Colorado State University

RECHARGE AS AUGMENTATION

In The

SOUTH PLATTE RIVER BASIN

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RECHARGE AS AUGMENTATION IN THE SOUTH PLATTE RIVER BASIN

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Preface

This study was conducted as a service to the citizens of the state of Colorado. Better water management in the South Platte River Basin has been identified as a major concern to the state. Of increasing interest are the augmentation/recharge projects being implemented in the South Platte River Basin. This report documents the current augmentation/recharge projects in the basin.

This report is one of a series of groundwater reports published by the Groundwater Program, Department of Civil Engineering, Colorado State University, and is an update of Report # 13 published in November, 1986.

ACKNOWLEDGEMENT

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Abstract

Artificial recharge is a recently implemented method of basin water management along the South Platte River. Currently there are about 60 artificial recharge projects being conducted in the South Platte River Basin. This represents about three-fourths of all the artificial recharge projects in the State of Colorado. The purpose of almost all of these projects is for streamflow augmentation 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. In 1975 the State Engineers Office issued a set of four rules specifically for the South Platte River Basin. These rules called for plans of augmentation and brought about the establishment of water-user organizations such as the Groundwater Appropriators of the South Platte River Basin (GASP). GASP is an important component of many of the artificial recharge projects in the South Platte River Basin. GASP does not implement its own recharge projects but instead encourages the development of recharge projects through purchase of recharge credits.

Two methods are currently used to calculate return flow to the river from these recharge/augmentation projects. One method is Glover's analytical solution for a well near a stream. The second, more commonly used method, is the Stream Depletion Factor (SDF) which is based on Glover's solution but uses a numerical groundwater model to compensate for varying aquifer properties and boundary conditions found in the field. Current research work at CSU is involved with verifying the results of return flow calculations using both Glover's solution and the SDF method.

The water supply situation along the South Platte River is a result of the combined effects of agricultural demands, limited water supply, legal, economic and engineering constraints. In response, the recharge/augmentation projects have evolved out of a progressive policy of basin water management in order to provide a plentiful water supply for the state, with its growing agricultural and urban water demands.

Table of Contents

LIST OF TABLES

Note: All Tables list inflows to recharge sites on a water year basis (Nov. - Oct)

LIST OF FIGURES

I. INTRODUCTION

Currently there are about 60 artificial groundwater recharge sites 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 Basin. 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 and to describe the engineering methods used to calculate the return flows to the 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 region, with its growing agricultural and urban water demands.

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 below Denver 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.

Before irrigation development, the South Platte River would be dry in the summer while now it flows continuously due to these return flows. Regulations have evolved to protect these return flows because water rights administration depends on the maintenance of adequate return flows.

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 recharge/augmentation 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 is low and the demand for water is high.

In the 1920s, farmers who had low priority surface water rights constructed wells to tap the groundwater in the alluvial aquifer of the South Platte River Basin. 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, recognizing the interrelationship between surface and groundwaters. 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 as part of the overall concept of maximization of beneficial use.(1)

In 1975, the State Engineer instituted a set of four rules of regulations 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 Ground Water Management Subdistrict (Central) and Ground Water Appropriators of the South Platte (GASP) are two water-user groups currently involved with augmentation throughout the lower South Platte River Basin.

1.2 Augmentation Plans

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 artificial recharge are considered here. The basic concept is that groundwater pumping 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 and augment the river when needed during the critical period of the irrigation season. This returned recharge water is therefore available in the river by the senior surface water right holder to meet his irrigation needs. In addition, a created mound can be pumped down later for a net zero effect to the river. Several methods are used to calculate return flow to the river. 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 an engineering report for an augmentation plan, along with the augmentation plan's water court decree, is given in Appendix B of this report.

1.3 Hydrogeology

The main source of groundwater in the South Platte River Basin is the Valley Fill aquifer, which consists of Pleistocene and Holocene 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 as deep as 300 feet at some places 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.(4)

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 five 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. Ground water 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 Valley aquifer consists of a heterogeneous mixture of cobbles, sand, gravel, silt, and clay deposits. Aquifer 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 ac-ft 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 were 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 O'Brian 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 Glover (10). The field measurements agreed with the theoretical description. It was also concluded that the Theis non-equilibrium equation is an accurate solution to the recharge problem.

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 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 nonirrigation (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 Proctor 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 ac-ft of water were pumped into a 525 acre series of depressions over a four 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 nonirrigation 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 6 months and an accretion for 6 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 in Logan County near the town of Crook 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 of 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

The Colorado State Engineers office currently lists about 60 augmentation/recharge projects along the South Platte River in Water Districts 1, 2, and 64. 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 to 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 eight recharge/augmentation projects. The eight sites are: (1A) Evans 2 - (Platte Valley Ditch), (1B) Farmers Independent, (1C) Miller Site, (1D) Mill Iron Draw, (1E) Kiowa Creek (50% credit), (1F) Western Mutual, (1G) New Cache la Poudre, and (1H) Boxelder Creek (Bootleg Reservoir). These sites are located primarily 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 in this area. The saturated thickness of the aquifer in this area is about 30-60 feet.

Of the eight sites operated by Central, one is no longer currently active (Evans 2). The New Cache la Poudre recharge project will probably not be used because accurate computation of seepage/recharge amounts is difficult due to unquantified inflows to sites. Six of the sites are decreed. Kiowa Creek is operated in conjunction with Bijou Irrigation Company with Central

receiving 50% of the recharge credit. The site was started in Spring of 1982 and consists of two ponds in the dry creek bed of Kiowa Creek. Total recharge between 1983 and 1992 was about 19,000 ac-ft. 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, and then restarted in 1987. Evans 2 diverted about 150 ac-ft for recharge in 1984 but has not been used since. Total recharge for the Central projects was about 43,000 ac-ft cumulative through 1992. Table 1 summarizes the Central recharge sites and lists measured inflows to the sites on a water year basis (i.e., water year 1984 is November 1983 through October 1984). Measured inflows are listed as either diverted or recharged. Recharge water means evaporation has been subtracted from the diverted water that inflowed to the site.

2.2.2 Henry Lyn Irrigation Company

The Henry Lyn Irrigation Company operates a single recharge site, (2A) Olds Reservoir (Figure 1). Olds Reservoir is a leaky irrigation reservoir located in Prospect Valley that has been used since the 1940's for recharge. Water is supplied to Olds 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 33,000 ac-ft has been recharged at Olds Reservoir, an average of about 2,800 ac-ft per year. Table 2 summarizes the recharge information for Olds Reservoir.

