RECHARGE AS AUGMENTATION IN THE SOUTH PLATTE RIVER BASIN

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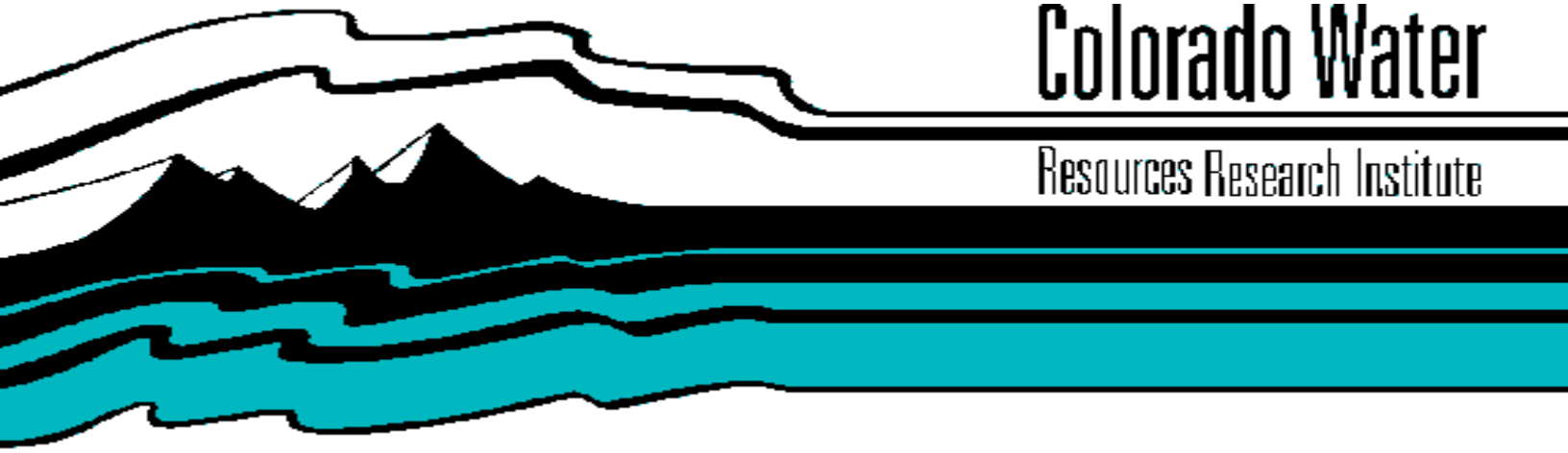
James W. Warner, Daniel Sunada, and Anne Hartwell



Completion Report No. 144

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by

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Recharge has become an emerging new technology in the search for better water supply management in the South Platte Basin. This study was made to assess the state-of-the-art as it is now practiced in the basin. Our objectives are threefold: (1) to document current recharge-site characteristics and operating procedures; (2) to investigate technological improvements that might be applied for better recharge effectiveness; and (3) to identify research needs which will improve the technology and make possible better basinwide water management.

Information and assistance were freely given by project operators and irrigation officials too numerous to name (see Appendix C). We wish, however, to acknowledge the special help given by Mr. Jack Odor, Manager, Groundwater Appropriators of the South Platte Inc., and Mr. Tom Cech, Manager, Central South Platte Conservancy District.

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augmentation is documented in complete detail including the court decree (Fort Morgan Reservoir and Irrigation Company).

Table of Contents

I. Introduction.....1
1.1 Historical Background.....2
1.2 Augmentation Plans.....4
1.3 Hydrogeology.....5

II. Augmentation/Recharge on the South Platte River.....7
2.1 Recharge Studies.....7
2.1.1 Olds Reservoir Recharge Study.....7
2.1.2 South Platte Ditch Demonstration Recharge Project.....8
2.1.3 Proctor Recharge Experiment.....9
2.1.4 Tamarack Recharge Experiment.....11
2.1.5 Proposed Badger-Beaver Creeks Recharge Project.....11

2.2 Augumentation/Recharge Projects.....13
2.2.1 Central Colorado Water Conservancy District...13
2.2.2 Henry Lyn Irrigation Company.....15
2.2.3 Groundwater Appropriations of the South Platte19
2.2.4 Bijou Irrigation Company.....20
2.2.5 Fort Morgan Reservoir and Irrigation Company..24
2.2.6 Pioneer Water and Irrigation Company.....29
2.2.7 Upper Platte and Beaver Canal Company.....33
2.2.8 Lower Platte and Beaver Canal Company.....33
2.2.9 Riverside Irrigation Company.....33
2.2.10 Other Recharge Sites.....40
2.2.11 Summary and Evaluation.....48

2.3 Methods for Calculation of Return Flows.....52
2.3.1 Glovers Solution.....52
2.3.2 Stream Depletion Factor Method.....58
2.3.3 Adequacy of Return Flow Calculations.....62

III. Conclusions.....63

IV. References.....66

Appendix A: Laws Pertaining to Augmentation on the South Platte River.....68
Appendix B: Example Augmentation Plan.....72
Appendix C: List of Contacts 114

LIST OF TABLES

Table		Page(s)
1	Recharge Sites for the Central Colorado Water Conservancy District	16-17
2	Recharge Sites for the Henry Lyn Irrigation Company	18
3	Recharge Sites for the Bijou Irrigation Company	22-23
4	Recharge Sites for the Fort Morgan Reservoir and Irrigation Company	26-28
5	Recharge Sites for the Pioneer Water and Irrigation Company	31-32
6	Recharge Sites for the Upper Platte and Beaver Canal Company	36
7	Recharge Sites for the Lower Platte and Beaver Canal Company	37-38
8	Recharge Sites for the Riverside Irrigation Company	39
9	Other Recharge Sites	44-47
10	Summary of total diversions for artificial recharge in the South Platte River Basin	50

LIST OF FIGURES

Figure		Page
1	Location Map for Recharge Sites Operated by the Central Colorado Water Conservancy District and the Henry Lyn Irrigation Company	14
2	Location Map for Recharge Sites Operated by the Bijou Irrigation Company	21
3	Location Map for Recharge Sites Operated by the Fort Morgan Reservoir and Irrigation Company	25
4	Location Map for Recharge Sites Operated by the Pioneer Water and Irrigation Company	30
5	Location Map for Recharge Sites Operated by the Upper Platte and Beaver Canal Company, the Lower Platte and Beaver Canal Company, and the Riverside Irrigation Company	35
6	Location Map for Other Recharge Sites	43
7	Total Annual Diversions for Artificial Recharge in the South Platte River Basin	51
8	Plot of Return Flow to River versus Time for Glover's Solution Example Problem	57
9	Plot of Cumulative Volume of Return Flow to River versus time for Glover's Solution Example Problem	57
10	Graphical Plot of Glover's Solution Used in Stream Depletion Factor Method	60

I. INTRODUCTION

Currently there are about sixty artificial groundwater recharge project sites in the state of Colorado. Approximately 44 of these are located along the South Platte River from Denver to the Nebraska border. The purpose of almost all of these sites is augmentation of stream flow to the South Platte River. This is needed to offset the stream depletion caused by pumping of irrigation wells located in the alluvium of the South Platte River Basin. It is the purpose of this study to document current artificial recharge operations in the South Platte River Basin, identify any problems associated with these augmentation/recharge projects and to describe the engineering methods used to calculate the return flows to the South Platte River. These augmentation/recharge projects along the South Platte River have evolved out of the quest for better basin water management in order to provide a constant, plentiful water supply for the state, with its growing agricultural and urban water demands. Of particular interest at this time are the augmentation/recharge projects being implemented in the South Platte River Basin.

The situation along the South Platte River is a result of the combined effects of agricultural demands, limited water supply, legal, economic and engineering constraints. The South Platte River is a gaining stream, because it receives return flow from the aquifer. This return flow is mostly due to deep percolation of applied irrigation water. Because of the unpredictable nature of surface water availability in this river basin, regulations have evolved to allocate the needed water.

1.1 Historical Background

Artificial groundwater recharge is a recently implemented method of basin water management along the South Platte River. It is the latest in a series of engineering attempts to provide water for agricultural use in the South Platte River basin. In chronological order of implementation canals, reservoirs, wells, and most recently augmentation/recharge projects have been developed and used by the farmers along the South Platte River to improve water availability and reliability. The extensive canal system of the South Platte River basin was built by the earliest settlers in the late 1800's (1). Later in the early 1900's reservoirs were constructed. These reservoirs were built to store excess water that flowed in the South Platte River during winter and spring. The stored water could then be released during the irrigation season, when flow in the river was low and the demand for water was high.

Starting in the 1920's, farmers who had low priority surface water rights constructed wells to tap the groundwater in the alluvial aquifer of the South Platte River Basin. Between 1947 and 1970, groundwater storage dropped by 456,000 acre-feet per year, and seepage to the river dropped by an estimated 250,000 acre-feet per year. By 1970, 6,700 wells had been drilled (2), and it had become apparent that this groundwater pumping was depleting the supply of water in the river. Several cases were filed in water court, which brought about the need to consider the relationship between surface and groundwaters.

In 1969 the "Water Rights Determination Act" was passed. The act states that the policy of the State of Colorado is to integrate groundwater and surface water use in order to maximize beneficial use. The following principles summarize the Water Rights Determination Act:

1. All previously vested rights and uses protected by law, including an appropriation from a well, shall be protected.

2. The present use of wells, either independently or in conjunction with surface rights shall be given the fullest possible recognition. However, this principle will be limited by existing vested rights. Each diverter must establish a reasonable means of diversion and he cannot command the whole flow to take his appropriation.

3. Use of a well may be an alternate or supplemental source for a surface decree.

4. No junior appropriator can be limited unless this reduction would result in an increased water supply available to the senior appropriator. This principle recognized the "futile call" concept whereby the overall concept of maximization of beneficial use.(1)

In 1975, the State Engineer issued a set of four rules prepared specifically for the South Platte Basin. These four rules are listed in Appendix A of this report. In RULE 1, "underground water" is defined as water that is hydraulically connected to the South Platte River, and is considered different from designated groundwater. RULE 2 sets a three year schedule (beginning with 1974) for curtailment of pumping, ending with complete curtailment in the year 1976. It further states that no curtailment will occur if a decreed augmentation plan exists for the well. RULE 3 discusses temporary plans for augmentation, which must be reviewed by the State Engineer's office every year. RULE 4 states the criteria by which the calculation of stream depletion is made.

These rules called for plans of augmentation and brought about the establishment of water-user organizations. These organizations charge membership fees which they use to develop augmentation plans and recharge projects. The Central Colorado Water Conservancy District (Central) and Ground Water Appropriators of the South Platte (GASP) are two water-user

groups currently involved with artificial recharge operations for augmentation.

1.2 Augmentation Plans

These plans of augmentation allow wells to be pumped at times and in amounts which would not otherwise be permitted under Colorado Law. These augmentation plans can take several forms but only augmentation plans concerned with artifical recharge are considered here. The basic concept is that groundwater pumped by wells from the alluvial aquifer of the South Platte River Basin causes a net depletion of streamflow in the river and resulting injury to senior water rights. In practice almost all of the surface water right holders on the South Platte are senior to almost all of the groundwater appropriators. Groundwater has an important role in the agricultural development of the river basin and to completely shut down all of the wells to prevent injury to the senior surface water rights would have drastic economic consequences.

The augmentation plans ensure that water is available to replace "the net groundwater extraction" caused by the wells and thus not diminish the flow in the South Platte during critical irrigation periods. The effect on stream flows caused by pumping wells is not immediate and results in a delayed response in the river. The effect can be calculated using mathematical methods. With augmentation by recharge, water is diverted during times of high flow for recharge to the groundwater. The South Platte river is a gaining stream and the recharged groundwater is returned at a later date. The concept is to time the recharge so that it will return to the river when needed during the critical period of the irrigation season. This returned recharge water is therefore available in the river for the

senior surface water right holders to meet their irrigation needs. Several methods are used to calculate this return flow. The method of calculation is important in that errors may result in no water in the river when it is needed. The State Engineers office gives credit for the recharge water that is returned to the river which in effect reduces or eliminates the diminishment caused by the pumping wells covered under the augmentation plan. An example of what the authors considered to be a well done augmentation plan is given in Appendix B of this report. Appendix B contains both the engineering report prepared for the plan of augmentation and the final decreed augmentation plan.

1.3 Hydrogeology

The main source of groundwater in the South Platte River Basin is the Valley Fill aquifer, which consists of pleistocene and recent alluvium deposited by the South Platte River. The alluvium is made up of clay, sand, and gravel. Larger particles, such as pebbles, cobbles and boulders occur less frequently. Groundwater in the alluvium is in close hydrologic connection with surface water in the South Platte River. The thickness of the alluvium ranges from less than a foot at the edges of the valley to about 300 feet in the center near the river. The alluvium has a high hydraulic conductivity. Most irrigation wells tap these alluvial deposits as their source of water.

The sand hills found along the edge of the valley are eolean deposits consisting of fine to medium sand. These deposits range from 1 foot to more than 100 feet in thickness. These areas provide good locations for recharge sites because they overlie the alluvium which is hydraulically connected to the river. Loess mantles much of the alluvium, and is less permeable. It is mostly silt with some fine sand. The loess deposits are thickest along

the gently sloping valley sides. The water table in the Valley Fill aquifer varies from 0 to 80 feet below the ground surface. The water table dips downstream at a rate of approximately 7.5 feet per mile.(3)

II. AUGMENTATION/RECHARGE ON THE SOUTH PLATTE RIVER

2.1 Recharge Studies

Several studies have been made to document the underground flow from recharge ponds/canals to the river. The following is a summary of 5 studies which illustrate the feasibility of artificial recharge as augmentation to the South Platte River.

2.1.1 Olds Reservoir Recharge Study

A groundwater recharge investigation was conducted in the early 1960's at Olds Reservoir in the Prospect Valley area by the Colorado Agricultural Experiment Station (4). The Prospect Valley area is about 40 miles northeast of Denver and about 15 miles south of the South Platte River. Groundwater pumping for irrigation use is widespread in Prospect Valley and is the major depletion from the aquifer. The major source of recharge to the aquifer is deep percolation from applied irrigation water. The Prospect Vally aquifer consists of a hetergeneous mixture of cobbles, sand, gravel, silt and clay deposits. Aquifier thickness varies from a few feet near the valley edges to about 150 feet in the central part.

Olds Reservoir has a storage capacity of about 450 acre-feet and was originally constructed in 1918 as a part of the Henry Lyn irrigation system. Due to excessive seepage losses the reservoir was soon abandoned. Water was purposely diverted into Olds Reservoir starting in 1939 for recharging the groundwater. The benefits of this recharge operation was noted by the rise of water levels in nearby irrigation wells. Since that time, artificial recharge has been conducted in Olds Reservoir whenever water is available. Water is supplied to Olds Reservoir through a series of canals. Water is diverted from the South Platte River near the north edge of Denver, through the Burlington and Obrien canals to Barr Lake. From there the water is

carried in the Denver-Hudson canal through Bootleg and Horsecreek reservoirs to Prospect Reservoir. The Prospect lateral transports water on to Olds Reservoir.

One of the purposes of the Olds Reservoir study was to compare actual field measurements of water-level changes with theoretically predicted water level changes. Thirty two observation wells were used to monitor water-table fluctuations at the recharge site. For five months the reservoir was kept at capacity, and an average infiltration rate (neglecting evaporation) of 1.2 feet per day was calculated. A groundwater mound was detected using the observation well network. This mound was compared to a mound which could be theoretically described by the analytical solution of Bittenger and Tralease (1960). The field measurements agreed with the theoretical description. It was also concluded that the Theis non-equilibrium equation was an accurate solution to the recharge problem for this case.

2.1.2 South Platte Ditch Demonstration Recharge Project

This recharge project was started in 1974 along the Sand Hill Ditch which is a leaky abandoned lateral of the South Platte Ditch located between Brush and Sterling and about two miles south of the South Platte River. The recharge operations were conducted in the ditch and several natural ponds. Recharge was conducted mainly in the spring and fall when excess water was available in the South Platte River. The capacity of the Sand Hill ditch was about 20 cfs and that of the ponds was about 59 ac-ft. There were 3 gaging stations in the ditch to monitor the amount of recharge, 32 observation wells and 31 irrigation and stock wells which were used to measure water table fluctuations in the area.

The Colorado Division of Water Resources, Colorado State University, South Platte Ditch Company, and Groundwater Appropriators of the South

Platte (GASP) all participated in the original study (5). A finite difference model was used to determine the change in groundwater storage resulting from the recharge operations and the recharge credit to the river. The recharge project demonstrated that it is economically feasible to recharge excess surface water during the nonirrigation season in a groundwater reservoir for later utilization during the irrigation season. It was determined using the digital groundwater model, that about 77 percent of the water recharged during the non irrigation season (from September to May) in the South Platte Ditch, remained in storage in the aquifer for available use by irrigation wells during the next irrigation season. The study also demonstrated that digital modeling of groundwater flow is a practical and convenient tool to determine recharge credit.

2.1.3 Proctor Recharge Experiment

The Procter recharge site is located northeast of Sterling near the town of Proctor. A recharge experiment was conducted in 1979 in which a pumped well was used to fill a potential recharge site located approximately one mile away in the sandhills and about three miles south of the South Platte River. Eight wells were used to monitor the recharge. During the recharge experiment 420 acre-feet of water were pumped into a 525 acre series of depressions over a 4 month period. The pumped well was located midway between the recharge site and the South Platte River. No water ponded in the depression during the entire four month period, and the water level in the observation well closest to the depression rose 25 feet. The water level in the pumped well was approximately 4 feet higher one month after the test than it was prior to the test, indicating that the recharge mound was moving toward the river.

The USGS studied this recharge experiment using a digital groundwater model (6). In the model study cyclic operation of the pumped well and the recharge pit were simulated. The well was pumped for four months and turned off. Similarly the recharge operations were conducted for the same four months and then stopped. The concept was that the pumped well, which was closer to the river, would deplete stream flow in the South Platte River sooner than the return flow to the river from the recharge operations would occur. Conversely, the return flow to the South Platte River from the recharge operations, which were located farther from the river, would be delayed and would occur after the depletion of the stream flow caused by the pumped well. With the proper configuration of the pumped well and recharge pit, located at the proper distances from the river, it was conceivable that the pumping and recharge operations could be timed so that the depletion caused by the pumped well would occur during the non irrigation season and the return flow to the river would be delayed to occur during the irrigation season. It was found that for the case studied it took seven years to reach dynamic equilibrium between the rate of stream depletion in the South Platte River caused by the pumping well and the rate of stream accretion due to the recharge operations. The model showed that for equilibrium conditions a depletion for six months and an accretion for six months would occur. The study recommended for augmentation purposes that the pumpage should occur during the months of November through February, so that the resulting stream depletions would occur from January through June, in order to avoid depletion during the critical low-flow months of July and August. However, during the first three years of operation (during the transient simulation period), depletion of stream flow caused by the pumped well was greater than return flow from the recharge operations over the entire year with the result of net depletion of stream flow occurring even during the irrigation

season. It was not until the end of five years of operation that the cyclic pattern of pumping and recharge resulted in a significant net accretion (augmentation of streamflow) to the South Platte River during the irrigation season.

2.1.4 Tamarack Recharge Experiment

An artificial recharge experiment was conducted during the winter of 1979-1980 at a site about 10 miles west of the Tamarack wildlife area (7). Water was pumped at a rate of 1,270 gallons per minute for 13 days, and was piped into a depression in the sandhills 3,000 feet away. A pond formed, and the water level rose for the first five days of pumping. Thereafter, the water level fell until 18 hours after the pumping stopped, at which time the pond was dry. This study indicated that artificial recharge in the South Platte Basin can be extremely efficient. In areas such as the sandhills that border the alluvial aquifer, infiltration rates are high. Evaporation is reduced and ground water storage is increased at a more rapid rate under these conditions.

2.1.5. Proposed Badger-Beaver Creeks Recharge Project

The Badger and Beaver Water Conservancy District was formed in 1976 to promote an artificial recharge project. The preliminary proposal was to divert about 43,000 acre feet per year from the South Platte River through Bijou Canal to these two creeks to recharge the groundwater system. The proposed purpose was to restore groundwater levels in the alluvium adjacent to these streams rather than for augmentation of streamflow. Beaver-Badger Creeks are two small tributaries to the South Platte River and are located just south of the city of Fort Morgan. These creeks are normally dry except during floods. Groundwater pumping has been extensive

in this area where the decline in water table has been more pronounced than in any other part of the South Platte River Basin (3). The project suffered from a low water priority right and has yet to be implemented. It is included in this review of recharge studies because the US Geological Survey conducted an extensive study of the proposed project (8). The USGS study concluded that recharge would raise groundwater levels sufficiently to create flowing streams and permit increased groundwater pumping during the irrigation season.

2.2 Augmentation/Recharge Sites

There are currently 44 augmentation/recharge projects along the South Platte River listed in Water Districts 1, 2, and 64 at the State Engineer's Office. Not all of these are decreed and some are no longer operated. Several are listed as "temporary exchange agreements," which must be reviewed once a year by the State Engineer. Most of these recharge sites were constructed with augmentation of stream flow in the South Platte River as their major purpose. However, several sites which are many miles from the river, or in tributary valleys are operated to replace groundwater that has been pumped from a nearby well, and not to augment streamflow. The following is a discussion of the currently active or recently active sites in the South Platte River Basin. The recharge sites are grouped according to the organization which operates the site.

2.2.1 Central Colorado Water Conservancy District

The Central Colorado Water Conservancy District (Central) has five augmentation/recharge projects. The five sites are: (1A) Evans 2 (Platte Valley Ditch), (1B) Farmers Independent, (1C) Boxelder Creek (Bootleg Reservoir), (1D) Mill Iron Draw, (1E) Kiowa Creek (50%). These sites are located south and east of Greeley, within five miles of the South Platte River mainly in Water District #2 (Figure 1). In this area the water table ranges from 0 to 10 feet below the land surface. Because of the shallow depth to groundwater, water logging during recharge is a problem. The saturated thickness of the aquifer in this area is about 30-60 feet.

