Table III-6
Expected
Farm Irrigation System Efficiencies, E_{is}
Related to Slope, Irrigation Requirement and Intake Rate[1/]

S Slope (ft./ft.)	D_u Req't (in.)	Intake Family, I 0.3	0.5	1.0	1.5	2.0	3.0	4.0
0 to 0.01	0 to 1.5	.45	.50	.55	.55	.55	.55	.55
	>1.5 to 2.5	.45	.50	.55	.55	.55	.60	.60
	>2.5 to 3.5	.40	.55	.60	.60	.60	.60	.60
	>3.5 to 4.5	.30	.55	.60	.60	.60	.60	.60
	>4.5 to 5.5	.30	.55	.60	.60	.60	.30	.30
>0.01 to 0.03	0 to 1.5	.30	.30	.45	.50	.50	.50	.30
	>1.5 to 2.5	.30	.30	.45	.50	.50	.55	.50
	>2.5 to 3.5	.30	.30	.45	.55	.55	.55	.50
	>3.5 to 4.5	.30	.30	.40	.55	.55	.55	.50
	>4.5 to 5.5	.30	.30	.30	.55	.55	.30	.30
>0.03 to 0.05	0 to 1.5	.30	.30	.45	.50	.50	.50	.30
	>1.5 to 2.5	.30	.30	.45	.50	.50	.55	.50
	>2.5 to 3.5	.30	.30	.45	.55	.55	.55	.50
	>3.5 to 4.5	.30	.30	.40	.55	.55	.55	.50
	>4.5 to 5.5	.30	.30	.30	.55	.55	.30	.50
>0.05	0 to 1.5	.30	.30	.30	.40	.30	.30	.30
	>1.5 to 2.5	.30	.30	.30	.40	.45	.30	.30
	>2.5 to 3.5	.30	.30	.30	.45	.45	.30	.30
	>3.5 to 4.5	.30	.30	.30	.40	.45	.30	.30
	>4.5 to 5.5	.30	.30	.30	.30	.30	.30	.30

1/ Adapted from USDA (1974), by reducing each "attainable" efficiency value by 0.10 and filling blank spaces with 0.30.

Table III-7

Base Values of Farm Irrigation System Efficiency, E_{is}, in Study Area

Irrig. Area No.[1/]	No. of model grid points	Mean E_{is}	Irrig. Area No.	No. of model grid points	Mean E_{is}
2	12	0.45	21	11	0.46
3	1	0.45	22	4	0.50
4	90	0.31	23	1	0.55
5	3	0.45	24	3	0.45
7	6	0.45	25	17	0.42
8	11	0.45	26	3	0.45
9	21	0.45	27	3	0.45
10	3	0.45	28	16	0.46
11	5	0.45	29	2	0.45
12	6	0.45	30	5	0.45
13	3	0.45	31	24	0.43
14	19	0.44	32	3	0.45
15	3	0.45	33	2	0.45
16	1	0.45	34	2	0.45
17	4	0.45	36	7	0.43
18	8	0.45	37	1	0.45
19	1	0.45	38	32	0.45
20	13	0.47	39	19	0.45

[1/] Identified in computer model.

First, select an appropriate base farm irrigation system efficiency, E_{is}, from Table 7 which is to be adjusted in accord with level of supply. Then calculate:

$$R = \frac{D_u}{D_d}$$

where D_u is the requirement at the time of irrigation and D_d is the amount of water delivered. The units of requirement and water delivered are depth or volume per unit area. Three levels of supply are considered.

<u>Case I</u> $E_{is} \geq R$; $D_d > D_u$

This implies that an excess of water over that required for good irrigation is available. All in excess is lost. Therefore,

$$D_\ell = D_d - D_u$$

where D_ℓ is the water lost, in the same units as D_d and D_u.

<u>Case II</u> $E_{is} < R$; $D_d > D_u$

This implies that there is not sufficient water to meet the requirement, although there could be enough if the irrigation efficiency were increased. Make an adjustment to the base efficiency by calculating a new value of field irrigation system efficiency.

$$E_{is}' = E_{is} + 0.2\,[D_u/E_{is}) - D_d]/[(D_u/E_{is}) - D_u]$$

where E_{is}' is the adjusted value of E_{is}. The losses are calculated as follows:

$$D_\ell = (1 - E_{is}')\,D_d$$

It is to be noted that the above calculation limits the value of E_{is}' to a maximum of $E_{is} + 0.2$.

<u>Case III</u> $E_{is} < R$; $D_d \leq D_u$

Water has become even more limiting. The maximum possible value of irrigation efficiency is used, and this is the base value plus 0.2 Thus,

$$D_\ell = (0.8 - E_{is})\,D_d$$

Farm irrigation efficiencies used in this study were selected by determining the level of supply for each model grid point and making the foregoing adjustment to the base efficiency for that point.