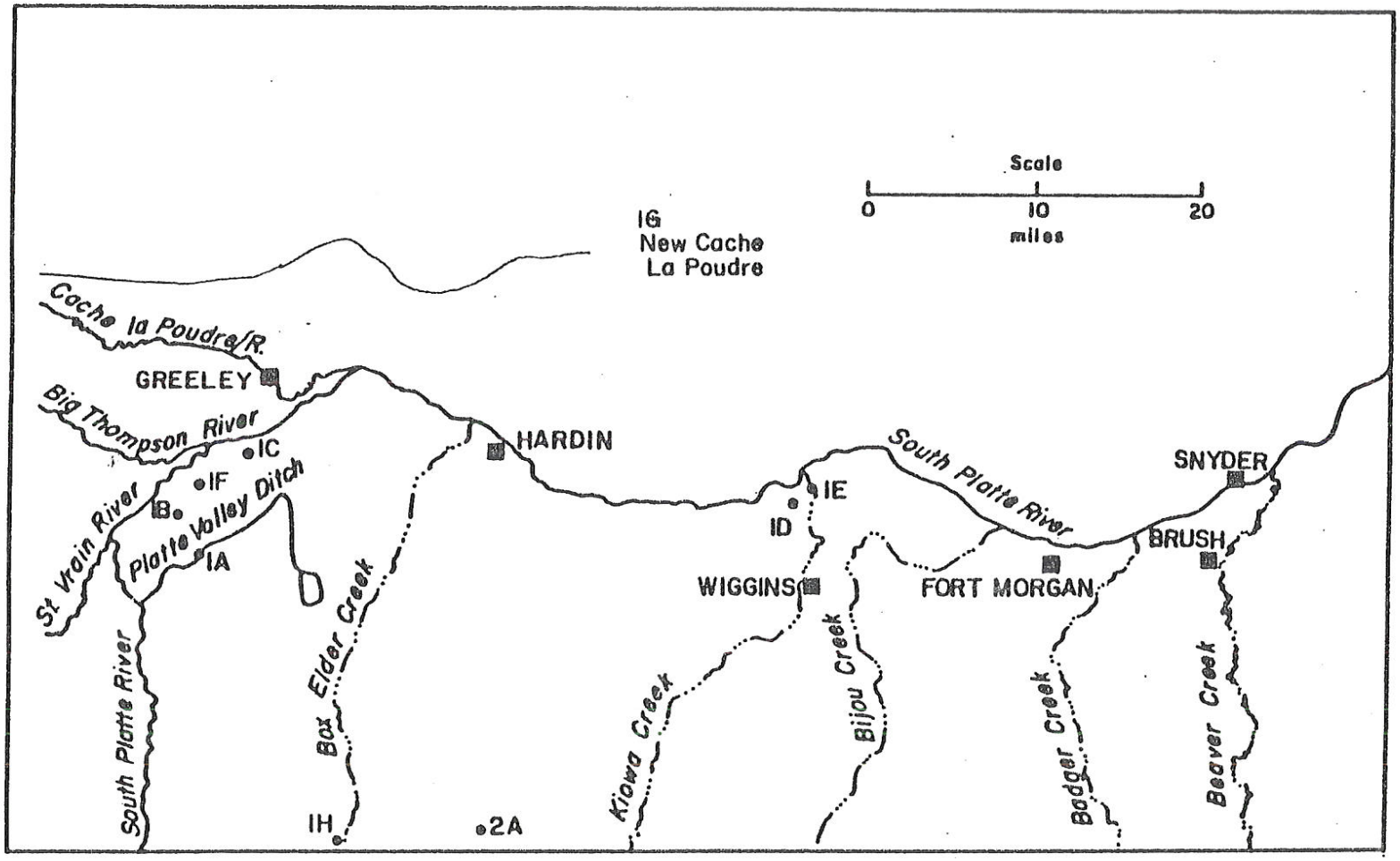


Figure 1 — Location map for Recharge Sites Operated by the Central Colorado Water Conservancy District and the Henry Lyn Irrigation Company

TABLE 1
SITES ON THE SOUTH PLATTE RIVER

Recharge Sites for the Central Colorado Water Conservancy District (see Figure 1 for location)

All Sites

Engineer:	Resource Consultants, except as noted
Analysis:	Central
Return Flow Calcs.:	Stream Depletion Factor (SDF) and Glover's Solution

Map Location No:	1A
Site Name:	Evans 2 - (Platte Valley Ditch)
ID Number (SEO):	2000
Water District:	2
Operator:	Central and Evans Ditch Company
Site Description:	Ditch
Stream Depln. Factor:	
Decree Date:	Temp. Plan, Started 1984

Diversion Info:

Year	Diverted Water (ac-ft)
1984	151*
1985	No longer in use

Map Location No:	1B
Engineer:	CCWCD
Site Name:	Farmers Independent
ID Number (SEO):	Not listed
Water District:	2
Operator:	Central and Farmers Independ. Ditch Company
Site Description:	Ditch
Stream Depln. Factor:	Variable, 30 to 1080 days
Decree Date:	1985 85-CW-370

Diversion Info:

Year	Recharged Water (Ac-ft)
1986	538
1987	475
1988	403
1989	1502
1990	992
1991	542
1992	159

Map Location No:	1C
Engineer:	CCWCD
Site Name:	Miller Site
ID Number (SEO):	
Water District:	2
Operator:	
Site Description:	Pond (7 ac-ft)
Stream Depln. Factor:	480 days
Decree Date:	1985 85-CW-37

Diversion Info:

Year	Recharged Water (Ac-ft)
1988	
1989	99
1990	155
1991	203
1992	22

TABLE 1, (continued)

Map Location No:	1D
Site Name:	Mill Iron Draw
ID Number (SEO):	2035
Water District:	1
Operator:	Central (as of 1986), Previously, Dave Greenwalt
Site Description:	5 Ponds
Capacity:	57 ac-ft total
Decree Date:	1982
Stream Depln. Factor:	73 to 291 days

Diversion Info:

Year	Recharged Water (Ac-ft)
1983	244*
1984	196*
1985	86*
1986	590
1987	877
1988	745
1989	786
1990	625
1991	974
1992	727

Map Location No:	1E
Site Name:	Kiowa Creek
ID Number (SEO):	2036
Water District:	1
Operator:	Central and Bijou Irrigation Company
Site Description:	3 Ponds
Capacity:	
Decree Date:	1982
Stream Depln. Factor:	30 to 750 days

Diversion Info:

Year	Recharged Water (Ac-ft)
1983*	2431*
1984*	1552*
1985*	2635*
1986	1166
1987	1195
1988	1464
1989	1928
1990	1802
1991	2180
1992	2659

Map Location No:	1F
Engineer:	CCWCD
Site Name:	Western Mutual
ID Number (SEO):	
Water District:	2
Operator:	
Stream Depln. Factor:	30 to 1920 days
Site Description:	Ditch
Capacity:	
Decree Date:	1987 87-CW-304

Diversion Info:

Year	Recharged Water (Ac-ft)
1987	1163
1988	0
1989	614
1990	531
1991	366
1992	381

*NOTE : Indicated data is NOT adjusted for evaporation
All other data is adjusted for evaporation

TABLE 1, (continued)

Map Location No:	1G
Site Name:	New Cache la Poudre
ID Number (SEO):	
Water District:	2
Operator:	
Site Description:	Ditch and creek bed
Capacity:	
Decree Date:	Pending Application

Diversion Info:

Year	Recharged Water (Ac-ft)
1988	522
1989	832
1990	No longer in operation

Map Location No:	1H
Site Name:	Boxelder Creek (Bootleg Reservoir)
ID Number (SEO):	2524
Water District:	2
Operator:	Central
Site Description:	Dammed Creek Bed
Capacity:	
Decree Date:	1982
Stream Depln. Factor:	Not Used (Allowable pumping equals net recharge)

Diversion Info:

Year	Recharged Water (Ac-ft)
1983	1162*
1984	0
1985	0
1986	0
1987	1220
1988	829
1989	504
1990	778
1991	678
1992	923

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
Operator:	
Site Description:	
Capacity:	450 ac-ft
Decree Date:	

Diversion Info:

Year	Recharged Water (Ac-ft)
1980	4703*
1981	2532*
1982	Not Available
1983	1425*
1984	2358*
1985	3549*
1986	1749
1987	5163
1988	2746
1989	2236
1990	1640
1991	2735
1992	2403

* Data IS NOT adjusted for evaporation

2.2.3 Groundwater Appropriators of the South Platte (GASP)

GASP is an important component for many of the 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 and private individuals. GASP's involvement with recharge projects have helped projects become economically stable.

The region covered by GASP encompasses the entire South Platte River Basin. However, recharge projects utilized by 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 utilized by GASP, it also has 17 large capacity wells which it uses to augment flow in the South Platte River and three irrigation canals. A description of these various recharge projects is given in the following sections of this report.