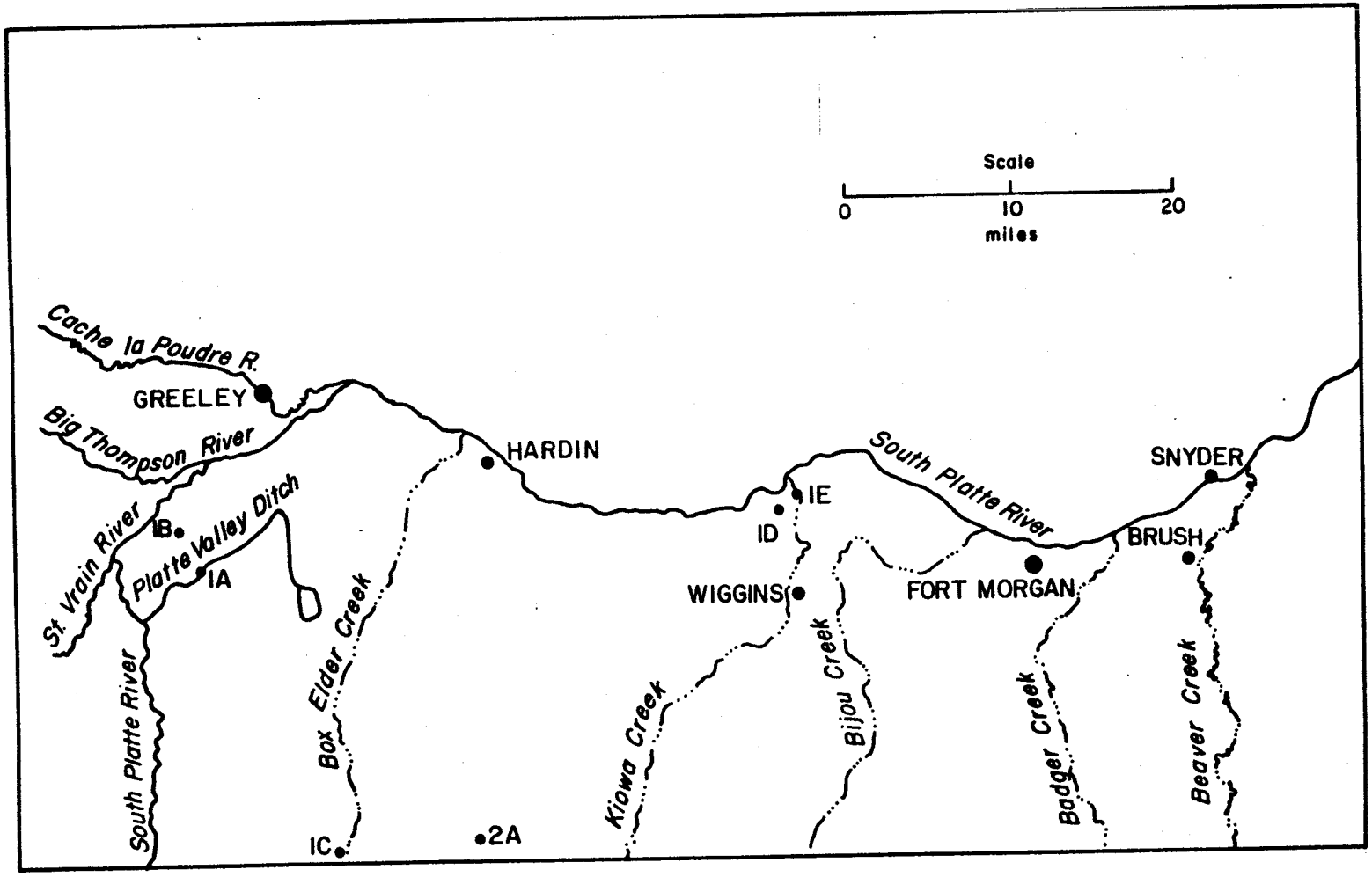

Figure 1 -- Location map for Recharge Sites Operated by the Central Colorado Water Conservancy District and the Henry Lyn Irrigation Company

Of the five sites operated by Central, only two are currently active (Evans 2 and Kiowa Creek). None of the sites are permanently decreed. However, Central has received recharge credit for two sites under a temporary exchange agreement with the State Engineer's Office. Kiowa Creek is operated in conjunction with the Bijou Irrigation Company. The site was started in Spring of 1982 and consists of two ponds in the dry creek bed of Kiowa Creek. Total diversions for recharge between 1983-85 were about 6,600 acre-feet. Boxelder Creek was started in 1983 when over 1,100 acre feet was diverted for recharge, but was stopped in 1984 because of water accounting problems. Mill Iron Draw and Farmers Independent are planned to start in the fall of 1986. Mill Iron Draw was active in 1983-85 period with total diversions for recharge of about 500 acre-feet. During this time period it was operated by a private individual. Evans 2 diverted about 150 acre-feet for recharge in 1984 but no diversion information is available for 1985. Total diversions for the Central projects were about 1,400 acre-feet in 1985. Table 1 summarizes the Central recharge sites.

2.2.2 Henry Lyn Irrigation Company

The Henry Lynn Irrigation Company operates a single recharge site, (2A) Olds Reservoir (Figure 1). Olds Reservoir is a leaky irrigation reservoir located in Propsect Valley that has been used since the 1940's for recharge. Water is supplied to Old's Reservoir through a series of canals which originate near the north edge of Denver. The primary purpose of recharge at this site is recharge to the groundwater system to offset a declining water table. Since 1980 an estimated 15,000 acre-feet has been recharged at Old's Reservoir, an average of about 3,000 acre-feet per year. In 1985, about 3,500 acre-feet were diverted for recharge. Table 2 summarizes the recharge information for Old's Reservoir.

TABLE 1 -- Recharge Sites for the
Central Colorado Water Conservancy District
(See Figure 1 for site locations)

All Sites

Engineer:	Resource Consultants
Analysis:	?
Return Flow Calcs:	Glover's Solution

Map Location No:	1A
Site Name:	Evans 2 - (Platte Valley Ditch)
ID Number (SEO):	2000
Water District:	2
Operator:	Central & Evans Ditch Company
Site Description:	Ditch
Capacity:	
Decree Date:	Temporary Plan, 1984
Diversion Info:	

Year	Diverted Water (Ac-Ft)
1984	151
1985	Not available

Map Location No:	1B
Site Name:	Farmers Independent
ID Number (SEO):	Not listed
Water District:	2
Operator:	Central & Farmers Independent Ditch Company
Site Description:	Abandoned ditch
Capacity:	
Decree Date:	Only initial agreement made
Diversion Info:	Planned to start in Fall 1986

Map Location No:	1C
Site Name:	Boxelder Creek (Bootleg Reservoir))
ID Number (SEO):	2524
Water District:	2
Operator:	Central
Site Description:	Dammed Creek Bed
Capacity:	
Decree Date:	Temporary Plan, 1980
Diversion Info:	

Year	Diverted Water (Ac-Ft)
1983	1162
1984	0
1985	0

TABLE 1 (Continued)

Map Location No:	1D
Site Name:	Mill Iron Draw
ID Number (SEO):	2520
Water District:	1
Operator:	Central (as of 1986), Previously under Dave Greenwalt
Site Description:	3 ponds
Capacity:	50-100 (Ac-Ft) each
Decree Date:	No Augmentation Plan
Diversion Info:	

Year	Diverted Water (Ac-Ft)
1983	244
1984	196
1985	86

Map Location No:	1E
Site Name:	Kiowa Creek
ID Number (SEO):	2521
Water District:	1
Operator:	Central & Bijou Irrigation Company
Site Description:	2 ponds
Capacity:	
Decree Date:	Temporary Plan, 1982
Diversion Info:	

Year	Diverted Water (Ac-Ft)
1983	2431
1984	1552
1985	2635

TABLE 2 - Recharge Sites for the
Henry Lyn Irrigation Company
(See Figure 1 for site location)

Map Location No:	2A
Site Name:	Olds Reservoir
ID Number (SEO):	2501
Water District:	2
Engineer:	
Operator:	
Analysis:	
Return Flow Calcs:	
Site Description:	Leaky Reservoir used for Recharge
Capacity:	450 Ac-Ft)
Decree Date:	
Diversion Info:	

Year	Diverted Water (Ac-Ft)
1980	4703
1981	2532
1982	Not available
1983	1425
1984	2358
1985	3549

2.2.3. Groundwater Appropriators of the South Platte

GASP is an important component for almost all other recharge projects in the South Platte River Basin. GASP does not implement its own recharge projects. Instead GASP encourages the development of recharge projects through purchase of recharge credits. The recharge projects are owned and operated mainly by ditch companies, with a few operated by individual farmers. GASP purchases recharge credits in excess of augmentation requirements from these irrigation companies and private individuals. As a result, these recharge projects linked to GASP are the most developed and economically stable recharge projects in the South Platte River Basin.

The region covered by GASP encompasses the entire South Platte River Basin. However, recharge projects associated with GASP are only in Water Districts #1 and #64 from Hardin to Sterling. In Water District #1, ditch companies primarily operate the recharge projects. These ditch companies have the necessary facilities and manpower resources to conduct the recharge operations. Ditch companies that conduct recharge projects are (1) Bijou Irrigation Company, (2) Fort Morgan Reservoir and Irrigation Company, (3) Pioneer Water and Irrigation Company, (4) Upper Platte and Beaver Ditch Company, (5) Lower Platte and Beaver Ditch Company, and (6) Riverside Irrigation Company. Each of these ditch companies operate multiple recharge projects. In Water District #64, most of the recharge projects are operated by individual farmers. In addition to the recharge projects sponsored by GASP, it also has 16 large capacity wells which it uses to augment flow in the South Platte River and three irrigation canals. A description of the recharge projects linked to GASP is given in the following sections of this report.

2.2.4 Bijou Irrigation Company

The Bijou Irrigation Company has a decreed plan of augmentation to operate seven recharge sites. The total area irrigated under the Bijou canal is approximately 24,000 acres of which only about 2,000 acres are irrigated with river water alone. There are about 200 irrigation wells within the Bijou Irrigation System. The seven recharge sites are: (3A) Bijou Ditch, (3B) Bijou #2 Reservoir, (3C) Bijou Creek, (3D) Weingardt Pond, (3E) Chase Lateral Pond, (3F) Kiowa Creek and (3G) Tormohlen. These sites are located south of the South Platte River and west of Fort Morgan (Figure 2). The sites vary in distance from the river from one mile to more than six miles. Water is diverted for recharge from the South Platte River through the Bijou Canal and releases from Empire Reservoir. Historically the Bijou Canal, Bijou #2 Reservoir and Kiowa Creek are the major recharge sites in the system. Diversion records indicate that 43 percent of the flow in the Bijou Canal is lost due mostly to seepage. Water from the Bijou Canal is delivered to the Bijou #2 reservoir. Only when the reservoir level is high can water be released to Bijou Creek for augmentation. Most of the water in the reservoir is lost to seepage for augmentation purposes. Excess water is diverted to Weingardt Pond, Chase Lateral Pond and Tormohlen for recharge. These sites are located at the tail of the system and have historically received lesser quantities of water for recharge. Total diversions for recharge for 1985 were about 16,400 acre-feet. Credit received was about 1,330 acre-feet or an overall credit percentage of about eight percent. Currently recharge credits do not exceed augmentation requirements for Bijou. With full implementation of recharge projects, excess credits are to be purchased by GASP. Table 3 summaries the Bijou recharge sites.

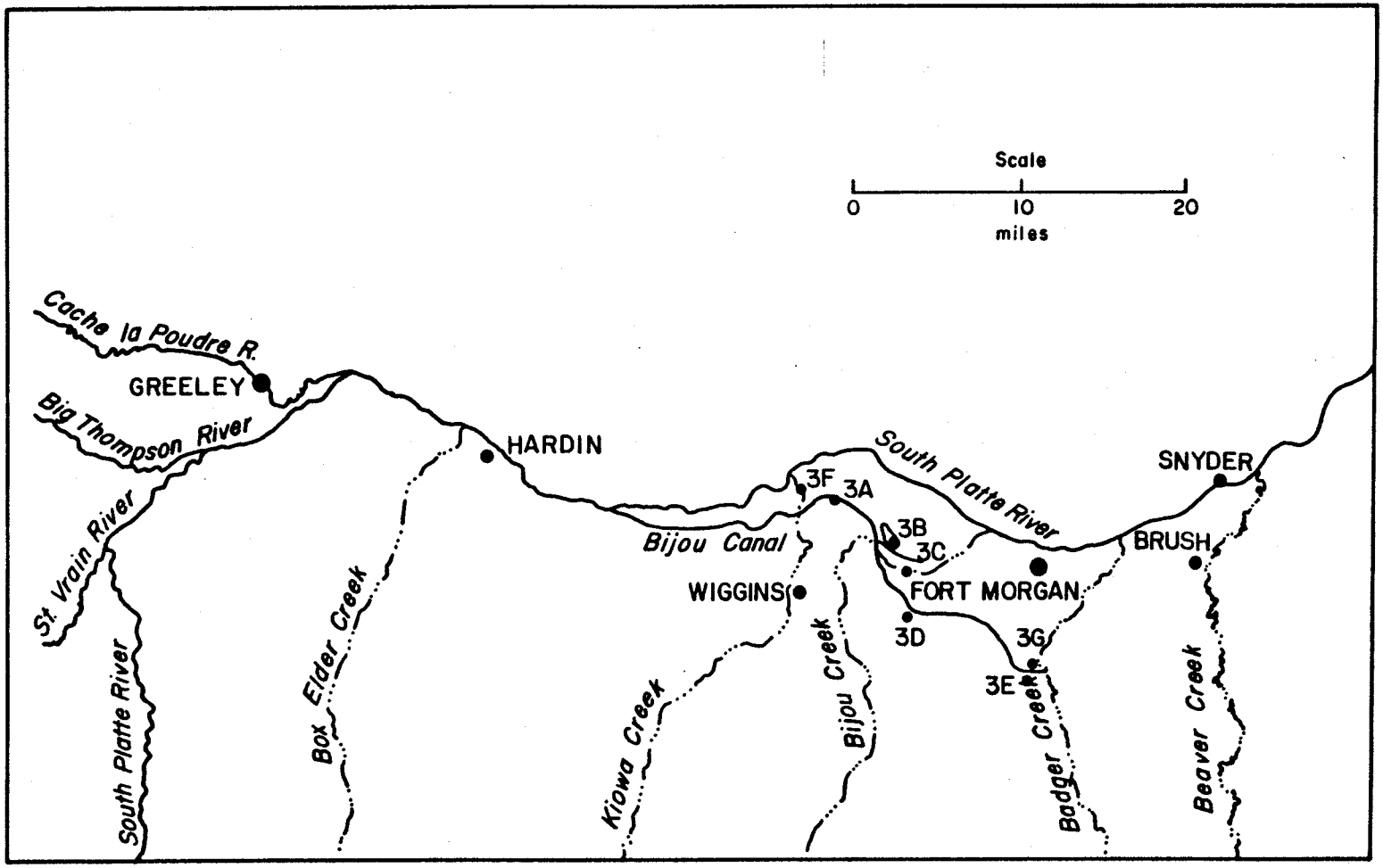

Figure 2 -- Location map for Recharge Sites Operated by the Bijou Irrigation Company

TABLE 3 - Recharge Sites for the
Bijou Irrigation Company

All Sites (unless otherwise noted below)

Water District:	1
Engineer:	HRS Consulting Engineers
Operator:	Bijou Irrigation Company
Analysis:	Northern Colorado Water Conservancy District
Return Flow Calcs:	Stream Depletion Factor (SDF)
Decree Date:	1972

Map Location No:	3A
Site Name:	Bijou Ditch
ID Number (SEO):	2508
Site Description:	13 reaches of canal
Capacity:	142 (Ac-Ft)
Diversion Info:	

Year	Diverted Water (Ac-Ft)
1983	Not available
1984	1321
1985	6062

Map Location No:	3B
Site Name:	Bijou #2 Reservoir
ID Number (SEO):	2509
Site Description:	Leaky Reservoir
Capacity:	7,500 (Ac-Ft)
Diversion Info:	

Year	Diverted Water (Ac-Ft)
1981	3392
1982	5185
1983	5186
1984	4201
1985	6583

Map Location No:	3C
Site Name:	Bijou Creek
ID Number (SEO):	Not Listed
Site Description:	Creek bed
Capacity:	49 (Ac-Ft)
Diversion Info:	Not Available

TABLE 3 (Continued)

Map Location No: 3D
Site Name: Weingardt Pond
ID Number (SEO): 2000
Site Description: Pond
Capacity: 48 (Ac-Ft)
Diversion Info:

Year	Diverted Water (Ac-Ft)
1983	133
1984	859
1985	1755

Map Location No: 3E
Site Name: Chase Lateral Pond
ID Number (SEO): 2001
Site Description: Pond
Capacity: 31 (Ac-Ft)
Diversion Info:

Year	Diverted Water (Ac-Ft)
1983	385
1984	272
1985	642

Map Location No: 3F
Site Name: Kiowa Creek
ID Number (SEO): 2521 (same as site 1E)
Operator: Bijou Irrigation Company & Central
Site Description: Creek Bed
Capacity: 14 (Ac-Ft)
Diversion Info:

Year	Diverted Water (Ac-Ft)
1983	2431
1984	1552
1985	2635

Map Location No: 3G
Site Name: Tormohlen
ID Number (SEO): 2002
Operator: Milton Tormohlen
Site Description:
Capacity:
Diversion Info:

Year:	Diverted Water (Ac-Ft)
1985	Not available

2.2.5. Fort Morgan Reservoir and Irrigation Company

Fort Morgan Reservoir and Irrigation Company has a decreed plan of augmentation to operate nine recharge sites. It is a mutual ditch company serving approximately 11,000 acres of irrigated crop lands southeast of Fort Morgan. Surface water supplies have not been sufficient to provide a full water supply to crops under the Fort Morgan Canal. With the exception of four or five farms, all farmers use groundwater supplies to supplement irrigation water needs with about 90 irrigation wells in the area. The Fort Morgan recharge sites are: (4A) Fort Morgan Canal, (4B) Badger Creek and (4C - 4I) a series of ponds near the lower end of the canal. These recharge sites are south and southeast of Fort Morgan (Figure 3) and are about 5 to 7 miles south of the South Platte River. This system of recharge sites is the oldest and most developed in the South Platte River Basin. Historically most of the recharge has been in the Fort Morgan Canal, Badger Creek, and Bolinger recharge area. Diversion records indicate that thirty percent of the flow in the Fort Morgan Canal is lost due mostly to seepage. Under the plan of augmentation only canal losses occurring during non irrigation use, receive credit for augmentation. Recharge credit in the Bolinger recharge area is split between the irrigation company and the owners of the Bolinger property. Credit is given for recharge in either a pond site or in Badger Creek, even though water for irrigation is being carried in the canal at the same time. These sites have a recharge capacity in excess of 13,000 acre-feet. Since 1980, diversions for recharge have totaled about 63,000 acre-feet or about 10,500 acre-feet annually. In 1985 a total of about 11,000 acre-feet were diverted for recharge. Credit was received for about 2,100 acre-feet or an overall credit percent of about nineteen percent. Table 4 summarizes the Fort Morgan Recharge sites.

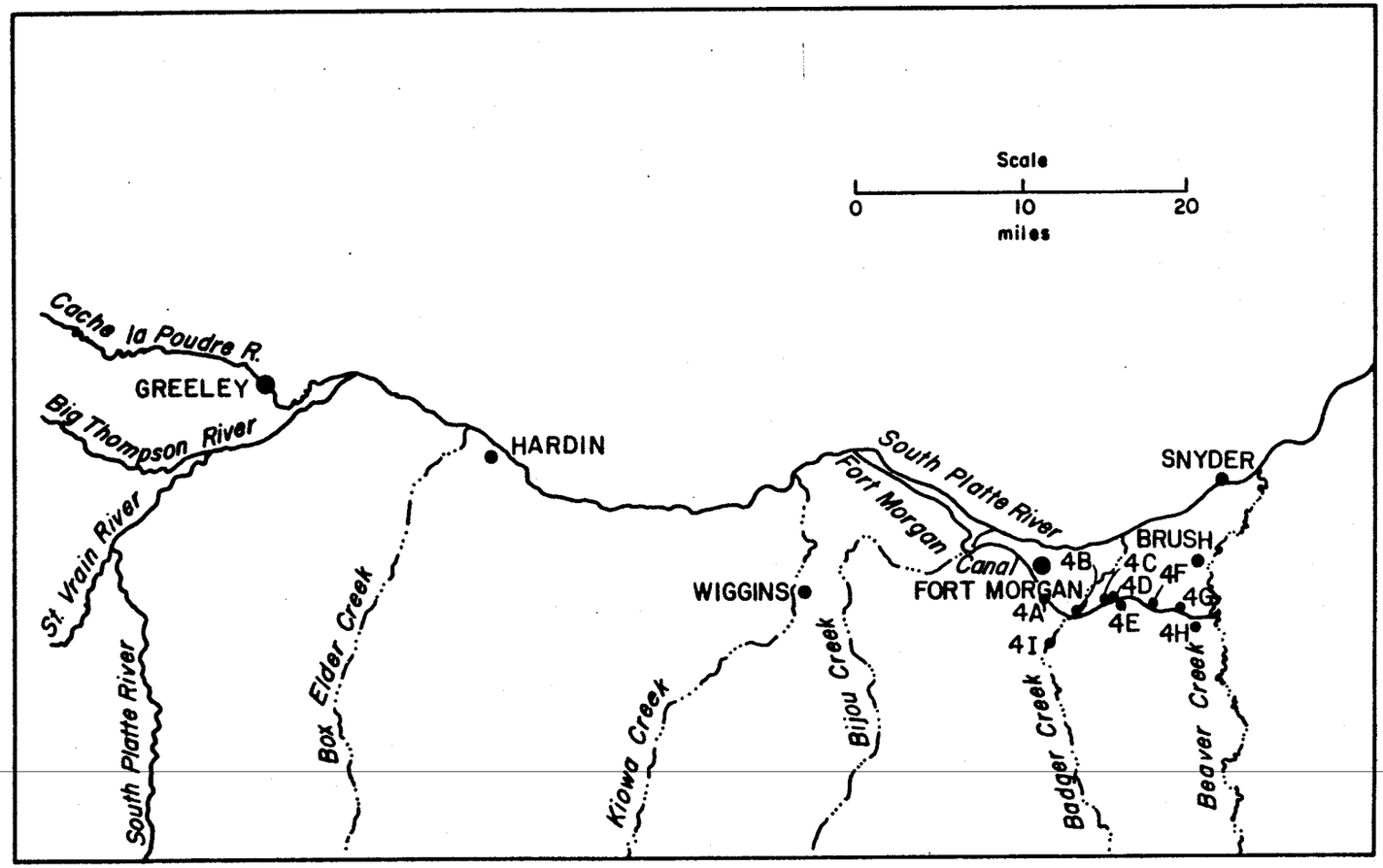

Figure 3 -- Location map for Recharge Sites Operated by the Fort Morgan Reservoir and Irrigation Company.

