthermore, leakage factors are very small so actual flow rates are quite small. Wytzes used values ranging from near zero to .0009 but most were .0001.

The ultimate effect of the above scenario is that a very long pumping duration would be required to induce a meaningful volume of increased leakage. Even then, the water level changes created by the induced leakage would most likely not cause significant changes in the shallow system flow regime. The changes would also be lagged from the actual time of pumping and thereby introduce other potential influences. These changes, however small, might cause subtle changes in ground-water interactions with surface-waters.

If there is an unsaturated zone either between the upper and lower aquifers or between the shallow system and the river, pumping will have no effect on surface-waters. This is because the gradient for these conditions is unity (one) so a change in the head difference will not result in a gradient change. This is probably not the case for the USBR exchange wells since they are located in areas where the shallow system is normally hydraulically connected to the rivers and the two aquifer systems seem to be intimately connected.

Historical pumping records indicate that realized impacts have been much less than potential impacts since pumping has been sporadic. In many years the USBR pumps have remained idle. Table 2 shows pumping records for the years 1978 through 1991 for the USBR exchange wells.

TABLE 2. EXCHANGE WELL PUMPED VOLUMES.

ACRE FEET

NAME	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Loosli	27		235										
USBR #2		293	481							2832	1391	3545	3545
Steveco		187	923	71	134		234	57	180	416	224	327	351
C.C. Lat.	1110	1018	2409				827		280	3699	958	544	1893
Parkinson[1]	1119	1111	1710	403			1167			1203			755
Schwendiman[1]	1063	1111	1710	403			1167			1203			755
Bott			613				384	20	25	418			
Hoopes	202	473	434				313			556			
USBR #5		335	615							3247	1574	3830	3837
Ricks						25	174	443	407	562		920	944
Hoopes Bros	391	691	1271						33	645			
EHCO Ranch												28	
Ard	226	647	1361				527		64	628			
HINK Inc.									9	589			
Brown	516	567	846	563	783	662	1013	1269	1228	1477	1210	1924	
USBR #3		170								1599	799		2055
USBR #1			502							3223	1236		4190
USBR #4										6798	770	1359	2537

[1] The total volume pumped by the B. Parkinson, M. Parkinson, and Schwendiman pumps is divided equally between B. Parkinson and Schwendiman.

*Data furnished by Fremont-Madison Irrigation District.

CONCLUSIONS

River flows are not measurably affected by USBR operation in the Fremont-Madison Irrigation District. There are probably extremely localized effects on the shallow aquifers that result from increased head differences between the shallow and regional aquifer systems. Increased leakage could possibly affect river flows but only to a slight degree.

Even if the impacts were significant the well locations are generally downstream of Fremont-Madison diversions and, therefore, would not directly affect physical water supplies. In addition, actual pumpage has been minimal compared to potential pumpage.

PRIVATE EXCHANGE WELLS

PURPOSE

The purpose of study for the privately owned exchange wells in Fremont-Madison's service area was basically the same as that for the USBR wells. However, since these wells were for the most part much closer to the streams it was generally thought that they may be drawing surface-water and simply recirculating at least a portion of the discharge. The primary objective was to estimate the source of water from which the wells pump as well as assessing aquifer effects to determine the actual or potential impact on Fremont-Madison's water supply.

PROCEDURE

Analysis for the private exchange wells was identical to that for the USBR wells. The first step was to obtain and review well construction data in order to identify the apparent ground-water source of each well. Pumping impacts on the ground-water regime were assessed. Potential effects of pumping on nearby streams were then evaluated and, finally, stream impacts were related to Fremont-Madison's water supply. Well pumping records were also obtained and reviewed in order to assess their historical use patterns and thereby compare actual to potential impacts.

RESULTS

Well logs, well permits/licenses, and field exam notes were obtained from the Idaho Department of Water Resources (IDWR) Eastern Region office. Additional information was obtained from the IDWR Hydrology Section. Figure 1 shows private exchange well locations and Table 3 lists relevant information for each well.

Available data on exchange well construction and lithology is sometimes suspect or lacking. It appears, however, that the source of ground-water for the private wells is variable. Some probably tap only the regional Snake Plain Aquifer, some likely draw from both the deep regional and shallow systems, and some wells may draw just from the shallow system. With the limited data available, it cannot be determined with certainty from which ground-water body each well is pumping. However, based generally on well logs, well construction data, and a comparison of water levels in the wells and suspected water levels in each of the aquifer systems, reasonable conclusions can be drawn.

The B. Parkinson, Schwendiman, Ard, and Hink wells appear to pump entirely from the deep Snake Plain Aquifer. None are completed as neatly as the USBR wells, however; grouting at depth is not reported on any of the well logs. Analysis for these wells is the same as described above in the discussion of the USBR wells. Unsaturated flow at these sites is much more likely to exist between the shallow and regional aquifer systems and/or from the streams. Therefore, it is unlikely that these wells have any impact on local stream flows.

The M. Parkinson, Bott, and C. Hoopes wells probably draw most, if not all, of their discharge from the deep Snake Plain Aquifer. Although the depth to first open hole in each case is below the estimated depth to basalt, depths are relatively close. Local variability may be such that the wells are actually developed in the basalt and the lower part of the alluvium. Measured water levels in the wells would likely reflect

TABLE 3. PRIVATE GROUND-WATER EXCHANGE WELLS

NAME	TRIBUTARY TO	LOCATION	PUMPING CAPACITY (cfs)	DEPTH TO WATER[1] (ft)	LOCATION OF PERFORATED OR OPEN HOLE (ft)
L. Loosli	Falls River	NESE Sec.21 T8N R42E	2.0[2]	50[3]	18-490
Steveco Canyon Farms	Teton River	NWSE Sec.10 T6N R44E	3.1[2]	N/A*	N/A*
Canyon Creek Lateral	South Fork Teton River via Canyon Creek Canal drain	NESE Sec.36 T7N R40E	14.0[2]	34[4]	N/A*
B. Parkinson	Teton River	SWNE Sec.29 T7N R41E	18.0	98.1	136-180
V. Schwendiman	Teton River	SWNE Sec.29 T7N R41E	16.6	99.2	138-180
M. Parkinson	Teton River	SWNE Sec.29 T7N R41E	21.8	97.1	55-75, 85-180
D. Bott	North Fork Teton River	SESE Sec.25 T7N R40E	9.6	73.5	84-148
C. Hoopes	North Fork Teton River	SESE Sec.25 T7N R40E	6.4	73.4	120-160
Hoopes Brothers	South Fork Teton River	NENE Sec.11 T6N R40E	11.9	31.5	N/A*
B. Ricks	South Fork Teton River	NENE Sec.11 T6N R40E	5.6	30.1	N/A* (358' total depth)
Ehco Ranch	South Fork Teton River	NENE Sec.11 T6N R40E	7.8[2]	30.4	N/A*
Ard	South Fork Teton River	SWSW Sec.15 T6N R40E	11.5	56.9	158-258
Hink, Inc.	South Fork Teton River	SWSW Sec.15 T6N R40E	12.0	57.2	205-305
R. Brown	South Fork Teton River	NWSE Sec.16 T6N R40E	14.9[2]	40[3]	82-88

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[1] Measured by IDWR, 10/7/91.

[2] Reported by Fremont-Madison Irrigation District.

[3] Reported by well driller.

[4] Cascading water reported by IDWR, unable to obtain accurate measurement.

*Not available

only the piezometric head in the lower aquifer, especially if the hydraulic conductivity of the lower aquifer is significantly greater than that of the overlying formation.

The Brown, Canyon Creek, and both Loosli wells probably draw at least some water from their respective shallow systems. The Brown well is open at a depth not far below the estimated depth to basalt. Furthermore, IDWR personnel have reported interference with nearby domestic wells when the Brown well is pumping. As noted in Table 3, cascading water was reported in the Canyon Creek well which implies at least a partial connection to the shallow system. The measured water level reflects that of the shallow system. Since the Loosli wells are essentially open hole throughout, they undoubtedly draw from both the perched aquifer and the regional Snake Plain Aquifer. In each case, the potential exists for the well to act as a drain from the shallow system to the deep system.

The ground-water source for all other exchange wells cannot be definitively identified because of insufficient data. The Ehco Ranch, Ricks, and Hoopes Bros. wells show water levels that indicate a potentially mixed source. Essentially, no data was located concerning the Steveco Canyon well.

Based on an analysis of water table contours in the Teton Island area, wells pumping from the shallow aquifer upstream of the Hoopes Bros.-Ehco Ranch-Ricks group generally do not appear to be recirculating surface-water. The water levels in the northeastern part of the shallow aquifer are far enough below the river throughout the year that unsaturated flow conditions always exist. In late summer when shallow water levels peak, a direct hydraulic connection may exist near the mentioned wells and all wells downstream. This condition is questionable in the area of the Hoopes Bros.-Ehco Ranch-Ricks wells and would only exist for a short time while the perched system is at its highest, normally during late summer or fall.

If the wells are tapping only the deep aquifer the impact would likely be insignificant. If, on the other hand, they were even partially completed in the shallow system and saturated flow conditions prevailed between the river and shallow aquifer, a significant recirculation could take place. In addition, water traveling towards the stream may be intercepted by the well, thus producing decreased seepage to the river rather than increased seepage from the river. In either case, the impact on the stream is the same, reduced streamflow.

For those wells pumping from the shallow system in locations where recirculation is not taking place on the immediate local scale there is still an impact on the ground-water flow regime. When a pump draws water from the shallow system the volume removed will no longer travel down-gradient in its "natural" course. Disregarding the potential for down-gradient pumping, the pumped water would have either eventually leaked to the deeper aquifer, discharged to the Henry's Fork, or supplied evapotranspiration requirements. For example, it is extremely likely that perched water (not coming from the river) pumped by the two Loosli wells would naturally discharge to the Falls River and become natural flow. Without regards to induced stream leakage, wells in the upper Teton Island area intercept water that is flowing toward discharge sites in the lower Teton Island area. Based on shallow system water table contour lines presented by Wytzes, Haskett (1977), and Baker (1991), all of the well groups probably affect flows in the lower part of the South Fork of the Teton River and/or the Henry's Fork near the Rexburg gaging station. The wells located farthest north would be more likely to affect flows upstream of the gaging station but, generally, shallow ground-water flow follows the South Fork.

The potential impact of private exchange wells is greater than actual pumping records would indicate. Table 2 shows the annual pumping of all private exchange wells as reported in Water District 01 records and furnished by the Fremont-Madison Irrigation District. Except for the Brown well, each has remained idle at least one year during the period of record shown.

CONCLUSIONS

Impacts of the private exchange wells are more uncertain than those for the USBR wells. It appears that some of the wells have been developed only in the regional Snake Plain Aquifer while others are drawing from the shallow system, too. The ground-water source for some wells could not be determined.

Wells that are developed solely in the Snake Plain Aquifer probably do not have a significant impact on surface-waters in the Fremont-Madison service area. Those developed at least partially in the shallow aquifer will have a direct effect on the nearby stream if in a location where the river and the aquifer are hydraulically connected. There is generally no hydraulic connection in any of the well locations for most of the year, but there seems to be potential for those conditions downstream of the Hoopes Bros.-Ehco Ranch-Ricks group in late summer when water levels reach their peak. The significance of their impact is dependent upon pumping capacity and operation and could not be quantified for the study.

Wells developed at least partially in the shallow aquifer will have an indirect effect on stream flows in the lower reaches of the South Fork of the Teton River and the Henry's Fork. The impact will be reduced ground-water recharge to the surface-waters by the amount that was pumped from the shallow aquifer that would not have been otherwise lost from it. Other paths for the water pumped are leakage to the regional Snake Plain Aquifer and evapotranspiration in the lower parts of the Teton Island.

Considering the potentially impacted stream reaches, surface-water effects would probably not significantly effect Fremont-Madison's physical water supply or ability to divert. However, changes in the shallow ground-water regime caused by exchange well pumping may cause difficulties with sub irrigation practices in the lower Teton Island. Real or potential changes in river flows caused by exchange well pumping, although not impacting diversion capabilities, may affect allocations computed for downstream or upstream users in the Water District 01 accounting program.

EGIN BENCH

PURPOSE

The effects of changes in winter diversion policy and conversion from surface to sprinkler irrigation techniques are two water management concerns on the Egin Bench. Since deep percolation of irrigation water is the primary recharge to the shallow aquifer, changes to the shallow ground-water flow regime under the bench and associated return flows to Henry's Fork were expected. The purpose of this aspect of the investigation was to analyze the actual and potential effects water management changes on the Egin Bench have or may have on the physical water supply for Fremont-Madison.

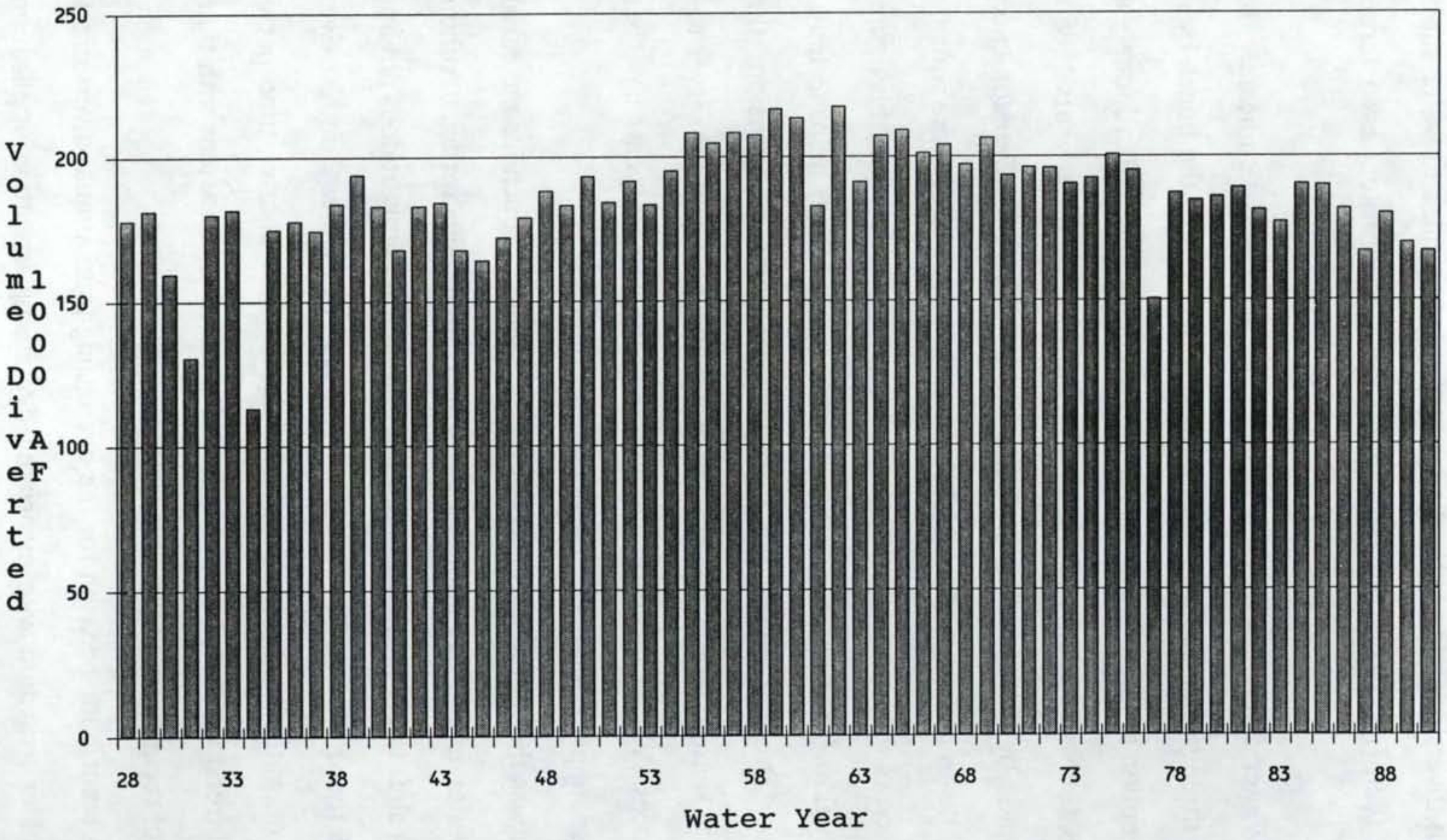
PROCEDURE

The analysis was basically to examine management changes, ground-water conditions, and likely impacts on the Henry's Fork in order to identify impacts on Fremont-Madison. Historical and current water management on the bench was quantified to the extent possible and likely trends were identified. The ground-water flow regime was reviewed, trends in that regime were identified, and potential impacts on flows in the Henry's Fork were assessed, especially with respect to Fremont-Madison member diversions.