Allocation of lost water to runoff and deep seepage. No attempt was made to determine whether lost water ran off or whether it went into deep seepage. On the flatter lands it is probable that most lost water goes into seepage or is evaporated. This is because if it is reused by the farmer, it probably goes into a borrow pit, and only those fields on the edge of an irrigated area would have runoff into another area. On the steeper lands this may not be the case. There is some evidence in the study area that water passes on down the hillside and is collected in the next lower irrigation canal. The amount of direct reuse of this type is a refinement that should be worked into the model as soon as the quantities can be better identified.

Canal and reservoir system efficiencies. Most of the canal systems and one of the three reservoirs in the study reach overlie the South Platte alluvium. Seepage losses from these result in an immediate recharge to the aquifer. This has been effectively shown by the monitoring of ground-water levels in the vicinity of the Sand Hill lateral of the South Platte Ditch in a demonstration recharge project (Colorado Division of Water Resources, 1977). However, portions of the North Sterling Reservoir Inlet Canal, the North Sterling Reservoir itself, and nearly all of the outlet canal overlie other geologic formations (Pierre shale, White River group and the Ogallala formation). Also, portions of the Julesburg Reservoir inlet canal, the Julesburg Reservoir itself and all of the Highline Canal overlie the White River group and/or the Ogallala formation. These formations, in general, have lower permeabilities than does the alluvium.

Very little published information on canal and reservoir losses or system efficiencies in the study reach are available. Therefore, canal and reservoir company personnel were interviewed to obtain information on their systems. Those interviewed were:

Paris Accomasso - - - -	Davis Bros. & Schneider Ditches
Charles Barttlett - - -	South Platte Ditch
Bud Bonesteel - - - -	Julesburg Irrig. District, including Harmony No. 1, Settlers and Peterson Ditches
Don Demers- - - - - - -	Ramsey Ditch

Tom DeSoto- - - - - - - Peoples (Farmers) Ditch
Tom Frame - - - - - - - Red Lion Supply Ditch
Marvin Gardner- - - - - Tamarack Ditch
John Held - - - - - - - Bravo Ditch
William Huey- - - - - - Iliff and Platte Valley Ditch
Alfred Leckler- - - - - Springdale Ditch
Don Liddle- - - - - - - Liddle Ditch
David Littler - - - - - Pawnee Ditch
Bob Littler - - - - - - Water Commissioner
George Meyerholz- - - - Sterling No. 1 Canal
Alex Michel - - - - - - North Sterling System
Hub Reichelt- - - - - - Carlson Ditch
Scalva Bros.- - - - - - Henderson & Smith Ditch
Albert Workman- - - - - Lowline Ditch

The following paragraphs summarize information about the individual ditch and reservoir companies in the study reach obtained from those interviewed plus other sources.

North Sterling Irrigation System. The North Sterling Reservoir inlet canal diverts from the South Platte River at a point 3 miles upstream from the Balzac gaging station. The system lies north of the river and consists of the inlet canal of about 56 miles in length, the North Sterling Reservoir (also known as the Point of Rocks Reservoir) and an outlet canal of also about 56 miles in length. The outlet canal delivers water to over 40,000 acres of irrigated land, much of which is served from several privately owned and operated laterals. The North Sterling outlet canal is the highest canal on the north side of the study reach, paralleling the river at a distance of 6 to 7 miles. The average annual diversion by the North Sterling inlet canal during the 15-year study period was 92,400 acre-feet, varying from a low of 50,200 acre-feet in 1956 to a high of 165,300 acre-feet in 1957 (USBR, 1965). Releases from the North Sterling Reservoir during the same period average 67,100 acre-feet (USBR, 1965). On the surface, these figures indicate an average efficiency of water delivery to the outlet of the North Sterling Reservoir compared to the river diversions of about 73 percent. However, another factor which needs to be considered in this calculation is the difference in the amount of water stored in the North Sterling Reservoir between the beginning of the period and the end. Records indicate that 32,700 acre-feet more water was in the reservoir on January 1, 1962, as compared to January 1, 1947. Cranking an average annual change in storage of +2200 acre feet into an efficiency calculation indicates 75%

efficiency between the point of diversion and the point of release from the reservoir.

Current-meter measurements in the inlet canal were made in October 1971 when 508.5 cfs were being diverted. These measurements showed a loss of 85.9 cfs in the first 17 miles (16.9%) and 131.9 cfs (26.0%) in the total length (Toren, 1971). This estimate is further supported by the fact that over 75 irrigation wells below the north Sterling inlet canal derive their supplies from that canal's seepage losses. Net evaporation losses from the North Sterling Reservoir itself probably average about 5,000 acre-feet per year. It is believed that the amount of seepage from the reservoir itself is rather small compared to the other losses in the system. Seepage losses from the outlet canal are estimated to be 25 to 30 percent of that amount released from the reservoir. Therefore, the average delivery efficiency to farm turnouts and the several laterals of the system is somewhat under 50 percent.