TABLE 4 - Recharge Sites for the
Fort Morgan Reservoir and Irrigation Company
(See Figure 3 for site locations)

All Sites (Unless otherwise noted below)

Water District:	2
Engineer:	HRS Consulting Engineers
Operator:	Fort Morgan Reservoir and Irrigation Company
Analysis:	Northern Colorado Water Conservancy District
Return Flow Calcs:	Stream Depletion Factor (SDF)
Decree Date:	1972

Map Location No:	4A
Site Name:	Fort Morgan Canal
ID Number (SEO):	2501
Site Description:	10 reaches of ditch
Capacity:	37.7 (Ac-Ft)
Diversion Info:	

Year	Diverted Water (Ac-Ft)
1979	7670
1980	2549
1981	8995
1982	1572
1983	8763
1984	6711
1985	3502

Map Location No:	4B
Site Name:	Badger Creek
ID Number (SEO):	2506
Engineer:	HRS/Thaemert
Site Description:	2 reaches of creek
Capacity:	11.3 (Ac-Ft)
Diversion Info:	

Year	Diverted Water (Ac-Ft)
1980	1489
1981	3066
1982	711
1983	1977
1984	2606
1985	4121

Map Location No:	4C
Site Name:	Lundock West Pond
ID Number (SEO):	Not Listed
Site Description:	Pond
Capacity:	3.3 (Ac-Ft)
Diversion Info:	Not Available

TABLE 4 (Continued)

Map Location No: 4D
Site Name: Lundock East Pond
ID Number (SEO): Not Listed
Site Description: Pond
Capacity: 3.5 (Ac-Ft)
Diversion Info: Not Available

Map Location No: 4E
Site Name: Keith Bath Pond
ID Number (SEO): Not Listed
Site Description: Pond
Capacity: 4 (Ac-Ft)
Diversion Info: Not Available

Map Location No: 4F
Site Name: Public Service Pond
ID Number (SEO): Not Listed
Engineer: Unknown
Site Description: Pond
Capacity: 27.7 (Ac-Ft)
Diversion Info: Not Available

Map Location No: 4G
Site Name: Bolinger Recharge Area
ID Number (SEO): 2502
Engineer: HRS/Bitinger
Site Description: Pond
Capacity: 36.4 (Ac-Ft)
Diversion Info:

Year	Diverted Water (Ac-Ft)
1979	1000
1981	4601
1982	1760
1983	3351
1984	2763
1985	2837

Location Map No: 4H
Site Name: Charles Henry Pond
ID Number (SEO): 2021
Site Description: Pond
Capacity: 5.5 (Ac-Ft)
Diversion Info:

Year	Diverted Water (Ac-Ft)
1985	500

TABLE 4 (Continued)

Location Map No: 4I
Site Name: Dagenhart
ID Number (SEO): 2015
Site Description: Pond
Capacity:
Diversion Info:

Year	Diverted Water (Ac-Ft)
1984	Not available
1985	37

2.2.6 Pioneer Water and Irrigation Company

The Pioneer Water and Irrigation Company has a temporary augmentation plan for five recharge sites. The irrigation company was formed to develop a plan of augmentation for well owners under the Tremont and Smith-Snyder ditch system. The total area irrigated under this ditch system is about 2,800 acres. About 28 irrigation wells are included in the plan of augmentation. The five recharge sites are: (5A) Pioneer Ditch, (5B) Woodward West Lake, (5C) Snyder Lake, (5D) Woodward East Lake and (5E) Peterson-Pioneer recharge site. These sites are located north of the South Platte River and northeast of the city of Fort Morgan (Figure 4). All of the sites were started in either 1982 or 1983. Historically, the Pioneer Ditch and the Woodward East and West Lake sites have been the major recharge sites. The estimated recharge capacity of these sites is about 30 acre-ft per day. Spring flooding of farmland between Woodward East Lake and the South Platte River has been a problem in the past. A network of 15 observation wells were installed in the vicinity of this site to detect whether the recharge operations at Woodward East Lake was responsible for this flooding. These wells were monitored for two years on a monthly basis. Indications are that recharge operations at Woodward East Lake were not the cause of this flooding. Current diversion information was not available for two of the five sites. The other sites had total diversions of about 3,700 acre-ft for 1985. Table 5 summarizes the Pioneer recharage sites.

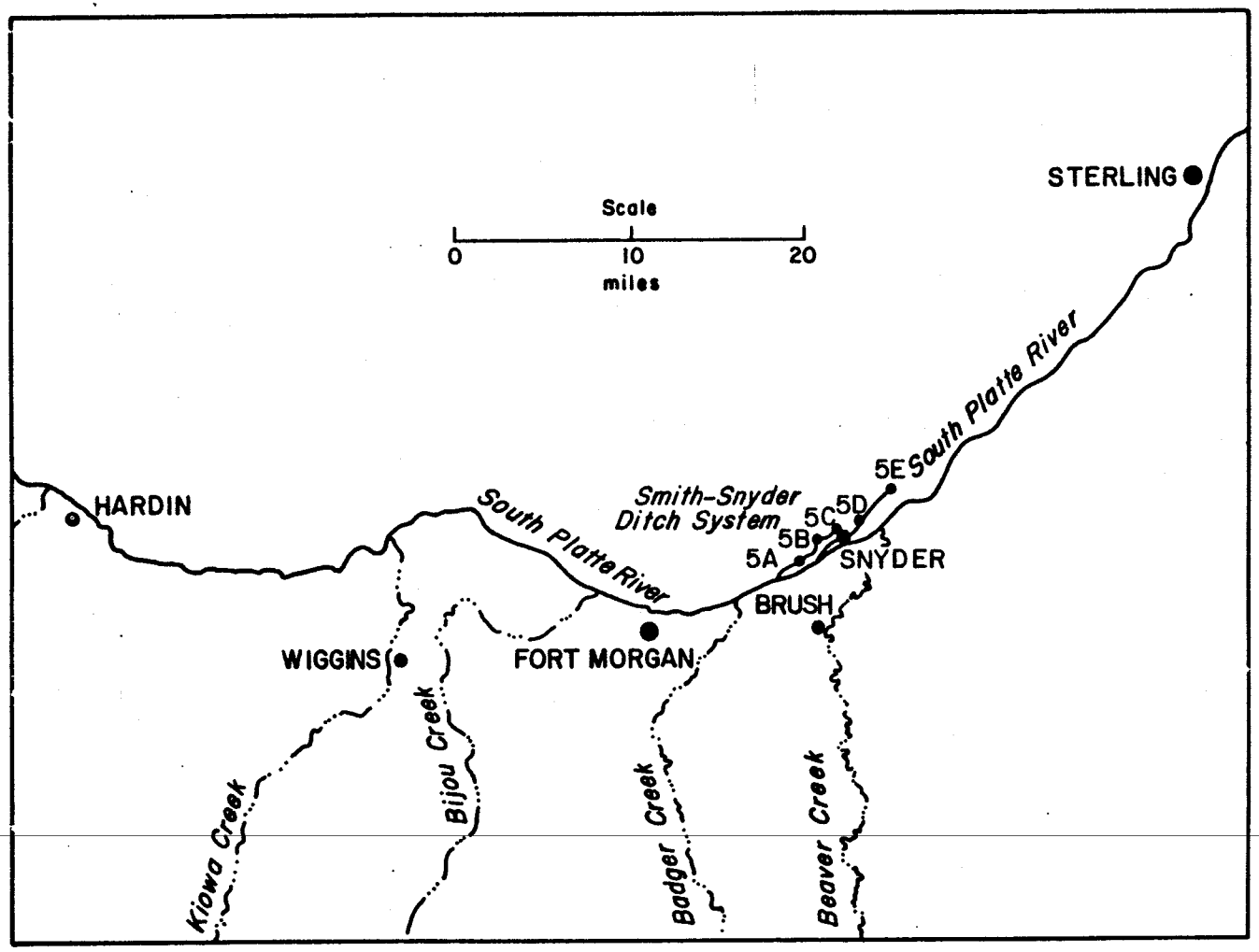

Figure 4 -- Location map for Recharge Sites Operated by the Pioneer Water and Irrigation Company

TABLE 5 - Recharge Sites for the
Pioneer Water and Irrigation Company
(See Figure 4 for site locations)

All Sites

Water District:	1
Engineer:	HRS Consulting Engineers
Operator:	Pioneer Water and Irrigation Company
Analysis:	Northern Colorado Water Conservancy District
Return Flow Calcs:	Stream Depletion Factor (SDF)
Decree Date:	1986 pending

Map Location No:	5A
Site Name:	Pioneer Ditch
ID Number (SEO):	2003
Site Description:	Ditch
Capacity:	75 cfs

Diversion Info:

Year	Diverted Water (Ac-Ft)
1982	556
1983	598
1984	1283
1985	1027

Map Location No:	5B
Site Name:	Woodward West Lake
ID Number (SEO):	2004
Site Description:	Pond
Capacity:	53.4 (Ac-Ft)

Diversion Info:

Year	Diverted Water (Ac-Ft)
1982	2998
1983	1534
1984	1898
1985	1235

Map Location No:	5C
Site Name:	Snyder Lake
ID Number (SEO):	2005
Site Description:	Pond
Capacity:	22.5 (Ac-Ft)

Diversion Info:

Year	Diverted Water (Ac-Ft)
1983	438
1984	Not available
1985	Not available

TABLE 5 (Continued)

Map Location No: 5D
Site Name: Woodward East Lake
ID Number (SEO): 2006
Site Description: Pond
Capacity: 53.4 (Ac-Ft)
Diversion Info:

Year	Diverted Water (Ac-Ft)
1982	95
1983	2527
1984	895
1985	1402

Map Location No: 5E)
Site Name: Peterson-Pioneer
ID Number (SEO): 2007
Site Description: Ditch
Capacity: 22.5 (Ac-Ft)
Diversion Info:

Year	Diverted Water (Ac-Ft)
1983	438
1984	Not Available

2.2.7 Upper Platte and Beaver Canal Company

The Upper Platte and Beaver Canal Company has developed three recharge projects. These recharge sites are: (6A) Upper Platte and Beaver Ditch, (6B) State-Kemple and (6C) Beaver Creek. The Upper Platte and Beaver Ditch and State-Kemple site are immediately south of the River between Fort Morgan and Brush (Figure 5). The Beaver Creek site is about four miles south of Brush (Figure 5). Total diversions for recharge in 1985 for the three sites were about 2,100 acre-ft.

2.2.8. Lower Platte and Beaver Canal Company

The Lower Platte and Beaver Canal Company operates four recharge sites. These sites are (7A) Lower Platte and Beaver Ditch, (7B) Emmerson Lake, (7C) Allyn Wind, and (7D) Daily recharge project. The Emmerson Lake and Allyn Wind Recharge sites are operated in conjunction with individual farmers. The recharge sites are located along the Lower Platte and Beaver Canal east of town of Brush (Figure 5). The Allyn Wind recharge site was started in 1978 and has diverted an average of 330 acre-feet for recharge per year. The Emmerson Lake Recharge site was started in 1981 and has diverted an average of about 450 acre-ft per year. The other two sites were started in 1984 but no diversion information was available. In 1985 total diversions were about 1100 acre-ft.

2.2.9. Riverside Irrigation Company

The Riverside Irrigation Company has developed two recharge projects. These recharge sites are: (8A) Headley recharge project, and (8B) Goodrich Farms. These recharge projects were started in 1982 and 1983 respectively. The operation of both of these sites was stopped due to financial difficulties. Recently efforts have been made to begin operation

again, this time by private individuals. Total diversions in 1985 for recharge were about 7,000 acre-ft.

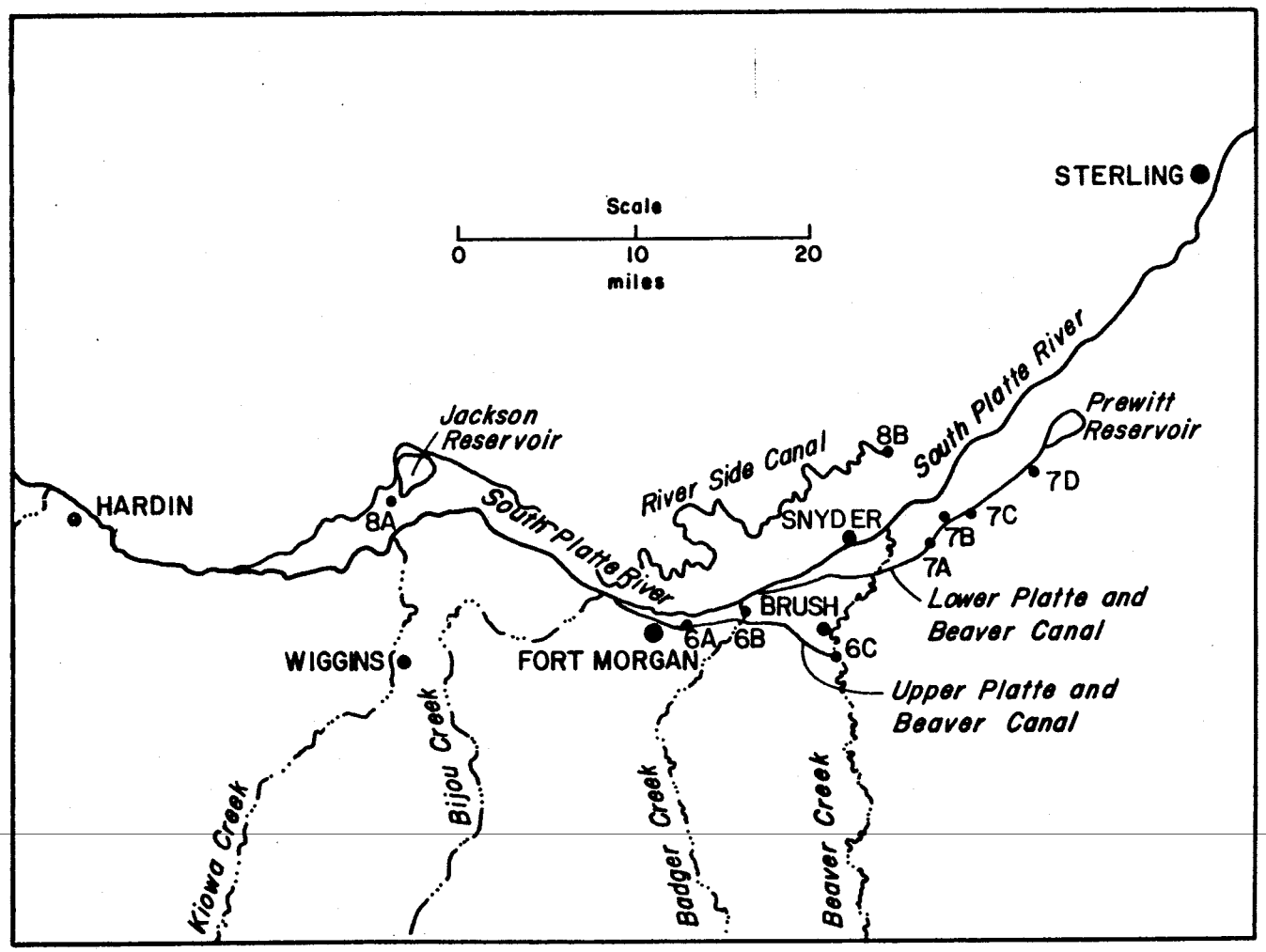

Figure 5 -- Location map for Recharge Sites Operated by the Upper Platte and Beaver Canal Company, the Lower Platte and Beaver Canal Company, and the Riverside Irrigation Company.

TABLE 6 - Recharge sites for the
Upper Platte and Beaver Canal Company
(See Figure 5 for site locations)

All Sites

Water District:	1
Engineer:	Ron Thaemert
Operator:	Upper Platte and Beaver Canal Company
Analysis:	?
Return Flow Calcs:	Glover's Solution
Decree Date:	1984

Map Location No:	6A
Site Name:	Upper Platte and Beaver Ditch
ID Number (SEO):	2517
Site Description:	Ditch
Capacity:	
Diversion Info:	

Year	Diverted Water (Ac-Ft)
1983	3606
1984	951
1985	1484

Map Location No:	6B
Site Name:	State-Kemble
ID Number (SEO):	2011
Site Description:	
Capacity:	
Diversion Info:	

Year	Diverted Water (Ac-Ft)
1984	306
1985	1484

Map Location No:	6C
Site Name:	Beaver Creek
ID Number (SEO):	2012
Site Description:	Lower reach of creek
Capacity:	
Diversion Info:	

Year	Diverted Water (Ac-Ft)
1984	1592
1985	617

TABLE 7 - Recharge Sits for the
Lower Platte and Beaver Canal Company
(See Figure 5 for site locations)

All Sites

Water District:	1
Engineer:	HRS Consulting Engineers
Operator:	Lower Platte and Beaver Canal Company
Analysis:	?
Return Flow Calcs:	Stream Depletion Factor (SDF)
Decree Date:	1972

Map Location No:	7A
Site Name:	Lower Platte and Beaver Ditch
ID Number (SEO):	
Site Description:	Ditch
Capacity:	62 (Ac-Ft)
Diversion Info:	

Year	Diverted Water (Ac-Ft)
1984	Not available
1985	Not available

Map Location No:	7B
Site Name:	Emmerson Lake
ID Number (SEO):	2018
Site Description:	Pond
Capacity:	40 (Ac-Ft)
Diversion Info:	

Year	Diverted Water (Ac-Ft)
1981	457
1982	112
1983	227
1984	721
1985	731

Map Location No:	7C
Site Name:	Allyn Wind
ID Number (SEO):	2500
Site Description:	Pond
Capacity:	1200 (Ac-Ft)
Diversion Info:	

Year	Diverted Water (Ac-Ft)
1978	348
1980	375
1981	269
1982	348
1983	306
1984	291
1985	353

TABLE 7 (Continued)

Map Location No: 7D
Site Name: Daily
ID Number (SEO):
Site Description: Pond
Capacity:
Diversion Info:

Year	Diverted Water (Ac-Ft)
1984	Not available
1985	Not available

TABLE 8 - Recharge Sites for the
Riverside Irrigation Company
(See Figure 5 for site locations

All Sites

Water District:	1
Operator:	Riverside Irrigation Company
Analysis:	Northern Colorado Water Conservancy District
Return Flow Calcs:	Stream Depletion Factor (SDF)

Map Location No:	8A
Site Name:	Headly Property
ID Number (SEO):	2523
Engineer:	Leonard Rice Engineering
Site Description:	Series of Ponds
Capacity:	
Decree Date:	Aborted
Diversion Info:	

Year	Diverted Water (Ac-Ft)
1982	1720
1983	1475
1984	3263
1985	500

Map Location No:	8B
Site Name:	Goodrich Farms
ID Number (SEO):	
Engineer:	HRS Consultants
Site Description:	Series of Ponds
Capacity:	
Decree Date:	Redeveloped 1986
Diversion Info:	As old Goodrich Farms Site:

Year	Diverted Water (Ac-Ft)
1983	1849
	Under new management
1984	2268
1985	6453

2.2.10 Other Recharge Sites

Between Prewitt Reservoir and town of Crook there are an additional eight recharge sites. Most of these recharge projects are operated by individual farmers. All but two of the sites have decreed plans of augmentation. Most of the sites have been in operation since 1979-80. All but one are still active. A brief description of these sites follows. The location of these sites are shown in Figure 6. A total of about 4,500 acre-ft was diverted in 1985 for recharge from these sites.

The Sandhill Ditch recharge project was started in 1974 and is a leaky abandoned lateral of the South Platte Ditch. The site is located just below Prewitt Reservoir. This recharge project was discussed in the recharge studies section of this report and will not be discussed in detail here. Since 1978, about 12,600 acre-ft has been diverted for recharge at this site. This averages about 1,600 acre-ft per year, for which GASP gave a recharge credit of 77 percent of the diverted flow. In 1985 diversions for recharge were about 1,250 acre-ft.