RESULTS

Historical diversion records for the four canals that serve the bench were obtained from IDWR. Canals serving the bench are the Last Chance, St. Anthony Union (and Feeder), Egin, and Independent. Figure 2 shows the combined summer diversions for the period of record. Although records are available from 1928 to the present, winter month diversions were not consistently measured until about 1978, so prior data are estimates (except for 1943). Winter diversions are therefore not

Figure 2. Summer Diversions to Egin Bench
May through September



reported for the period of record. Since 1960 there appears to be a slight downward trend in diversions. Over this 30 year period, responses to water supply conditions can be seen (i.e. 1977), but the general trend is consistent even through the "wet" 1980s.

Winter diversions to Egin Bench have decreased significantly during the last two or three years. Figure 3 shows winter diversions to the bench by month. With the exception of large diversions for the Independent Canal in January and February of 1988, the vast majority of winter diversions during water years 1988 through 1990 were made by the Egin Canal. Disregarding those two diversion categories leaves essentially no flow to the bench over the winter months of those water years. Figure 4 also shows the effect of new winter diversion practices. In this figure, normalized monthly flow (monthly flow as a percent of annual flow) helps to limit the effect of drought. Drought affects the seasonal distribution of diversions throughout the irrigation season, although averaging of multiple year periods serves to buffer yearly differences. Winter diversion decisions over the past few years have been based less on water supply availability than on matters of policy.

It was thought that to make up for the winter reductions the canals may divert more water in the irrigation season, especially in the spring. Although Figure 4 shows a shift in the distribution of total annual diversions, it does not appear that the full difference is being recovered, as evidenced by Figures 2 and 5. Even though the effects of water supply are more prevalent on the shorter time period graph the general trend towards decreasing total diversions is consistent with that seen on the period of record graph for summer diversions.

A contributing reason for the decreasing total annual diversions is conversion to sprinkler irrigation with associated decreasing irrigation application. Sprinkler irrigation methods are increasing in popularity (or necessity) on Egin Bench. Conversions have proceeded very rapidly since 1985 and especially in the last few

Figure 3. Winter Diversions to Egin Bench
November through February

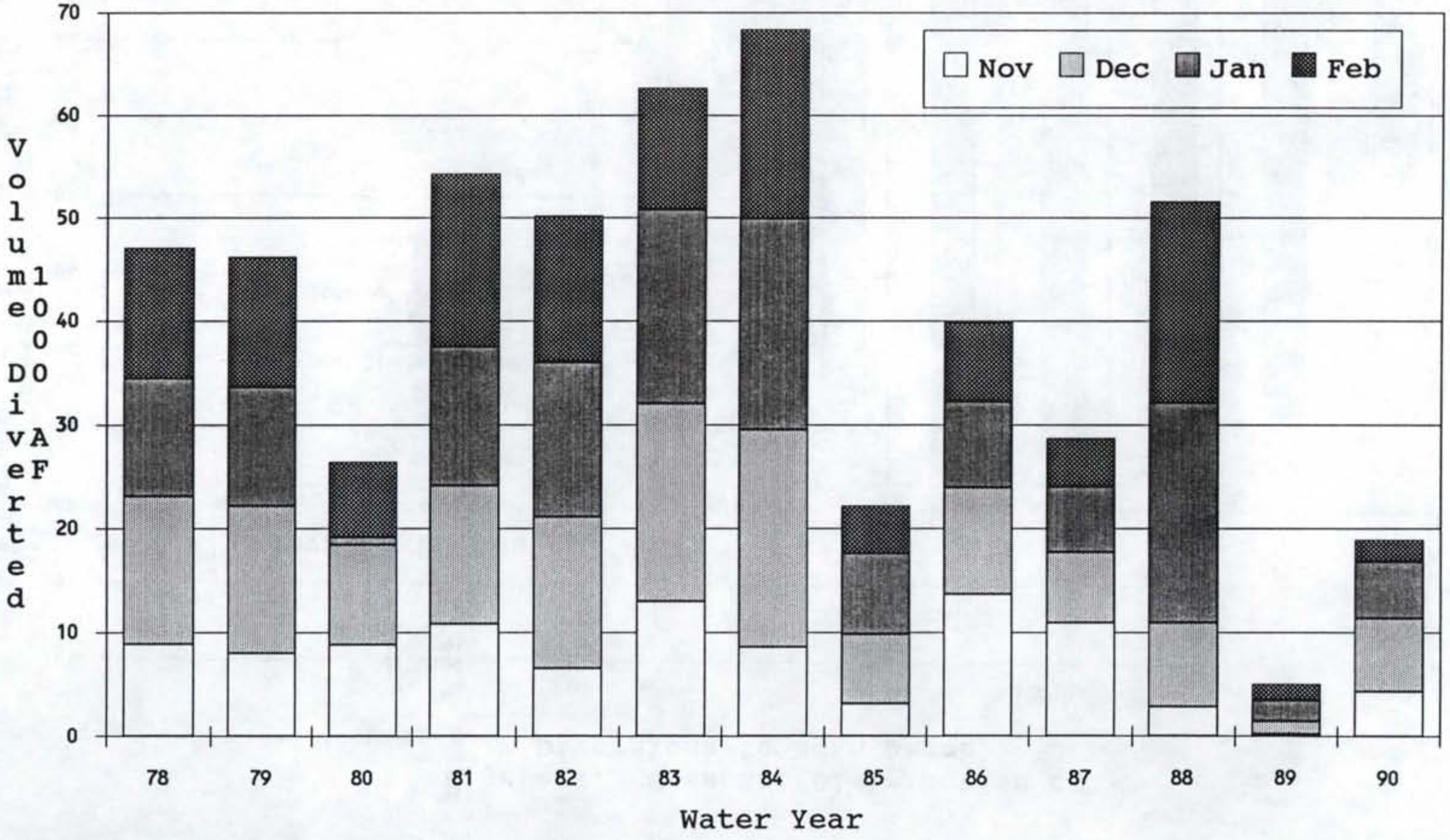


Figure 4. Seasonal Distribution of Diversions to Egin Bench

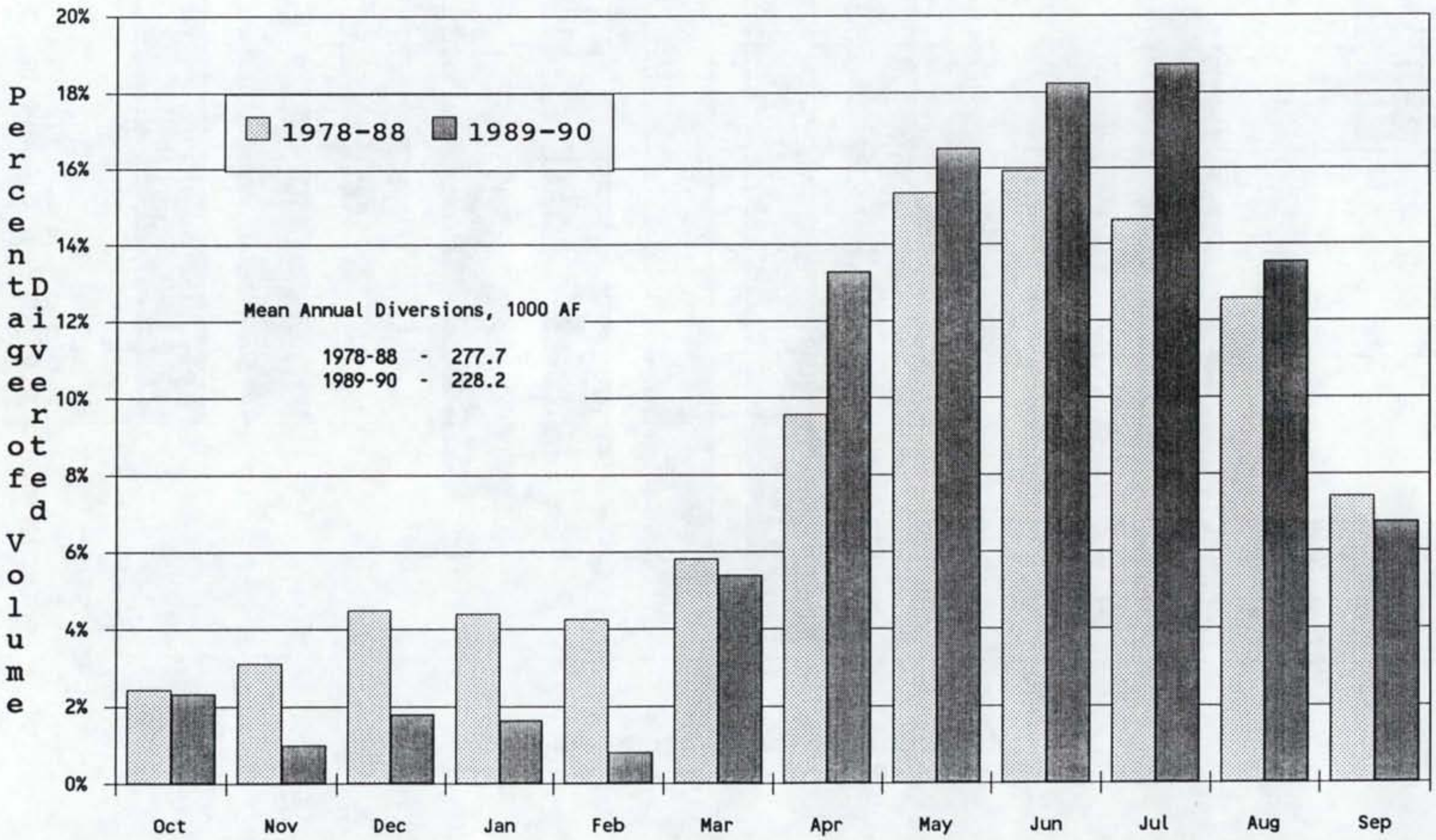
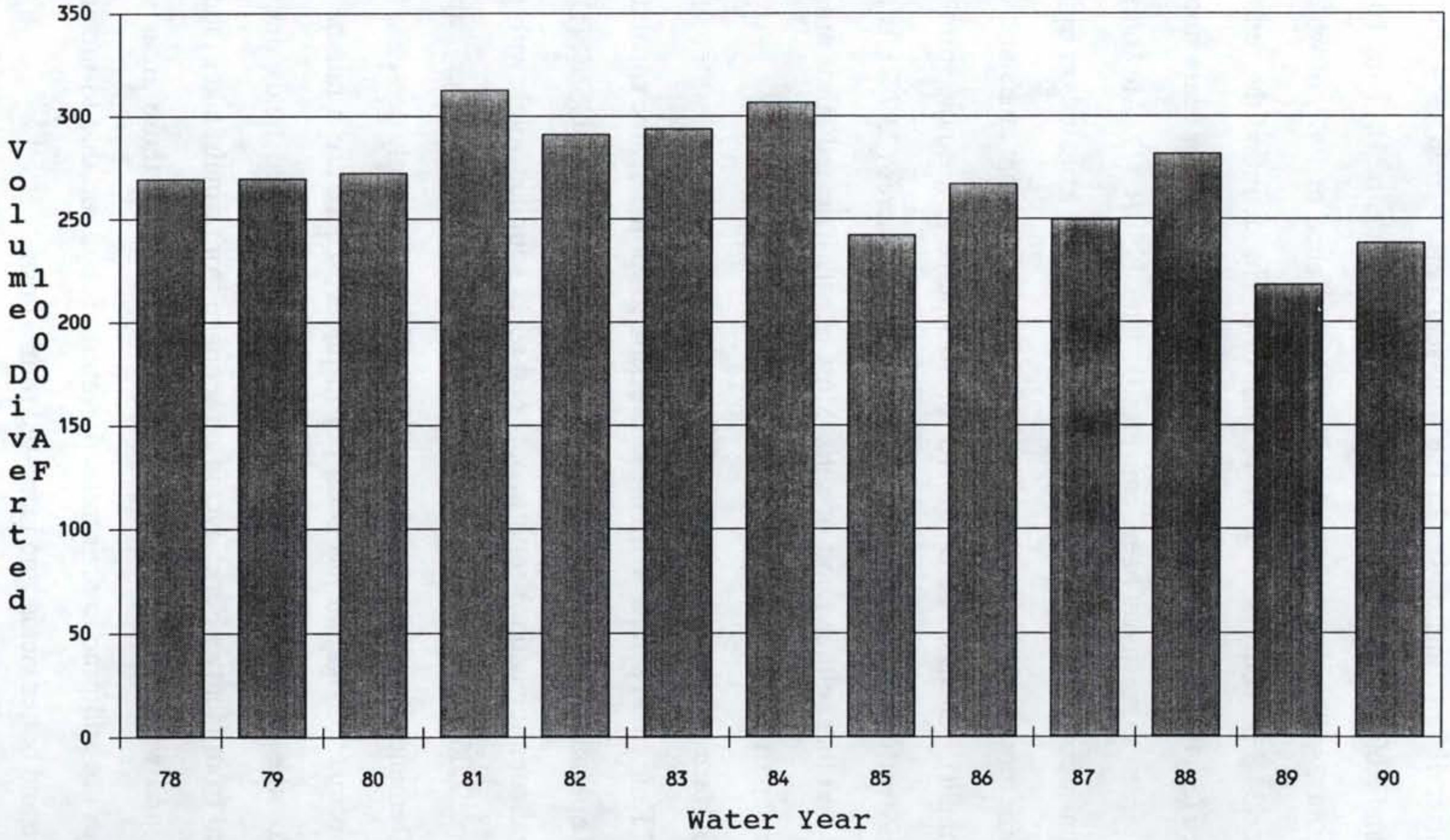


Figure 5. Total Annual Diversions to Egin Bench



years. By 1984 about 6,000 acres were sprinkler irrigated, most conversions taking place after 1975 (King, p. 4). In the four year period from 1984 through 1987 an additional 3,600 acres were put under sprinklers (King, p. 4). King (p. 1) reported that about 28,000 acres were irrigated on Egin Bench in 1987, of which only 9,600 acres, or 34.8 percent (p. 9, 12) were sprinkler. He identified the remainder as sub irrigated (55.4%) and "river bottom land" (9.8%). In the four years since 1987 about 11,000 acres more have been converted. The USBR (D. McAndrew, personal communication) reports that 27,235 acres are currently irrigated on Egin Bench (the main difference in total acreage hinges on how river bottom lands and wet meadows are defined). Of those acres, 20,785, or 76.3 percent, are now sprinkler irrigated, primarily with center pivot systems. The rest, 6,450 acres (23.7%), is irrigated with gravity methods, either flood or sub. Most gravity irrigated lands are found in the northeast part of the bench, north of St. Anthony.