Tetsel Ditch.[1/] The Tetsel Ditch diverts from the river 2.2 miles upstream from the Balzac gaging station and serves about 1,000 acres of irrigated land on the north side of the river. All of the irrigated land is close to the river and is immediately below the North Sterling inlet canal. During the 15-year study period the Tetsel Ditch diverted an average of 5,100 acre-feet per year. The lowest annual diversion was 2,600 acre-feet in 1947 and the largest was 6,400 acre-feet in 1956 and 1961. No Tetsel Ditch Company officials were interviewed, but based on similar small systems close to the river the efficiency of delivery is estimated to be about 75 percent. Most of the loss involved would be to seepage.

Johnson and Edwards Ditch. The Johnson and Edwards Ditch diverts from the river using the Prewitt Reservoir inlet canal. It serves approximately 1,700 acres of irrigated land on the south side of the river. The average annual diversion by the Johnson and Edwards system during the 15-year study period was 3,200 acre-feet. The lowest annual diversion was 2,100 acre-feet in 1959 and the highest was 5,200 acre-feet in 1952. The estimated delivery efficiency for the Johnson and Edwards Ditch is 75 percent.

[1/] No attempt has been made in this report to differentiate between "canals" and "ditches", but terminology common in each system has been used where known.

Prewitt Reservoir. The inlet canal to the Prewitt Reservoir diverts from the river 2.1 miles upstream from the Balzac gaging station. Releases from the reservoir come back into the river about 5.8 miles downstream from the gage. The Prewitt Reservoir has an available storage capacity of 28,960 acre-feet which is divided into 31,000 rights. The rights are held as follows:

1. Logan Irrigation District--17,000 rights (includes the South Platte, Pawnee, Davis Bros., Schneider and Springdale ditches)
2. Iliff Irrigation District--8,000 rights (includes the Bravo, Farmers, Iliff and Platte Valley, Lone Tree, Powell, Harmony No. 2, Ramsey and Harmony No. 1 ditches)
3. Morgan-Prewitt Reservoir Company--6,000 rights (Some of these rights are used by exchange upstream, but most are held by individuals under nearby downstream ditches such as the South Platte, Pawnee, Davis Bros., Springdale and Sterling No. 2.)

During the 15-year study period, an average of 41,000 acre-feet of water was diverted from the river to storage and an average of 10,400 acre-feet was released back to the river (USBR, 1965). Storage records show that there was 1,950 acre-feet more storage in January 1, 1962, than on January 1, 1947. Therefore the average river-diversion to reservoir-release efficiency was about 26 percent. The water released to the river suffers losses in transit to the receiving ditch (as much as 40 river miles downstream) and in the receiving ditch before delivery to farm headgates.

A large portion of the loss in the Prewitt Reservoir system is by seepage from the reservoir. Officials report that the seepage rate from the reservoir when it is full is 130 acre-feet per day. This water becomes available for diversion by ditches and wells downstream, although there is a significant loss to evapotranspiration from a high water table and phreatophytes supported by the seepage between the reservoir and the river.

South Platte Ditch. The South Platte Ditch diverts from the river 1.6 miles downstream from the Balzac gaging station and serves about 4,900 acres of irrigated land on the south side of the river. The average annual diversion during the 1947 to 1961 study period was 10,400 acre-feet, ranging from a minimum of 7,700 acre-feet in 1959 to a maximum of 13,400 acre-feet in 1948. The ditch diverted nearly the average amount during the drought year of 1977 indicating the stability of a senior water right. It is estimated that the delivery efficiency of the South Platte Ditch is about 67 percent. Most of the loss is due to seepage.

Farmers Pawnee Ditch. The Farmers Pawnee Ditch diverts from the river 6.2 miles downstream from the Balzac gaging station and serves about 10,600 acres of irrigated land on the north side of the river. A detailed study of this ditch system in 1969 (Bittinger & Associates, 1969) showed a high percentage of the Farmers Pawnee Company stockholders also had irrigation wells as a supplemental source of water. In addition, slightly over 900 acres within the ditch service area were being irrigated from ground water only.

The average annual diversion of river water by the Farmers Pawnee Ditch during the 1947 through 1961 study period was 26,200 acre-feet. The lowest annual diversion was 19,100 acre-feet in 1960 and the greatest was 37,000 acre-feet in 1948. It is estimated that the system delivers about 65 percent of the amount diverted. Most of the loss is due to seepage from the ditch.