The Hessler Recharge Project consists of a 20 acre recharge pond and 3 reaches of the Davis Brothers Ditch. The site is operated by a Mr. Robert Hessler in cooperation with the Davis Brothers Ditch Company. Since 1980, total diversions for recharge has been about 5,800 acre-ft or about 970 acre-ft per year. In 1985, 1,444 acre-ft was diverted for irrigation for which GASP gave credit for 532 acre-ft or about 37 percent. Of this, Hessler received recharge credit for 35 acre-ft and Davis Brothers Ditch company received about 500 acre-ft credit.

The Pivonka recharge site was a pond located adjacent to Pawnee Ditch. Recharge operations were conducted in 1979 and 1980. No recharge credit was given and the project was aborted.

The Country Club Hills recharge site is located on the Pawnee Ditch west of the City of Sterling. The project is operated for the city of Sterling by Mr. Andy Anderson. The site has been operated continuously since 1980 with total diversions during this time period of 391 acre-ft or about 65 acre-ft annually. In 1985, 48 acre-ft was diverted for recharge.

The Monahan recharge site is a 10 acre pond adjacent to Farmer's Pawnee Canal. The site is operated by Mr. Rex Monahan which is entitled to divert up to 1,500 acre-ft per year at a maximum rate of 25 cfs. The site has been operated intermittently since 1979. Available records indicate about 1,000 acre-ft has been diverted for recharge since 1979. No diversion information was available for 1985.

The Home Ranch of Wyoming owns and operates the Simpson Recharge Lake No. 1. The site is located south of the town of Iliff. Water is diverted from Bravo Ditch for recharge. Since 1979, about 1,150 acre-ft has been diverted for recharge, or about 165 acre-ft annually. Recharge credits have been about 50 percent of total diversions. In 1985, about 57 acre-ft was diverted for recharge.

The Wilhelm (Sonneberg) site is a 10 acre pond which is filled from water diverted from Lone Tree Ditch. The site was constructed in 1980 to receive credit from GASP for seven irrigation wells. Three wells are owned by the Painted Rock Development Company and four wells are owned by the Wilhelm Company. These two companies split the recharge credit. Since 1980, total diversions for recharge has been about 1,470 acre-ft or about 245 acre-ft annually. The recharge credit from GASP is about 100 acre-ft per year. In 1985, about 180 acre-ft was diverted for recharge.

The Condon recharge site consists of a 20 acre pond near city of Sterling and a reach of Chambers Ditch. The site is owned and operated by Mr. Bill Condon. He pumps water from the South Platte River into his pond

during the period of November to June. The decreed plan of augmentation for this site includes a conditional storage priority of 5,000 acre-ft per year. Since 1981, about 9,400 acre-ft has been diverted for recharge, or about 1,900 acre-ft per year. GASP has given recharge credit for about 37 percent of total diversions. In 1985, diversions for recharge was about 1,300 acre-ft.

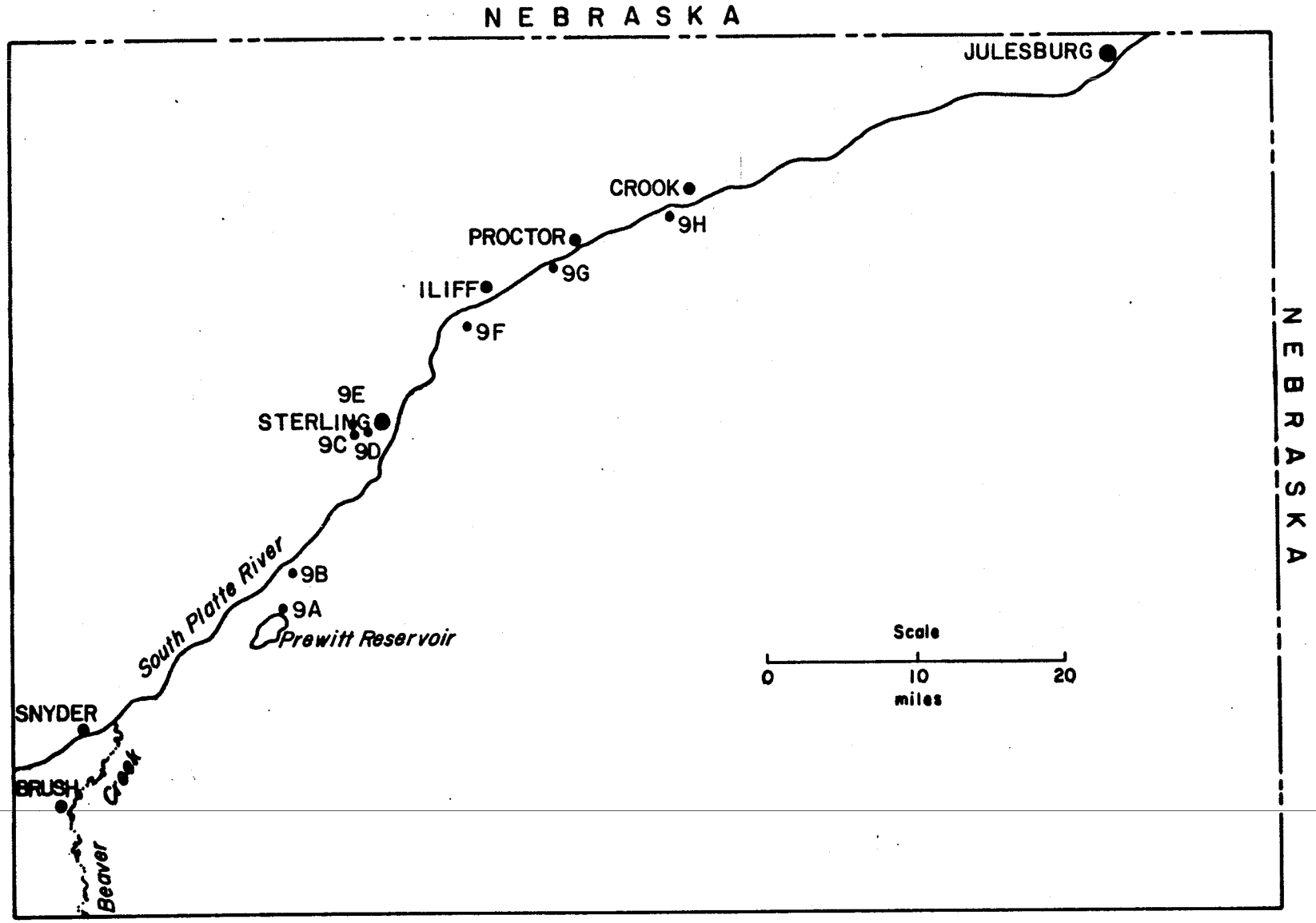

Figure 6 -- Location map for Other Recharge Sites.

TABLE 9 - Other Recharge Sites
(See Figure 6 for site locations)

All Sites
Water District: 64

Map Location No: 9A
Site Name: Sandhill Ditch
ID Number (SEO): 2504
Engineer: none
Operator: South Platte Ditch Company
Analysis: State Engineer Office (SEO)
Return Flow Calcs: 77% credit for recharge
Site Description: Abandoned Lateral
Capacity:
Decree Date: 1974
Diversion Info:

Year	Diverted Water (Ac-Ft)
1978	1131
1979	1333
1980	796
1981	2214
1982	1931
1983	2056
1984	1935
1985	1249

Map Location No: 9B
Site Name: Hessler Recharge
ID Number (SEO): 2506
Engineer: HRS Consultants
Operator: R. Hessler & Davis Bros Ditch
Analysis:
Return Flow Calcs: Stream Depletion Factor (SDF)
Site Description: 30 Ponds, 3 ditch reaches
Capacity: Pond Capacity - 20 (Ac-Ft)
Decree Date: 1978
Diversion Info:

Year	Diverted Water (Ac-Ft)
1980	662
1981	832
1982	823
1983	1290
1984	763
1985	1444

TABLE 9 (Continued)

Map Location No: 9C
Site Name: Pivonka
ID Number (SEO):
Engineer: None
Operator: John Pivonka
Analysis:
Return Flow Calcs: None
Site Description: Pond
Capacity:
Decree Date: Aborted
Diversion Info:

Year	Diverted Water (Ac-Ft)
1979	576
1980	194

Map Location No: 9D
Site Name: Country Club Hills
ID Number (SEO): 2505
Engineer: None
Operator: Anderson & Vandemoer
Analysis:
Return Flow Calcs: None
Site Description: Pond
Capacity:
Decree Date: 1978
Diversion Info:

Year	Diverted Water (Ac-Ft)
1980	63
1981	93
1982	70
1983	76
1984	41
1985	48

TABLE 9 (Continued)

Map Location No:	9E
Site Name:	Monahan
ID Number (SEO):	2501
Engineer:	HRS Consultants
Operator:	Rex Monahan
Analysis:	
Return Flow Calcs:	Stream Depletion Factor (SDF)
Site Description:	Pond
Capacity:	10 (Ac-Ft)
Decree Date:	Pending
Diversion Info:	

Year	Diverted Water (Ac-Ft)
1979	705
1980	235
1981	?
1982	No water wanted
1983	Structure not useable
1984	114
1985	Not available

Map Location No:	9F
Site Name:	Home Ranch of Wyoming
ID Number (SEO):	2500
Engineer:	None
Operator:	Robert Giacomini
Analysis:	
Return Flow Calcs:	Replacement for well
Site Description:	Pond
Capacity:	
Decree Date:	1979
Diversion Info:	

Year	Diverted Water (Ac-Ft)
1979	68
1980	258
1981	183
1982	254
1983	155
1984	177
1985	57

TABLE 9 (Continued)

Map Location No: 9G
Site Name: Wilhelm (Sonnenberg)
ID Number (SEO): 2507
Engineer: Frank Tralease, Wright Engineering
Operator: Painted Rock Development Company & Wilhelm Company
Analysis:
Return Flow Calcs:
Site Description: Ponds
Capacity: 10 (Ac-Ft)
Decree Date: 1983
Diversion Info:

Year	Diverted Water (Ac-Ft)
1980	370
1981	193
1982	99
1983	178
1984	450
1985	180

Map Location No: 9H
Site Name: Condon Pond, Chambers Ditch
ID Number (SEO): 2514
Engineer: HRS Consulting Engineers
Operator: Bill Condon
Analysis:
Return Flow Calcs: Stream Depletion Factor (SDF)
Site Description: Pond and Ditch
Capacity: 20 (Ac-Ft)
Decree Date: 1979
Diversion Info:

Year	Diverted Water (Ac-Ft)
1981	1330
1982	2110
1983	2428
1984	2255
1985	1295

2.2.11 Summary and Evaluation

Several factors affect the selection of a site for artificial recharge. First a permeable aquifer must underlie the recharge site and be hydraulically connected to the river. The depth to the water table must be great enough so that the recharge mound build up will not create water logging at the land surface. The site is best if the return flow to the river occurs during the irrigation season. Socio-economic considerations are also extremely important. Cooperation with the land owner is essential before a recharge project can be implemented.

Currently financial considerations are such that it is only practical to conduct artificial recharge operations in the South Platte River Basin if the necessary distribution systems and holding structures are already in place. As a result, most current recharge operations are being conducted by irrigation companies in cooperation with water user organizations such as GASP. Shown on Table 10, is a summary of total diversions by operator for artificial recharge from 1981 to 1985 in the South Platte River Basin. During this time period, Fort Morgan and Bijou Irrigation Companies have been the major recharge operators.

Shown on Figure 7 is the total annual diversions for each year from 1978 to 1985. Total diversions have increased from less than 5,000 acre-feet a year in 1978 to about 55,000 acre-feet in 1985. This obviously represents a dramatic increase in recent years. Artificial recharge for stream augmentation is quickly becoming a major water management tool in the South Platte River Basin. This will be beneficial to all water users in the basin.

In the rush to establish water rights for artificial recharge, concern must be expressed whether a more optimal recharge policy can be established. Water returned to the river during noncritical times, does little good in

meeting demands of water users in the basin. In some instances it appears that the artificial recharge policy being followed is to conduct recharge operations whenever the water is available with little regards to timing of return flows. For example it does little good to recharge in November at sites located a short distance from the river. All of the recharged water will have returned to the river by start of next irrigation. Establishing these water rights will in general preclude establishing recharge operations at more optimal sites. This in general will be detrimental to all water users in the basin.

Table 10 -- Summary of Total Diversions For Artificial Recharge in South Platte, 1981-1985.

Operator	# of sites	1981	1982	1983	1984	1985	TOTAL
CENTRAL	5			3837	1899	2721	8,457
HENRY LYN	1	2532	NA	1425	2358	3549	14,567
BIJOU	7	3392	5185	8135	8205	17677	42,594
FT MORGAN	9	16662	4043	14091	12080	10997	70,581
PIONEER	5		3649	5535	4076	3664	16,924
UPPER PLATTE BEAVER	3			3606	2849	3585	10,040
LOWER PLATTE BEAVER	4	726	460	533	1012	1084	4,538
RIVERSIDE	2		1720	3324	5531	6953	17,528
INDIVIDUAL	8	4845	5287	6183	5735	4273	32,714
TOTAL	44	28,000	20,300	46,669	43,700	54,500	218,400

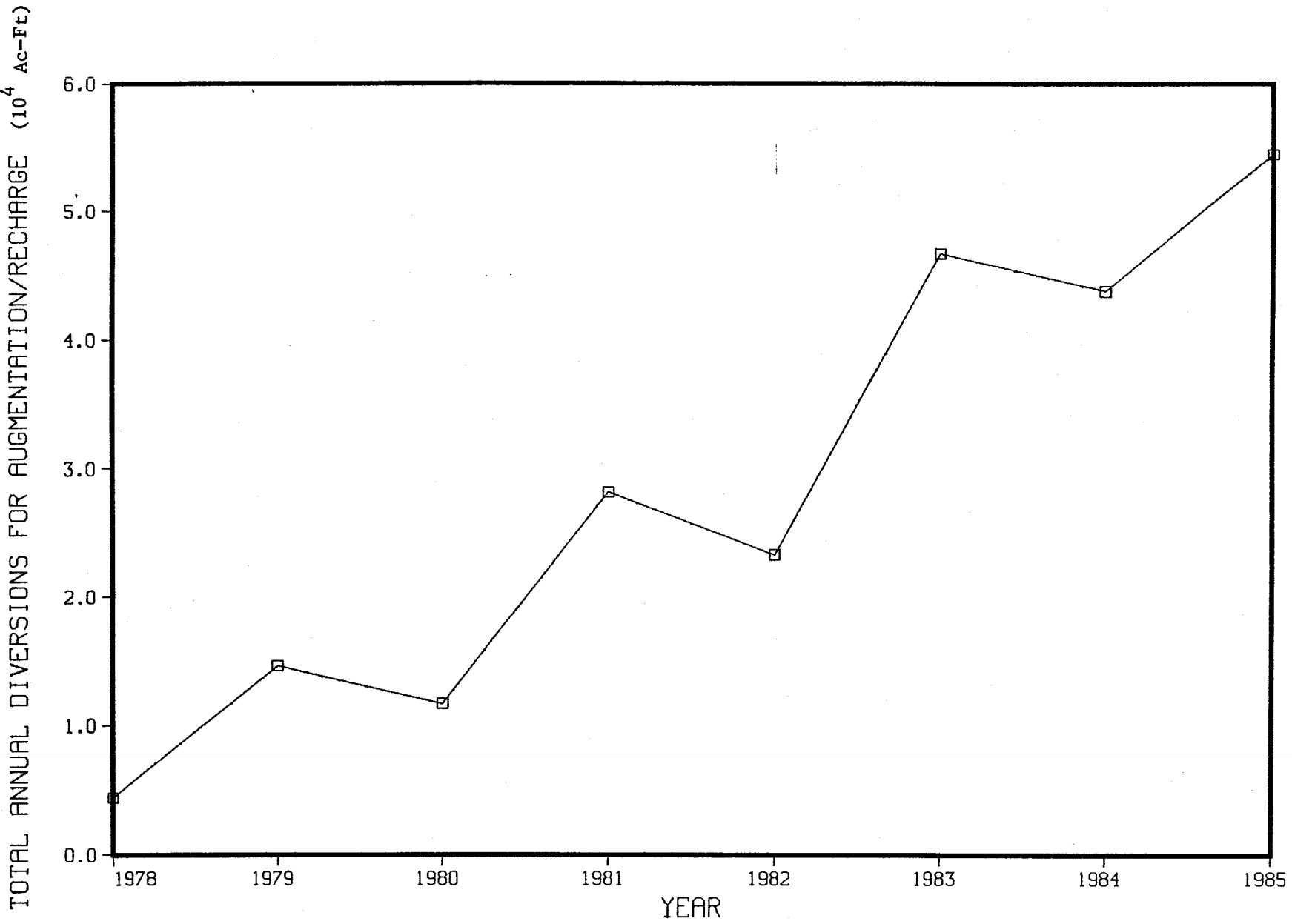

Figure 7 -- Total Annual Diversions for Artificial Recharge in the South Platte River Basin

2.3 Methods for Calculation of Return Flows

Return flow calculations estimate the amount of water from a augmentation/recharge project which is returned to the river through groundwater flow. Two methods currently are used to calculate return flows for the augmentation/recharge projects along the South Platte River . These are Glover's analytical solution decribing stream depletion due to a nearby pumping well (9), and the Stream Depletion Factor method (10). Glover's solution is the method which is recommended by the State Engineer's Office. The Stream Depletion Factor method is based on Glover's solution and a numerical groundwater model. The following is a description of each method:

2.3.1 Glover's Solution

The solution for stream depletion by a pumping well is given by Glover (9) as:

$$\frac{Q_s}{Q_w} = 1 - \text{erf}\left(\frac{a}{\sqrt{4tT/S}}\right) \qquad (1)$$

where

Q_s = rate of stream depletion,

Q_w = rate of well discharge,

a = perpendicular distance from well to the stream,

t = pumping time,

T = transmissivity,

S = specific yield, and

erf(z)= error function of z defined by

$$\text{erf}(z) = \frac{2}{\sqrt{\pi}} \int_0^z e^{-z^2}\, dz. \qquad (2)$$

The error function is very common in groundwater hydrology and extensive tables can be easily found (11). Equation (1) is commonly written as

$$\frac{Q_s}{Q_w} = \text{erfc}(z) \qquad (3)$$

where

$$z = \frac{a}{\sqrt{4tT/S}} \quad \text{and} \qquad (4)$$

erfc(z) = complementary error function of z defined as

$$\text{erfc}(z) = 1 - \text{erf}(z) = \frac{2}{\sqrt{\pi}} \int_z^\infty e^{-z^2}\, dz. \qquad (5)$$

Equation (1) gives the rate of stream depletion caused by the pumping well at any specified time. Glover's solution (equation 1) can be used to calculate return flow to the river from a recharge pond if a negative pumping rate is used and if the pond is approximated as a point source (ie. a well).

Equation (1) can be integrated to obtain the volume of stream depletion. This yields

$$\frac{V_s}{Qt} = \text{erfc}(z) - z^2 \frac{2}{\sqrt{\pi}} \int_z^\infty \frac{e^{-z^2}}{z^2}\, dz \qquad (6)$$

where

V_s = volume of water depleted from the stream since pumping was started,

Qt = volume of pumping and $z = \frac{a}{\sqrt{4tT/s}}$.

This is equivalent to Hantush (12)

$$\frac{V_s}{Qt} = 4i^2 \operatorname{erfc}(z) \qquad (7)$$

where

$i^2\operatorname{erfc}(z)$ = the second repeated integral of the error function.

From the recursive relationship for the repeated integrals of the error function, then equation (7) can be expressed in terms of the error function as (10):

$$\frac{V_s}{Qt} = (2z^2 + 1)\operatorname{erfc}(z) - z\frac{2}{\sqrt{\pi}}e^{-z^2} \qquad (8)$$

Equation (8) can then be used to calculate the volume of stream depletion, or in the case of recharge, the volume of water returned to the river since recharge operations were started.

Like all analytical solutions, Glovers solutions is based on the following highly idealized assumptions.

1. The aquifer is homogeneous, isotropic and of infinite extent.
2. Drawdown is small compared to the well depth.
3. The well fully penetrates the aquifer.
4. The river is a constant head source.
5. The coarse of the river is idealized as a straight line.
6. Pumping is constant.
7. Water is released instantaneously from storage.

The Central Colorado Water Conservancy District uses Glovers solution in the calculation of return flows to the river.

The following example is presented to illustrate use of Glover's Solution,

Example 1

A recharge pond located 2000 feet from the South Platte River, recharges water at the rate of 5 cfs. The aquifer transmissivity is 30,000 ft^2/day and the specific yield is 0.20. What is the return flow to the river after 10, 30, 50, 100, 150, and 300 days of operation? What is the volume of return flow?

To calculate the return flow to the river the Glover's Solution equation (1) is used. Only the calculation for t = 10 days will be shown.

$$z = \frac{a}{\sqrt{4tT/S}} = \frac{2000}{\sqrt{(4)(10)(30,000)/(.20)}} = .82$$

From Table 7.1 in Abramowitz and Stegun (11) then erf (.82) = .754. Substitution into equation (1) yields

$$Q_s = Q(1-erf(z)) = 5(1 - .754)$$

$$Q_s = 1.23 \text{ cfs}$$

Which is the rate of return flow to the river after ten days. The return flow at the other times are shown in Figure 8.

The volume of water returned to the river at any specified time is the area under the curve in Figure 8, up to that specified time. To calculate the volume of return flow then equation (8) is used. Again only the calculation for a time of 10 days will be shown. From before t = 10 days, then z = 0.82. Substitution into equation (8) then

$$\frac{V_s}{Qt} = (2(.82)^2 + 1)\ (1 - \text{erf}\ (.82)) - .82\ (\frac{2}{\sqrt{\pi}})e^{-(.82)^2}$$

From before erf (.82) = .754 and

$$\frac{V_s}{Qt} = .577 - .472 = .105$$

or

$$V_s = \frac{(.105)\ (5)\ (86,400)\ (10)}{43,560} = 10.4 \text{ acre-feet.}$$

The ratio of volume of return flow to the river to the volume recharged at other times are shown on Figure 9.