Surface-water from the Henry's Fork is still the principal water supply. In fact, in 1987 King (p. 9) stated "With the conversion to sprinklers, the canal diversions and system operations have remained relatively unchanged." The USBR (D. McAndrew, personal communication) reports only 660 acres supplied solely with ground-water and some 2,060 acres as having a mixed (ground- and surface-water) supply.

Demand at the farm headgate on Egin Bench has likely decreased as more and more sprinkler irrigation has been put in place. There are a number of potential sinks for the water not applied in the sprinkler irrigated fields that may still be diverted from Henry's Fork: increased seepage from canals, lakes (such as Quayles Lake), and waste areas; increased water application on those areas where gravity methods are still practiced; increased evapotranspiration due to increased cropped acreage and better yields; and increased return flows.

Evapotranspiration increases are likely insignificant since cropped acreage appears stable (King and McAndrew, personal communication) and water use-yield curves are essentially flat over the expected range of yields.

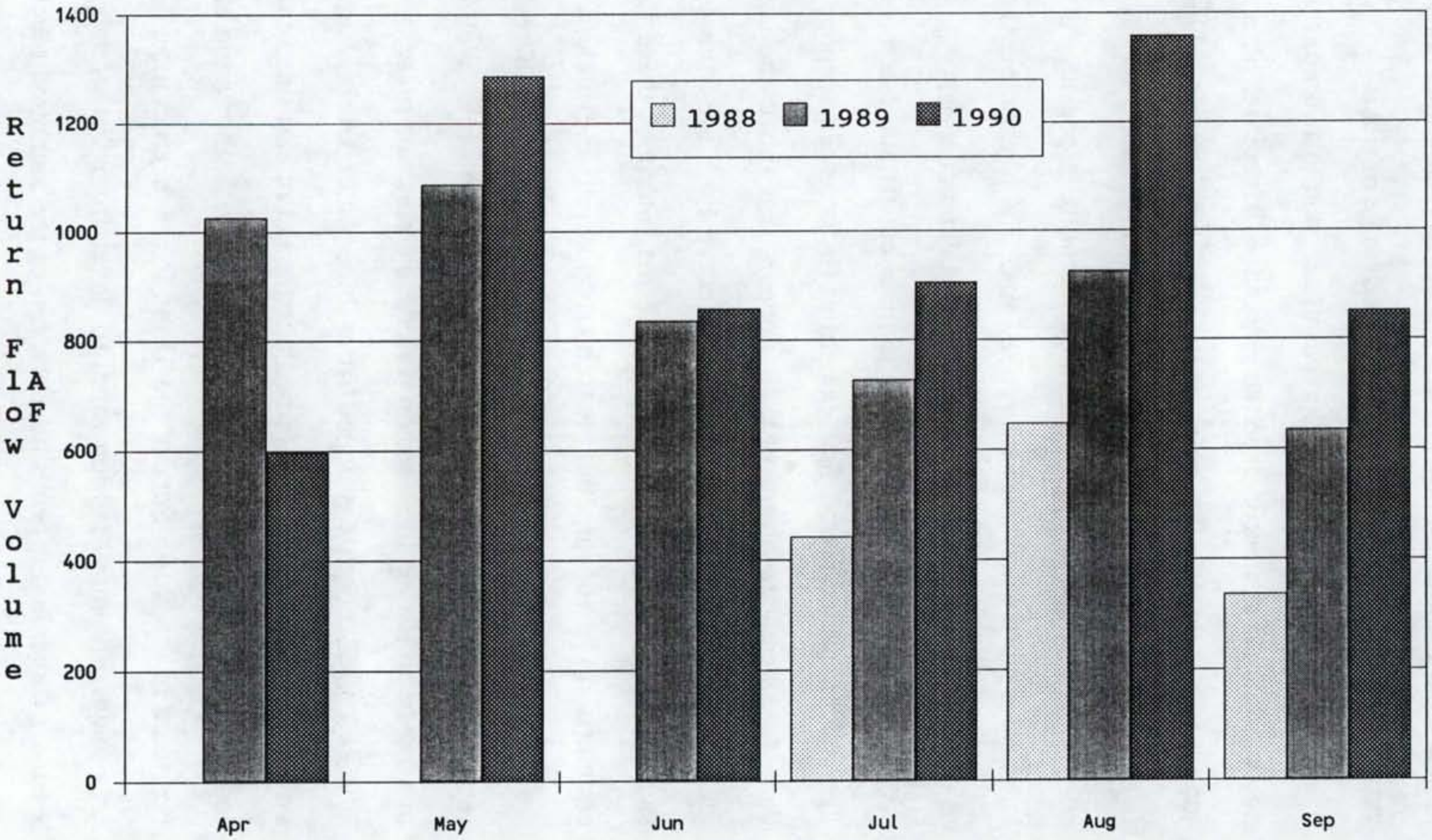
If the water table drops, increased seepage in hydraulically connected canals and waste areas can occur since the gradient will increase. This most likely occurs to the greatest degree in the spring of the year since water level lows in the winter are falling deeper as a result of winter diversions curtailment.

In areas where gravity irrigation methods, especially sub irrigation, are still employed, more water must be applied since the water table is not being recharged as uniformly throughout the bench as it has been in the past.

If water is not taken out of the main canals and laterals as it used to be, an increase in surface return flow can result (if increased seepage does not offset the decreased headgate diversions). It appears that this is the case. Figure 6 shows increasing surface return flows to the Henry's Fork even though diversions for the same time period have decreased. The magnitude of these flows is very small in comparison to diversions, but the trend is apparent nevertheless.

Ground-water level data on Egin Bench were gathered from four USGS-reported observation wells and previously reported work. Well locations and names are shown on Figure 1. Based on water table contours presented by King (p. 8) and Wytzes (p. 62), both developed from June water levels, water from the shallow system recharges the Henry's Fork along the entire east side of the bench. The river reach starting about 2.5 miles downstream of St. Anthony and ending about .5 miles upstream of the North Fork of the Teton River receives most of the recharge. The only major Fremont-Madison canal to divert from this stretch is the Consolidated Farmers Canal and it heads near the top of the identified reach. Hence, from the position of physical supply to Fremont-Madison members, changes in subsurface return flows to the Henry's Fork from Egin Bench do not have a significant impact.

Figure 6. Independent Canal Surface Return Flow
Henry's Fork Drain near Rexburg



Analyses of past and current shallow aquifer water levels serve to confirm suspected impacts of the recent water management changes. A trend seen in the last two or three years indicates a lowering of the water level, especially the seasonal low of late winter. Figure 7 shows water levels in the perched aquifer system since 1969. Water levels during the last three winters are at record lows. Wells 7N-40E-5cbd and 7N-39E-29cdc show similar seasonal fluctuations and general trends.

Although influenced by many more factors, the regional ground-water system under Egin Bench appears to be experiencing similar impacts. Figure 8 shows piezometric water levels in the regional system at the same site as the shallow aquifer observation well.

CONCLUSIONS

It appears that total annual diversions to the Egin Bench are decreasing slightly. New winter diversion practices are probably a primary reason, but decreasing summer time diversions seem apparent, too. Conversion to sprinkler irrigation methods has proceeded rapidly since 1987 which is likely the most significant factor causing decreased diversions. Increased surface return flows from the bench are probably signs of the decreased demand at the farm headgate that accompanies the change in application method.

A result of decreased summer diversions is increased flows remaining in the Henry's Fork and thereby greater physical supply to those diversions downstream of the Egin Bench canals' headworks.

Water levels in the shallow aquifer system underlying Egin Bench and the deeper Snake Plain Aquifer are decreasing. Lower minimum levels in the winter months are especially apparent. Probable increases in main canal and lateral seepage and increased gravity applications do not appear sufficient to offset the decreased winter recharge and impacts of sprinkler irrigation. Ground-water return

Figure 7. Hydrograph of Well 7N-39E-16dbb3
Egin Bench Shallow Aquifer

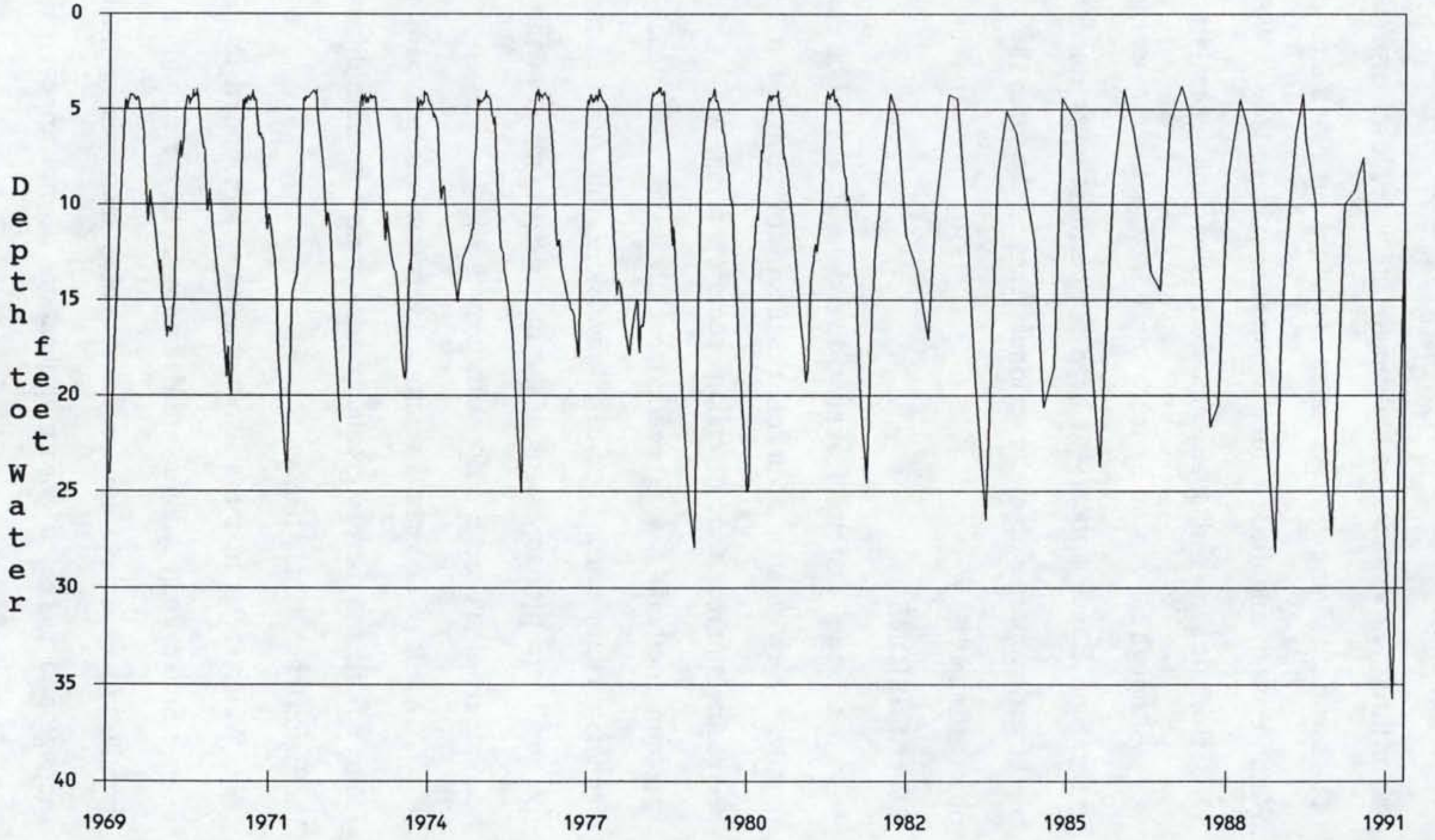
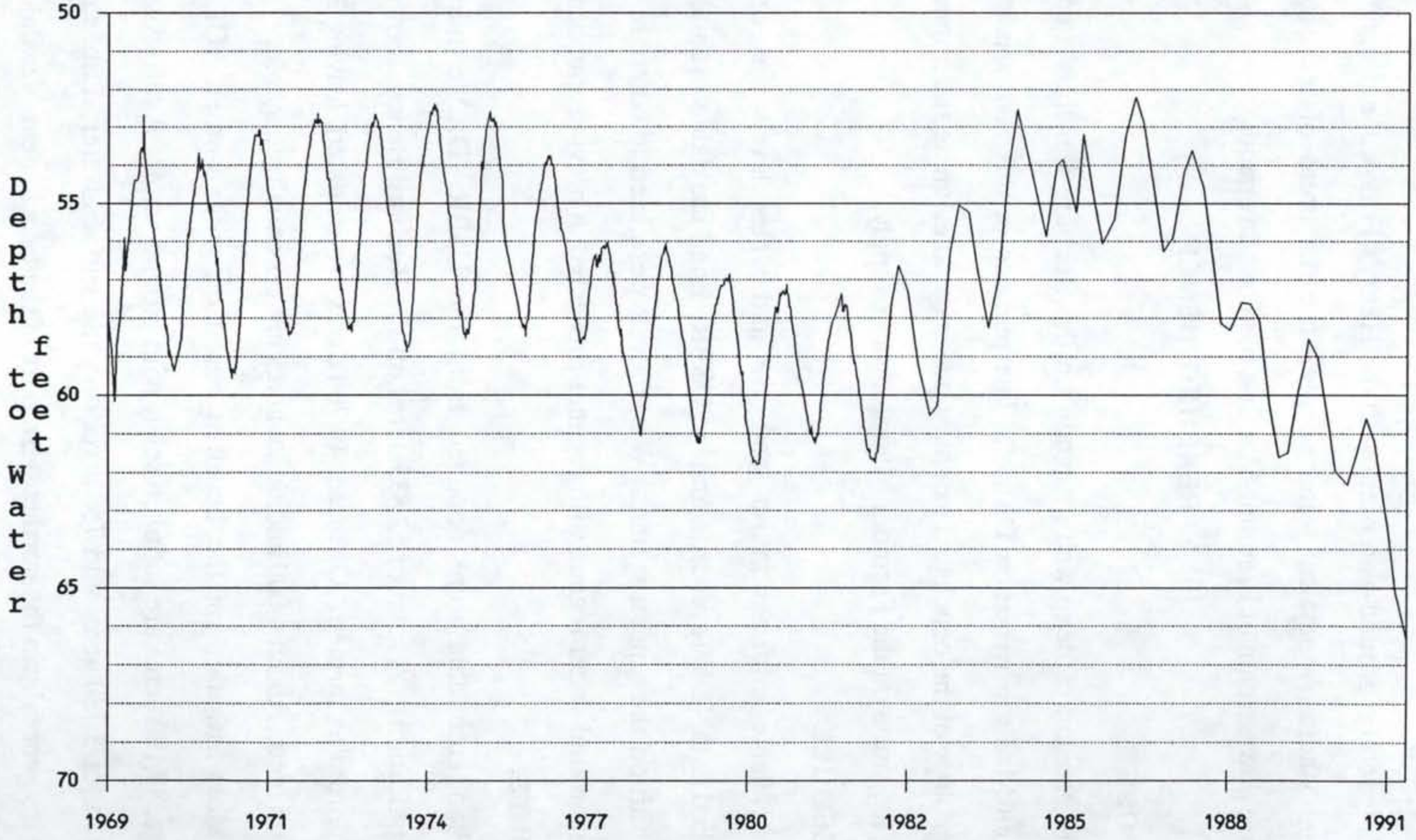


Figure 8. Hydrograph of Well 7N-39E-16dbb1
Egin Bench Deep Aquifer



flow to the Henry's Fork and the Snake Plain Aquifer have likely decreased as a result.