Davis Bros. Ditch. The Davis Bros. Ditch is a relatively short ditch which diverts from the river 7.0 miles downstream from the Balzac gaging station. It serves about 2,000 acres of irrigated land within 1.5 miles of the river. The average annual diversion by the Davis Bros. Ditch during the 1947 through 1961 study period was 3,900 acre-feet, ranging from a minimum of 2,700 acre-feet in 1955 to a maximum of 5,400 acre-feet in 1948. It is estimated that the Davis Bros. Ditch delivers at least 75 percent of the water diverted to farm turnouts.

Schneider Ditch. The Schneider Ditch diverts from the river 11.8 miles downstream from the Balzac gaging station and serves about 2,400 acres of irrigated land on the south side of the river. The average annual diversion by the Schneider Ditch during the 15-year study period was 8,600 acre-feet. The smallest annual diversion was 5,600 acre-feet in 1957 and the largest was 11,200 acre-feet in 1950. The Schneider Ditch diverted about 1,000 acre-feet more river water during the drought year of 1977 than the 15-year average given above. A large proportion of the Schneider Ditch service area is also served by irrigation wells. The Schneider Ditch divides into two branches, north and south. It is estimated that the north branch (nearest the river) loses only 5 to 10 percent of the water carried, whereas the south branch loses about 30 percent.

Springdale Ditch. The Springdale Ditch diverts from the river 15.1 miles downstream from the Balzac gaging station, and serves about 4,000 acres of irrigated land on the north side of the river. The average annual diversion by the Springdale Ditch during the 15-year study period was 5,800 acre-feet, ranging from a minimum of 1,900 acre-feet in 1959 to a maximum of 9,000 acre-feet in 1948. The Springdale Ditch is a "slow" ditch with heavy losses, especially in the lower one half. The delivery efficiency is probably about 55 to 60 percent because of large seepage losses. Many wells in the service area of the Springdale Ditch undoubtedly benefit from this seepage.

Sterling No. 1 Ditch. The Sterling No. 1 Ditch diverts from the river 18.1 miles downstream from the Balzac gage and serves about 10,000 acres of irrigated land on the north side of the river. The average annual diversion by the Sterling No. 1 Ditch during the 15-year study period was 24,900 acre-feet. The lowest annual diversion amount was 16,300 acre-feet in 1957 and the largest was 32,700 acre-feet in 1954. The ditch diverted only 14,700 acre-feet of river water during the drought year of 1977, but received about 4,000 acre-feet of water from wells into the ditch by the Ground Water Appropriators of the South Platte (GASP) as replacement of surface-water depletions caused by ground-water pumping. The delivery efficiency of the Sterling No. 1 Ditch is estimated to be about 70 percent, with especially high seepage losses occurring from the ditch northwest of Sterling. Although the Sterling No. 1 Ditch service area overlies areas of significant saturated thickness of the alluvium, stockholders of the company have only a few irrigation wells--principally because of the senior surface-water rights.

Sterling No. 2 Ditch. The Sterling No. 2 Ditch diverts from the river 21.5 miles downstream from the Balzac gaging station and irrigates 1,000 to 1,200 acres on the north side of the river, all of which is within a mile of the river. The average annual diversion of river water by the Sterling

No. 2 Ditch during the 15-year study period was 1,800 acre-feet, ranging from a minimum of 300 acre-feet in 1959 to a maximum of 3,700 acre-feet in 1950. The high variability of diversions reflects the difficulty experienced by a relatively junior water right diverting immediately downstream from a senior water right. It is understood that as of 1977, all of the irrigated area under the Sterling No. 2 Ditch is being served by wells as alternate points of diversion. The efficiency of delivery during the 15-year study period is estimated to be 75 percent.

Henderson and Smith Ditch. The Henderson and Smith Ditch is a small ditch system on the south side of the river diverting from a point 22.7 miles downstream from the Balzac gaging station. Estimates of the area irrigated from this ditch vary widely between different sources, but it appears that about 900 acres is correct. The average annual diversion of river water during the 15-year study period by the Henderson and Smith Ditch was 2,100 acre-feet. The lowest annual diversion was 1,100 acre-feet in 1947 and the largest was 3,000 acre-feet in both 1954 and 1956. This reflects a favorable seniority and position on the river in order to record maximum diversions in dry years. The ditch diverted 2,558 acre-feet of river water in 1977. It is estimated that the delivery efficiency of the Henderson and Smith Ditch is about 75 percent.

Lowline Ditch. The Lowline Ditch diverts from the river 23.0 miles downstream from the Balzac gaging station and serves a little over 2,000 acres of irrigated land on the north side of the river. The average annual diversion of river water during the 15-year study period was 6,900 acre-feet. The lowest annual diversion amount was 4,300 acre-feet in 1957 and the largest was 9,900 acre-feet in 1950. The delivery efficiency of the Lowline Ditch is estimated to be about 80 percent of the water diverted.