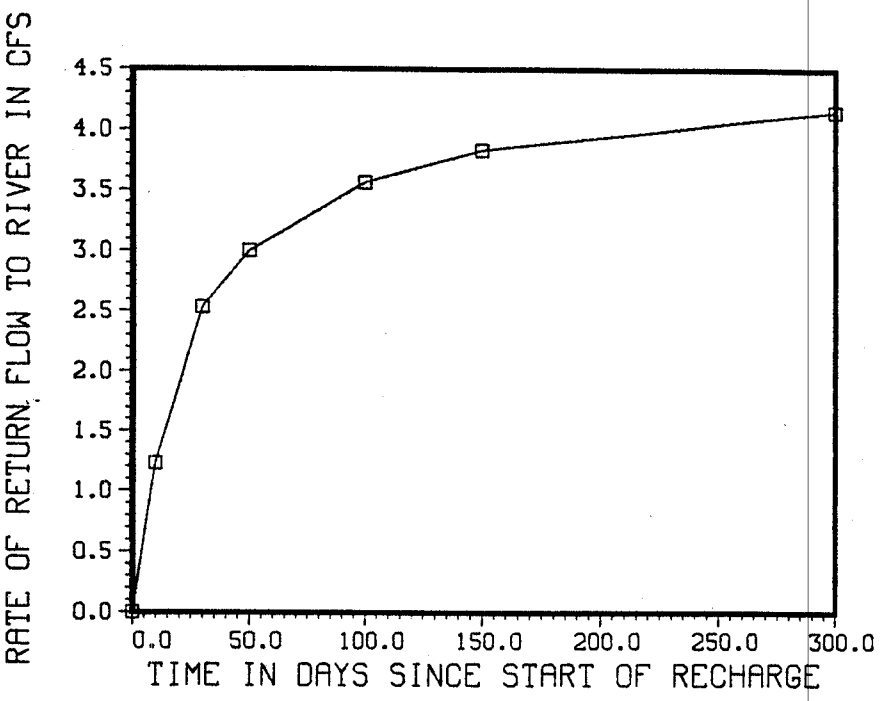

Figure 8 -- Plot of Return Flow to River versus Time for Glover's Solution Example Problem

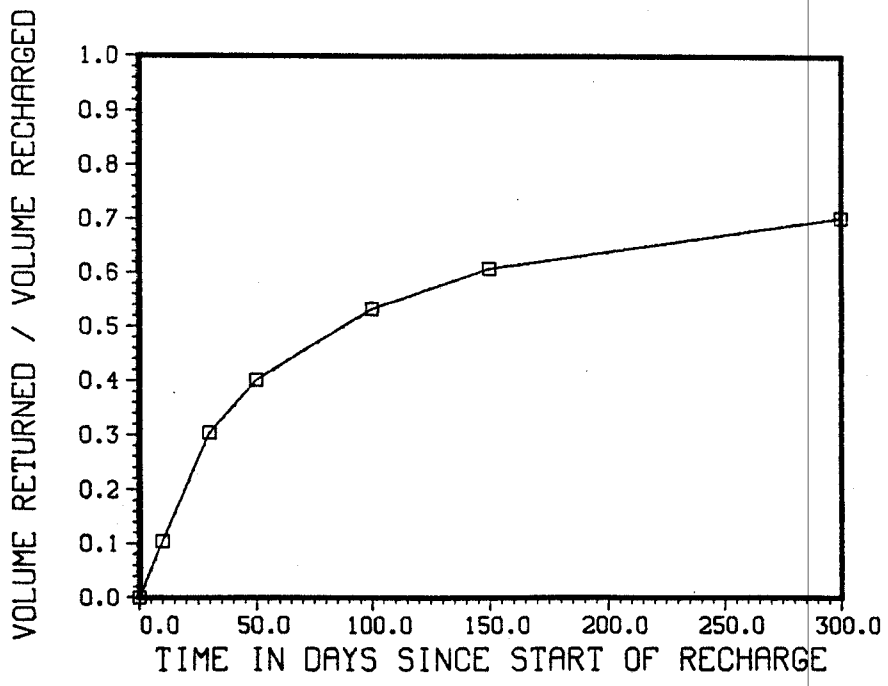

Figure 9 -- Plot of Cumulative Volume of Return Flow to River versus time for Glover's Solution Example Problem

2.3.2 Stream Depletion Factor Method

The Stream Depletion Factor (SDF) method is derived using Glover's solution (equations 1 and 8) and a curve fitting process which attempts to compensate for varying aquifer properties. Glover's Solution is based on a highly idealized set of geometry and aquifer properties. Jenkins (10) developed the SDF method in which a numerical model is used to simulate the irregular boundary conditions and hetergenous aquifer properties that occur in field situations. Glover's Solution is then modified so as to attempt to match theory with field observations. The SDF method calculates the time at which the volume of stream depletion is 28 percent of the volume pumped by the well. From equation (8) this occurs when

$$z = \frac{a}{\sqrt{4tT/S}} = .5 \tag{9}$$

or when

$$\frac{a^2 S}{Tt} = 1. \tag{10}$$

Jenkins defined the SDF as

$$SDF = \frac{a^2 S}{T} \tag{11}$$

The relationship between z and SDF is

$$SDF = 4tz^2 \tag{12}$$

From equations (8) and (12) when z = .5 then a SDF of one equals the time when the volume of stream depletion is 28 percent of the volume pumped.

With the SDF method Glover's Solution (equations (1) and (8)) are graphically solved. Two curves are constructed (Figure 10). Curve A is a plot of Q_s/Q_w versus t/SDF. This curve is obtained from solution of

equation (1). Curve B is a plot of V_s/Qt versus t/SDF and is obtained from the solution of equation (8). An example problem illustrating the use of these curves follows.

Example 2

A recharge pond located 2000 feet from the South Platte River, recharges water at the rate of 5 cfs. The aquifer transmissivity is 30,000 ft^2/day and the specific yield is 0.20. What is the time after recharge begins when the return flow to the river is 2 cfs? What is the time after recharge begins when 50 percent of the volume recharged has returned to the river?

Note this example problem is the reverse of the previous example problem. The SDF for this problem is calculated from equation (11)

$$SDF = \frac{a^2 S}{T} = \frac{(2000^2)(.2)}{30,000} = 26.67 \text{ days}$$

The ratio of rate of stream depletion to rate of well pumpage is

$$\frac{Q_s}{Q_w} = \frac{2}{5} = .4$$

From Figure 10, curve A, when $Q_s/Q_w = .4$ then t/SDF = .7, thus

$$t = (.7)\ (26.67) = 18.7 \text{ days.}$$

which is the time when the return flow to the river is 2 cfs. For V_s/Qt = .5 from Figure 10, curve B, then t/SDF = 3.2. Thus

$$t = (3.2)\ (26.67) = 85.3 \text{ days.}$$

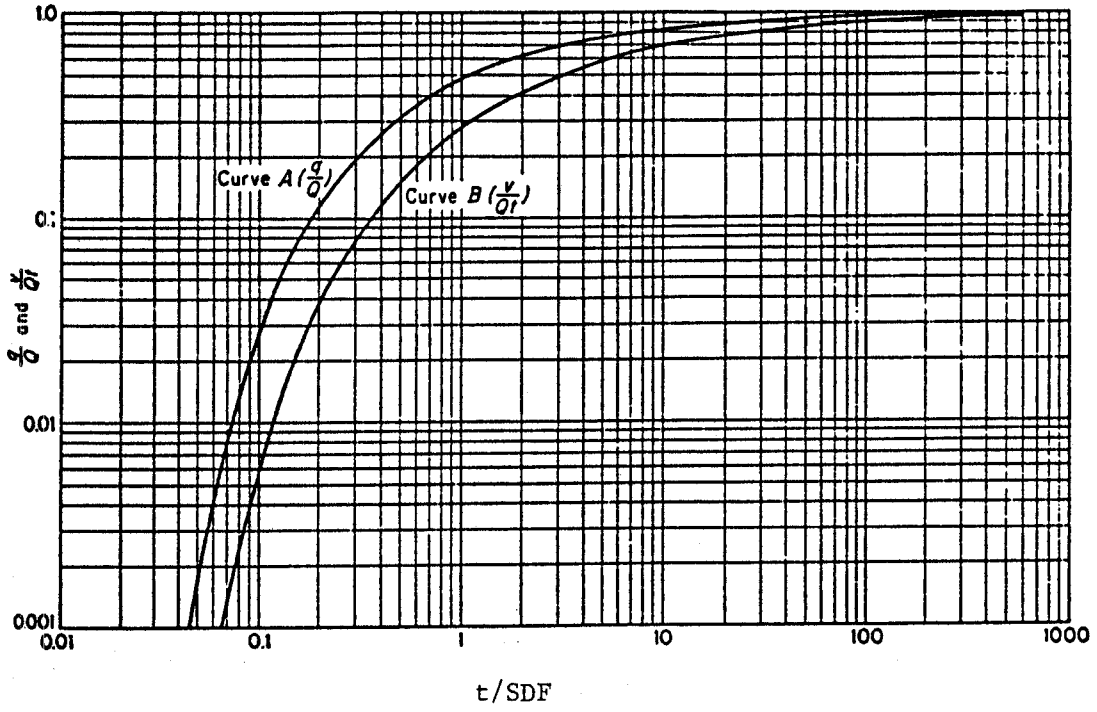

Figure 10 -- Graphical Plot of Glover's Solution
Used in Stream Depletion Factor Method

which is the time when volume of return flow is 50 percent of volume recharged. The use of Figure 10 simplifies the calculations in that it is not necessary to look up in tables the error function or interpolate between table values.

In practice to account for heterogeneous aquifer properties and irregular boundary conditions, a digital groundwater model is employed to determine the SDF (not equation 11). For the South Platte River Basin, the USGS constructed a finite difference model of the basin. In the model a unit (1 cfs) steady pumping rate was simulated for each grid individually. The model was run until 28 percent of total volume of pumped water from the grid came from the river. This occurs when $V_s/Qt = 0.28$ and $t/SDF = 1$. The time in the model at which 28 percent of the total volume of pumped water comes from the river is therefore the model determined SDF. This represents a one point curve fitting process in which the theoretical curves (Figure 10) are matched to the model results. The SDF values derived from this model were plotted and contoured. No documentation describing the modeling of the South Platte River Basin was published. However, maps of SDF contours for six reaches of the river were published and widely used. The model generated SDF value is determined from these SDF maps published by the USGS. Using this value for the SDF, the computations proceed as in Example 2 except the model calculated value of the SDF is used in replacement of the theoretical value determined from equation (11).

2.3.3 Adequacy of Return Flow Calculations

A need exists to verify the results of return flow calculations using both Glover's Solution and the SDF method. In both methods a non point source is approximated as a point source (ie. well). Glover's Solution is based on highly idealized boundary conditions and uniform aquifer properties which are not the situation in the South Platte River Basin. The SDF method attempts to compensate by using a digital groundwater model. However only a single point matching process is used. Questions remain as to whether the shape of these curves are valid for field situations and whether a better curve fitting process could be utilized. Errors in these analyses could result in either overestimation or underestimation of return flow to the river. Either error could have serious consequences for water users in the basin.

Currently CSU is conducting additional research into the adequacy of these return calculations. The results of these two methods are being compared with the results from numerical finite-difference and finite-element groundwater models. This will aid in evaluating the magnitude of errors in the return flow calculations and under what field conditions can either Glover's or the SDF method be applied with negligible errors. Consideration should also be given to replacing the use of Glover's solution and SDF method with these numerical groundwater models. The latest generation of numerical groundwater models are very user friendly and have been adapted to run efficiently on microcomputers.

III. CONCLUSION

This report represents the first comprehensive documentation of the augmentation/recharge projects in the South Platte River Basin. These augmentation/recharge projects are rapidly developing as an essential part of the water management practices of the South Platte River Basin. The purpose of almost all of these projects is augmentation of streamflow to the South Platte River. This is needed to offset the stream depletion caused by pumping of irrigation wells located in the alluvium of the South Platte River Basin.

Because these augmentation/recharge projects have been developing so rapidly, little information had previously been available about these projects. During this study data was compiled on the number, location and on the total annual diversions for these projects. In the South Platte River Basin there are about 44 recharge/augmentation projects. This represents about three-fourths of all the recharge projects in the State of Colorado. Total annual diversions have increased from less than an estimated 5,000 acre-feet in 1978 to about 55,000 acre-feet in 1985 in the South Platte River Basin. Most of the current recharge operations are being conducted by irrigation companies in cooperation with water user organizations such as GASP and Central. Fort Morgan Reservoir and Irrigation Company and Bijou Irrigation Company are two of the major recharge operators.

Several factors influence the feasibility of conducting recharge operations. The physical limiting factors in site selection are the depth to the water table and the presence of a permeable geologic formation. In general, the Valley Fill Alluvium that occurs in the South Platte River Basin is permeable enough to allow recharge. Locally waterlogging may be a

problem. Socio-economic considerations are also extremely important. Cooperation with the landowners is essential before a recharge project can be implemented. Currently financial considerations are such that it is only practical to conduct artificial recharge operations if the necessary distribution systems and holding structures are already in place. As a result irrigation companies are the most active in conducting recharge operations. Finally the recharge site must be located the proper distance from the river so that a substantial part of the return flow to the river occurs during the critical summer irrigation season.

Currently two methods are predominantly used to calculate return flow to the river in the South Platte River Basin. These two methods are Glover's solution and the Stream Depletion Factor method (SDF). Both of these methods are either analytical or semi-analytical in approach. A need exists to verify the results of return flow calculations using both Glover's solution and the SDF method. Current CSU research is involved in determining the adequacy of these methods and in development and evaluation of other methods which may improve the precision of return flow computations.

Another area of concern relating to these augmentation/recharge projects is the question of water rights. In the rush to establish water rights for artificial recharge, concern must be expressed for the optional recharge operation which will give the greatest benefit to all water users. Water returned to the river during noncritical times is of little benefit to the water users in the basin. Random establishment of recharge sites and associated water rights may tend to preclude recharge at more optional sites.

A related question is the credit received by these recharge/augmentation projects (i.e., the credit received is that percent of

total annual diversion for recharge that is returned to the river during the critical irrigation season). GASP is very helpful in this regards in that this organization encourages these augmentation/recharge projects by purchasing excess credits. Some effort was expended during this study to compile the recharge credit given for these projects. This data was difficult to obtain and the data collected was not complete. In general from the available data, the recharge credit is relatively low and is usually less than 30 or 40 percent of total annual diversions for recharge. It may be possible to increase this through a more optimal site selection process. Additional data needs to be compiled to accurately ascertain the recharge credits received.

The rapid rate at which these augmentation/recharge projects have been developing in the South Platte River Basin is indicative that water users in the basin recognize the benefits from these types of operations. Part of this rapid rate of development may be the result of a rush to establish water rights but undoubtly a large part of it is that water users are concerned about developing an adequate and reliable water supply. They view these recharge projects as an essential element of the overall water management practices of the South Platte River Basin. Even when recharge credits are in general low, water users view these projects as being beneficial. The rapid development and implementation of these augmentation/recharge projects indicate they are worth the effort. These projects have developed into an integral element of the water supply of the South Platte River Basin and should have benefits to all water users in the basin.

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APPENDIX A: Laws Pertaining to Augmentation on the South Platte River

RULES AND REGULATIONS

RULE 1. Except as specifically noted below, these Rules and Regulations shall apply to all underground water of the South Platte River and its tributaries as defined in Colorado Revised Statutes Annotated, 1963, ss37-91-103 (Supplement 1969), and reproduced below, as follows:

> (4) 'Underground water' as applied in this act for the purpose of defining the waters of a natural stream, means that water in the unconsolidated alluvial aquifer of sand, gravel, and other sedimentary materials, and all other waters hydraulically connected thereto which can influence the rate or direction of movement of the water in that alluvial aquifer or natural stream. Such 'underground water' is considered different from 'designated ground water' as defined in 37-90-103(3).

These Rules and Regulations shall not apply to water withdrawn from wells, such as domestic and livestock wells, which are exempted from administration under Colorado Revised Statutes Annotated, 1963, ss37-92-602 (Supplement 1972), and these Rules and Regulations shall not apply to water withdrawn from wells which are exempted from administration by Court decree or statute.

RULE 2. (a) Ground water diversions will be continuously curtailed according to the following schedule to provide for a reasonable lessening of material injury to senior appropriators:

1. During the Calendar Year 1974, five-sevenths (5/7) of the time;
2. During the Calendar Year 1975, six-sevenths (6/7)of the time; and
3. During the Calendar Year 1976, and thereafter, total curtailment.

Pumping shall be permitted on every Monday and Tuesday of each week in 1974 and on every Monday of each week in 1975. The Division Engineer shall administer this rule so that the operator of a well, or wells, may have a cycle of operation to make more efficient use of the water available; provided that senior appropriators are not materially injured thereby.

RULE 2. (b) Ground water diversions shall be curtailed as provided under part (a) hereof unless the ground water appropriator submits proof to the Division Engineer and upon the basis of that proof the Division Engineer shall find:

1. That the well is operating pursuant to a decreed plan of augmentation, that the well is operating pursuant to a decree as an alternate point of diversion, or that a change in point of diversion to the well has been decreed for a surface water right; or

2. That the ground water appropriation can be operated under its priority without impairing the water supply to which a senoir appropriator is entitled; or

3. That the water produced by a well does not come within the definition of underground water in RULE 1.

RULE 3. Any ground water appropriator affected by these Rules and Regulations may use a part or all of the water diverted without regard to curtailment described in RULE 2 (a) to the extent his ground water diversion is in compliance with a temporary augmentation plan approved by the Division Engineer in accordance with Colorado Revised Statutes Annotated, 1963, ss37-92-307(4) and where there is a plan for augmentation filed in the Water Court in accordance with Colorado Revised Statutes Annotated, 1963, ss37-92-302 (Supplement 1971). The Division Engineer will promptly approve or disapprove such temporary augmentation plans submitted to him. The guidelines for any such temporary augmentation plan will be expected to meet at least the following criteria:

1. That replacement water for stream depletion shall be made equal to 5 percent of the projected annual volume of a ground water diversion, and may be used by him at a rate of flow sufficient to compensate for any adverse effect of such ground water diversion on a lawful senior requirement, as evidenced by a valid senior call, but at a rate not exceeding 5% of the capacity of the diversion structure.

2. Such capacity shall be determined by Court decree, if adjudicated, by application for a water right, if filed in the Water Court, by well permit, or by registration. If none of these means of determination is available, the capacity will be the maximum pumping or delivery rate, which must be substantiated by the appropriator.

3. The operation of the temporary augmentation plan shall not be used to allow ground water withdrawl which would deprive senior surface rights of the amount of water to which said surface rights would have been entitled in the absence of such ground water withdrawal, and ground water diversions shall not be curtailed nor required to replace water withdrawn, for the benefit of surface right priorities, even though such surface right priorities be senior in priority date, when, assuming the absence of ground water withdrawal by junior priorities, water would not have been available for diversion by such surface right under the priority system.

RULE 4. Whenever the Division Engineer is satisfied, upon the basis of competent evidence, that operation of a temporary plan of augmentation pursuant to RULE 3.1. will not meet the requirements of RULE 3.3. above, modification of the plan will be undertaken by reference to criteria as follows:

1. The stream depletion caused by a well will be calculated by the method shown in The Pumped Well by Robert E. Glover, Technical Bulletin 100, Colorado State University, or by other accepted engineering formulae appropriately modified to reflect the pertinent physical conditions.

2. The transmissivity value will be obtained from the U.S. Geological Survey Open-File Reports, Hydrogeologic Characteristics of the Valley-Fill Aquifer in the South Platte River Valley, Colorado, 1972, or from updated editions, or from calculations using accepted engineering methods.

3. The specific yield or effective voids ratio generally descriptive of the material in the aquifer will be assumed to be twenty percent (20%), or a different value may be used when it can be sub stantiated generally or as to any particular area or situation.

4. The consumptive use for irrigation purposes will be assumed to be forty percent (40%) of the total quantity pumped for irrigation uses, subject to modification upon proof that a different consumptive use situation exists with respect to a particular diversion. For uses other than irrigation, the amount will be determined from actual conditions. (16)

APPENDIX B: Example Augmentation Plan

Engineering Report

Prepared by HRS Consulting
Engineers for Fort Morgan
Reservoir and Irrigation Company

FORT MORGAN RESERVOIR AND IRRIGATION COMPANY

PLAN FOR AUGMENTATION

Prepared by

HRS WATER CONSULTANTS, INC.
80110-01 January, 1985

FORT MORGAN RESERVOIR AND IRRIGATION COMPANY
PLAN FOR AUGMENTATION

INTRODUCTION

This report presents the engineering data necessary for the development of a Plan for Augmentation for the irrigation wells under the Fort Morgan Canal. These data were developed in the course of an investigation of the Fort Morgan Canal, and its operation in recent years.

The Plan for Augmentation will optimize beneficial use of water in the system by allowing irrigation wells to pump at times when they would otherwise be out of priority. If these wells were administered strictly under the priority doctrine, they would seldom be allowed to pump during the irrigation season because of the "call" that generally exists on the South Platte River by the more senior surface water rights. The Plan for Augmentation makes use of "free river" water, which is available throughout the winter season. This water is recharged to the underground aquifer to offset subsequent stream depletions.

Plate I is a general location map which depicts each of the components of this Plan for Augmentation.