2.2.4 Bijou Irrigation Company

The Bijou Irrigation Company has a decreed plan for augmentation and operates nine 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 212 irrigation wells within the Bijou Irrigation System. The nine 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) Lost Creek East, (3H) Lost Creek West, and (3I) Weimer Pond. 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. Historically the Bijou Ditch, Bijou #2 Reservoir and Kiowa Creek are the major recharge sites in the system. Diversion records indicate that up to 43 percent of the flow in the Bijou Canal can be lost to seepage*. Bijou #2 Reservoir has a capacity of about 5,000 ac-ft and is filled by the Bijou canal. There is no longer a reservoir outlet with all water now seeping out and credited for augmentation purposes. The Weingardt Pond and Chase Lateral Pond are located at the tail of the system and have historically received lesser quantities of water for recharge. Since 1980 recharge totaled about 158,000 ac-ft or about 13,200 ac-ft annually. Total recharge for 1992 was about 16,300 ac-ft. Excess accretion credit received at the river was about 2,800 ac-ft for 1992 as a result of all previous recharge. Currently recharge credits exceed augmentation requirements for Bijou. Excess credits have been purchased by GASP and the Central Colorado Water Conservancy District. Table 3 summarizes the Bijou recharge sites and Table 10 contains a yearly total for all the sites of the Bijou Plan.

* Seepage credit from the ditch is allowed only during non-irrigation periods.

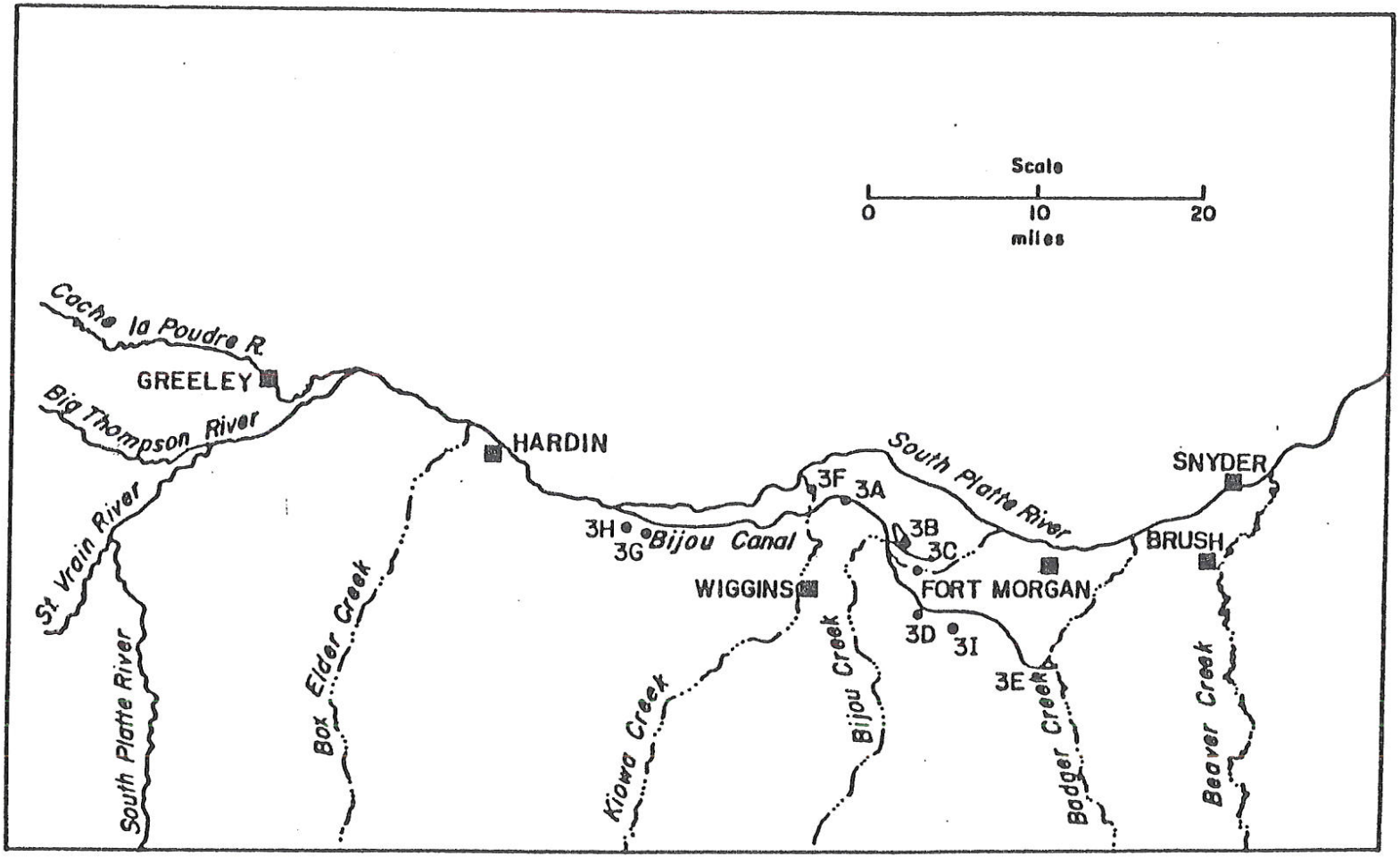


Figure 2 -- Location map for Recharge Sites Operated by the Bijou Irrigation Company

TABLE 3 - Recharge Sites for
the Bijou Irrigation Company
(See Figure 2 for locations)

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 (Administration) Date:	1972 (Cases W-2704 and W-9172-78)

Map Location No:	3A
Site Name:	Bijou Ditch
ID Number (SEO):	2028
Site Description:	13 reaches of canal
Capacity:	142 (ac-ft)
Stream Depln. Factor:	125 to 7100 days

Diversion Info:

Year	Recharged Water (ac-ft)
1983	Not Available
1984	1321
1985*	6062*
1986	3085
1987	3613
1988	4666
1989	5079
1990	4314
1991	4537
1992	3862

Map Location No:	3B
Site Name:	Bijou #2 Reservoir
ID Number (SEO):	
Site Description:	Leaky Reservoir
Capacity:	5000 (ac-ft)
Stream Depln. Factor:	3310 days

Diversion Info:

Year	Recharged Water (ac-ft)
1981	3392
1982	5185
1983	5186
1984	4201
1985*	6583*
1986	8119
1987	6016
1988	4943
1989	847
1990	6399
1991	8548
1992	4074

*NOTE : Data prior to 1986 is NOT adjusted for evaporation

TABLE 3 (Continued)

Map Location No: 3C
Site Name: Bijou Creek
ID Number (SEO): 2029
Site Description: Creek Bed
Capacity: 49 (ac-ft)
Stream Depln. Factor: 1080 to 5070 days

Diversion Info:

Year	Recharged Water (ac-ft)
1986	3900
1987	3452
1988	2220
1989	1418
1990	2870
1991	3442
1992	2529

Map Location No: 3D
Site Name: Weingardt Pond
ID Number (SEO): 2000
Site Description: Pond
Capacity: 48 (ac-ft)
Stream Depln. Factor: 5880 days

Diversion Info:

Year	Recharged Water (ac-ft)
1983	133
1984	859
1985*	1755*
1986	1327
1987	1675
1988	722
1989	409
1990	890
1991	296
1992	741

Map Location No: 3E
Site Name: Chase Lateral Pond
ID Number (SEO): 2001
Site Description: Pond
Capacity: 31 (ac-ft)
Stream Depln. Factor: 7825 days

Diversion Info:

Year	Recharged Water (ac-ft)
1983	385
1984	272
1985*	642*
1986	586
1987	442
1988	97
1989	301
1990	307
1991	135
1992	118

*NOTE : Data prior to 1986 is NOT adjusted for evaporation

TABLE 3 (Continued)

Map Location No: 3F
Site Name: Kiowa Creek
ID Number (SEO): 2036 (same as site 1E)
Site Description: Creek Bed
Capacity: 14 (ac-ft)
Stream Depln. Factor: 30 to 750 days

Diversion Info:

Year	Recharged Water (ac-ft)
1983	2431
1984	1552
1985*	2635*
1986	1166
1987	1195
1988	1464
1989	1928
1990	1803
1991	2180
1992	2659