Bravo Ditch. The Bravo Ditch diverts from the river 27.6 miles downstream from the Balzac gaging station and serves an area estimated by different sources as being as low as 1,200 and as high as 3,300 acres. During the 15-year study period, the Bravo Ditch diverted an average of 6,300 acre-feet and a minimum of 4,400 acre-feet (1954). With these diversions, it would appear that an irrigated area of about 3,000 acres may be correct. It is estimated that the delivery efficiency of the Bravo Ditch is about 70 percent.

Farmers (Peoples) Ditch. The Farmers Ditch diverts from the river 28.7 miles downstream from the Balzac gaging station and serves a small acreage (probably less than 400 acres) on the south side of the river within a short distance of the river. The average annual diversion of river water during the 15-year study period was 1,800 acre-feet. The lowest annual diversion was 600 acre-feet in 1959 and the largest was 2,900 acre-feet in 1951. The first 1/2 mile of the 5.3-mile ditch loses considerable water, but the remaining portion is not large. The overall efficiency of delivery by the Farmers Ditch is estimated to be about 80 percent.

Iliff and Platte Valley Canal. The Iliff and Platte Valley Canal diverts from the river 31.7 miles downstream from the Balzac gaging station and serves about 10,000 acres of irrigated land on the north side of the river. The ditch follows the north edge of the alluvium for a distance of about 35 miles. Because of its position, it picks up runoff and seepage from land above irrigated from the North Sterling Reservoir Outlet Canal and its laterals. During the 15-year study period the Iliff and Platte Valley Canal diverted an average of 18,500 acre-feet ranging from a minimum of 14,000 acre-feet in 1958 to a maximum of 23,000 acre-feet in 1948. The Iliff and Platte Valley Ditch seepage losses are quite variable along its length, but an overall delivery efficiency of about 80 percent is estimated for the system.

Lone Tree Ditch. The Lone Tree Ditch diverts from the river 35.1 miles downstream from the Balzac gaging station and serves approximately 1,000 acres of irrigated area on the south side of the river, all within a mile of the river. The average annual diversion by the Lone Tree Ditch during the 15-year study period was 3,800 acre-feet. The lowest annual diversion was 1,100 acre-feet in 1959 and the greatest was 6,500 acre-feet in 1954. It is estimated that the delivery efficiency of the Lone Tree Ditch is about 75 percent.

Powell Ditch. The Powell Ditch diverts from the river 39.2 miles downstream from the Balzac gaging station and irrigates about 2,200 acres on the north side of the river. The average annual diversion of river water during the 15-year study period was 4,400 acre-feet. The lowest annual diversion was 1,800 acre-feet in 1948 and the largest was 6,300 acre-feet in 1954 and 1956. Officials estimate the seepage losses from Powell Ditch as being only about 10 percent of the amount diverted.

Ramsey Ditch. The Ramsey Ditch diverts from the river 42.6 miles downstream from the Balzac gaging station and 41.2 miles upstream from the Julesburg gaging station. It serves a small irrigated area on the north side of the river within 1/2 mile of the river. The average diversion during the 15-year study period was 1,100 acre-feet ranging from 200 acre-feet in 1952 to 2,300 acre-feet in 1955. The delivery efficiency of the Ramsey Ditch is estimated to be about 75 percent.

Harmony No. 2 Ditch. The Harmony No. 2 Ditch diverted, at one time, from the river at the same point as the Ramsey Ditch. In recent years the diversion has not been maintained. Apparently the ditch received sufficient runoff and seepage from lands above it irrigated from the North Sterling Reservoir Outlet Canal in order to supply its irrigated acreage in combination with irrigation wells.

Harmony No. 1 Ditch. The Harmony No. 1 Ditch diverts from the river 46.4 miles downstream from the Balzac gaging station. It carries both direct-flow water for irrigation of about 14,000 acres under the Harmony No. 1 and storage water for the Julesburg Reservoir. The average annual diversion for the 15-year study period was 25,500 acre-feet ranging from a low of 10,900 acre-feet in 1959 to a high of 39,400 acre-feet in 1957. The major losses in the Harmony No. 1 Canal are in the first few miles which traverse the alluvium. It is estimated that the delivery efficiency is about 75 percent.

Julesburg Reservoir and Highline Ditch. Water diverted to storage in the Julesburg Reservoir through the Harmony No. 1 Ditch during the 15-year study period averaged 14,600 acre-feet. The lowest diversion during the period was 4,200 acre-feet in 1956 and the largest was 24,000 acre-feet in 1955. Approximately 9,000 acres are irrigated from the Julesburg Reservoir through the Highline Canal. Besides the seepage losses in the inlet canal seepage and evaporation losses occur from the reservoir and from the Highline Canal. It is estimated that the overall efficiency of the system is in the neighborhood of 50 percent.