THE FORT MORGAN RESERVOIR AND IRRIGATION COMPANY

The Fort Morgan Reservoir and Irrigation Company is a mutual ditch company serving approximately 11,000 acres of irrigated crop lands in Morgan County, Colorado. The headgate of the Fort Morgan Canal is located on the South Bank of the South Platte River at a point twenty-three chains north and five chains west of the southeast corner of Section 31, Township 5 North, Range 59 West of the 6th Principal Meridian, Morgan County, Colorado. The canal runs in southeasterly direction and serves lands in Townships 3 and 4 North, Ranges 56, 57, and 58 West. At the headgate, the ditch is thirty feet wide on the bottom, with a grade of one and one-half feet per mile, bank slopes of one and one-half to one, and is capable of carrying water four feet in depth.

The canal carries direct flow irrigation water, reservoir water, and augmentation water. There are two organizations involved in supplying water to land under the Fort Morgan Canal. These are the Fort Morgan Reservoir and Irrigation Company, and the Jackson Lake Reservoir Company.

The Fort Morgan Reservoir and Irrigation Company owns and controls the Fort Morgan Canal, with a decree for 323 cubic feet per second and a priority date of October 18, 1882. In addition, the Company owns 1,030 shares (66.5%) of the 1,550 outstanding shares of the Jackson Lake Reservoir Company. The Fort Morgan Reservoir and Irrigation Company has 2,839 outstanding shares. Seasonal transfers of stock within the system are allowed by the Company, but the Company does not permit seasonal transfers of foreign water into its system, and it does not allow transfer out of its system. The Company does not allow its water users to individually lease or purchase water from the Jackson Lake Reservoir Company.

The Jackson Lake Reservoir Company is a mutual company which owns and operates the Jackson Lake Reservoir and its inlet and outlet canals. The Company also holds a storage decree measured in terms of a rod reading of 30.0 feet, having a priority date of May 18, 1901. Storage capacity is approximately 30,000 acre-feet. The Jackson Lake Reservoir Company has 1,550 shares or "rights" outstanding. As stated above, the Fort Morgan Reservoir and Irrigation Company holds 1,030 of these shares. The remaining 520 shares are held by other ditch companies, irrigation districts, and private individuals. The Fort Morgan shares are always used under the Fort Morgan Canal, but the remaining shares are subject to sale and lease by anyone outside the Fort Morgan system.

There are 90 irrigation wells under the Fort Morgan Canal which will be included in this plan for augmentation. Each of these well owners is also a stockholder in the Fort Morgan Reservoir and Irrigation Company. Appendix A lists the wells to be included in this Plan for Augmentation.

ANALYSIS OF AUGMENTATION WATER REQUIREMENTS

A Plan for Augmentation should, to the extent possible, offset effects which result from pumping by the wells covered by the plan, which would adversely affect any other water rights. In order to properly design the augmentation

plan for the Fort Morgan Reservoir and Irrigation Company, the operation of that system during the period from 1960 through 1980 was analyzed. This analysis involved a calculation of the average annual irrigation water requirement of the crops under the Fort Morgan system, and a calculation of the portion of that requirement satisfied by direct flow and reservoir deliveries, to determine the remaining portion of that requirement which is considered to be supplied by well pumping. The quantity of augmentation water required to offset the adverse effects of that pumping was then calculated, based on the quantity of that pumping.

TOTAL DEMAND

Based on crop records maintained by the Fort Morgan Reservoir and Irrigation Company, an average of 10,628 acres under the Fort Morgan Canal have been irrigated in recent years. The average crop distribution has been as follows:

Corn	8,184 acres
Beans	850
Sugar Beets	319
Alfalfa	850
Grain	425
TOTAL	10,628 acres

Irrigation water requirements for these crops were calculated using the Blaney-Criddle method, as described in the USDA Soil Conservation Service Technical Release No. 21. Climatic data for Fort Morgan, required for this calculation, were obtained from the records of the National Oceanic and Atmospheric Administraiton. Table I lists historical irrigation water requirements for the period 1960 - 1980, for the crop distribution indicated above. The average annual irrigation water requirement for the crops irrigated under the Fort Morgan Canal is 15,849 acre-feet.

SURFACE WATER SUPPLY

Table II lists monthly diversions by the Fort Morgan Canal under its 1882 decree for the period 1960 - 1980. Table III lists monthly diversions of Jackson Lake Reservoir releases during the same period. Table IV is the sum of direct

flow diversions (Table II) and reservoir water diversions (Table III). This represents the total surface water supply available at the headgate of the Fort Morgan Canal. The average annual headgate diversion for the Fort Morgan Canal, including both direct flow and reservoir deliveries, has been 39,539 acre-feet.

In the early part of the irrigation season, stockholders take water from the ditch as needed. Once the demand for water exceeds the delivery capacity of the ditch, deliveries are made in two "sections". Water is delivered to the upper part of the ditch (section) for 3 days, and then to the lower section for 3 days. Stockholders are not allowed to maintain an "account" of water from which they may "borrow" or "save". Instead, they must use the water when available, or forfeit the opportunity. Rarely do stockholders forfeit the use of their water when it is in their section.

Stock ownership is such that sixteen shares (of 2,839 shares outstanding) are allotted to 80 acres of land. As a general rule, farm headgates are operated so that 1.5 cubic feet per second (cfs) are delivered to sixteen shares.

GROUNDWATER SUPPLY

Surface water supplies have not been sufficient to provide a full water supply to crops under the Fort Morgan Canal. With the exception of 4 or 5 farms under the canal, all farmers use groundwater supplies to supplement their deliveries of surface water.

Monthly groundwater requirements can be calculated as the difference between the irrigation water requirement and the amount of surface water supplied. Table V lists groundwater requirements for the period 1960 to 1980. These estimates were based on a river headgate-to-farm headgate efficiency of 70%, and an assumed headgate-to-crop efficiency of approximately 65%, resulting in an overall river-to-crop efficiency of 45%. Each value listed in Table V can be calculated as the irrigation water requirement for that month (from Table I) less 45% of the river headgate supply (from Table IV). It is important to note that Table V does not list pumping amounts. Groundwater is pumped in excess of the amounts listed, and water which is not consumed returns to the underground system.

Records of pumping have been collected by the Company in the years 1977 through 1983 in the course of operating the temporary Plan for Augmentation. The average quantity reported pumped for the years 1977 to 1980 was 6,752 acre-feet per year; the calculated groundwater consumption for the same period is 3,811 acre-feet per year.

Table V also provides an estimate of the annual augmentation water requirement for this plan. All consumption of groundwater is considered to be eventually manifested as a depletion to the river. In order to fully augment all pumping by the 90 wells covered by this Plan for Augmentation, the company must replace all depletions as they occur at the river. However, the Company is obligated to replace only those depletions which occur when there is a "call" on the river.

RECHARGE PROGRAM

The Fort Morgan Reservoir and Irrigation Company has implemented a recharge program which will result in accretions to the South Platte River equal to or in excess of depletions caused by pumping of the wells, during periods of "call" on the river.

The South Platte alluvial aquifer will be recharged through the sites listed in Table VI. These sites are also depicted on Plate I. Water will be diverted from the South Platte River under the priority of this plan, and carried to the site or sites determined to be most appropriate at a particular time. Each of the sites will be equipped with a measuring device so that recharge quantities can be precisely determined. Evaporation from each site will be calculated based on observations of pan evaporation at Akron, Colorado, and the surface area of each site.

The recharge sites included in this plan are the Fort Morgan Canal, which has been divided into two reaches; a section of Badger Creek, which is normally a dry stream channel; and several ponds near the lower end of the canal. Based on operation of the temporary plan in recent years, these recharge sites can provide a total recharge capacity in excess of 13,000 acre-feet.

OPERATIONAL PROCEDURE

This Plan for Augmentation will be continuously monitored and operated so that the maximum beneficial use of water can be obtained and to ensure that no injury will result to prior vested water rights. The plan is operated on a monthly basis and includes the following components:

1. Calculation of groundwater consumption.
2. Measurement of aquifer recharge.
3. Calculation of net stream effects.
4. Reporting to State officials.

Each of these components is described below:

1. Calculation of Groundwater Consumption

Under operation of the temporary plan for augmentation, pumping reports were collected from each of the well owners under the system. In the absence meters on each well, each user reported the number of hours each well was in operation each month. Pumping quantities were estimated using hours of operation and rated well capacity. Groundwater consumption was then calculated as a percentage of the amount pumped. This method is not suitable for incorporating into a permanent plan for the following reasons:

a. Inaccuracies of reporting.
b. Reports are collected at the end of the irrigation season only.
c. Lack of a suitable method for converting from hours pumped or kilowatts used to acre-feet pumped.
d. Inconvenience to well operators.

Instead, crop reports will be collected at the beginning of the irrigation season, and all irrigation and water use calculations will be based on actual cropping data. Projections of groundwater consumption and the resulting stream depletions will be based on average climatic conditions. At present, we propose to use the Blaney-Criddle method for calculating crop water requirements; however, we recognize that science may provide an improved

method that may be substituted later. Projected crop water requirements will be updated monthly with actual observed climate data as the irrigation season progresses. In addition, cropping patterns can be modified if, for example, a hail storm destroys large areas of irrigated crops.

The Company has recently instituted a practice of measuring and recording the amount of water delivered to each "turnout" off the main canal. Recordkeeping during 1984 indicated that the Fort Morgan canal is able to deliver 70% of its river headgate diversion to its main turnouts. For those turnouts which are farm headgates, 65% of the amount delivered to the farm is available for crop consumption. For those turnouts which are laterals, losses between the lateral headgate and the farm headgate are estimated to be approximately 10% of the lateral headgate delivery, so that 60% of the amount diverted at the lateral is available for crop consumption. For those farms using a sprinkler irrigation system, crop water requirements will be enlarged by 5% to account for spray evaporation losses. All groundwater calculations will be maintained on a monthly basis.

2. Measurement of Aquifer Recharge

Records of flow into each recharge site will be maintained on a daily basis. The Water Commissioner will provide measurements of augmentation inflow at the river headgate, and Company officials will record distribution of augmentation water within the system. A sample form for reporting recharge credit is contained in Appendix B. The Company will measure flow into and flow out of each site, where it occurs. Evaporation losses will be calculated based on the surface areas listed in Table VI, using pan evaporation data measured at Akron, Colorado.

The Bolinger Ponds will be cooperatively administered with the owner(s) of that property according to the provisions of previous decrees: Case Number W7889-75 and Case Number W-8073. Briefly stated, these decrees award the first 1,000 acre-feet of recharge inflow to the owner(s) of the "Bolinger" property, the next 4,000 acre-feet to the Company, and a split of all inflows after 5,000 acre-feet, with 80% credit to the Company.

The Company will not claim augmentation credit for any canal seepage that occurs at times when the canal is being used for irrigation purposes. However, the Company may claim credit for any augmentation water that is measured into a pond site or in Badger Creek, even though water for irrigation is being carried in the canal at that same time.

3. Calculation of Net Stream Effect

The wells which are a part of this Plan for Augmentation are located in an area which is underlain by alluvium of the South Platte River. Due to the nature of the alluvial material, which is composed of sand, gravel, and clay, the movement of the water in this material is much slower than surface flow in the river. Because of this, even though the water in the aquifer and in the surface stream are part of the same hydrologic system, the removal of water from this aquifer does not affect the surface stream to any significant extent until sometime after the actual pumping occurs. The timing of this depletive effect depends upon the distance of the well from the river and upon the hydrologic characteristics of the aquifer. Not only are these effects delayed, but they are also "stretched out" so that the effect on the surface stream occurs over a longer period of time and with less intensity than the original pumping event. Consequently, the effects on the surface stream continue to occur for some period after the pumping has ceased.

The length of the delay referred to above can be described by the "Stream Depletion Factor" (SDF) value for the location of the well. The SDF concept was developed by the U.S. Geological Survey for the purpose of determining and describing the effect on a surface stream resulting from the pumping of water in the alluvial aquifer associated with that stream. The SDF value for each well in the augmentation plan is included in Appendix A. These values were derived from information in the U.S. Geological Survey publication entitled "Hydrogeologic Characteristics of the Valley Fill Aquifer in the Brush Reach of the South Platte River Valley, Colorado".

Although recharge involves addition to, instead of removal from, the underground aquifer, the hydrologic process is identical. Recharge effects are simply manifested at the river as accretion, instead of as depletion in the case of well pumping. Therefore, the same SDF method will be employed to calculate the accretive effects which result from recharge. SDF values for each recharge site are listed in Table VI.

Each month, a calculation of the net stream effect resulting from all prior operations will be made. In addition, a 12-month projection of monthly stream effects will be calculated. This 12-month projection will include an estimate of future groundwater withdrawals based on current crop irrigation patterns. Each month, as data become available, the projections will be updated to reflect actual operation. Future recharge quantities will not be projected so that the 12-month projection will always be conservative, reflecting a worst-case scenario in which recharge water is not available.

4. Reporting

Each month, a report of each of the items listed above, as well as the net stream effect, will be provided to officials of the State. A sample reporting form appears in Appendix B. This report will also provide the Company with necessary information for planning the disposition of future recharge waters. For example, if the 12-month projection indicates a large net positive effect to the river, additional recharge water can be placed at sites with large SDF values so that the water is effectively "saved" to offset future depletions.

The report will also provide estimates of excess recharge waters which can be made available to other water users, or recaptured at the canal headgate. This report will also allow the State to monitor the operation of the plan. In the unlikely event that a net negative effect is projected, the following options are available to prevent injury to other users:

a. Release Jackson Lake water directly to the South Platte River, to offset calculated stream depletions.

b. By-pass water diverted under the 1882 priority.

c. Purchase/lease additional rights.

d. Curtail pumping by wells.

CONCLUSION

If operated properly, the Plan for Augmentation described above will effectively replace all stream depletions resulting from irrigation pumping under the Fort Morgan Canal. This plan provides sufficient flexibility to allow maximum beneficial use of ground and surface water supplies. Most important, the plan will operate so that no injury to prior vested water rights will occur.

Table I
Fort Morgan Canal
Historical Irrigation Water Requirements
(acre-feet)

Year	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
1960	0	0	0	0	0	79	644	3,803	5,513	5,540	1,552	0	17,131
1961	0	0	0	0	0	24	134	3,148	4,813	4,780	432	0	13,331
1962	0	0	0	0	0	112	213	2,148	4,044	5,249	1,860	0	13,626
1963	0	0	0	0	0	133	1,647	2,970	6,525	3,885	1,643	0	16,803
1964	0	0	0	0	0	26	1,092	2,251	7,323	4,769	1,676	0	17,137
1965	0	0	0	0	0	136	1,161	1,943	3,169	4,326	465	0	11,200
1966	0	0	0	0	0	40	1,729	2,487	7,197	3,733	1,411	0	16,597
1967	0	0	0	0	0	39	0	1,379	5,234	4,344	1,755	0	12,751
1968	0	0	0	0	0	21	540	3,524	6,437	3,554	1,955	0	16,031
1969	0	0	0	0	0	92	713	2,971	5,751	6,297	2,029	0	17,853
1970	0	0	0	0	0	7	1,848	2,559	6,947	4,755	1,416	0	17,532
1971	0	0	0	0	0	0	1,173	3,516	6,227	5,903	506	0	17,325
1972	0	0	0	0	0	284	1,282	3,511	5,232	3,912	1,323	0	15,544
1973	0	0	0	0	0	0	564	3,645	5,196	5,474	76	0	14,955
1974	0	0	0	0	0	66	2,129	3,539	5,644	5,030	1,736	0	18,144
1975	0	0	0	0	0	32	83	3,338	5,772	4,649	1,809	0	15,683
1976	0	0	0	0	0	57	774	3,839	6,330	4,537	1,008	0	16,545
1977	0	0	0	0	0	0	1,103	4,284	6,465	4,680	2,292	0	18,824
1978	0	0	0	0	0	86	58	2,984	6,650	3,523	2,367	0	15,668
1979	0	0	0	0	0	53	180	1,919	5,395	3,066	2,343	0	12,956
1980	0	0	0	0	0	50	203	4,513	6,319	4,390	1,724	0	17,199
Average	0	0	0	0	0	64	822	3,061	5,818	4,590	1,494	0	15,849

Table II
Fort Morgan Canal
Monthly Diversions under 1882 Decree
(acre-feet)

Year	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
1960	0	0	0	0	0	1,284	6,590	8,170	3,544	0	1,740	1,240	22,568
1961	0	0	0	0	0	0	9,280	9,120	5,796	5,352	5,570	0	35,118
1962	0	0	0	0	0	3,810	2,800	5,032	10,820	3,876	4,950	0	31,288
1963	0	0	0	0	0	2,560	0	2,982	0	5,138	3,812	0	14,492
1964	0	0	0	0	0	1,718	1,698	8,140	0	0	0	4,634	16,190
1965	0	0	0	0	0	1,400	4,140	2,060	0	4,540	6,550	0	18,690
1966	0	0	0	0	0	4,336	750	0	0	0	4,576	600	10,262
1967	0	0	0	0	0	5,594	5,604	1,340	8,816	170	8,608	1,616	31,748
1968	0	0	0	0	0	4,980	1,820	7,612	300	6,484	7,724	3,200	32,120
1969	0	0	0	0	0	3,818	5,878	4,814	7,856	400	8,252	270	31,288
1970	0	0	0	0	0	0	568	5,358	14,082	8,592	4,990	0	33,590
1971	0	0	0	0	0	0	3,012	7,588	7,096	1,284	1,680	0	20,660
1972	0	0	0	0	0	5,298	3,388	8,764	0	2,364	3,126	1,294	24,234
1973	0	0	0	0	0	0	2,736	8,762	11,354	8,906	302	0	32,060
1974	0	0	0	0	0	286	5,704	9,695	6,119	4,681	5,639	0	32,124
1975	0	0	0	0	0	3,751	4,376	4,810	11,270	8,299	2,186	0	34,692
1976	0	0	0	0	0	5,028	2,934	2,668	855	1,876	5,123	0	18,484
1977	0	0	0	0	0	3,400	2,025	974	1,987	2,291	5,016	988	16,681
1978	0	0	0	0	0	4,219	3,473	8,670	1,839	2,454	7,174	393	28,222
1979	0	0	0	0	0	0	4,641	4,618	10,655	5,320	4,891	1,117	31,242
1980	0	0	0	0	0	0	3,560	8,364	12,052	11,256	1,494	887	37,613
Averag	0	0	0	0	0	2,452	3,570	5,692	5,450	3,966	4,448	773	26,351

Table III
Fort Morgan Canal
Monthly Diversions of Jackson Lake Water
(acre-feet)

Year	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
1960	0	0	0	0	0	0	0	2,186	5,526	5,810	2,518	0	16,040
1961	0	0	0	0	0	0	0	0	3,084	6,018	600	0	9,702
1962	0	0	0	0	0	0	2,230	348	1,402	11,304	3,274	0	18,558
1963	0	0	0	0	0	946	4,094	0	5,476	2,494	2,562	0	15,572
1964	0	0	0	0	0	0	2,640	0	7,756	5,648	0	0	16,044
1965	0	0	0	0	0	1,624	2,844	0	0	1,934	1,784	0	8,186
1966	0	0	0	0	0	0	2,750	4,020	6,680	2,640	1,130	270	17,490
1967	0	0	0	0	0	0	0	0	1,926	10,250	550	0	12,726
1968	0	0	0	0	0	0	0	1,772	7,610	3,676	732	0	13,790
1969	0	0	0	0	0	0	0	0	5,030	9,228	100	0	14,358
1970	0	0	0	0	0	0	0	0	0	3,470	5,776	0	9,246
1971	0	0	0	0	0	0	0	240	5,950	8,320	4,064	0	18,574
1972	0	0	0	0	0	0	0	1,378	8,450	5,106	0	0	14,934
1973	0	0	0	0	0	0	0	0	0	3,752	1,918	0	5,670
1974	0	0	0	0	0	0	1,470	0	4,889	8,275	0	0	14,634
1975	0	0	0	0	0	0	2,376	0	1,978	4,060	6,508	0	14,922
1976	0	0	0	0	0	0	1,020	3,374	7,388	5,260	1,474	0	18,516
1977	0	0	0	0	0	0	0	4,719	5,552	5,421	502	0	16,194
1978	0	0	0	0	0	0	0	0	8,081	4,657	0	0	12,738
1979	0	0	0	0	0	0	0	0	397	3,392	2,013	0	5,802
1980	0	0	0	0	0	0	0	0	179	1,636	1,041	397	3,253
Average	0	0	0	0	0	122	925	859	4,160	5,350	1,740	32	13,188

Table IV
Fort Morgan Canal
Total Irrigation Supply
(acre-feet)

Year	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
1960	0	0	0	0	0	1,284	6,590	10,356	9,070	5,810	4,258	1,240	38,608
1961	0	0	0	0	0	0	9,280	9,120	8,880	11,370	6,170	0	44,820
1962	0	0	0	0	0	3,810	5,030	5,380	12,222	15,180	8,224	0	49,846
1963	0	0	0	0	0	3,506	4,094	2,982	5,476	7,632	6,374	0	30,064
1964	0	0	0	0	0	1,718	4,338	8,140	7,756	5,648	0	4,634	32,234
1965	0	0	0	0	0	3,024	6,984	2,060	0	6,474	8,334	0	26,876
1966	0	0	0	0	0	4,336	3,500	4,020	6,680	2,640	5,706	870	27,752
1967	0	0	0	0	0	5,594	5,604	1,340	10,742	10,420	9,158	1,616	44,474
1968	0	0	0	0	0	4,980	1,820	9,384	7,910	10,160	8,456	3,200	45,910
1969	0	0	0	0	0	3,818	5,878	4,814	12,886	9,628	8,352	270	45,646
1970	0	0	0	0	0	0	568	5,358	14,082	12,062	10,766	0	42,836
1971	0	0	0	0	0	0	3,012	7,828	13,046	9,604	5,744	0	39,234
1972	0	0	0	0	0	5,298	3,388	10,142	8,450	7,470	3,126	1,294	39,168
1973	0	0	0	0	0	0	2,736	8,762	11,354	12,658	2,220	0	37,730
1974	0	0	0	0	0	286	7,174	9,695	11,008	12,956	5,639	0	46,758
1975	0	0	0	0	0	3,751	6,752	4,810	13,248	12,359	8,694	0	49,614
1976	0	0	0	0	0	5,028	3,954	6,042	8,243	7,136	6,597	0	37,000
1977	0	0	0	0	0	3,400	2,025	5,693	7,539	7,712	5,518	988	32,875
1978	0	0	0	0	0	4,219	3,473	8,670	9,920	7,111	7,174	393	40,960
1979	0	0	0	0	0	0	4,641	4,618	11,052	8,712	6,904	1,117	37,044
1980	0	0	0	0	0	0	3,560	8,364	12,231	12,892	2,535	1,284	40,866
Average	0	0	0	0	0	2,574	4,495	6,551	9,609	9,316	6,188	805	39,539