Impacts on ground-water inflow to the Henry's Fork will not significantly affect Fremont-Madison's physical water supply since the areas of recharge to Henry's Fork are downstream of Fremont-Madison member diversions.

REXBURG BENCH

PURPOSE

Expansion of deep well irrigation on the Rexburg Bench is a concern of the Fremont-Madison Irrigation District. The purpose of this task was to analyze the hydrogeology of the bench and extent of pumpage to estimate the impact of Rexburg Bench irrigation on the Fremont-Madison water supply.

PROCEDURE

Available information on land use and water levels was obtained from published data, IDWR records, and the USBR. Land use data were used to estimate total draft on the aquifer system. Water levels were used to compare the apparent current ground-water regime with regimes presented in previous publications.

RESULTS

Land use data were obtained from the USBR (D. McAndrew, personal communication). A total of 52,835 acres on the Rexburg Bench, shown in Figure 1, are reported as farmed. Of those, 49,700 acres are irrigated, leaving 3,135 acres of dry-farm land. About 4,000 additional acres are potentially irrigable.

Most irrigation on the bench is based on ground-water. Of the irrigated acreage, 45,180 acres are supplied solely with ground-water. A mixed water supply is reported for 3,780 acres and 760 acres only use surface-water. Lands using surface-water are generally in the northeastern part of the bench, near Newdale, served by a number of canals diverting from the Teton River.

Based on a value of 47,000 acres irrigated with ground-water and a seasonal consumptive use of 2.2 acre-ft/acre (based on Allen and Brockway), consumptive use from these lands is about 103,000 acre-ft per year. At an average application efficiency of 70 percent total annual pumpage is estimated to be 147,000 acre-ft. This value indicates a significant increase from past estimates. Total annual pumpage from the bench was estimated to be 25,000 acre-ft in 1962 (Crosthwaite et al, 1970, p. C18) and 40,000 acre-ft in 1970 (Haskett, 1972, p. 12). Haskett indicated that although pumping was apparently at or beyond recharge to the bench, ground-water levels did not show any declines at that time.

Water level data were obtained for five USGS-reported Rexburg Bench observation wells. Well locations and names are shown on Figure 1. Water levels measured at each site are shown in Figures 9, 10, 11, 12 and 13. In the order given, the wells span the bench from the southcentral section to the northeastern edge. There appears to be a slight trend of decreasing water levels, but it may only be a result of drought and not a response to ground-water drafting in excess of recharge.

Increased pumping from the ground-water system with no dramatic water level declines evidenced in the observation wells may be explained by two possible hydrological changes. The first is that the recharge estimate was originally low or it has since increased. Haskett (1972, p. 12) suggested that inflow may come from Teton River seepage losses in the Newdale area, seepage losses from the Snake River in the Heise area, and leakage from the southern end of the Teton Island area shallow aquifer. These potential components were not included by Crosthwaite et al (1967). If water levels in the regional system have decreased, creating greater gradients, recharge from these potential components and/or seepage in the Big Hole mountains may have increased.

The other possible explanation for the apparent overpumping without a corresponding water level decline comes from an analysis of the observation wells. It