Settlers Ditch. The Settlers Ditch diverts from the river 54.5 miles downstream from the Balzac gage and serves about 4,000 acres of irrigated land on the north side of the river extending about 30 miles to near the State line. The average diversion of river water by the Settlers Ditch in the 15-year study period was 1,800 acre-feet. The lowest diversion was 0 acre-feet in 1956 and the highest was 5,100 acre-feet in 1958. The Settlers Ditch picks up water both directly and indirectly from the Julesburg Reservoir and the Highline Ditch. Many irrigation wells in the service area supplement the ditch water. The estimated efficiency of the Settlers Ditch delivery system is 75 percent.

Peterson Ditch. The Peterson Ditch diverts from the river 66.6 miles downstream from the Balzac gaging station (17.2 miles upstream from the Julesburg gaging station) and irrigates 9,000 to 10,000 acres of land on the north side of the river extending to the State line. The Peterson Ditch diverted an average of 8,700 acre-feet per year during the 15-year study period. The lowest diversion was 3,900 acre-feet in 1954 and the highest was 15,500 acre-feet in 1947. The estimated delivery efficiency of the Peterson Ditch is 70 percent. Many irrigation wells are in use between the Peterson Ditch and the river.

South Reservation Ditch. The South Reservation Ditch diverts from the river 11.6 miles upstream from the Julesburg gage and irrigates about 1,600 acres on the south side of the river, all within 1/2 mile of the river. During the 15-year study period, the South Reservation Ditch diverted an average of 3,700 acre-feet per year. The lowest annual diversion was 1,700 acre-feet in 1948 and the highest was 5,600 acre-feet in 1952. Ditch personnel estimate that only 5 percent of the water diverted is lost to seepage.

Liddle Ditch. The Liddle Ditch diverts 9.4 miles upstream of the Julesburg gaging station and serves about 1,350 acres of irrigated land on the north side of the river. The average diversion during the 15-year study period by the Liddle Ditch was 2,300 acre-feet, ranging from a low of 1,100 acre-feet in 1949 to a high of 3,300 acre-feet in 1959. The delivery efficiency of the Liddle Ditch is estimated to be about 75 percent.

Carlson Ditch. The Carlson Ditch is the last ditch diverting in Colorado, its diversion point being 8 miles upstream from the Julesburg gaging station. The Carlson Ditch irrigates about 2,000 acres on the south side of the river. The average diversion during the 15-year study period was 1,600 acre-feet per year. The lowest diversion was 0 acre-feet in 1960 and the highest was 3,000 acre-feet in 1954. The estimated delivery efficiency of the Carlson Ditch is 75 percent.

River reach efficiency

For the study reach, the outflow items of the stream-aquifer budget in Table 2 which have the greatest potential for reduction in order to increase beneficial consumptive use and thus increase river reach efficiency are (1) the stream outflow at Julesburg, and (2) phreatophyte consumptive use.

Except for the May and June snowmelt-runoff period, most of the water passing the Julesburg station is composed of irrigation return flow. About 127,500 acre-feet of the 314,500 acre-feet average annual outflow at Julesburg during the 15-year period occurred during the 5-1/2 months when the Colorado-Nebraska Compact was not in effect. The last opportunity for diversion to storage during the non-compact season in Colorado is by the Julesburg Reservoir. The point of diversion for the Julesburg Reservoir (headgate of the Harmony No. 1 Canal) is 37 miles upstream from the Julesburg gage. Therefore, any return flow to the stream within this 37-mile subreach during the non-irrigation season is physically unavailable even if legally available. Return flows reaching the river above the Julesburg Reservoir inlet is also often lost because the Julesburg Reservoir has no difficulty in filling during most years.

Studies by the U. S. Bureau of Reclamation indicate that operation of the proposed Narrows Reservoir would reduce the average annual flow at Julesburg by about 75,000 acre-feet. The effect of the reservoir would be to reduce the flow during the spring runoff period and provde more water to the study reach during the late summer and early fall months. It is likely that the return flow accruing in the reach during the winter months will be increased somewhat by operation of the Narrows Reservoir.

Additional surface reservoir sites, on stream or off stream, are essentially nonexistent in the study reach and therefore do not provide a viable solution to reducing the stream outflow lost to Colorado during the winter months. However, the groundwater reservoir offers the possibility for storage of outflow in excess of compact requirements. It may be possible to manage conjunctively the ground and surface waters during the irrigating season so as to minimize the amount of return flow reaching the river in the winter months. It may also be possible to draw more heavily on groundwater to meet crop irrigation requirements in below-average runoff years and then recharge groundwater heavily during wetter years.

The second item, phreatophyte consumptive use, is a sizable loss of water (53,400 acre feet) particularly when one realizes that it has an impact on the availability of water at the very times the crop irrigation requirements are highest. The reduction in streamflow during a hot July or August day by the evapotranspiration losses from high water table and phreatophyte areas probably exceeds 200 cfs. Control of the water table and phreatophytic growth is admittedly quite controversial and it is beyond the scope of this study to get into that aspect of the efficiency picture.