Map Location No: 3G
Site Name: Lost Creek East
ID Number (SEO): 2042
Operator:
Site Description: Pond
Capacity: 60 (ac-ft)
Stream Depln. Factor: 87 days

Diversion Info:

Year	Recharged Water (ac-ft)
1985	
1986	36
1987	568
1988	420
1989	329
1990	517
1991	675
1992	1258

Map Location No: 3H
Site Name: Lost Creek West
ID Number (SEO): 2043
Operator:
Site Description: Pond
Capacity: 150 (ac-ft)
Stream Depln. Factor: 32 days

Diversion Info:

Year	Recharged Water (ac-ft)
1985	
1986	
1987	262
1988	123
1989	377
1990	890
1991	647
1992	1106

*NOTE : Data prior to 1986 is NOT adjusted for evaporation

TABLE 3 (Continued)

Map Location No: 3I
Site Name: Weimer Pond
ID Number (SEO): 2045
Operator:
Site Description: Pond
Capacity:
Stream Depln. Factor: 5880 days

Diversion Info:

Year	Recharged Water (ac-ft)
1985*	
1986	
1987	53
1988	
1989	
1990	
1991	
1992	

*NOTE : Data prior to 1986 is NOT adjusted for evaporation

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 92 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 mainly 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 Ft. Morgan Canal, Badger Creek, and Bolinger recharge area . Diversion records indicate that thirty percent of the flow in the Fort Morgan Canal is lost 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. Since 1980 recharge has totaled about 121,300 ac-ft or about 10,100 ac-ft annually. In 1992 a total of about 9,950 ac-ft were recharged. Excess accretion credit at the river was about 3,700 ac-ft for 1992 as a result of all previous recharge. In the 1980's, excess credits were purchased by GASP. Excess credits are now sold to Public Service Company to augment Public Service Company's well pumping depletions. Table 4 summarizes the Fort Morgan Recharge sites and Table 10 contains a yearly total for all the sites of the Ft. Morgan plan. Appendix B of this report contains the engineering report and water court decree for the Fort Morgan Augmentation Plan.

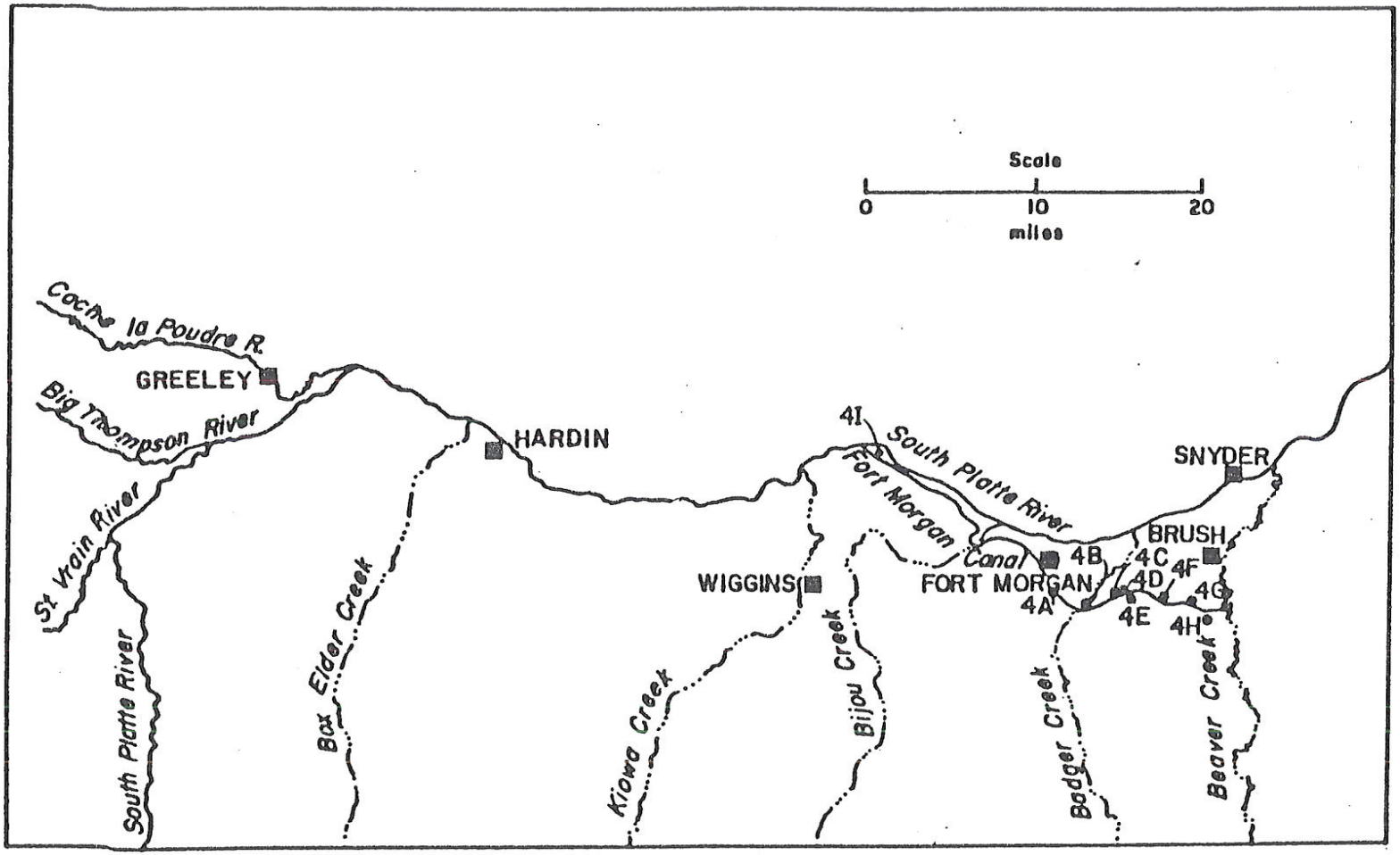


Figure 3 -- Location map for Recharge Sites Operated by the Fort Morgan Reservoir and Irrigation Company.

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: 1
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 (Administration) Date: 1972 (Case W-2692)

Map Location: 4A
Site Name: Fort Morgan Canal
ID Number (SEO): 2023
Site Description: 16 reaches of ditch
Capacity: 37.7 ac-ft
Stream Depln. Factor: 120 to 3760 days

Diversion Info:

Year	Recharged Water (ac-ft)
1979	7670
1980	2549
1981	8995
1982	1572
1983	8763
1984	6711
1985*	3502*
1986	4132
1987	4194
1988	2117
1989	1733
1990	2948
1991	2804
1992	2222

Map Location: 4B
Site Name: Badger Creek
ID Number (SEO): 2026
Site Description: 2 reaches of creek
Capacity: 11.3 ac-ft
Stream Depln. Factor: 550 to 2300 days

Diversion Info:

Year	Recharged Water (ac-ft)
1979	Not available
1980	1489
1981	3066
1982	711
1983	1977
1984	2606
1985*	4121*
1986	3576
1987	3017
1988	3367
1989	1982
1990	4948
1991	4745
1992	4874

TABLE 4 (Continued)

Map Location: 4C
Site Name: Lundock West Pond
ID Number (SEO): Not listed
Site Description: Pond
Capacity: 3.3 ac-ft
Stream Depln. Factor: 1080 days

Diversion Info:

Year	Recharged Water (ac-ft)
1986	32
1987	29
1988	22
1989	0
1990	15
1991	17
1992	26

Map Location: 4D
Site Name: Lundock East Pond
ID Number (SEO): Not Listed
Site Description: Pond
Capacity: 3.5 ac-ft
Stream Depln. Factor: 1116 days

Diversion Info:

Year	Recharged Water (ac-ft)
1986	32
1987	29
1988	22
1989	0
1990	14
1991	17
1992	26