Figure 9. Hydrograph of Well 5N-40E-01dcc
Rexburg Bench Aquifer

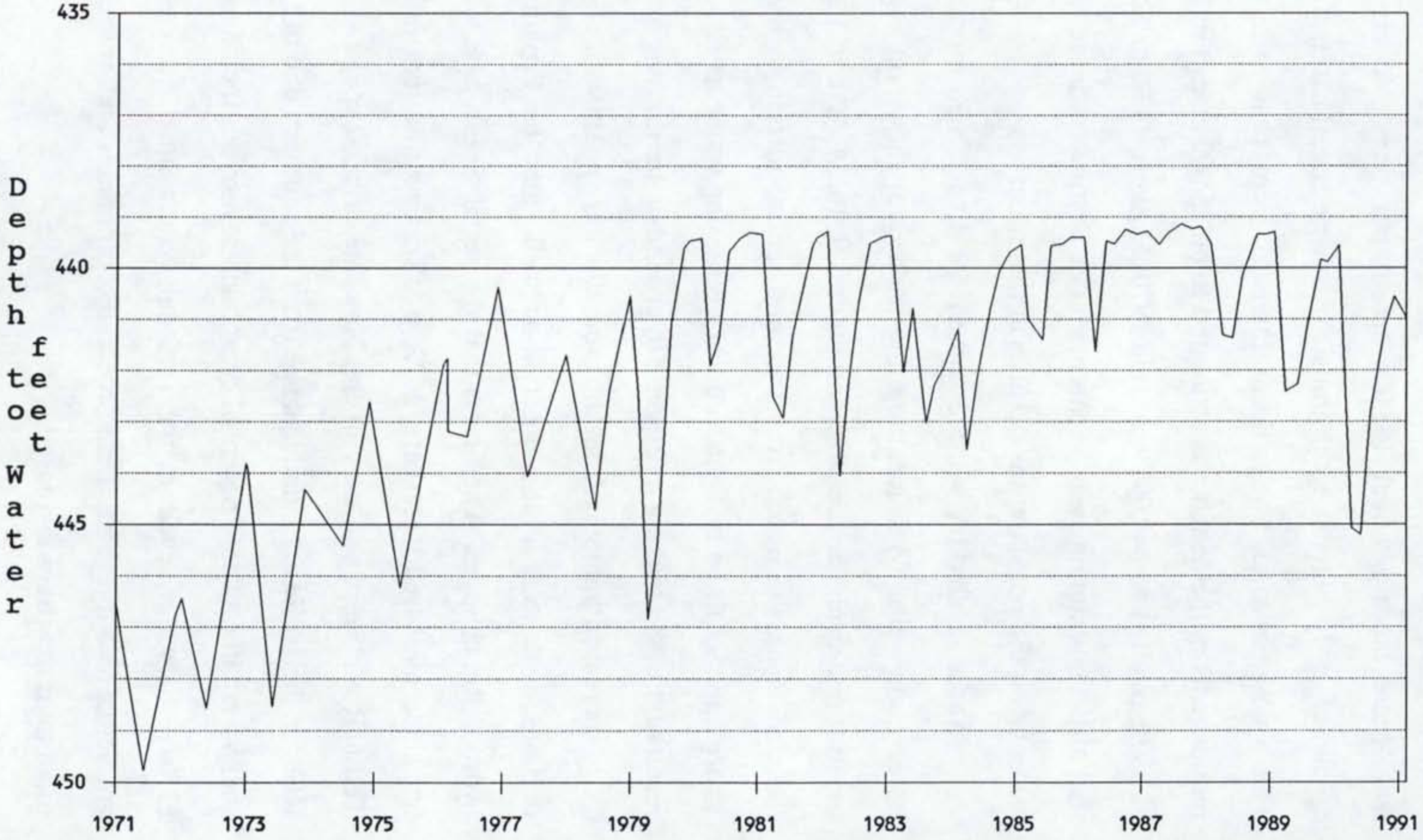


Figure 10. Hydrograph of Well 6N-41E-20cdb
Rexburg Bench Aquifer

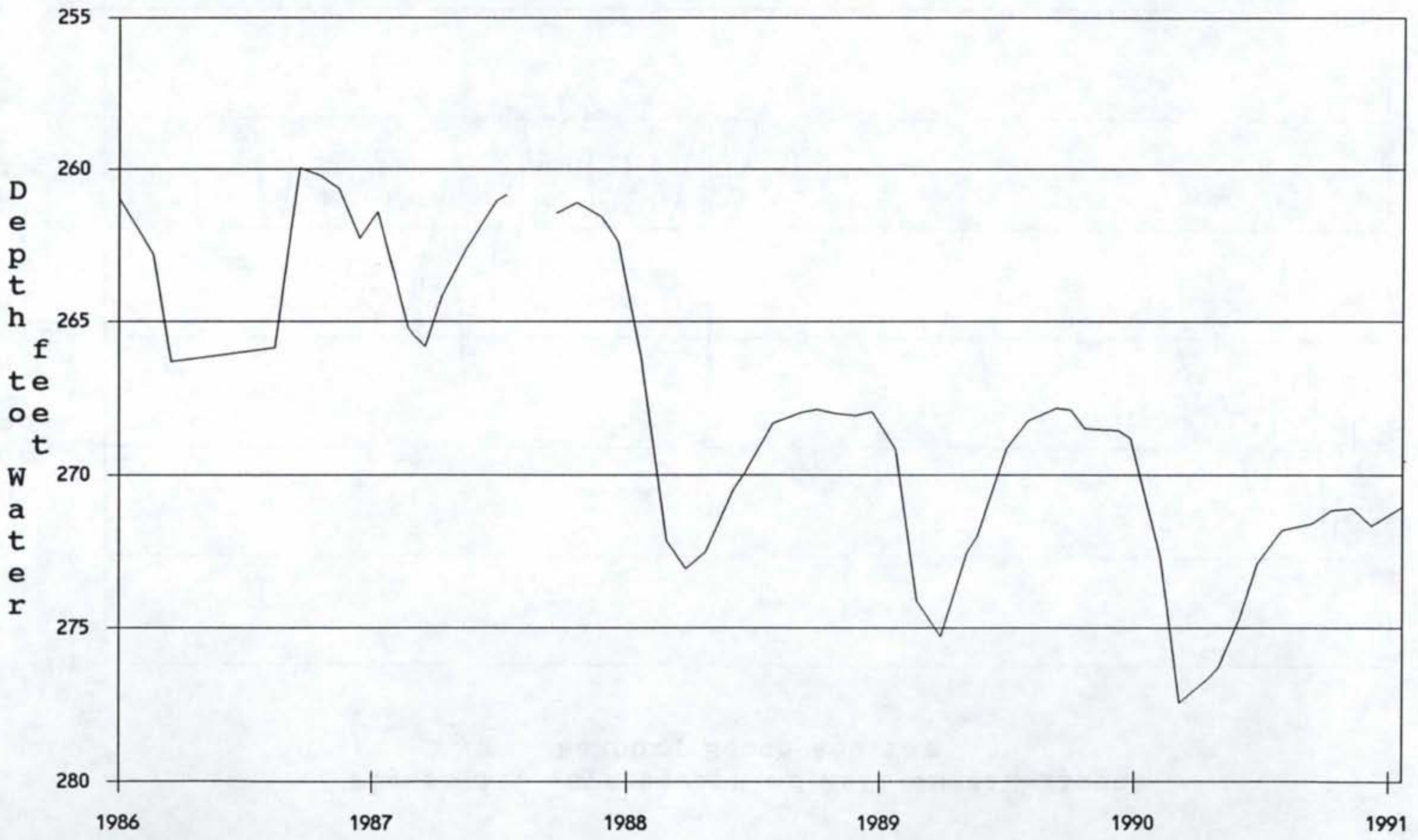


Figure 11. Hydrograph of Well 6N-41E-11cdb1
Rexburg Bench Aquifer

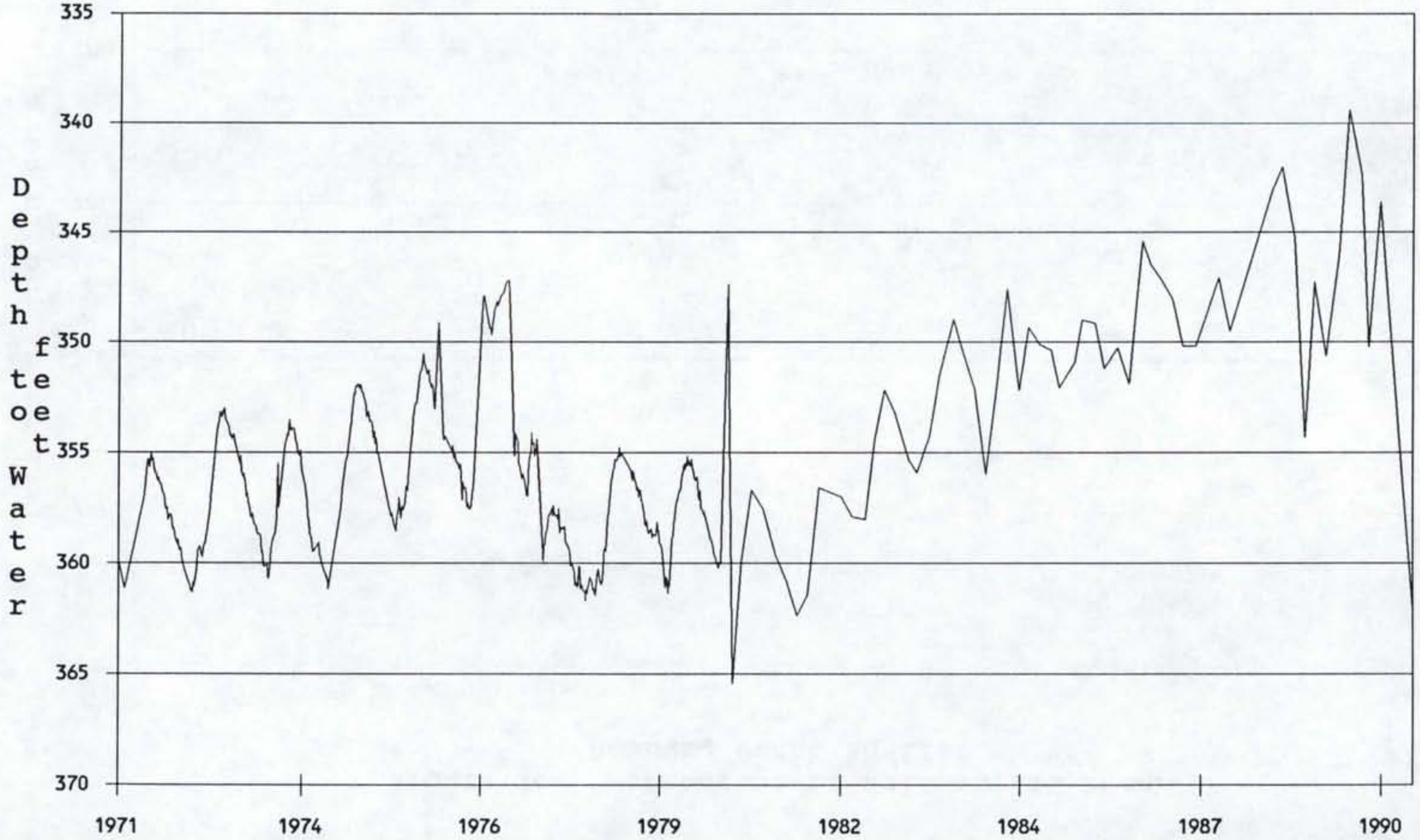


Figure 12. Hydrograph of Well 6N-41E-02bdc1
Rexburg Bench Aquifer

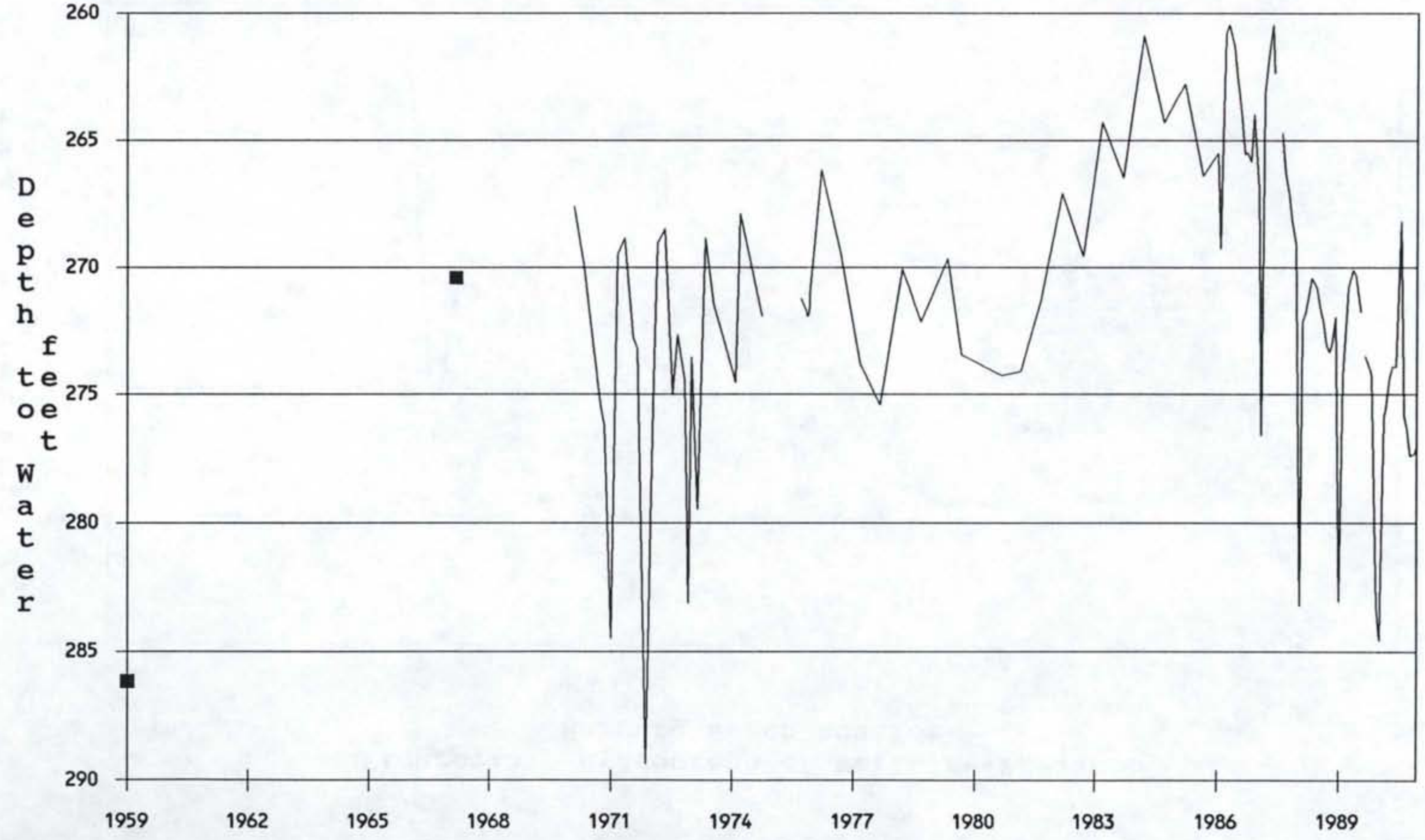
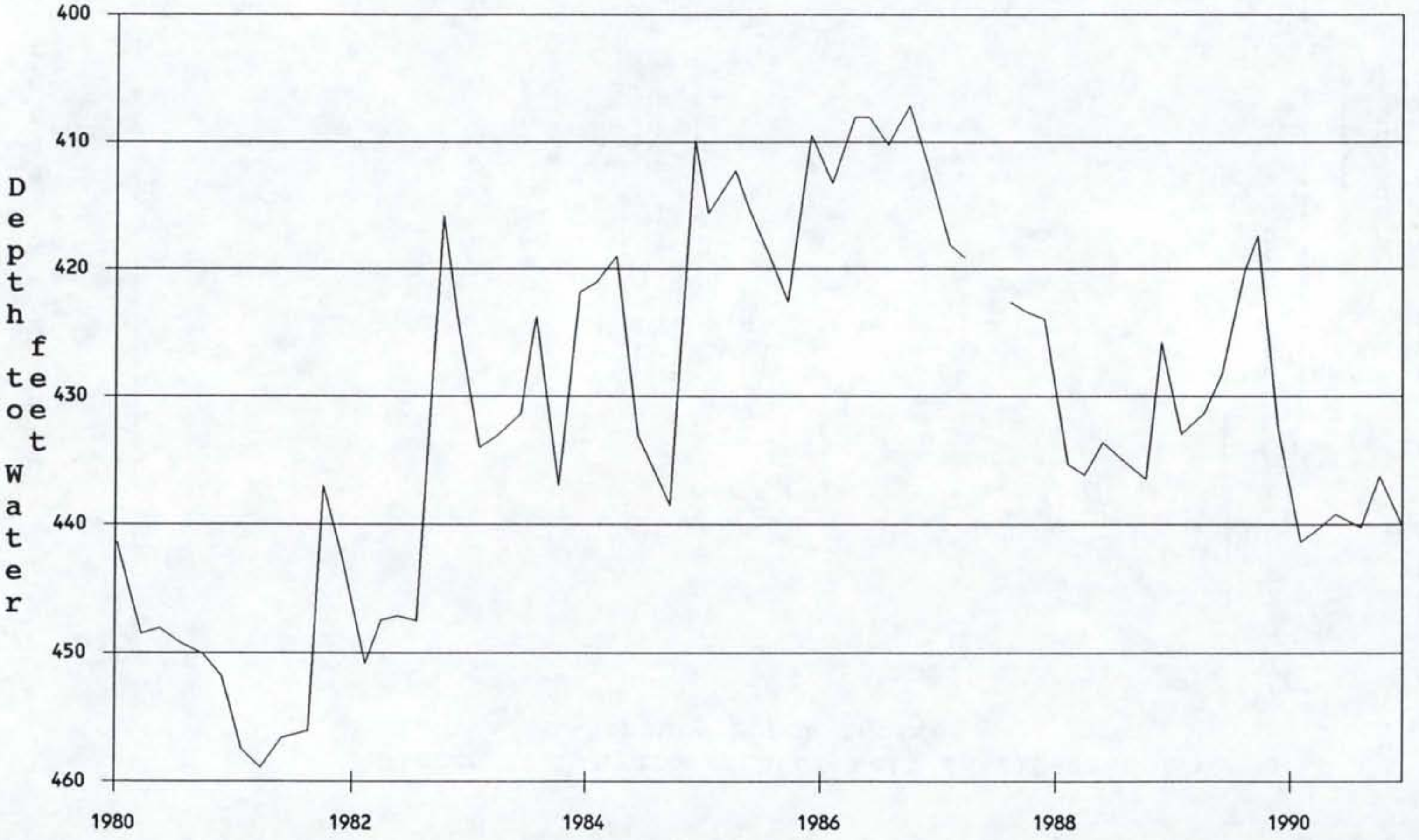


Figure 13. Hydrograph of Well 7N-42E-32bbb
Rexburg Bench Aquifer



is not unlikely that these wells are responding to water levels in both the regional Snake Plain Aquifer and the perched systems. If so, relatively steady measured water levels may be disguising an actual decrease in regional system water levels if the perched system water levels have increased. Increased perched water levels may have resulted from the increase in irrigated acreage and associated increase in deep percolation.

Impacts on the flow of Moody and Canyon Creeks, waters which serve Fremont-Madison members, are difficult to identify. Crosthwaite et al (1967, p. 38) addressed this potential but concluded that "If the surface and ground-water relationships are as postulated, the pumping generally will not affect streamflow within the Rexburg Bench." Haskett (1972) mapped the regional Snake Plain Aquifer water table as being far enough below Moody Creek so that no hydraulic connection could exist. Canyon Creek is presumed to have a similar relationship.

The perched systems on the Rexburg Bench do have an impact on the flows in Moody Creek. Springs that are apparently fed by these systems discharge in the creek. If recharge to the perched systems has increased, spring discharges have undoubtedly increased as well. On the other hand, if pumping from the perched systems is such that it offsets any increased recharge the spring discharges may actually have decreased. No discharge measurements on springs are available.

CONCLUSION

Irrigated acreage on the Rexburg Bench is about 49,700 acres. Annual ground-water drafting is estimated to be 147,000 acre-ft, which far exceeds a previous recharge estimate of about 35,000 acre-ft per year.

The effect on the ground-water regime could not be determined conclusively. Water levels in USGS-reported wells do not indicate definite long term trends.

Since impact on the ground-water regime could not be identified, neither can the effect on the Fremont-Madison water supply. It is postulated that the effect is minimal, but more detailed analysis needs to be done in order to reach defensible conclusions.

TETON BASIN

PURPOSE

Expansion of irrigated acreage and conversion from surface to sprinkler irrigation techniques in the Teton Basin may affect Teton River flows and water availability to Fremont-Madison. The purpose of this element of the investigation was to assess the magnitude of acreage and irrigation changes and estimate associated differences in Teton River flows with respect to both quantity and timing.

PROCEDURE

The location and magnitude of land use changes and conversion to sprinkler irrigation were first identified. Aquifer water levels and flows in the Teton River were obtained and reviewed in order to determine any apparent trends. Ground-water travel times from the areas of major irrigation changes to discharge areas were estimated. Hydrographs for the Teton River were analyzed for trends in both quantity and seasonal distribution. Travel times were then compared to the changes in seasonal hydrographs to confirm the results.

RESULTS

Land use and irrigation application method data were obtained from the USBR (D. McAndrew, personal communication). The definition of wet meadows and "river bottom" land presented a consistency problem when comparing current levels of irrigated acreage to historical data. Inconsistencies were similar to those reported for the Egin Bench. In addition, boundaries of the Teton Basin study area posed a problem. Figure 1 shows the generalized study area boundaries and those of Teton County. Acreage and crop data for Teton County were more easily compiled than those for the defined basin area, which includes lands in Wyoming. Past records only addressed the county as a whole. Hence, county data is presented first followed by current data for the Teton Basin study area.

In the mid 1960s, the USBR estimated that 49,700 acres were irrigated and about 81,000 acres dry-farmed in Teton County. In 1990, those values had changed to levels of about 98,400 acres irrigated and only 45,000 acres dry-farmed. This indicates an increase in cropped lands of about 12,700. The current irrigated acreage levels include about 39,700 acres of "wet meadow". It is presumed that the wet meadow areas have remained unchanged. Hence, "irrigated" acreage has increased by about 48,700 acres in Teton County.

County figures are probably more exaggerated with respect to increased acreage than for the Teton Basin itself. Past values are not available for the study area, but most of the conversion from dry land farming to irrigated agriculture has taken place north of the study area. Of the newly developed irrigated land, most is supplied with ground-water. Ground-water was reported as supplying only about 3,400 acres in Teton County during the mid 1960s, while it was estimated at about 20,000 acres for 1990.

Current levels of acreage in the Teton Basin study area show 17,500 acres of dry-farmed ground and 78,400 acres of irrigated lands. The entire 39,700 acres of "wet meadow" are found in the study area. They are again included in the irrigated acreage value. This leaves about 38,700 acres that are labeled as irrigated by the USBR.

Increased water use in the Teton Basin is difficult to define because of the lack of historic data. It was estimated that about 5,000 acres of land has been developed in the last 30 years or so (D. McAndrew, personal communication). Using a value of 1.5 acre-ft/acre of *increased* consumptive water use on newly developed lands in the Teton Basin (based on Allen and Brockway), approximately 7,500 acre-ft more water is consumed now than prior to about 1960. Since discharge from the basin measured at the gage above South Leigh Creek averages about 275,000 acre-ft per year for the period of record, the increased consumption is around 2.5% at that point in the river.