The flow at Julesburg during the period April 1 to October 15 is subject to the Colorado-Nebraska Compact. As mentioned earlier, the compact functions as a call on the river during this 6-1/2 month period whenever the flow at Julesburg is less than 120 cfs. Table 8 shows the number of days per week during the 15-year study period that the Julesburg flow was less than 120 cfs. It can be seen that the Compact "call" was on over 90 percent of the time during the dry years of 1954 and 1956. Obviously, it is years like 1954 and 1956 that additional ground-water use in the study reach would be desirable--but could further reduce the flow at Julesburg.

Table III-8

Days per Week South Platte River Flow at Julesburg was Below 120 cfs 1947 through 1961

Week No.	Week Begin-ning	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	Total	Percent
14	Apr 2	0	0	0	0	7	0	0	0	4	7	0	0	0	0	0	18	17
15	9	0	0	0	0	3	0	0	3	3	7	0	0	0	0	0	16	15
16	16	0	0	0	0	0	0	0	7	7	7	0	0	0	0	0	21	20
17	23	5	3	2	6	0	0	0	7	7	7	3	0	0	0	0	40	38
18	30	7	0	4	6	0	0	0	4	7	7	7	0	0	0	7	49	47
19	May 7	7	0	1	4	5	0	0	7	7	7	2	0	0	0	7	47	45
20	14	7	5	0	7	6	0	1	7	3	7	0	0	0	0	1	44	42
21	21	1	7	0	7	0	0	7	7	5	7	0	0	0	0	0	41	39
22	28	0	1	0	7	0	0	7	7	0	7	0	0	0	0	0	29	28
23	Jun 4	0	1	0	7	4	0	6	7	4	7	0	0	0	0	0	36	34
24	11	0	6	0	7	0	0	7	7	0	7	0	0	6	0	0	40	38
25	18	0	0	0	7	0	5	7	7	0	6	0	0	7	0	0	39	37
26	25	0	0	0	7	0	7	6	7	3	7	0	0	7	4	0	48	46
27	Jul 2	0	0	0	7	0	7	6	7	7	7	0	0	7	7	2	57	54
28	9	0	3	0	7	2	7	7	7	7	7	4	0	7	7	1	66	63
29	16	0	1	0	7	7	7	7	7	7	7	4	1	7	7	7	76	72
30	23	0	4	4	4	7	7	7	7	7	7	0	0	7	7	5	73	70
31	30	0	7	7	7	7	7	7	7	7	7	0	5	7	7	0	82	78
32	Aug 6	7	7	7	0	0	7	6	7	7	7	2	7	7	7	4	82	78
33	13	7	7	5	3	0	7	6	7	7	7	7	7	7	7	7	91	87
34	20	7	7	2	7	7	7	7	7	7	7	7	7	7	7	7	100	95
35	27	7	7	3	7	6	7	7	7	7	7	3	7	7	7	7	96	91
36	Sep 3	7	7	0	7	0	7	7	7	7	7	7	7	7	7	6	90	86
37	10	3	7	0	7	0	7	7	7	7	7	7	7	7	7	0	80	76
38	17	0	7	0	0	0	7	7	7	7	7	1	2	7	7	1	60	57
39	24	0	7	0	0	0	7	7	7	7	7	0	5	7	7	0	61	58
40	Oct 1	1	7	0	0	0	7	7	7	7	7	0	0	1	7	0	51	48
41	8	2	3	0	0	0	2	7	7	7	7	0	0	0	7	0	42	40
	Total	68	104	35	128	61	112	143	182	155	195	54	55	112	109	62	1575	

REFERENCES - Chapter III

Bittinger, Morton W. & Assoc., 1969, Development of Model Procedures Pursuant to Provisions of Senate Bill 81, 47th General Assembly, State of Colorado: Report prepared for Colorado Water Conservation Board.

Colorado Division of Water Resources et al., 1977, South Platte Ditch Recharge Demonstration, Second Annual Report: Unnumbered publication available from Colo. Div. of Water Resources.

Glover, Robert E., 1975, South Platte River Flow Correlations: Jour. of the Irrigation and Drainage Division, ASCE, Vol. 101, No. IR3, pp. 175-186.

Hurr, R. T., Schneider, P. A., Jr. and Minges, D. R., 1975, Hydrology of the South Platte River Valley, Northeastern Colorado: Colo. Water Conservation Board Circular No. 28.

Hurr, R. T. et al., 1972, Hydrogeologic Characteristics of the Valley-Fill Aquifer in the Brush, Sterling and Julesburg Reaches of the South Platte River Valley, Colorado: U. S. Geological Survey Open-File Report prepared in cooperation with the Colo. Water Conservation Board.