Map Location: 4E
Site Name: Keith Bath Pond
ID Number (SEO): Not Listed
Site Description: Pond
Capacity: 4 ac-ft
Stream Depln. Factor: 1116 days

Diversion Info:

Year	Recharged Water (ac-ft)
1986	451
1987	318
1988	112
1989	23
1990	0
1991	0
1992	0

Map Location: 4F
Site Name: Public Service Pond
ID Number (SEO): 2016
Site Description: Pond
Capacity: 27.7 ac-ft
Stream Depln. Factor: 2510 days

Diversion Info:

Year	Recharged Water (ac-ft)
1985*	394*
1986	356
1987	357
1988	328
1989	297
1990	346
1991	349
1992	359

*NOTE : Data prior to 1986 is NOT adjusted for evaporation

TABLE 4 (Continued)

Map Location: 4G
Site Name: Bolinger Recharge Area
ID Number (SEO): 2024
Engineer: HRS/Bitinger
Site Description: Pond
Capacity: 36.4 ac-ft
Stream Depln. Factor: 3300 days

Diversion Info:

Year	Recharged Water (ac-ft)
1979	1000
1980	
1981	4601
1982	1760
1983	3351
1984	2763
1985*	2837*
1986	1548
1987	827
1988	892
1989	600
1990	1149
1991	1047
1992	755

Map Location: 4H
Site Name: Charles Henry Pond
ID Number (SEO): 2021
Site Description: Pond
Capacity: 5.5 ac-ft
Stream Depln. Factor: 5100 days

Diversion Info:

Year	Recharged Water (ac-ft)
1986	867
1987	895
1988	598
1989	501
1990	666
1991	601
1992	773

Map Location: 4I
Site Name: DT Ranch Pond
ID Number (SEO): 2052
Site Description: Pond
Capacity:
Stream Depln. Factor: 75 days

Diversion Info:

Year	Recharged Water (ac-ft)
1991	557
1992	917

*NOTE : Data prior to 1986 is NOT adjusted for evaporation

2.2.6 Pioneer Water and Irrigation Company

The Pioneer Water and Irrigation Project has a decreed plan for augmentation and operates 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 2800 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 Brush (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 ac-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 were 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. The total recharge for 1992 was about 4,700 ac-ft. Table 5 summarizes the Pioneer recharge sites and Table 10 contains yearly totals.

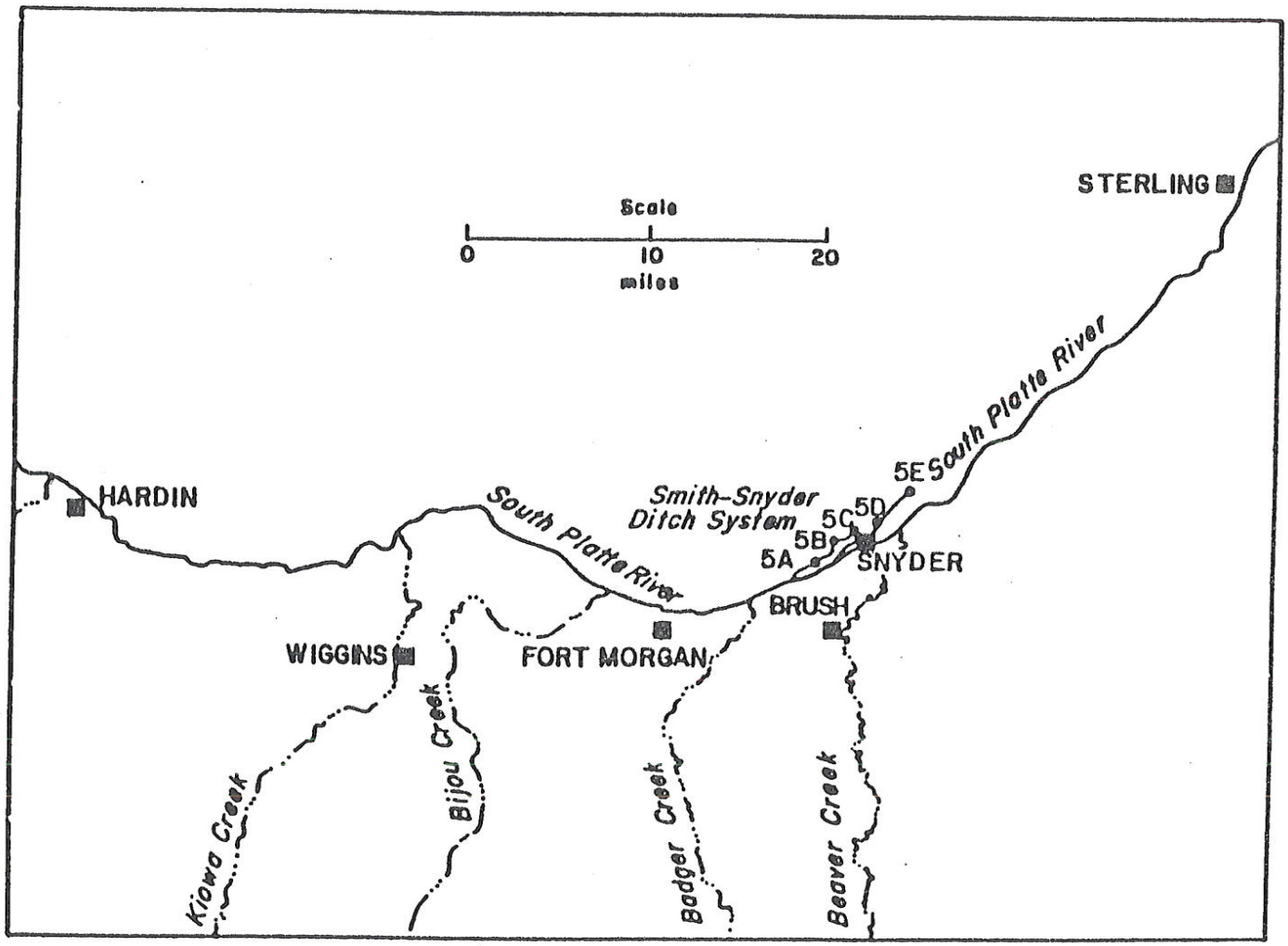


Figure 4 -- Location map for Recharge Sites Operated by the Pioneer Water and Irrigation Company

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 (Administration) Date:	1981

Map Location No:	5A
Site Name:	Pioneer Ditch
ID Number:	2003
Site Description:	Ditch
Capacity:	75 cfs
Stream Depln. Factor:	75 and 125 days

Diversion Info:

Year:	Recharged Water (Ac-Ft)
1982	556
1983	598
1984	1283
1985*	1027*
1986	1665
1987	1592
1988	2048
1989	2324
1990	1822
1991	2834
1992	2315

Map Location No:	5B
Site Name:	Woodward West Lake
ID Number:	2004
Site Description:	Pond
Capacity:	53.4 ac-ft
Stream Depln. Factor:	170 days

Diversion Info:

Year:	Recharged Water (Ac-Ft)
1982	2998
1983	1534
1984	1898
1985*	1235*
1986	1187
1987	1329
1988	658
1989	377
1990	455
1991	579
1992	702

*NOTE : Data prior to 1986 is NOT adjusted for evaporation

TABLE 5 (Continued)

Map Location No: 5C
Site Name: Snyder Lake
ID Number: 2005
Site Description: Pond
Capacity: 22.5 ac-ft
Stream Depln. Factor: 85 days

Diversion Info:

Year:	Recharged Water (Ac-Ft)
1982	
1983	60
1984	468
1985*	283*
1986	387
1987	547
1988	0
1989	0
1990	0
1991	0
1992	0

Map Location No: 5D
Site Name: Woodward East Lake
ID Number: 2006
Site Description: Pond
Capacity: 53.4
Stream Depln. Factor: 270 days

Diversion Info:

Year:	Recharged Water (Ac-Ft)
1982	
1983	2746
1984	752
1985*	1312*
1986	1454
1987	2806
1988	1613
1989	1185
1990	1401
1991	1150
1992	1361

Map Location No: 5E
Site Name: Peterson-Pioneer
ID Number: 2007
Site Description: Ditch
Capacity: 22.5 ac-ft
Stream Depln. Factor: 85 days

Diversion Info:

Year:	Recharged Water (Ac-Ft)
1982	
1983	438
1984	0
1985*	0*
1986	0
1987	656
1988	699
1989	0
1990	0
1991	0
1992	365

2.2.7 Upper Platte and Beaver Canal Company

The Upper Platte and Beaver Canal Company has developed five recharge projects. These recharge sites are: (6A) Upper Platte and Beaver Ditch (North Ditch), (6B) State-Kemple, (6C) Beaver Creek (South Ditch), (6D) Degenhart, and (6E) Clark. The Upper Platte and Beaver Ditch, State-Kemple, Degenhart and Clark sites 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 recharge for 1992 for the five sites was about 4,600 ac-ft. Table 6 summarizes the Upper Platte and Beaver recharge sites.