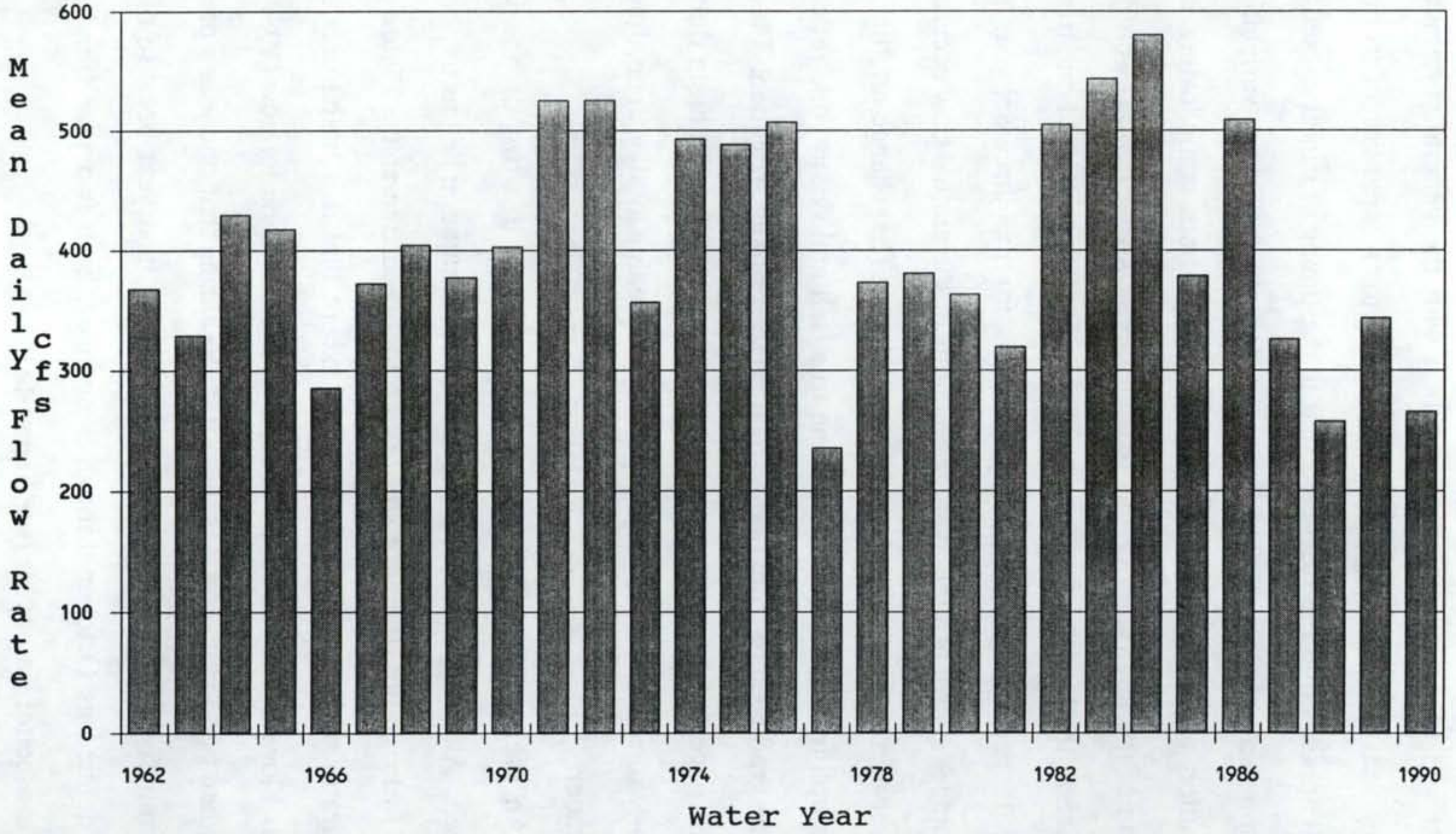
As on the Egin Bench, there has been a dramatic shift in water application from surface to sprinkler methods in the Teton Basin. About 32,550 acres of the irrigated acreage total, or about 84%, are sprinkler irrigated, leaving 6,150 acres (16%) irrigated by traditional surface methods. Prior to 1960 there was very little sprinkler irrigation.

Again assuming wet meadow land has not changed, the conversion of approximately 26,400 acres from surface or no irrigation to sprinkler methods has taken place. These changes affect the timing of basin outflow because in the past surface-waters used for gravity irrigation were diverted from the tributary creeks throughout the cropping season. The diversions were especially large in the spring. "Wild flooding" was practiced in order to raise the water table and thus make flood irrigation easier. These practices, and the conversion trend in general, are not unlike that seen on the Egin Bench.

Consumptive water use for the converted acreage is probably very nearly identical. The only significant effect on Teton River flows would be a change in timing. Lands converted from dry-farm to irrigation experience a slight increase in total water use, but the 5,000 acres or so of newly developed land effect a greater increase in consumptive use. New acreage will create a tempering of both spring runoff and yearly runoff, while sprinkler conversions will only create a shift of historical fall runoff to spring runoff.

Teton River flow data were obtained for the USGS's gage located above South Leigh Creek. It was chosen because of the location near the mouth of the basin, period of record, and availability. Figure 14 shows the mean daily flow for each year from 1962 through 1990. Although flows measured in the water years 1987 through 1990 were generally lower than the average over the period of record, a correlation

Figure 14. Annual Discharge
Teton River above South Leigh Creek



to increased acreage in the basin above the gage cannot be made. The effects of drought and other factors, in conjunction with the general variability shown, are indistinguishable from increased water use due to an expansion of cropped acreage.

It appears that the suspected shift in the timing of runoff caused by changes in irrigation methods is real. The effects of drought and yearly variability in seasonal distribution of precipitation to the basin were both complicating factors in this segment of the analysis. For this reason, three six year periods were first analyzed, one each at the beginning and end of the period of record and one from the middle. Figure 15 presents normalized hydrographs for the three six year periods. The percentages shown are the average fractions of the annual flow occurring in each of the twelve months for each six year period. The change in the shape of the hydrograph from a "short and fat" one to a "tall and skinny" one reflects, at least in part, the gradual shift from flood irrigation to sprinkler irrigation. Flow that used to pass the gage in late summer and winter is now leaving the basin during the spring and early summer. The trend is especially noticeable in May, June, July, August, and September.

An even more dramatic change is apparent if a two or one year period is analyzed. Although seasonal distribution of precipitation begins to play a larger role in the hydrographs, they are still representative of the shift. Figure 16 presents a hydrograph similar to that of Figure 15 except that it is based only on a two year period. Flows in May and June are shown to be 5% greater now (1989-90) than they were when flood irrigation was the norm. Realizing that one year's precipitation will affect runoff and ground-water discharge in the next year because of a water year being defined as October through September, both two year trends were from a lesser to a better water year (see Figure 14).

Figure 15. Seasonal Distribution of Discharge
Teton River above South Leigh Creek

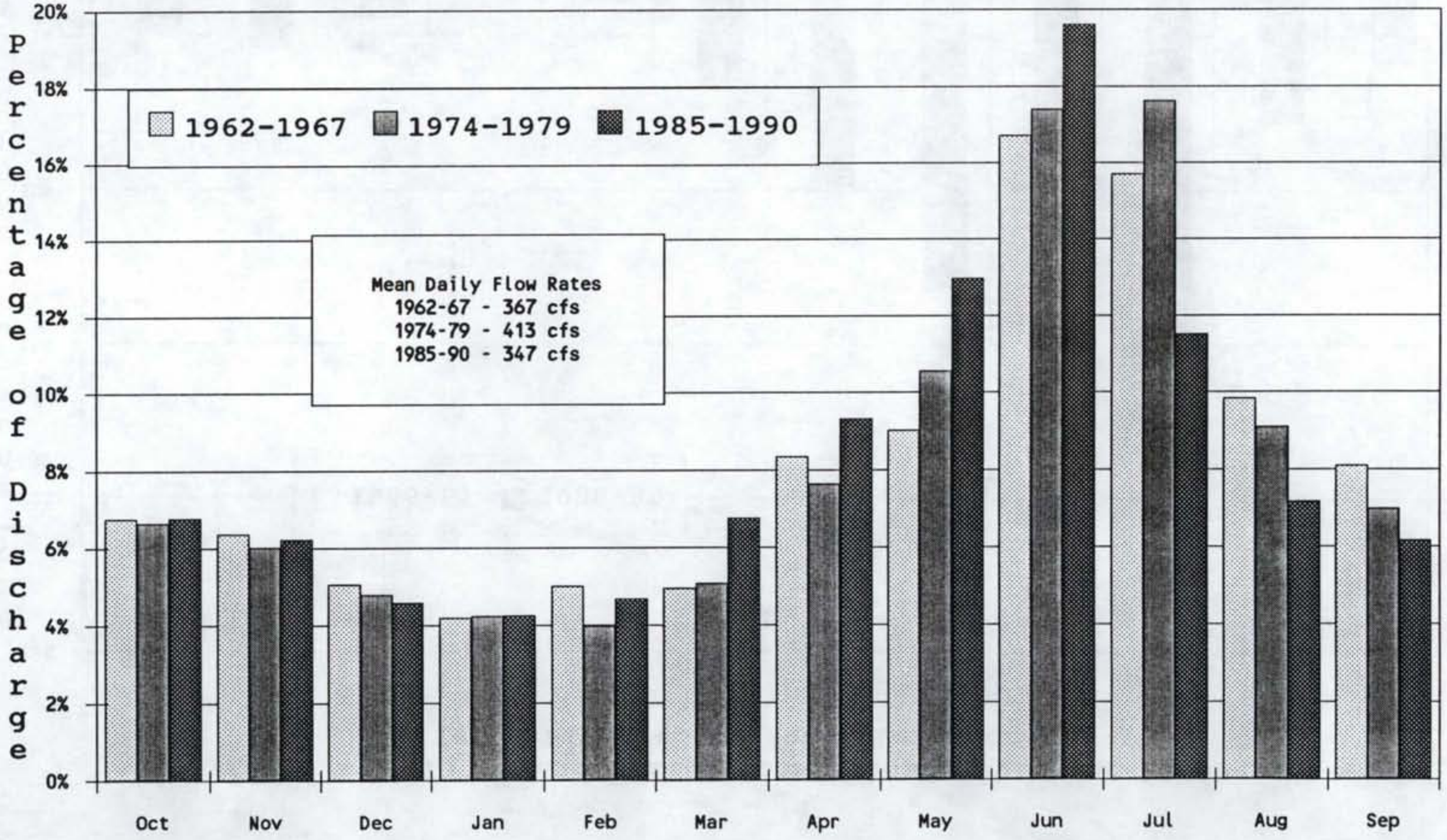
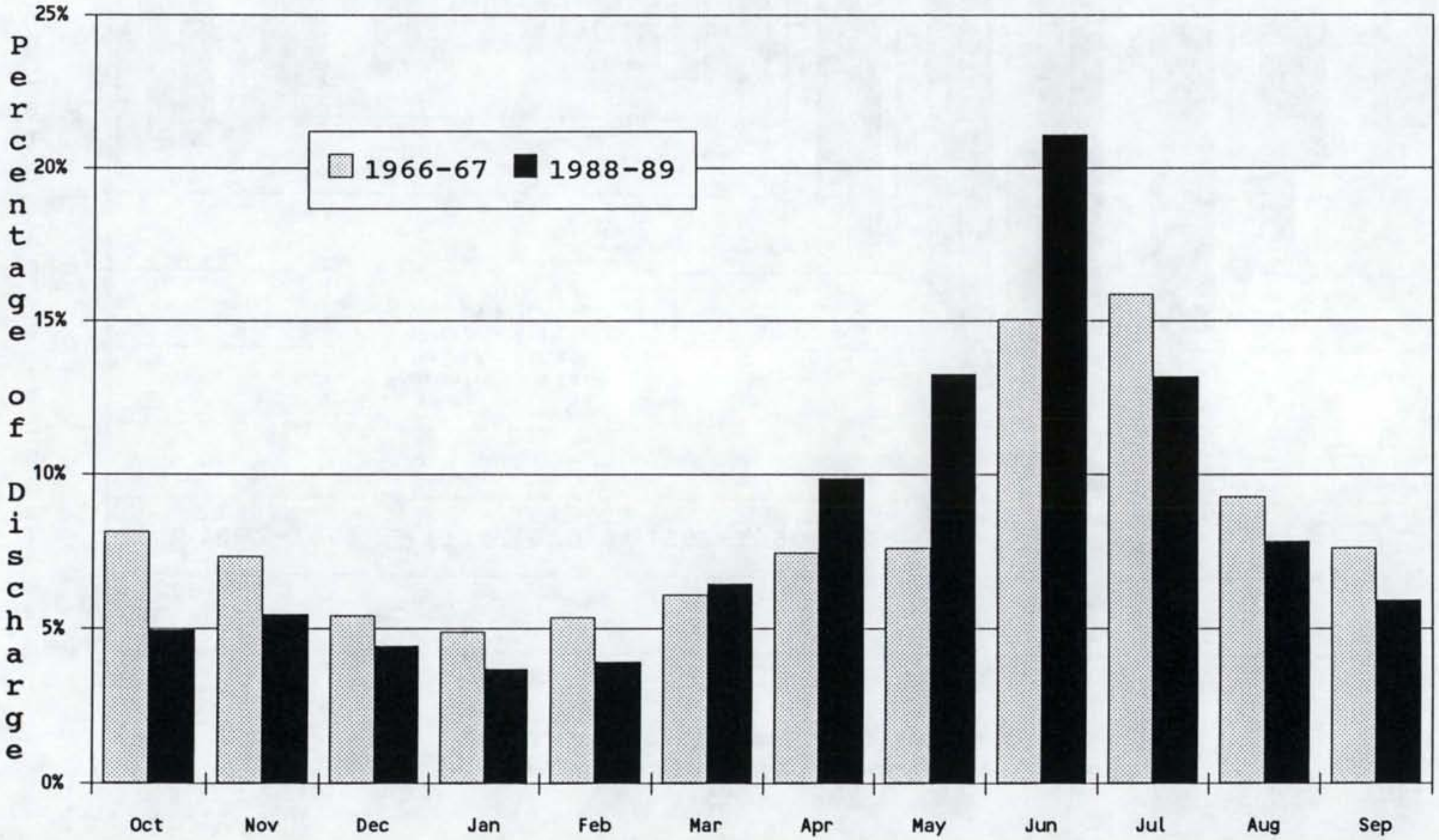


Figure 16. Difference in Seasonal Distribution of Discharge Teton River above South Leigh Creek



One year normalized hydrographs show the same trend. Figures 17, 18, and 19 show the trend for drought, average, and abundant water years at the extremes of the period of record. The most dramatic case is the 1966 and 1990 drought year comparison. In 1966, it appears the hydrograph peak was essentially diverted, with the majority of the surplus reaching the aquifer and resulting in the highest monthly flow occurring in October.

The actual ground-water analysis for the Teton Basin was hampered by limited data. Only two USGS observation wells have been consistently maintained in Teton County. Water level data for these two sites are shown in Figures 20 and 21. Monitoring intervals have been inconsistent since continuous recorder charts have been discontinued at various times. For example, the water levels presented for well 4N-45E-13ada may fail to show extremes for the period from about 1972 to 1978 since reporting dates were more than two months apart; whereas, the reporting interval prior to and after that period was only five days.

At both sites the greatest depth to water appears stable. Peak water levels may be declining, but this cannot be confirmed because of the large water monitoring interval.