Table V
Fort Morgan Canal
Historical Consumptive Use of Groundwater
(acre-feet)

Year	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
1960	0	0	0	0	0	0	0	0	1,432	2,926	0	0	4,357
1961	0	0	0	0	0	24	0	0	817	0	0	0	841
1962	0	0	0	0	0	0	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0	1,628	4,061	451	0	0	6,140
1964	0	0	0	0	0	0	0	0	3,833	2,227	1,676	0	7,736
1965	0	0	0	0	0	0	0	1,016	3,169	1,413	0	0	5,598
1966	0	0	0	0	0	0	154	678	4,191	2,545	0	0	7,568
1967	0	0	0	0	0	0	0	776	400	0	0	0	1,176
1968	0	0	0	0	0	0	0	0	2,878	0	0	0	2,878
1969	0	0	0	0	0	0	0	805	0	1,964	0	0	2,769
1970	0	0	0	0	0	7	1,592	148	610	0	0	0	2,357
1971	0	0	0	0	0	0	0	0	356	1,581	0	0	1,938
1972	0	0	0	0	0	0	0	0	1,430	551	0	0	1,980
1973	0	0	0	0	0	0	0	0	87	0	0	0	87
1974	0	0	0	0	0	0	0	0	690	0	0	0	690
1975	0	0	0	0	0	0	0	1,174	0	0	0	0	1,174
1976	0	0	0	0	0	0	0	1,120	2,621	1,326	0	0	5,067
1977	0	0	0	0	0	0	192	1,722	3,072	1,210	0	0	6,196
1978	0	0	0	0	0	0	0	0	2,186	323	0	0	2,509
1979	0	0	0	0	0	53	0	0	422	0	0	0	475
1980	0	0	0	0	0	50	0	749	815	0	583	0	2,198
Average	0	0	0	0	0	6	92	467	1,575	786	108	0	3,035

TABLE IV

Recharge Sites
Fort Morgan Reservoir and Irrigation Company
Plan for Augmentation

Site	Name	Location	Surface Area (acres)	SDF (days)	
A	Canal Reach 1	SE SW 36-4-58 to Center 20-3-57	17.5	15%	270
				25%	480
				19%	750
				13%	1,080
				10%	1,470
				18%	1,800
B	Canal Reach 2	Center 20-3-57 to SW NW 18-3-56	19.9	29%	2,300
				21%	1,920
				9%	1,470
				41%	1,150
C	Badger Creek Reach 1	SW SW 21-3-57 to NW NW 22-3-57	5.9	28%	1,470
				37%	1,920
				35%	2,300
D	Badger Creek Reach 2	NW NW 22-3-57 to SW NE 11-3-57	5.4	20%	1,080
				38%	750
				42%	550
E	Lundock West Pond	NW SE 14-3-57	3.3		1,080
F	Lundock East Pond	NE SE 14-3-57	3.5		1,116
G	Keith Bath Pond	NW SE 13-3-57	4.0		1,116
H	Public Service Pond	NW 20-3-56	27.7		2,510
I	Bolinger Recharge Area	Beginning at SE NW 20-3-56	36.4	50%	3,000
				50%	3,630

HRS WATER CONSULTANTS, INC.
80110-01 January, 1985

APPENDIX A
Wells included in Plan for Augmentation
Fort Morgan Reservoir and Irrigation Company

Permit No.	Location	SDF (days)
7015-R	NWSE 16-03-57	953
9348-F	SWSW 18-04-58	992
1265-R	NWSW 33-04-57	24
0562-R	NWSW 12-03-57	480
8367-R	SWNE 02-03-57	163
8353-R	SWNW 17-03-57	902
R192(5827-R)	SWNW 08-03-56	805
RF484(5828-R)	SWNW 08-03-56	750
8368-R	SESW 35-04-57	68
4446-R	NWSE 12-03-57	639
6825-R	NWSW 06-03-56	251
14604-R	SWSE 17-03-57	1172
14605-R	NWSW 09-03-57	480
9607-F(10972)	SWSE 20-04-58	285
7631-F	NENE 33-04-58	335
R-286(5837-R)	SWSW 11-03-57	612
04304-F	NENE 19-04-58	323
R4305-RF	SWSE 18-04-58	720
1261-R	SENW 03-03-57	281
6659	NWNW 28-04-58	270
8511-R	NESE 18-03-57	1307
0687-R	SWNE 08-03-57	468
6116-R	NESE 05-03-57	199
1674-R	NESE 05-03-57	173
1678-R	SWNE 20-03-57	1783
12662-R	SWNE 17-03-57	875
0004	SWNW 03-03-57	180
10571-R	SWNW 11-03-57	445
02999F	SWNW 12-03-57	435
6525-R	SWSW 03-03-57	270
8560-R	SWSE 07-03-56	848
2048-F	NWSE 07-03-56	811
2610-F	NWSW 07-03-56	750
2611-F	NWSW 07-03-56	682
	NWSW 27-04-58	6
12666-R	SWSE 09-03-57	621
10572-R	NWNW 16-03-57	720
8509-R	NWNW 20-03-57	1590
12661-R	NWSE 03-03-57	203
R-230(12663-R)	SWNE 12-03-57	516
12664-R	SWSE 01-03-57	279
1266-R	SWSW 36-04-57	86
8707-R	NWNW 22-03-57	1512
8708-R	NENE 22-03-57	1515
8709-R	SENE 22-03-57	1700

Permit No.	Location	SDF (days)
RF184(7339-R)	SWNE 16-03-57	908
7127-R	SWNE 09-03-57	419
12656-R	SWSW 10-03-57	555
6706-R	NWNE 09-03-57	361
8406-R	NWSE 08-03-56	1116
10354-R	NESW 04-03-57	185
7031-R	SENW 04-03-57	155
10390	SESE 02-03-57	281
14642-R	NWNE 18-03-57	827
10389	SWSW 02-03-57	292
12156-F	SWSW 16-03-57	1225
3550-F	SWSE 02-03-57	242
6749-R	SWNE 10-03-57	456
6965-R	NWNE 10-03-57	327
8489-R	NWNE 11-03-57	342
8365-R	SWNE 11-03-57	431
8366-R	SWSE 11-03-57	653
6977-R	SWNW 09-03-57	450
RF1069(7332-R)	NWNE 15-03-57	730
1677-R	NENW 06-03-56	152
20787-R	SWNE 01-03-57	178
14611-R	NESW 20-04-58	188
14612-R	NESW 20-04-58	307
14613-R	SESW 20-04-58	307
7152-R	SWNE 21-03-57	1867
12665-R	NENW 15-03-57	750
RF632(6461-R)	SWNW 15-03-57	941
6938-R	SENE 03-03-57	157
7340-R	NWNW 02-03-57	82
7136-R	SENW 10-03-57	405
5836-R	NWNW 14-03-57	684
5835-R	NWNW 14-03-57	730
8428-R	SWSW 01-03-57	270
6546-F	SWNE 15-03-57	867
R283(7125-R)	NWSE 15-03-57	943
16078-R	SWSW 03-03-57	296
8349-R	SESE 07-03-57	664
20923-R	SWNW 07-03-56	585
7129-R	SENE 29-04-58	468
2602-F	SWNE 07-03-56	691
1670-R	NENE 14-03-57	720
6057-R	SWSW 05-03-57	270
0967-R	NWSE 20-03-57	2101
11017-R	NENW 09-03-57	377
12309-F	NWNW 13-03-57	750

APPENDIX B

Recharge Accounting Form
Fort Morgan Reservoir and Irrigation, Inc.
for month ending _____, 19__

Observed Pan Evaporation = _____ inches (A)

Site Name	Measured In (acre-feet)	Measured Out (acre-feet)	Recharge (acre-feet)	Surface Area (acres)	Evaporation (acre-feet)	Recharge Credit (acre-feet)	SDF (days)	Percent Credit	Credit (acre-feet)
Formula	(B)	(C)	(D)=B-C	(E)	(F)=AxEx0.7/12	(G)=D-F	(H)	(I)	(J)=GxI/100
Canal Reach 1				17.5			270	15	
							480	25	
							750	19	
							1,080	13	
							1,470	10	
							1,800	18	
Canal Reach 2				19.9			2,300	29	
							1,920	21	
							1,470	9	
							1,150	41	
Badger Creek Reach 1				5.9			1,470	28	
							1,920	37	
							2,300	35	
Badger Creek Reach 2		0		5.4			1,080	20	
							750	38	
							550	42	
Lundock West Pond		0		3.3			1,080	100	
Lundock East Pond		0		3.5			1,116	100	
Keith Bath Pond		0		4.0			1,116	100	
Public Service Pond		0		27.7			2,510	100	
Bolinger Pond				36.4			3,000	50	
							3,630	50	

Operation Summary
Fort Morgan Reservoir & Irrigation Company
Plan for Augmentation
for _____, 19____ through _____, 19____

CROP DISTRIBUTION:

Crop	Acres Irrigated
Corn	
Beans	
Hay	
Beets	
Grain	
Other	

(all values in acre-feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1. Irrigation Water Requirement*												
2. Total Surface Supply*												
3. Consumptive Use of Groundwater*												
4. South Platte depletion from current year pumping*												
5. Recharge												
6. South Platte accretion from current year recharge												
7. Net effect from prior years												
8. Total effect*												
9. Augmentation Water Available from other sources*												

Negative sign indicates depletion to South Platte River

* Projections are indicated for months following the date of this report. Explanation sheet attached.

HRS WATER CONSULTANTS, INC.
80110-01 October, 1984

Decreed Plan of Augmentation
for Fort Morgan Reservoir and
Irrigation Company

DISTRICT COURT, WATER DIVISION NO. 1, STATE OF COLORADO

Case No. W-2692

FILED
'22 P2:14

FINDINGS OF FACT, CONCLUSIONS OF LAW, JUDGMENT AND DECREE

IN THE MATTER OF THE APPLICATION FOR WATER RIGHTS OF THE FORT MORGAN RESERVOIR AND IRRIGATION COMPANY

The above-captioned matter, coming before this Court for hearing on February 27, 1985 and on April 22, 1985 upon the application of the Fort Morgan Reservoir and Irrigation Company ("Fort Morgan"), and the Court having considered the pleadings, evidence, and the Consent Decree submitted herein, and being fully advised in the premises, does hereby make and enter the following Findings of Fact, Conclusions of Law, Judgment and Decree:

I. Findings of Fact

1. This Application was filed on May 19, 1972, containing three causes of action. A Decree was entered by this Court in this matter on December 3, 1974 regarding the first and second causes of action as follows:

A. Adjudicated the individual wells designated as B-1 through B-73 inclusive, each of said wells having its individual priority date and diversion rate, all of said wells having a priority date prior to 1969.

B. That the subject wells as attached to said Decree as Exhibit "A" have a cumulative total diversion of 251.93 c.f.s. and that all of said wells are used to irrigate the same lands irrigated under the Applicant's water priority No. 23. That said wells listed in Exhibit "A" to the 1974 Decree were also adjudicated as alternate points of diversion for Priority No. 23 which has a priority date of October 18, 1882, and is decreed for a total of 323 c.f.s.

The only matter remaining for hearing in this case is Fort Morgan's Third Cause of Action constituting the Plan for Augmentation covering only those wells adjudicated and decreed in this matter on December 3, 1974.

2. Statements of Opposition or Entries of Appearance were filed by:

A. City and County of Denver

B. Public Service Company

C. Great Western Sugar Company

3. Timely and adequate notices of this application were published according to law, and the Court has jurisdiction of the subject matter of this proceeding and over all persons and water rights affected thereby. The time for filing Statements of Opposition or Entries of Appearance has expired.

4. Attached to this Decree as Exhibit A is a list of all irrigation wells within Fort Morgan's system which are to be augmented under this Decree. All of said wells have been individually adjudicated and decreed in this action under a date of December 3, 1974, or have otherwise been separately and independently adjudicated under individual decrees. All of said wells have a date of priority prior to 1969; however, for the purposes of administration of this Decree, the depletions from all of the wells will be administered as having a common priority date of June 7, 1969. All of said wells divert water tributary to the South Platte River.

5. Fort Morgan has certain previously decreed water rights which are described as follows:

A. Priority No. 23 with a priority date of October 18, 1882, for a total of 323 c.f.s., as adjudicated on November 21, 1895.

B. Fort Morgan owns 1,030 shares of the 1,550 outstanding shares of Jackson Lake Reservoir & Irrigation Company, which has a decree for 30,992 acre feet with a priority date of May 18, 1901, as adjudicated on January 15, 1914; and also a decree for 4,637 acre feet with a priority date of May 18, 1901, as adjudicated on May 11, 1915; and also a decree for 8,269.92 acre feet with a priority date of December 31, 1929, as adjudicated on June 8, 1965.

6. The Fort Morgan Canal headgate is located on the South Bank of the South Platte River at a point 23 chains North and 5 chains West of the SE corner of Section 31, Twp. 5 North, Range 59 West of the 6th P.M., Morgan County, Colorado.

7. The headgate of the Jackson Lake Reservoir & Irrigation Company is located at a point on the North Bank of the South Platte River 900 feet South and 200 feet West of the center of the SE1/4 of Section 18, Twp. 4 North, Range 61 West of the 6th P.M., Weld County, Colorado.

8. Fort Morgan seeks approval of its Plan for Augmentation. This Plan for Augmentation will allow the wells listed in Exhibit "A" to be pumped at times and in amounts which would not otherwise be permitted under Colorado law. The Plan for Augmentation, if operated and administered in accordance with the Decree entered herein, will prevent injury to vested water rights or decreed conditional water rights by replacing out of priority depletions resulting from the consumptive use of water diverted from the wells listed in Exhibit "A." This consumptive use is sometimes referred to herein as "net groundwater extractions."

Sources of Supply of Water for Plan for Augmentation

9. The primary method that Fort Morgan will use to replace out of priority depletions will be a recharge program. Fort Morgan will construct, develop and acquire the recharge sites identified in Exhibit "B" attached hereto, which will be used to inject water into aquifers tributary to the South Platte River. Fort Morgan shall receive augmentation credit, as calculated under this Decree, for waters delivered and measured into the recharge sites. The recharge water will be diverted under this Decree at the headgate of the Fort Morgan Canal, with a priority date of May 19, 1972, at a rate not to exceed 323 c.f.s. The recharge water will replace net groundwater extractions from the wells listed in Exhibit A which diminish the flow of the South Platte River during times in which the wells listed in Exhibit A are not in priority. In the operation of this Plan for Augmentation, Fort Morgan will advise the Water Commissioner or the Division Engineer that the 1972 water right decreed herein is being exercised for recharge purposes rather than any of the Company's other decreed priorities.

10. Fort Morgan may also, subject to the following conditions, use water owned by it in Jackson Lake Reservoir to prevent material injury to vested and decreed conditional water rights either by direct release to the South Platte River to offset otherwise unreplaced depletions from the wells or by delivery to the recharge sites described in Exhibit B for recharge of the alluvial aquifer. If water stored in Jackson Lake under its 1901 decrees, described in paragraph 5B above, is used by direct release to offset depletions to the South Platte River, Fort Morgan shall receive credit for 42% of the amount of water so released and measured at the outlet of Jackson Lake. If water stored in Jackson Lake under its 1901 decrees is used for recharge purposes under this Plan, Fort Morgan shall receive credit for 65% of the amount of such water which is recharged through the sites described in Exhibit B as measured and calculated under the methods and

conditions provided in this Decree. The foregoing 42% and 65% credit factors shall no longer apply to limit the credit received for use of Fort Morgan's Jackson Lake water for augmentation or recharge purposes if reservoir water is ever determined by the Colorado Supreme Court not to be subject to historic use constraints, in which case Fort Morgan shall receive any additional credit allowed by law.

Fort Morgan may also use water stored in Jackson Lake Reservoir for direct augmentation release or for recharge under this Plan and receive 100% credit for the amount of such direct augmentation water delivered or recharge credit measured and calculated under the methods and conditions provided in paragraph 18 of this plan less reasonable carriage losses as may be imposed by the Division of Water Resources if the water so used was stored in Jackson Lake between May 1 and October 15 and if, at the time of storage, the 1972 water right decreed herein was in priority.

11. In the event that the actual or projected accretions to the South Platte River are insufficient to offset the out-of-priority actual or projected depletions caused by the wells described in Exhibit "A," and if the alternate sources of water identified in paragraph 10 above are also not available for use in this plan for augmentation to replace actual or projected out-of-priority depletions, Fort Morgan may, with the approval of the office of the State Engineer and notice to the objectors in this case when such approval is sought, make up such depletions on a temporary basis with water to which it is legally entitled from other sources, or the operation of and diversions from said wells shall be curtailed. In the event that Applicant uses such other sources of water to make up depletions not replaced by Fort Morgan's recharge activities under this Decree in three (3) consecutive years or for a cumulative total of five (5) years, Fort Morgan shall then be required to apply to the Court for, and obtain, a decree authorizing such use in order for such use to continue.

Operation of Plan for Augmentation

12. Fort Morgan's Plan for Augmentation, including calculations of crop-water requirements, available surface water, net groundwater extractions, depletions, augmentation requirements and recharge credits is based upon the engineering studies performed by its consultant engineer, HRS Water Consultants, Inc.

13. Each farmer and owner of the wells described in Exhibit "A" will be required to report on or before May 1 of

each year the type of crops and number of acres of each crop to be planted and the number of acres of each such crop to be irrigated by sprinklers in the upcoming season upon the lands to be irrigated by his subject well or wells.

14. In the event the amount of water pumped from each well included in this Augmentation Plan is measured and recorded, then the net groundwater extraction shall be calculated as 65% of the measured groundwater pumping; provided, however, that if Fort Morgan elects to have this Plan administered on the basis of said metered well pumping measurements, Fort Morgan, any of the Objectors herein or the State Engineer may invoke the retained jurisdiction of the Court to review and determine the net groundwater extractions which result from the use of sprinkler irrigation systems. All such pumping measurements shall be recorded on a monthly basis. All meters shall be totalizing flow meters and shall be properly maintained so as to assure reasonable accuracy.

15. In the event that the pump measurements as set forth in paragraph 14 above are not used, then the net ground water extractions shall be calculated as follows:

A. The total crop irrigation requirements of the lands included in this Augmentation Plan will be calculated on a monthly basis by means of the modified Blaney-Criddle Method described in the Soil Conservation Service Technical Release No. 21 using the crop irrigation data obtained from the farmers pursuant to paragraph 13 above in conjunction with weather data obtained from the Fort Morgan Weather Station. Such weather data may be supplemented by precipitation data from station(s), approved by the Division Engineer, located in the Fort Morgan System. The portion of the total crop irrigation requirement that is supplied by surface water diversions (hereinafter "effective surface water delivery"), will be calculated by measuring the amount of water delivered to each "turnout" off the main canal. For those turnouts which are farm headgates, the effective surface water delivery will be calculated as 65% of the amount measured at the turnout. For those turnouts which are laterals, the effective surface water delivery will be calculated as 60% of the amount measured at the lateral headgate. Water delivered through laterals will be assumed to be apportioned in proportion to the number of shares owned and leased in connection with each well. For those farms using a sprinkler irrigation system, crop water requirements will be enlarged by 5% to account for spray evaporation losses. Groundwater consumption calculations will be maintained for each well on a monthly basis.

B. The amount of effective surface water delivery to the lands irrigable by each well during the month will then be subtracted from the total crop irrigation requirement for that land during that same month to determine the consumptive use of groundwater attributable to that well for that month. This calculation will be performed and reported in accordance with the applicable provisions of the form attached hereto as Exhibit "C."

16. On or before May 1 of each year, a computer analysis will be made to project the net effect on the South Platte River in the upcoming year resulting from the prior and projected pumping and from prior recharge operations under Fort Morgan's system. This analysis will contain projections for the upcoming months based upon crop reports submitted by the well owners pursuant to paragraph 13 and the calculations made pursuant to paragraph 15.A above. On or before the tenth of each month, the analysis and projection will be updated and reported on the form attached hereto as Exhibit "C" using the actual consumptive use and recharge data supplied in the monthly report prepared by Fort Morgan regarding the actual consumptive use of groundwater.

17. The effects on the South Platte River resulting from the consumptive use of water caused by pumping from wells, or from recharge, pursuant to this plan will be calculated by means of the stream depletion factor (SDF) concept developed by the U.S. Geological Survey (Jenkins) and by means of a digital computer program based upon the SDF method. The SDF values for each of the wells and recharge sites which are a part of this Plan were determined from the U.S. Geological Survey Publication entitled "Hydrogeologic Characteristics of the Valley Fill Aquifer in the Brush Reach of the South Platte River Valley, Colorado" and are contained in Exhibits A and B.