2.2.8 Lower Platte and Beaver Canal Company

The lower Platte and Beaver Canal Company operates five recharge sites. These sites are: (7A) Lower Platte and Beaver Ditch, (7B) Emmerson Lake/Seaman, (7C) Allyn Wind, (7D) Daily, and (7E) Beaver Creek. The Emmerson Lake/Seaman and Allyn Wind Recharge sites are operated in conjunction with individual farmers. The recharge sites are located along the lower Platte and Beaver Canal northeast of the city of Brush (Figure 5). The Allyn Wind recharge site was started in 1978 and has recharged an average of 260 ac-ft per year. The Emmerson Lake/ Seaman Recharge site was started in 1981 and has recharged an average of about 450 ac-ft per year. In 1992 total recharge for the Lower Platte and Beaver recharge system was about 2,300 ac-ft. Table 7 summarizes the Lower Platte and Beaver recharge sites.

2.2.9 Riverside Irrigation District

The Riverside Irrigation District has worked in conjunction with individual entities on three separate decreed recharge projects. These recharge projects are: (8A) Goodrich Farms, (8B) Headley recharge project, and (8C) Equus (Figure 5). Total recharge in 1992 for these three projects was about 11,600 ac-ft. In recent years, the Riverside Irrigation District has developed Vancil Reservoir and Recharge Project. Vancil Reservoir (8D on Figure 5) is a 7,000 ac-ft reservoir which is decreed so that reservoir seepage along with canal seepage of waters delivered

to Vancil can be claimed for recharge credit. Riverside Irrigation is also developing recharge ponds in conjunction with the National Hog Farms Company at location 8E on Figure 5. W. W. Wheeler and Associates is doing the engineering and analysis for the Vancil and National Hog Farm Recharge Projects. Table 8 summarizes the Riverside recharge site.

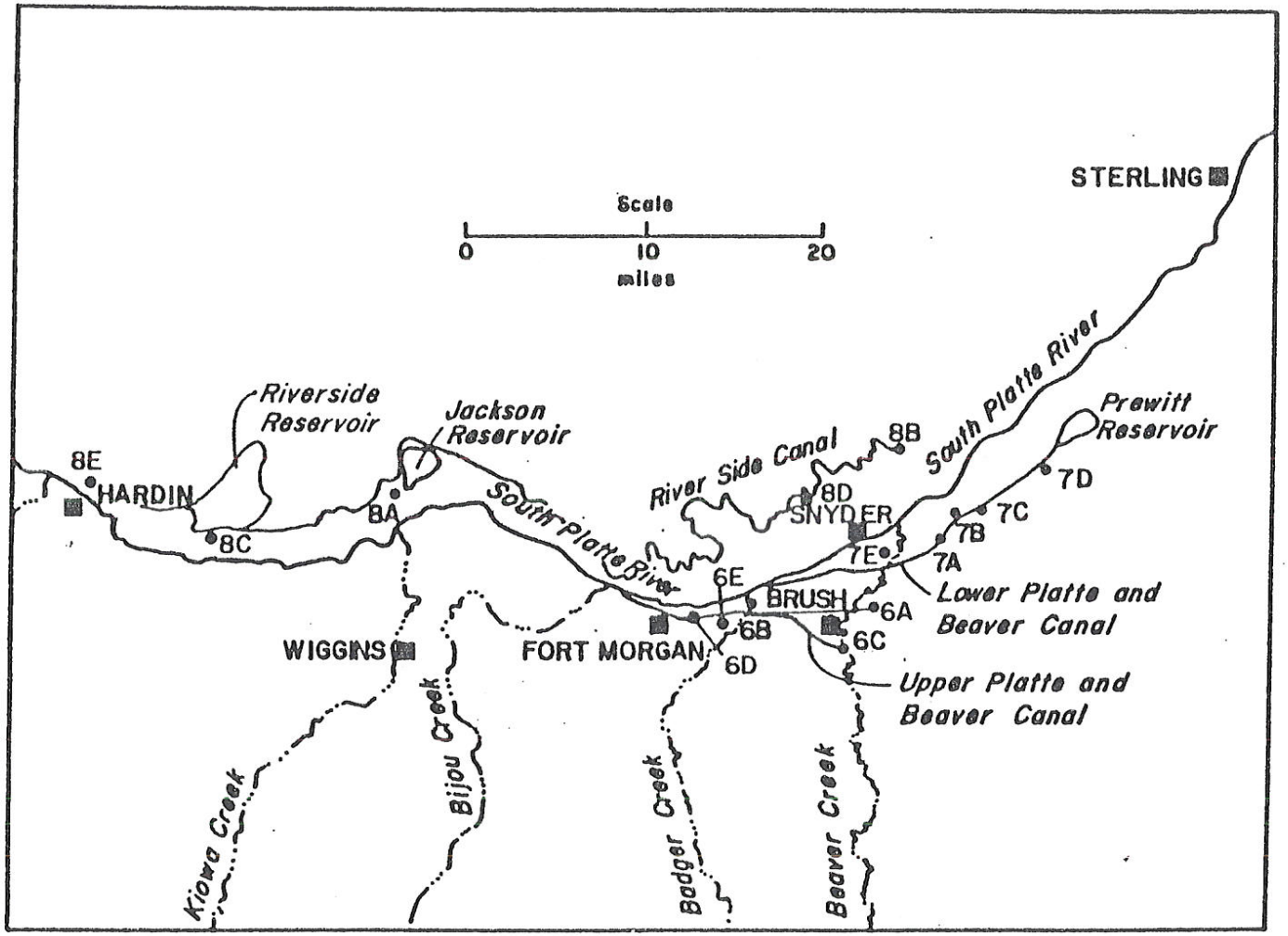


Figure 5 -- Location map for Recharge Sites Operated by the Upper Platte and Beaver Canal Company, the Lower Platte and Beaver Canal Company, and the Riverside Irrigation Company.