In order to estimate a travel time for the waters that were historically percolated and now are not reaching the aquifer, a number of parameters needed to be established. Probably the most obvious of these is distance. The beginning point of an average path of travel was chosen near the Darby Creek observation well shown in Figure 1. This area was chosen because it is representative of the areas where the conversion has taken place and because the aquifer characteristics in the basin are based on a pumping test conducted at the same location. The end point was chosen as about one half mile from the Teton River. Some distance from the river was felt appropriate since Kilburn showed the lowest water table elevations to

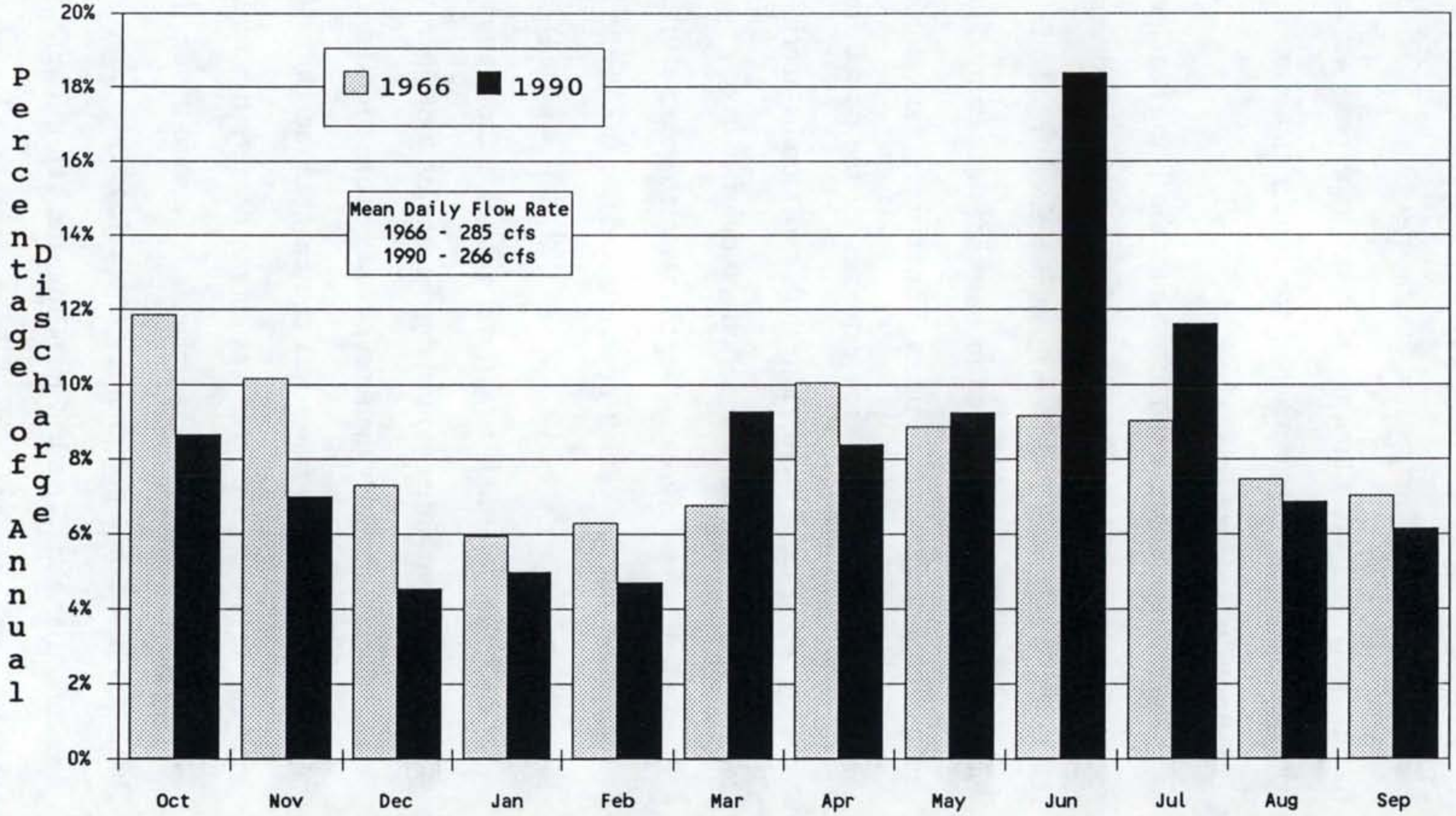


Figure 17. Difference in Seasonal Distribution of Discharge
Typical Dry Year
Teton River above South Leigh Creek

Figure 18. Difference in Seasonal Distribution of Discharge
Typical Average Year
Teton River above South Leigh Creek

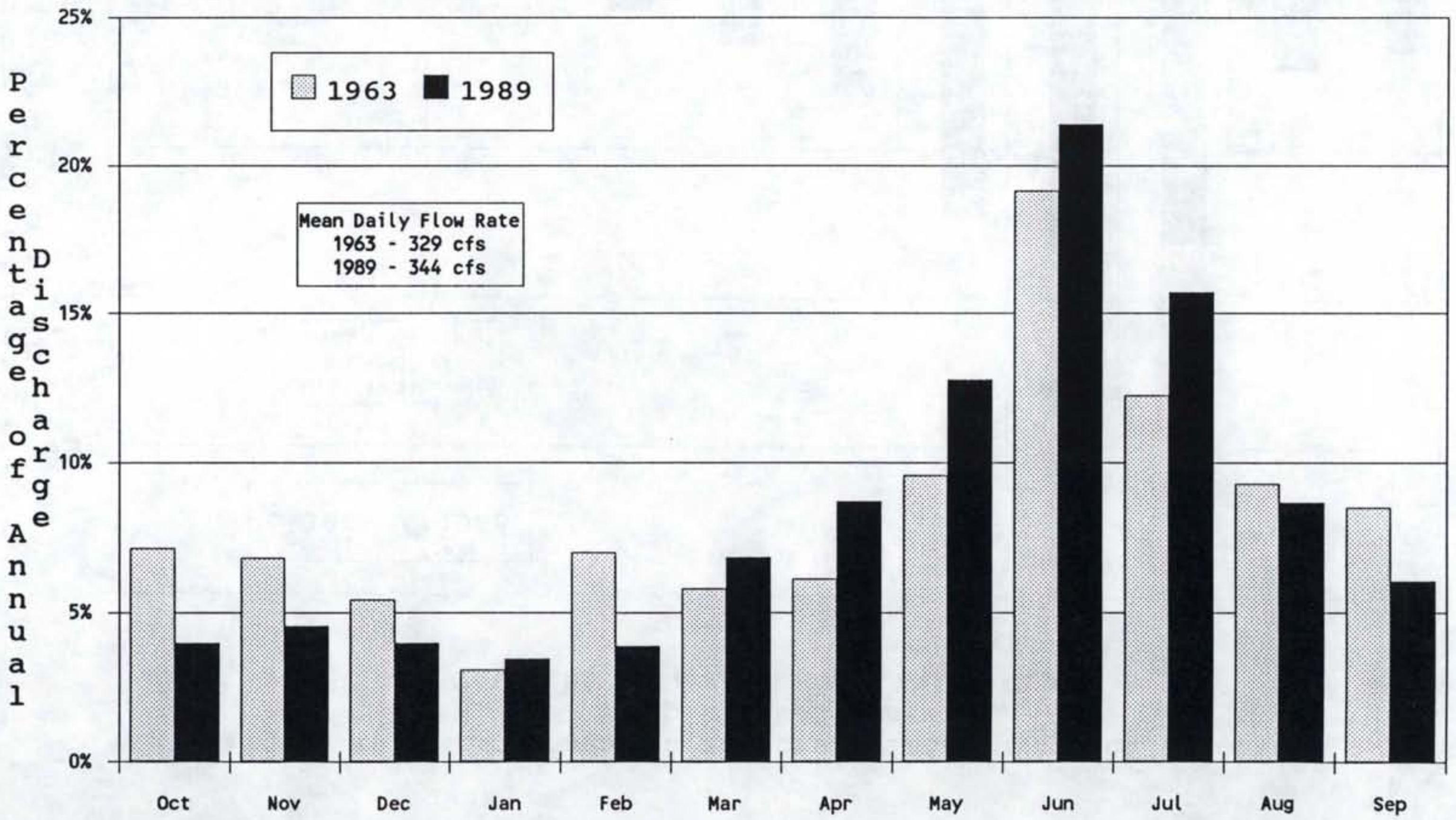


Figure 19. Difference in Seasonal Distribution of Discharge
Typical Wet Year
Teton River above South Leigh Creek

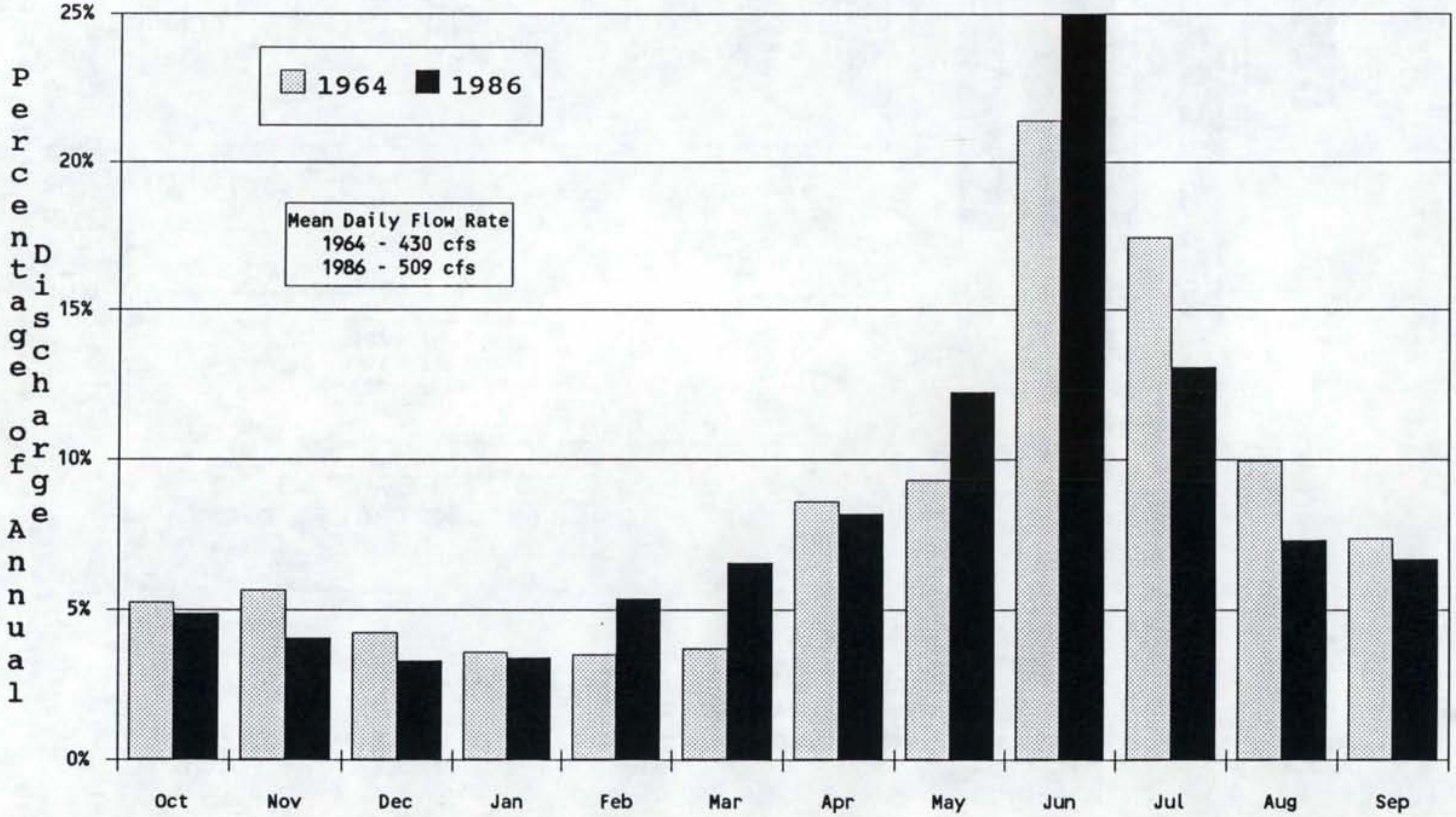


Figure 20. Hydrograph of Well 4N-45E-13ada
Teton Basin Aquifer

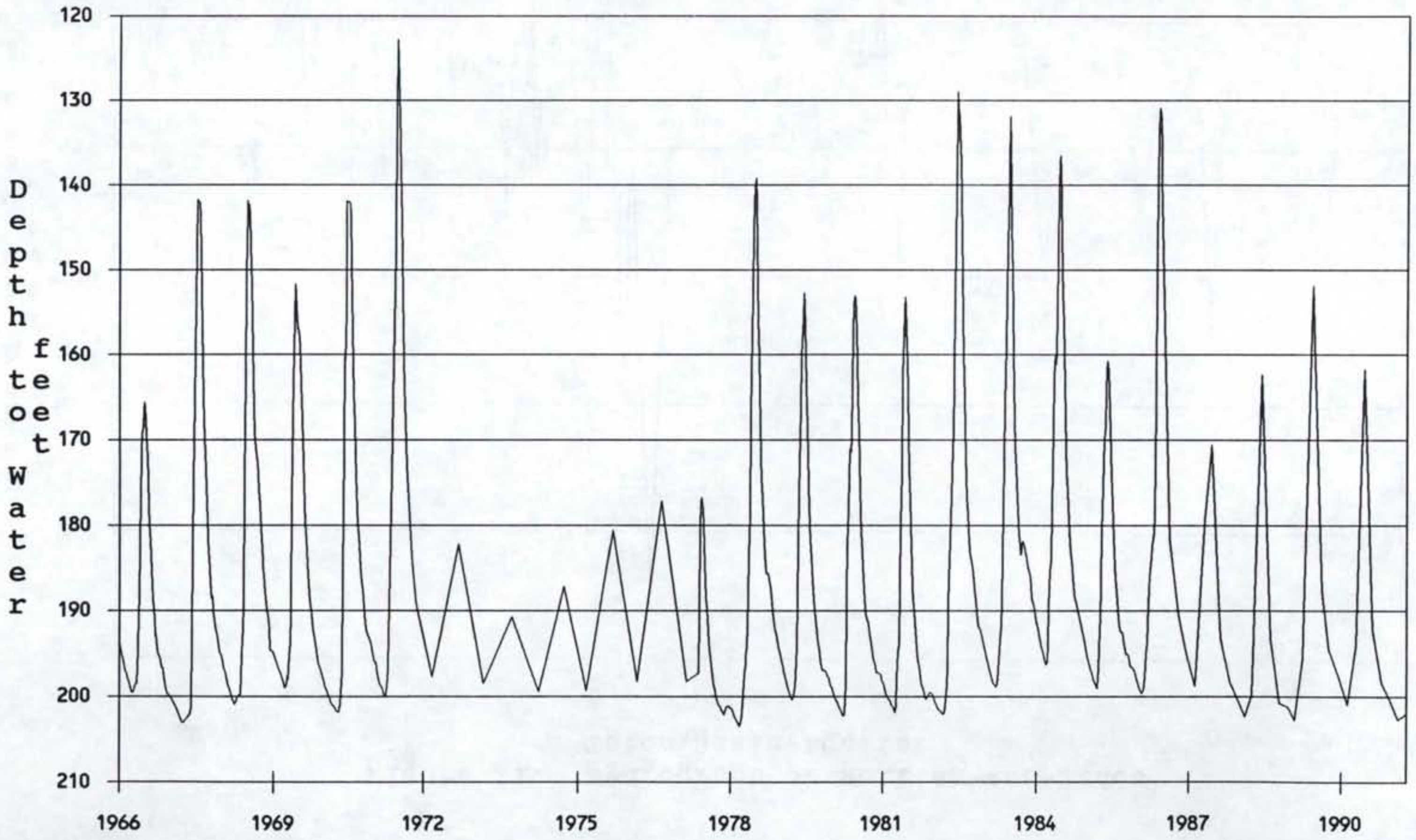
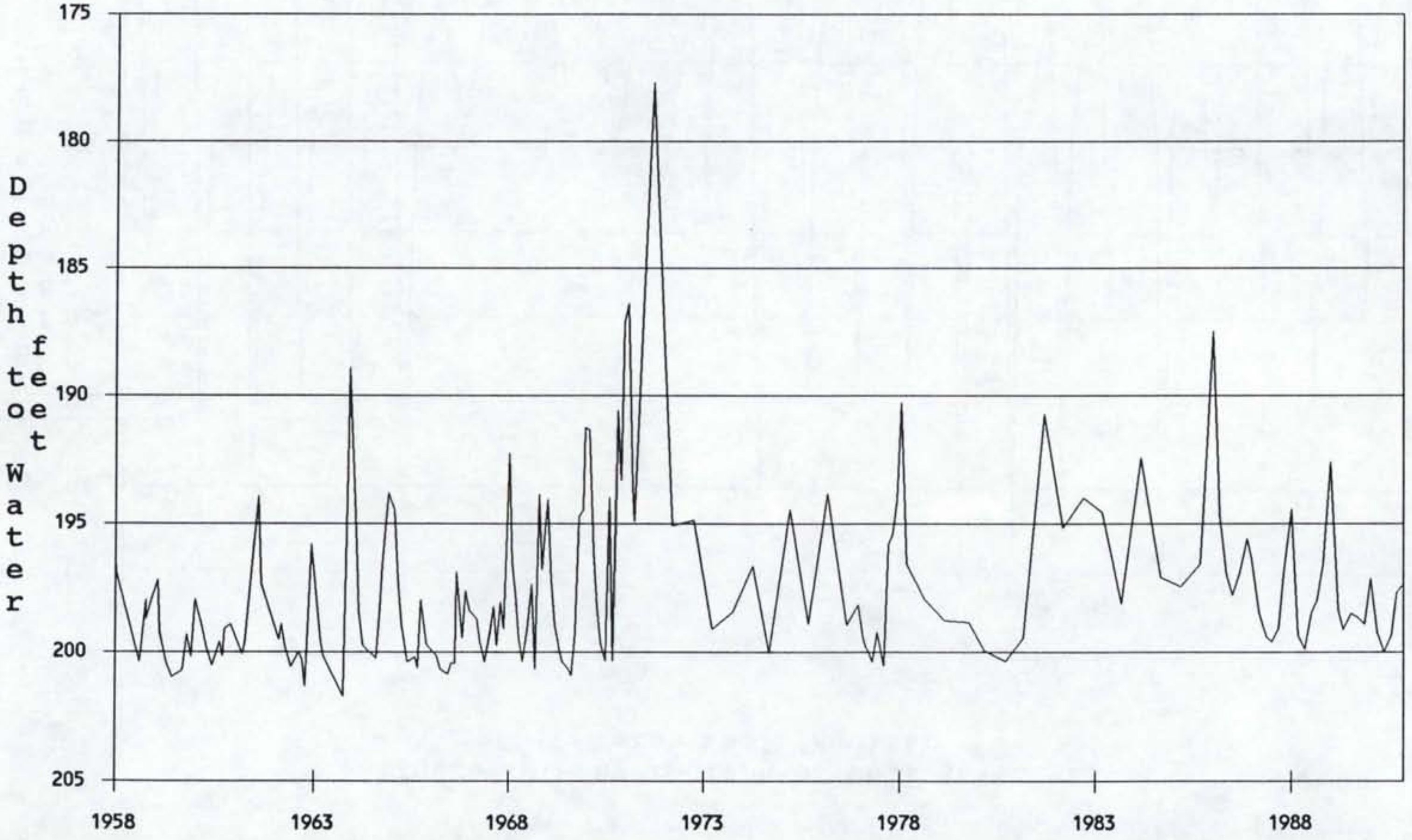