Toren, Ralph, 1971, Letter from Wright Water Engineers, Inc., to the Lower South Platte Water Conservancy District, dated Oct. 11, 1971.

U. S. Bureau of Reclamation, 1965, Historic Basin Analysis--Historic Farm Water Utilization Study: Computer Output for Missouri River Basin Project, Narrows Unit.

U. S. Bureau of Reclamation, 1965, Historic River Operation Study--Recorded and Computed Flow: Computer Output for Missouri River Basin Project, Narrows Unit.

U. S. Department of Agriculture, 1977, Soil Survey of Logan County, Colo.: USDA Soil Conservation Service and Colo. Agr. Expt. Sta.

U. S. Department of Agriculture, 1974, Border Irrigation: Soil Conservation Service National Engineering Handbook, Sec. 15, Chap. 4.

U. S. Department of Agriculture, 1969, Soil Survey of Sedgwick County, Colo.: USDA Soil Conservation Service and Colo. Agr. Expt. Sta.

U. S. Department of Agriculture, 1967, Irrigation Water Requirements: Technical Release No. 21.

Waltz, J. P. and Sunada, D. K., 1972, Geohydraulics at the Unconformity Between Bedrock and Alluvial Aquifers: Colo. State Univ., Environmental Resources Center, Completion Report No. 30.

Whittlesey, Norman K., 1977, Irrigation Development Potential in Colorado: Report submitted to the State of Colorado Department of Natural Resources by the Environmental Resources Center, Colorado State University, Fort Collins, Colorado (Norman A. Evans, Director) May.

IV. ESTIMATED COSTS OF EFFICIENCY IMPROVEMENTS

Farm Irrigation Efficiency Improvement Costs

The United States Bureau of Reclamation (USDI, 1970) reported detailed studies of field irrigation efficiencies of projects in the McCook, Nebraska, and Torrington, Wyoming, areas. They studied existing efficiencies, which were measured on 7 farms (31 fields), over a 5-year period. From these data they concluded that there are three levels of attainable efficiencies.

(1) Existing system, improved management, no additional labor

On-farm irrigation efficiency can be increased by scheduling irrigations according to monitored plant needs, rather than from a predetermined schedule or advice from neighbors. Such scheduling can be carried out by the farmer using resistance blocks and/or tensiometers, frequent sampling with an Oakfield probe, or by keeping a detailed day-to-day moisture budget using climatic data. The farmer would have to know the approximate water-holding capacity of his soil and the approximate infiltration rates to carry out this exercise.

Although the cited reference claims that favorable results can be obtained with a minimum effort on the part of the farmer, it is probable that he will use management services to attain this level of control if such services are available. In eastern Colorado they are offered by at least one company, at a rate of $4.50 to $5.50 per acre per year, depending on farm size. This is a total management service and includes advice on weed and pest control, planting dates, fertilization, etc. It is probable that the irrigation scheduling cost is no more than half the quoted cost for the entire package, or about $2.50 to $3.00 per acre per year.

The level of improved on-farm irrigation efficiencies to be expected were reported by the Bureau (USDI, 1970). They concluded that on-farm efficiencies could be raised from a 44 percent average without improved management to a 62 percent average with improved management. These values may be compared with an estimate made in this study of 41 percent for the study area without improved management. Whittlesey (1977) used a value of 44 percent for the South Platte River Valley.

(2) Existing system, improved management, additional labor

The second level of efficiency is attainable by additional improvements in water management, which include such practices as cut-back flows in row crops. These practices require additional labor. Farm irrigation efficiency can be raised from 41 percent to 68 percent by this approach.

(3) Improved system, improved management, additional labor

No estimated attainable efficiencies are given by the Bureau (USDI, 1970) for this level of improvement. However, it is expected to include a complete tailwater reuse system with a concrete-lined pond, a pipe conveyance system, and gated pipe for delivery to furrows. Alternatively, (1) an automatic surface irrigation system with an underground conveyance system and vertical risers to gated pipe, in conjunction with a reuse system and irrigation scheduling, or (2) sprinkler systems could be used.

The writer's experience indicates that in reality most farms in the study area obtain improved performance by going to a reuse system or center-pivot irrigation. The reuse system usually consists of an unlined pond, plus a pump and pipeline to the upper end of the field. As the result of conversations with the experts mentioned in an earlier portion of this report, it was concluded that center pivots operated without the benefit of irrigation scheduling would average about 63 percent field irrigation efficiency. Those operated with an irrigation scheduling program--one that determines the time and amount of water to apply based upon monitoring crop use--would have a field irrigation efficiency of about 83 percent.

For the purposes of the cost estimate it is assumed that the 75 percent farm irrigation system efficiency could be met in the study area if half the area in surface irrigation was provided with reuse systems, and if half was converted to center-pivot irrigation. The costs for these conversions can be estimated as follows from data in the literature.