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

All Sites
Water District: 1
Engineer: Ron Thaemert
Operator: Upper Platte and Beaver Canal Company
Analysis: Northern Colorado Water Conservancy District
Return Flow Calcs: Glover's Solution
Decree (Administration)Date: 1984 (Case W-2968)

Map Location No: 6A
Site Name: Upper Platte and Beaver Ditch (N. Ditch)
ID Number (SEO): 2034
Site Description: Ditch
Capacity:
Stream Depln. Factor: 230 days

Diversion Info:

Year	Recharged Water, ac-ft*
1983	3612
1984	953
1985	1574
1986	598
1987	353
1988	165
1989	143
1990	337
1991	660
1992	223

Map Location No: 6B
Site Name: State-Kemble
ID Number (SEO): 2011
Site Description:
Capacity:
Stream Depln. Factor: 60 days

Diversion Info:

Year	Recharged Water, ac-ft*
1984	306
1985	1488
1986	1034
1987	961
1988	2439
1989	820
1990	1847
1991	2140
1992	1428

*NOTE : No evaporation deduction for the UP&B Accounting Procedure

Table 6 (Continued)

Map Location No: 6C
Site Name: Beaver Creek (S. Ditch)
ID Number (SEO): 2041
Site Description: Lower reach of creek
Capacity:
Stream Depln. Factor: 1550 days

Diversion Info:

Year	Recharged Water, ac-ft*
1984	1571
1985	618
1986	230
1987	990
1988	1457
1989	251
1990	384
1991	1525
1992	227

Map Location No: 6D
Site Name: Degenhart
ID Number (SEO): 2054
Site Description: Pond
Capacity:
Stream Depln. Factor: 60 days

Diversion Info:

Year	Recharged Water, ac-ft*
1992	526

Map Location No: 6E
Site Name: Clark
ID Number (SEO): 2053
Site Description: Pond
Capacity:
Stream Depln. Factor: 80 days

Diversion Info:

Year	Recharged Water, ac-ft*
1992	2228

*NOTE : No evaporation deduction for the UP&B Accounting Procedure

Table 7 Recharge Sites 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:	Northern Colorado Water Conservancy District
Return Flow Calcs:	Stream Depletion Factor

Decree (Administration) Date: 1972 (Case W-2969)

Map Location No:	7A
Site Name:	Lower Platte and Beaver Ditch
ID Number (SEO):	2033
Site Description:	Ditch
Capacity:	62 ac-ft
Stream Depln. Factor:	30 to 690 days

Diversion Info:

Year	Recharged Water, ac-ft
1986	757
1987	0
1988	0
1989	0
1990	1901
1991	0
1992	1388

Map Location No:	7B
Site Name:	Emmerson Lake/Seaman
ID Number (SEO):	2018
Site Description:	Pond
Capacity:	40 ac-ft
Stream Depln. Factor:	850 days

Diversion Info:

Year	Recharged Water, ac-ft
1981	457
1982	112
1983	227
1984	721
1985*	731*
1986	568
1987	342
1988	517
1989	470
1990	509
1991	389
1992	357

Table 7 (Continued)

Map Location No: 7C
Site Name: Allyn Wind
ID Number (SEO): 2022
Site Description: Pond
Capacity: 1200 ac-ft
Stream Depln. Factor: 480 days

Diversion Info:

Year	Recharged Water, ac-ft
1978	348
1980	375
1981	269
1982	348
1983	306
1984	291
1985*	353*
1986	207
1987	195
1988	250
1989	261
1990	164
1991	116
1992	179

Map Location No: 7D
Site Name: Daily
ID Number (SEO): 2009
Site Description: Pond
Capacity:
Stream Depln. Factor: 430 days

Diversion Info:

Year	Recharged Water, ac-ft
1986	0
1987	0
1988	0
1989	0
1990	0
1991	828
1992	412

Map Location No: 7E
Site Name: Beaver Creek
ID Number (SEO): 2040
Site Description: Creek Bed
Capacity:
Stream Depln. Factor: 120 days

Diversion Info:

Year	Recharged Water, ac-ft
1986	783
1987	0
1988	0
1989	0
1990	837
1991	0
1992	0

*NOTE : Data prior to 1986 is NOT adjusted for evaporation

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

All Sites

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

Map Location No: 8A
Site Name: Goodrich Farms
ID Number (SEO): 2032
Engineer: HRS Consultants
Site Description: Series of Ponds
Capacity:
Decree Date: Admin. Date 1978 (Case W-2919)
Stream Depln. Factor: 2100 to 4400 days

Diversion Info:

Year	Recharged Water, ac-ft
1983	1849
1984	2268
1985*	6453*
1986	932
1987	1708
1988	2111
1989	1053
1990	2020
1991	2546
1992	2430

Map Location No: 8B
Site Name: Headly Property
ID Number (SEO): 2037, 2038
Engineer: Leonard Rice Egr & HRS
Site Description: Series of Ponds
Capacity:
Decree Date: Admin. Date 1990 (Case 90-CW-189)
Stream Depln. Factor: 150 to 3600 days

Diversion Info:

Year	Recharged Water, ac-ft
1982	1720
1983	1475
1984	3263
1985*	500*
1986	22
1987	0
1988	526
1989	509
1990	2478
1991	0
1992	1224

Map Location No: 8C
Site Name: Equus
ID Number (SEO): 2049, 2050, 2051
Site Description: Series of Ponds (Agnes, George, and K4)
Engineering: HRS Consultants
Decree Date: Admin. Date 1988 (Case 88-CW-239)
Stream Depln. Factor: 270 to 900 days

Diversion Info:

Year	Recharged Water, ac-ft
1986	37
1987	831
1988	784
1989	1689
1990	3655
1991	6105
1992	7924

*NOTE : Data prior to 1986 is NOT adjusted for evaporation

2.2.10 Condon Recharge Site

The Condon Recharge Site is 20 acres including a pond and sand hill pockets/depressions east of Sterling and near the Town of Crook. The site is owned and operated by Mr. Bill Condon. He pumps water from three groundwater wells next to the South Platte River into his pond mainly during the period of November to June. The decreed plan of augmentation for this site includes a storage priority for 5,000 ac-ft per year and the right to claim augmentation credit for not diverting the water right of the Chambers Ditch. Since 1981, about 21,000 ac-ft has been recharged, or about 1,800 ac-ft annually. This project also has the capability of flowing from the pond directly back into the river if desired. GASP purchases the accretion credits at the South Platte River that result from this recharge. Recharge data for the Condon Site (9H on Figure 6) is given in Table 9 with other individual sites.

2.2.11 Other Recharge Sites

Between Prewitt Reservoir and the town of Crook there are an additional nine recharge sites. Most of these recharge projects are operated by individual farmers. Most of the sites have been in operation since 1979. All but two are still active. A brief description of these sites follows. Recharge data for these sites is given in Table 9 along with map location number. The location of these sites are shown on Figure 6. A total of about 3,800 ac-ft was recharged in 1992 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 23,400 ac-ft has been recharged at this site. This averages about 1,600 ac-ft per year, for which GASP gave a recharge credit of 77 percent of the diverted flow. In 1992 about 1,624 ac-ft was recharged.

The Hessler Recharge Project consists of three recharge ponds and three reaches of the Davis Bothers Ditch. The site is operated by a Mr. Robert Hessler in cooperation with the Davis

Brothers Ditch Company. Recharge operations ended in October 1991. Since 1980, cumulative recharge has been about 15,000 ac-ft or about 1,200 ac-ft per year. 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 abandoned.

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 cumulative recharge during this time period of 640 ac-ft or 53 ac-ft annually. In 1992, 46 ac-ft were recharged.

The Monahan recharge site is a ten acre pond adjacent to Farmer's Pawnee Canal. The site, operated by Mr. Rex Monahan, which is entitled to divert up to 1,500 ac-ft per year at a maximum rate of 25 cfs. The site has been operated intermittently since 1979. In 1992, 15 ac-ft were recharged.

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 2,070 ac-ft have been recharged, or about 148 ac-ft annually. After augmenting well pumping, excess recharge credits have been sold to GASP. In 1992, about 260 ac-ft were recharged.

The Wilhem (Sonnenberg) site is a ten acre pond which is filled with 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 Wilhem Company. These two companies split the recharge credit. Since 1980, cumulative recharge has been about 9,430 ac-ft.

The Smart site consists of four recharge ponds with a total surface area of 4.5 acres. The ponds are filled by the South Platte Ditch and are operated by the Smart Land and Livestock Company. The site has been operational since 1988 with 523 ac-ft recharged in 1992.

The Julesberg recharge site was developed by the State Engineers Office and the Lower South Platte Water Conservancy District. It began in 1991 and recharged 1,322 ac-ft in 1992.