Figure 21. Hydrograph of Well 6N-44E-22ddc
Teton Basin Aquifer



be slightly east of the river and springs are prevalent in the wet meadows there. From these two "points", a travel distance of 2.5 miles was established.

Another required parameter is the gradient, or slope, of the water table along the given route. Although the gradient is highly variable throughout the year because of the differing ranges of water level fluctuations, a value of 80 ft/mile was chosen. Since the targeted water is applied during the irrigation season, the gradient to which the targeted water is subject is at or near the seasonal maximum. Gradients shown by Crosthwaite et al (1964, plate 4) are somewhat smaller, but they were developed from April data and are, therefore, not representative of summertime conditions.

The other required parameters are hydraulic conductivity and effective porosity of the aquifer. Hydraulic conductivity is an indicator of how easily the aquifer transmits water and effective porosity is the fraction of aquifer volume in which water can actually travel. Based on a 550,000 gpd/ft transmissivity reported by Kilburn (1964) and 75 feet of saturated thickness, the hydraulic conductivity was estimated to be about 1000 ft/day. This is a fairly gross estimate since it is based on only one aquifer pumping test. For the alluvial material in the area, an effective porosity of about .15 was determined. Effective porosities are generally greater for gravels and sands than for clays.

Based on the above determinations, the actual velocity of travel for the waters is probably about 100 ft/day. Given the 2.5 mile travel route, then, the time it would take is about 120 days, or four months. In general, this value corresponds to the changes seen in the Teton River's runoff in the Teton Basin. Changes in the hydrograph are spread out over a number of months, but the travel time calculated is meant to represent an average. Actual travel times will vary with area of water application, water table gradients, and aquifer characteristics so that discharge will also be spread out over many months.

CONCLUSIONS

Long range decreases in outflows from the Teton Basin cannot be certainly identified from flow records at the Above South Leigh Creek gaging station. However, increases in cropped acreage in the Teton Basin are estimated to be about 5,000 acres more now than in the mid 1960s. This acreage is estimated to consumptively use about 7,500 acre-ft of water which would otherwise have reached the Teton River. Most of the new acreage in the Teton Basin, and the whole of Teton County, appears to be supplied with ground-water. These changes will impact Fremont-Madison by decreasing flows in the Teton River.

Conversion to sprinkler irrigation methods since the mid 1960s is significant. About 31,000 acres in the basin are now sprinkler irrigated. This compares to only about 6,000 acres that are irrigated with the more traditional gravity methods. This massive conversion appears to have created a change in the seasonal distribution of flows in the Teton River near the basin's mouth. A higher percentage of annual flow is occurring in the spring and early summer, especially May and June, than historically. A corresponding decrease in late summer and fall flows is evident. These changes create an impact on the timing of water supplies for Fremont-Madison. By shifting more runoff to the spring, which may not be useable to Fremont-Madison, and decreasing late season flows that would provide natural flow, the ultimate effect is a decrease in total water supply.

The travel time of water historically applied with surface irrigation methods generally agrees with the changes seen in the hydrograph. The average travel time is estimated to be four months.

SUMMARY

There are six significant ground-water bodies found within the Fremont-Madison service area. The most widely known is the Eastern Snake Plain Aquifer, which underlies most of the Snake River Plain from Hagerman eastward. The

Rexburg Bench aquifer system is closely related hydrologically to the Snake Plain Aquifer. An alluvial valley-fill aquifer underlies the Teton Basin. The other three are local systems recharged primarily by stream seepage and deep percolation of irrigation water. The largest is found in the Rexburg-St. Anthony-Newdale area where the South and North Forks of the Teton River are located. This shallow body is often called the lower Henry's Fork perched aquifer. The next most extensive shallow system, often considered part of the lower Henry's Fork system, underlies the Egin Bench. A perched system in the Ashton area lies between the Falls River and the Henry's Fork.

River flows are probably not measurably affected by operation of USBR exchange wells in the Fremont-Madison service area. Any affects on the shallow aquifers are localized and result from increased head differences between the shallow system and the Snake Plain Aquifer. The increased leakage could possibly affect river flows but only to a slight degree.

Even if the impacts were significant the well locations are generally downstream of Fremont-Madison diversions and therefore would not directly affect physical water supplies. In addition, actual pumping of these wells has been infrequent.

Impacts of the private exchange wells are more uncertain than those for the USBR wells. It appears that some of the wells have been developed only in the Snake Plain Aquifer while others appear to be drawing from the shallow system, too. The ground-water source for some wells could not be determined.

Wells that are developed solely in the Snake Plain Aquifer probably do not have a significant impact on surface-waters in the Fremont-Madison service area.

Those developed at least partially in the shallow aquifer will have a direct effect on the nearby stream if they are in a location where the river and the shallow aquifer are hydraulically connected. There is generally no hydraulic connection in any of the well locations for most of the year, but there seems to be potential for those conditions at and downstream of the Hoopes Bros.-Ehco Ranch-Ricks group in late summer when water levels reach their peak. The significance of their impact is dependent upon pumping capacity and operation.

Wells developed at least partially in the shallow aquifer will have an indirect effect on stream flows in the lower reaches of the South Fork of the Teton River and the Henry's Fork. The impact will be reduced ground-water recharge to the surface-waters by the amount that was pumped from the shallow system and which would not have been otherwise lost from the shallow system. Other paths for the pumped water are leakage to the deeper Snake Plain Aquifer and evapotranspiration in the lower parts of the Teton Island.

Considering the potentially impacted stream reaches, surface-water effects would probably not significantly effect Fremont-Madison's physical water supply. However, changes in the shallow ground-water regime catalyzed by exchange well pumping may cause difficulties with sub irrigation practices in the lower Teton Island.

It appears that total diversions to the Egin Bench are decreasing slightly. New winter diversion practices are probably a primary reason but decreasing summer time diversions seem apparent, too. Rapid conversion to sprinkler irrigation methods has proceeded since 1987 and is likely a driving factor in the decreased diversions. Increased surface return flows from the bench are probably signs of the decreased demand at the farm headgate that accompanies the change in application method.

A result of decreased summer diversions is increased flows remaining in the Henry's Fork and thereby greater physical supply to those diversions downstream of the Egin Bench canals' headworks.

Water levels in the shallow aquifer system on Egin Bench and the underlying Snake Plain Aquifer appear to be decreasing. Lower minimum elevations occurring in the winter months are especially apparent. Probable increases in main canal and lateral seepage and increased gravity applications do not appear sufficient to offset decreased winter recharge and impacts of sprinkler irrigation. Seepage to the Henry's Fork and the Snake Plain Aquifer have likely decreased as a result.

Impacts on ground-water inflow to the Henry's Fork will not significantly affect Fremont-Madison's physical water supply since the primary areas of recharge to Henry's Fork are downstream of Fremont-Madison member diversions.

Irrigated acreage on the Rexburg Bench has increased to a level of about 49,700 acres. Annual ground-water drafting is estimated to be 147,000 acre-ft, which far exceeds a previous recharge estimate of about 35,000 acre-ft per year.

The effect on the ground-water regime could not be determined conclusively. Water levels in USGS-reported wells do not indicate conclusive long term trends.

Since impact on the ground-water regime could not be identified, neither can the effect on the Fremont-Madison water supply. It is postulated that the effect is minimal, but more detailed analysis needs to be done in order to reach defensible conclusions.

Long range decreases in outflows from the Teton Basin cannot be definitely identified from flow records at the Above South Leigh Creek gaging station. However, increases in cropped acreage since the mid 1960s are estimated to total about 5,000 acres. This acreage is estimated to consumptively use about 7,500 acre-ft of water which would otherwise have reached the Teton River. Most of the new acreage in the Teton Basin, and the whole of Teton County, appears to be supplied with ground-water. These changes will impact Fremont-Madison by decreasing flows in the Teton River throughout the year.

Conversion to sprinkler irrigation methods since the mid 1960s is significant. About 31,000 acres in the basin are now sprinkler irrigated. This compares to only about 6,000 acres that are irrigated with the more traditional gravity methods. The extensive conversion appears to have created a change in the seasonal distribution of flows in the Teton River near the basin mouth. A higher percentage of annual flow is occurring in the spring and early summer, especially May and June, than has occurred historically. A corresponding decrease in late summer and fall flows is evident. These changes create an impact on the timing of water supplies for Fremont-Madison. By shifting more runoff to the spring, which may not be useable to Fremont-Madison, and decreasing late season flows the ultimate effect may be a decrease in total water supply.

The travel time of water historically applied with surface irrigation methods generally agrees with the changes seen in the hydrograph. The average travel time is estimated to be four months.

RECOMMENDATIONS

In the course of this cursory investigation certain ground-water concerns that have the potential to impact Fremont-Madison Irrigation District member water supplies were identified. Some obviously have greater impact than others. The following recommendations for further study are based on the findings of this study and are presented on two levels. Only areas of significant potential impact to Fremont-Madison are included. The first level is composed of areas that are amenable to relatively inexpensive studies that are likely to produce definitive results.

Ground—water Exchange Wells

1. Each of the exchange wells for which well construction data was not obtained should be analyzed for potential shallow water drafting.

2. Wells found on the South Fork of the Teton River and downstream of the Ricks-Hoopes Bros.-Ehco Ranch group may be intercepting water flowing to the river or drawing water from the river when the shallow aquifer system reaches its peak in late summer. Their ground-water source should be definitively identified. Water level monitoring and possibly pumping tests should be conducted at these sites in order to determine if an hydraulic connection exists between the river and the shallow aquifer.
3. Exchange wells found on the Falls River (Loosli) and Canyon Creek (Steveco Canyon) should be examined to determine the extent that they are pumping waters that would otherwise naturally reach surface-water supplies upstream of Fremont-Madison member diversions.

Egin Bench

1. The entire ground-water regime should be watched closely in the ensuing years. Diversion and return flow data should be monitored closely as well. Since winter diversion reductions are relatively new and conversion to sprinkler irrigation has been very rapid in the last few years, the potential impact of these changes is difficult to define. Diversion curtailments to the bench have the greatest potential to impact the Fremont-Madison water supply but ground-water changes on Egin Bench have the potential to affect downstream Water District 01 users and ground-water conditions in the Snake Plain Aquifer.
2. The feasibility of installing a river gaging station above the North Fork of the Teton River should be determined. A gage there could help establish magnitude and trends in gains to the Henry's Fork from Egin Bench.

The second level presents areas of study that involve and/or address situations that are very complex and would be difficult to define, thus demanding substantial resources.

Rexburg Bench

1. The extent of perched aquifer systems on the bench needs to be established.
2. The extent and source of pumping needs to be better identified and analyzed.
3. The current condition of the regional Snake Plain Aquifer under the Rexburg Bench needs to be reassessed, especially with respect to gradients and flow direction.

Teton Basin

1. The ground-water system in the Teton Basin should be reexamined and defined. Kilburn's (1964) work is about 30 years old and significant changes in land use and irrigation methods have occurred since then. Ground-water flow needs to be better understood, especially with respect to discharge to the Teton River in the basin and valley underflow. Additional pumping tests to define aquifer characteristics should be performed.
2. Irrigated agriculture north of the defined study area should be examined in order to assess impacts on Fremont-Madison. Much of the increased irrigated acreage in Teton County appears to be in that area, with most tapping ground-water supplies.
3. A comparison of precipitation in the basin, cropped acreage, and runoff could be made to detect any correlations that might serve to substantiate suspected impacts of increased acreage and changes in irrigation methods.
4. A ground-water model could be developed that would better define effects of changes in land use and irrigation methods. The model could be used to determine and manage surface-water supplies in the basin, possibly under conjunctive management with ground-waters.

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