18. The amount of water recharged to the alluvial aquifer at each of the recharge sites described in Exhibit "B" will be determined by measuring the amount of water released to each site or facility, subtracting the amount of water which flowed out of or was discharged from that site or facility, and subtracting the amount of water that was lost to evaporation from that site or facility. Recharge sites used in this plan shall have the necessary measuring devices to make such measurements on a daily basis as required by the Division Engineer. Records of such recharge supply to each site will be maintained on a monthly basis and reported on the accounting form attached hereto as Exhibit "D." Evaporation losses from the recharge sites will be calculated on the basis of the average water surface area for each month, the length of time of such evaporation and evaporation data obtained from

the Akron Weather Station or from any other station approved by the Division Engineer. The average water surface area will be calculated in a manner acceptable to the Division Engineer. Fort Morgan shall not receive recharge credit for seepage that occurs in any reach of the canal at any time water is being delivered for any purpose other than recharge under this Plan, unless all water so delivered may legally be used, reused or successively used to extinction.

This augmentation plan shall be administered by the Division Engineer, and the data prescribed below shall be furnished to his representative as reasonably required by the Division Engineer. Such data will be measured and/or recorded on a daily basis and shall include farm headgate and/or lateral deliveries (if pumping is not determined by meters), flows in and out of each recharge site and their source, water released from Jackson Reservoir for augmentation or recharge purposes, and all weather data to be used in the calculations required by this decree. In addition, no credit will be given if accounting is not completed and submitted to the Division Engineer or his representative on a timely basis.

19. The Court finds that for the period March 15, 1974, to October 31, 1984, Fort Morgan has operated this Plan for Augmentation in such a manner so as to result in the replacement of all depletions resulting from the pumping of the wells listed in Exhibit A during that period, and further, that the operation of this Plan for Augmentation will result in a net accrual of water to the river in the future, as set forth in Exhibit E. Fort Morgan may claim and use the recharge credit as set forth in Exhibit E in accordance with this decree. All calculations and accounting for depletions and recharge for this Plan will be in accordance with this decree from November 1, 1984.

II. Conclusions Of Law

The Court concludes as a matter of law:

20. The Plan for Augmentation proposed by Fort Morgan and approved herein is one which is contemplated and authorized by law and if implemented and administered in accordance with the requirements herein, will permit continued pumping of the subject wells and the resulting depletions to the South Platte River, all without adversely affecting any other vested water rights or decreed conditional water rights in the South Platte River Basin.

21. Fort Morgan is entitled, as a matter of law, to an absolute direct flow decree in the amount of 80 c.f.s. and

a conditional direct flow decree in the amount of 243 c.f.s. for the purposes of augmentation and recharge with an appropriation date of May 19, 1972.

22. The State Engineer and Division Engineer may lawfully be required under the terms hereof to administer this Plan for Augmentation in the manner set forth herein, and not to curtail ground water diversions from the subject wells in times of shortage, the depletions for which have been fully replaced. Pursuant to C.R.S. § 37-92-305(8), to the extent said depletions are not fully replaced under the terms of this Decree, the State Engineer shall curtail Fort Morgan's out-of-priority diversions.

23. So long as this Decree and Plan for Augmentation is in effect and implemented, the wells shall be operated with an assumed common priority date of June 7, 1969 without regard to the Decree previously entered in this case on December 3, 1974. The wells shall not be administered in accordance with the alternate point of diversion theory contained in the December 3, 1974 Decree. Nothing herein, however, shall prevent the owners of the subject wells from subsequently petitioning the Court to remove any well or wells from this Plan for Augmentation and to operate said wells otherwise in accordance with law and under the previous Decree in this case.

24. The State Engineer and the Division Engineer of Water Division No. 1 shall administer the rights and interests in water enumerated herein in accordance with the specific conditions set forth, including paragraphs 1 through 19 inclusive, of the "Findings," and so long as the operation of these rights and interests is in compliance with said conditions, they shall not curtail the diversion and use of ground water by Fort Morgan's shareholders which is in accordance with this Plan.

III. Decree

Fort Morgan's Plan for Augmentation is hereby approved as follows:

25. Each of the Findings of Fact and Conclusions of Law is incorporated by reference in this decretal portion as though set forth in full.

26. Fort Morgan's right to divert for recharge and augmentation purposes from the South Platte River is hereby granted and confirmed as follows:

A. Name and Address of the Claimant:

Fort Morgan Reservoir & Irrigation Company
410 East Railroad Avenue
P. O. Box 38
Fort Morgan, Colorado 80701

B. The name of the structure:

Fort Morgan Canal

C. The legal description of the structure:

The Fort Morgan Canal headgate is located on the South Bank of the South Platte River at a point 23 chains North and 5 chains West of the SE corner of Section 31, Twp. 5 North, Range 59 West of the 6th P.M., Morgan County, Colorado.

The headgate of the Jackson Lake Reservoir & Irrigation Company is located at a point on the North Bank of the South Platte River 900 feet South and 200 feet West of the center of the SE1/4 of Section 18, Twp. 4 North, Range 61 West of the 6th P.M., Weld County, Colorado.

D. Source of water:

South Platte River

E. Date of Appropriation:

May 19, 1972

F. Amount: 323 c.f.s. total

80 c.f.s. Absolute

243 c.f.s. Conditional

G. Use of Water:

For recharge and augmentation purposes. The subject plan of augmentation will provide augmentation of the wells described in Exhibit "A" hereto attached.

Fort Morgan may make use of or dispose of any recharge credit in excess of the depletions attributable to the operation of wells included within this Plan for Augmentation by lease, rental or sale of said credit. Excess recharge credit may be used, reused or successively used to extinction. In the event Fort Morgan or any recipient of excess credit under this Plan uses such excess credit for any use not provided for in this Decree, the user of such credit shall give prior written notice to the objectors herein of such use. In the event such excess credits are used in connection with the same structure, exchange plan or temporary plan for augmentation in five separate years the user of such credit shall be required to apply to the Court for, and obtain, a decree authorizing a permanent practice of substitution or exchange or an augmentation plan for the use of such credits in order for such use to continue, or, in the alternative, obtain the written consent of all Objectors herein for such continued use.

H. Fort Morgan has proceeded with reasonable diligence since May 19, 1972, toward completion of the appropriation claimed in this proceeding.

I. It is ordered that the conditional right herein awarded is hereby continued in full force and effect until February 28, 1989. If Fort Morgan desires to maintain such conditional Applicant decree, an application for a quadrennial finding of reasonable diligence shall be filed on or before February 28, 1989, or a showing made on or before such date that the conditional right has become an absolute water right by reason of the completion of the appropriation.

J. The priority herein awarded said Fort Morgan Canal was filed in the Water Court in the year 1972 and shall be administered as having been filed in that year and shall be junior to all priorities filed in previous years. As between all rights filed in the same calendar year, priorities shall be determined by historical dates of appropriation and not affected by the date of entry of this Decree.

27. Fort Morgan's Plan for Augmentation as decreed herein shall be administered in accordance herewith commencing April 1, 1985.

28. In order to assure that no injury will occur to any vested water rights by virtue of the operation under this Plan by Fort Morgan, or through its administration by the Division Engineer, this Court shall retain continuing jurisdiction in this case, which may be invoked by any of the Objectors:

A. For the purpose of reconsidering the adequacy, in preventing material injury to any other vested water rights in Colorado, of the SDF method, and SDF values selected pursuant thereto, proposed to be utilized by Fort Morgan in the manner described hereinabove as the means for determining Fort Morgan's effect on the South Platte River resulting from its alluvial well pumping and recharge to the alluvium.

B. For the purpose of considering the validity or accuracy of any calculation made by Fort Morgan pursuant to the SDF method as described in paragraph 28.A hereof or in this Decree.

C. For the purpose of considering the validity or accuracy of any data supplied by Fort Morgan to the Division Engineer.

D. For the purpose of considering the adequacy of Fort Morgan's compliance with, or the Division Engineer's administration, of this Decree.

E. For the purpose of reconsidering the net groundwater extractions which result from the use of sprinkler irrigation systems if Fort Morgan elects to have this Plan operated on the basis of metered well pumping reports pursuant to paragraph 14 above.

In no event, however, shall the Court's retained jurisdiction be invoked under paragraphs 28.B., C., D. or E. herein unless a petition seeking to invoke said jurisdiction, and stating the factual grounds therefor, is filed within three (3) years after the date on which the act, calculation, or determination which is sought to be reviewed occurred.

29. In the event that material changes in the operation of this Plan for Augmentation are planned from that described in this Decree such that any of the assumptions or methodologies involved herein are no longer applicable, Fort Morgan shall notify the parties hereto and the Court in

writing of such anticipated changes, and any of such parties shall be entitled to a prompt factual and legal hearing on the modifications to said Plan, if any, which must be imposed by the Court to prevent material injury to any other vested water right in Colorado. The Court shall retain jurisdiction of this case for this purpose.

30. In addition to the continuing jurisdiction retained herein pursuant to paragraphs 28 and 29 above, this Court shall also retain continuing jurisdiction herein which may be invoked by Fort Morgan:

A. For the purposes of reconsidering the adequacy, in preventing injury to any other vested water rights in Colorado, of the SDF method, and SDF values selected pursuant thereto, proposed to be utilized by Fort Morgan in the manner described herein as the means of determining Fort Morgan's effect on the South Platte River resulting from its alluvial well pumping and recharge to the alluvium.

B. For the purpose of amending the aforedescribed Plan for Augmentation by including therein additional alluvial wells, water rights, additional methods of augmentation (specifically including, but not limited to, the use of surface or subsurface storage facilities) or additional exchange opportunities whose appropriations are initiated after the effective date hereof, with the terms and conditions of such amended plan to be determined pursuant to such continuing jurisdiction.

C. For the purpose of reconsidering the adequacy, in preventing material injury to any other vested water rights in Colorado, of the modified Blaney-Criddle method, and appropriate adjustments to the computed consumptive use of irrigation water to account for application losses.

D. For the purpose of reconsidering the method of predicting daily depletions due to alluvial well pumping.

E. For the purpose of approving the use of excess recharge credit by a sale, lease, rental or exchange pursuant to paragraph 26.G. above.

F. For the purpose of reviewing the use by Fort Morgan of any alternate source of water in this Plan for Augmentation pursuant to paragraph 11 herein.

G. For the purpose of reviewing any determination of the Division Engineer with respect to administration of this Plan.

H. For the purpose of determining any additional recharge credit to be awarded to Fort Morgan pursuant to the last sentence of paragraph 19 above.

I. For the purpose of reconsidering the net groundwater extractions which result from the use of sprinkler irrigation systems if Fort Morgan elects to have this Plan operated on the basis of metered well pumping reports pursuant to paragraph 14 above.

31. Fort Morgan shall, within one year of the date of this Decree, adopt a policy regarding the distribution and use of all recharge credits accruing to Fort Morgan as the result of this Decree. Objector Great Western Sugar Company shall have the right, for a period of ten (10) years from the date of this Decree, to invoke the retained jurisdiction of this Court in this case for the purpose of reviewing the substantive and procedural legality of said policy.

32. In the event that continuing jurisdiction is involved in this case pursuant to paragraphs 28, 29, 30 or 31, written notice thereof shall be promptly given to all of the parties hereto of the pendency of such action.

33. This Plan for Augmentation shall also be subject to reconsideration by the Water Judge on the question of injury to the vested rights of others for a period of five (5) years from the date of this Decree, pursuant to C.R.S. 37-92-304(6).

Dated this 22nd day of April, 1985.

BY THE COURT:

Robert A. Behrman
Water Judge
Water Division No. 1
State of Colorado

Certified to be a full, true and correct copy of the original in my custody.

Dated April 22, 1985

CLERK, WATER DIVISION 1
STATE OF COLORADO

Wells included in Plan for Augmentation
Fort Morgan Reservoir and Irrigation Company

Permit No.	Location	SDF (days)
7015-R	NWSE 16-03-57	953
9348-F	SWSW 18-04-58	992
1265-R	NWSW 33-04-57	24
0562-R	NWSW 12-03-57	480
8367-R	SWNE 02-03-57	163
8353-R	SWNW 17-03-57	902
R192(5827-R)	SWNW 08-03-56	805
RF484(5828-R)	SWNW 08-03-56	750
8368-R	SESW 35-04-57	68
4446-R	NWSE 12-03-57	639
6825-R	NWSW 06-03-56	251
14604-R	SWSE 17-03-57	1172
14605-R	NWSW 09-03-57	480
9607-F(10972)	SWSE 20-04-58	285
7631-F	NENE 33-04-58	335
R-286(5837-R)	SWSW 11-03-57	612
04304-F	NENE 19-04-58	323
R4305-RF	SWSE 18-04-58	720
1261-R	SENW 03-03-57	281
6659	NWNW 28-04-58	270
8511-R	NESE 18-03-57	1307
0687-R	SWNE 08-03-57	468
6116-R	NESE 05-03-57	199
1674-R	NESE 05-03-57	173
1678-R	SWNE 20-03-57	1783
12662-R	SWNE 17-03-57	875
0004	SWNW 03-03-57	180
10571-R	SWNW 11-03-57	445
02999F	SWNW 12-03-57	435
6525-R	SWSW 03-03-57	270
8560-R	SWSE 07-03-56	848
2048-F	NWSE 07-03-56	811
2610-F	NWSW 07-03-56	750
2611-F	NWSW 07-03-56	682
	NWSW 27-04-58	6
12666-R	SWSE 09-03-57	621
10572-R	NWNW 16-03-57	720
8509-R	NWNW 20-03-57	1590
12661-R	NWSE 03-03-57	203
R-230(12663-R)	SWNE 12-03-57	516
12664-R	SWSE 01-03-57	279
1266-R	SWSW 36-04-57	86
8707-R	NWNW 22-03-57	1512
8708-R	NENE 22-03-57	1515
8709-R	SENE 22-03-57	1700

Recharge Sites
Fort Morgan Reservoir and Irrigation Company
Plan for Augmentation

Site	Name	Location	Surface Area (acres)	SDF (days)	
A	Canal Reach 1	SE SW 36-4-58	17.5	15%	270
		to		25%	480
		Center 20-3-57		19%	750
				13%	1,080
				10%	1,470
				18%	1,800
B	Canal Reach 2	Center 20-3-57	19.9	29%	2,300
		to		21%	1,920
		SW NW 18-3-56		9%	1,470
				41%	1,150
C	Badger Creek Reach 1	SW SW 21-3-57	5.9	28%	1,470
		to		37%	1,920
		NW NW 22-3-57		35%	2,300
D	Badger Creek Reach 2	NW NW 22-3-57	5.4	20%	1,080
		to		38%	750
		SW NE 11-3-57		42%	550
E	Lundock West Pond	NW SE 14-3-57	3.3		1,080
F	Lundock East Pond	NE SE 14-3-57	3.5		1,116
G	Keith Bath Pond	NW SE 13-3-57	4.0		1,116
H	Public Service Pond	NW 20-3-56	27.7		2,510
I	Bolinger Recharge Area	Beginning at	36.4	50%	3,000
		SE NW 20-3-56		50%	3,630

HRS WATER CONSULTANTS, INC.
80110-01 January, 1985

EXHIBIT C

Operation Summary
Fort Morgan Reservoir & Irrigation Company
Plan for Augmentation
for _____, 19____ through _____, 19____

CROP DISTRIBUTION:

Crop	Acres Irrigated
Corn	
Beans	
Hay	
Beets	
Grain	
Other	

(all values in acre-feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1. Irrigation Water Requirement*												
2. Total Surface Supply*												
3. Consumptive Use of Groundwater*												
4. South Platte depletion from current year pumping*												
5. Recharge												
6. South Platte accretion from current year recharge												
7. Net effect from prior years												
8. Total effect*												
9. Augmentation Water Available from other sources*												

Negative sign indicates depletion to South Platte River

* Projections are indicated for months following the date of this report. Explanation sheet attached.

HRS WATER CONSULTANTS, INC.
80110-01 October, 1984

EXHIBIT D

Recharge Accounting Form
Fort Morgan Reservoir and Irrigation, Inc.
for month ending _____, 19__

Observed Pan Evaporation = _____ inches (A)

Site Name	Measured In (acre-feet)	Measured Out (acre-feet)	Recharge (acre-feet)	Surface Area (acres)	Evaporation (acre-feet)	Recharge Credit (acre-feet)	SDF (days)	Percent Credit	Credit (acre-feet)
Formula	(B)	(C)	(D)=B-C	(E)	(F)=AxEx0.7/12	(G)=D-F	(H)	(I)	(J)=GxI/100
Canal Reach 1				17.5			270	15	
							480	25	
							750	19	
							1,080	13	
							1,470	10	
							1,800	18	
Canal Reach 2				19.9			2,300	29	
							1,920	21	
							1,470	9	
							1,150	41	
Badger Creek Reach 1				5.9			1,470	28	
							1,920	37	
							2,300	35	
Badger Creek Reach 2		0		5.4			1,080	20	
							750	38	
							550	42	
Lundock West Pond		0		3.3			1,080	100	
Lundock East Pond		0		3.5			1,116	100	
Keith Bath Pond		0		4.0			1,116	100	
Public Service Pond		0		27.7			2,510	100	
Bolinger Pond				36.4			3,000	50	
							3,630	50	

EXHIBIT E

Fort Morgan Reservoir and Irrigation Company
Recharge and Pumping Net Effect
1983-2001
(acre-feet)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1983	37.0	62.7	80.8	96.8	117.1	162.2	195.1	158.5	118.7	104.1	120.3	147.5	1400.8
1984	177.9	205.7	229.8	254.8	261.1	241.3	259.7	264.0	260.9	255.1	254.4	253.9	2918.6
1985	252.4	252.0	246.4	242.6	237.2	232.7	226.3	220.7	215.4	209.0	203.9	197.8	2736.3
1986	191.9	189.1	181.8	177.6	172.0	168.0	162.8	158.5	154.7	150.4	146.9	142.7	1996.3
1987	139.0	137.2	132.4	129.6	126.2	123.6	120.3	117.7	115.6	112.6	110.5	107.7	1472.6
1988	105.5	104.7	101.4	99.7	96.9	95.9	93.3	91.3	90.5	88.1	86.8	84.8	1139.0
1989	83.2	83.2	80.7	79.5	77.7	76.8	75.3	73.7	73.1	71.5	70.7	69.0	914.2
1990	67.9	67.9	65.9	65.3	64.1	63.1	62.0	61.1	60.5	59.3	58.7	57.8	753.6
1991	56.5	57.0	55.5	54.6	53.6	53.6	52.2	51.6	51.0	50.4	49.6	49.1	634.7
1992	48.3	48.6	47.4	46.8	46.2	45.6	45.1	44.2	44.3	43.3	43.2	42.4	545.4
1993	41.7	42.2	40.8	40.7	39.9	39.7	39.3	38.5	38.7	37.7	37.6	37.1	473.8
1994	36.6	37.1	36.0	35.5	35.5	34.9	34.4	34.2	34.0	33.3	33.6	32.7	418.0
1995	32.3	32.9	31.8	31.7	31.1	31.3	30.7	30.3	30.1	29.9	29.7	29.1	370.9
1996	29.1	29.6	28.5	28.3	28.2	28.0	27.5	27.2	27.3	26.8	26.7	26.3	333.4
1997	26.0	26.6	25.8	25.6	25.3	24.9	24.9	24.8	24.7	24.1	24.4	23.9	300.9
1998	23.8	24.0	23.1	23.2	23.0	22.8	22.7	22.3	22.3	22.3	22.2	21.8	273.7
1999	21.6	21.8	21.2	21.3	21.1	21.1	20.7	20.4	20.4	20.4	20.3	19.9	250.3
2000	19.8	20.1	19.4	19.6	19.3	19.3	19.2	18.8	19.0	18.6	18.5	18.6	230.1
2001	18.3	18.5	18.2	18.0	17.5	17.8	17.3	17.7	17.4	17.4	17.3	17.1	212.6

APPENDIX C: List of Contacts

Bijou Irrigation Company
Fort Morgan, CO 80634
Bill Sample, Secretary

Bureau of Reclamation LM-730
P.O. Box 25247
Denver, CO 80225
Darrel Ewing, Hydrologist

Bureau of Reclamation
Water Resources Division
Grand Island, NE
Fred Ostradovsky

Central Colorado Water Conservancy District
2308 29th Street, Suite 2
Greeley, CO 80631
Tom Cech, Secretary/Manager

Colorado State Engineer's Office
1313 Sherman Street, Rm 818
Denver, CO
Dick Stenzel, Civil Engineer

Division Engineer's Office
8th & 8th
Greeley, CO 80631
Les Dahlby, Water Commissioner

Fort Morgan Reservoir and Irrigation Company
Fort Morgan, CO 80634
Harold Griffith, President of Board
Cindy Goldsmith, Secretary

Frenchman Ground Water Project
Holyoke, CO
Ben Saunders, Manager

Ground Water Appropriators of the South Platte
617 Main Street, P.O. Box 944
Fort Morgan, CO 80634
Jack Odor, Manager

HRS Water Consultants, Inc.
1350 Independence Street, Suite 3-A
Lakewood, CO 80215
Karen Rudeen, Water Resources Engineer
Bob Tafelski, Water Resources Engineer

Northern Colorado Water Conservancy District
1250 N. Wilaon Ave.
Loveland, CO 80537
Jon Altenhofen

Plains Ground Water Management
1453 Martin Avenue
Burlington, CO
Clifford Hawthorne, Manager

Resource Consultants, Inc.
402 Mountain Avenue
Fort Collins, CO 80521
George Palos, Executive Vice President

South Platte Basin Water Coalition
2308 29th Street, Suite 2
Greeley, CO 80631
Robert Walker, President

United States Geological Survey
Mail Stop #415, Box 25046
Denver Federal Center
Lakewood, CO 80225
Alan Burns, Hydrologist

United States Geological Survey
Grand Island, NE
Fred Ostradovsky

Willows Water District
7200 East Dry Creek Road
Englewood, CO
Kahn Lee, Engineer

Williamson, Stephen, Attorney at Law
813 Main Street
Louisville, CO 80027