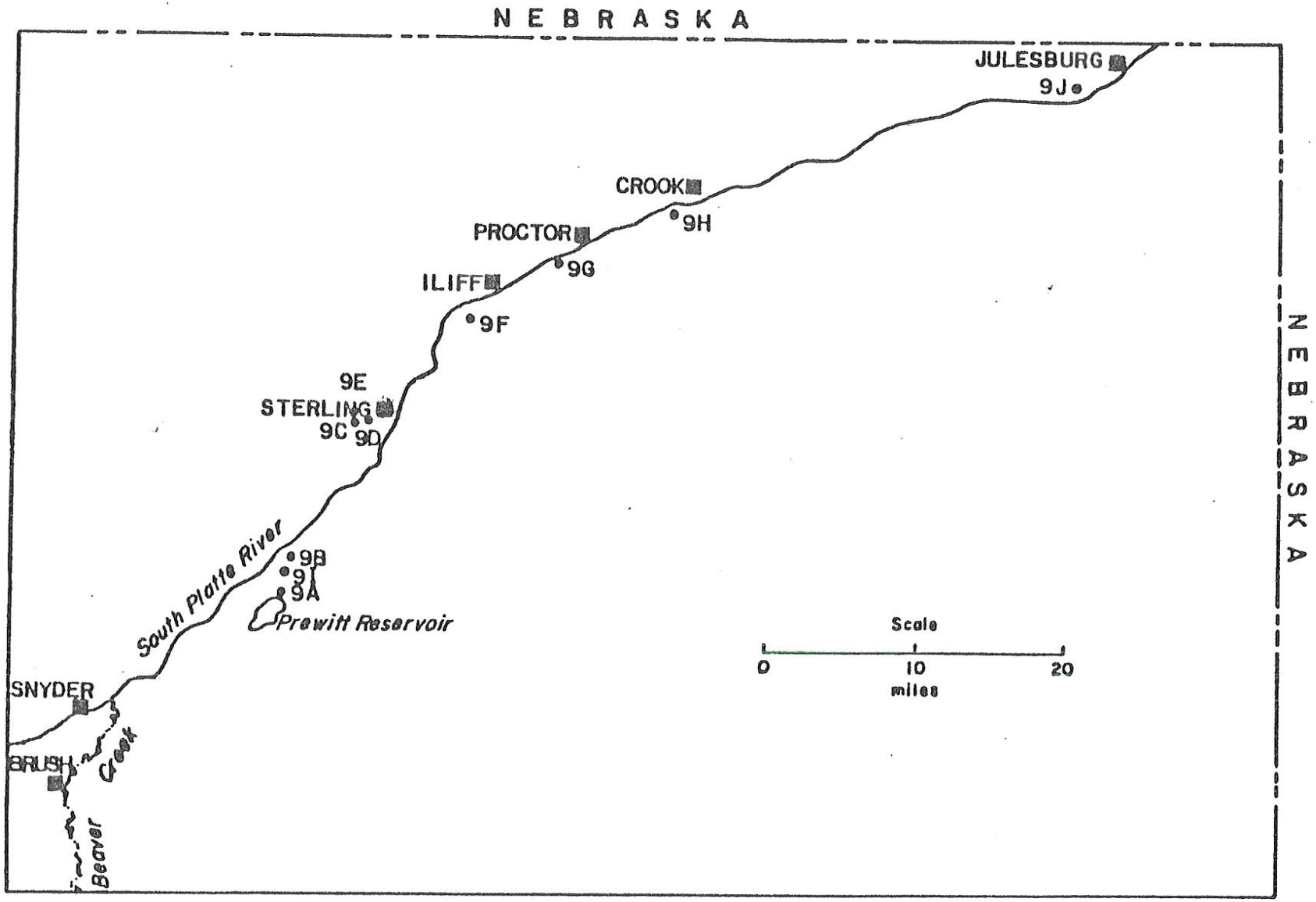


Figure 6 -- Location map for Other Recharge Sites.

TABLE 9 - Other Recharge Sites
Water District #64 (see Figure 6)

All Sites
Water District : 64

Map Location No:	9A
Site Name:	Sandhill/South Platte 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
Stream Depln. Factor:	

Diversion Info:*

Year	Recharged Water (ac-ft)
1978	1131
1979	1333
1980	796
1981	2214
1982	1931
1983	2056
1984	1935
1985	1249
1986	1306
1987	860
1988	1321
1989	1853
1990	1620
1991	2176
1992	1624

Map Location No:	9B
Site Name:	Hessler Recharge
ID Number (SEO):	2506
Engineer:	HRS Consultant
Operator:	R. Hessler & Davis Bros. Ditch
Analysis:	NCWCD
Return Flow Calcs:	Stream Depletion Factor
Site Description:	3 Ponds, 3 Ditch Reaches
Capacity:	20 ac-ft (in the ponds)
Decree Date:	1978
Stream Depln. Factor:	30 to 410 days

Diversion Info:*

Year	Recharged Water (ac-ft)
1980	662
1981	832
1982	823
1983	1290
1984	763
1985	1444
1986	801
1987	2033
1988	1220
1989	1755
1990	1721
1991	1764
1992	0

*NOTE : None of the data is adjusted for evaporation

TABLE 9 (Continued)

Map Location No:	9C
Site Name:	Pivonka
ID Number (SEO):	2502
Engineer:	None
Operator:	John Pivonka
Analysis:	
Return Flow Calcs:	None
Site Description:	Pond
Capacity:	
Decree Date:	
Stream Depln. Factor:	

Diversion Info:*

Year	Recharged Water (ac-ft)
1979	576
1980	194
1981	0
1982	0
1983	0
1984	0
1985	0
1986	0
1987	0
1988	0
1989	0
1990	0
1991	0
1992	0

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
Stream Depln. Factor:	

Diversion Info:*

Year	Recharged Water (ac-ft)
1980	63
1981	93
1982	70
1983	76
1984	41
1985	48
1986	32
1987	70
1988	
1989	42
1990	31
1991	28
1992	46

*NOTE : None of the data is adjusted for evaporation

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
Site Description:	Pond
Capacity:	10 ac-ft
Decree Date:	
Stream Depln. Factor:	

*None of Monahan's data is adjusted for evaporation

Diversion Info:*

Year	Recharged Water (ac-ft)
1979	705
1980	235
1981	
1982	None
1983	Structure Unusable
1984	114
1985	
1986	196
1987	963
1988	
1989	
1990	
1991	
1992	15

Map Location No:	9F
Site Name:	Home Ranch of Wyoming
ID Number (SEO):	2500
Engineer:	None
Operator:	George Faris
Analysis:	NCWCD
Return Flow Calcs:	Replacement for Well
Site Description:	Pond
Capacity:	
Decree Date:	Admin. Date 1976 (Case W-8376-76)
Stream Depln. Factor:	75 days

Diversion Info:

Year	Recharged Water (ac-ft)
1979	68
1980	258
1981	183
1982	254
1983	155
1984	177
1985	57
1986	127
1987	36
1988	95
1989**	109**
1990	132
1991	165
1992	258

**NOTE : Data prior to 1989 is NOT adjusted for evaporation

TABLE 9 (Continued)

Map Location No:	9G
Site Name:	Wilhem (Sonnenberg)
ID Number (SEO):	2507
Engineer:	Frank Tralese, Wright Egr.
Operator:	Painted Rock Development Company & Wilhem Co.
Analysis:	
Return Flow Calcs:	
Site Description:	Ponds
Capacity:	10 ac-ft
Decree Date:	1983
Stream Depln. Factor:	

*None of Wilhem's data is adjusted for evaporation

Diversion Info:*

Year	Recharged Water (ac-ft)
1980	370
1981	193
1982	99
1983	178
1984	450
1985	180
1986	0
1987	0
1988	0
1989	0
1990	0
1991	0
1992	12

Map Location No:	9H
Site Name:	Condon Pond
ID Number (SEO):	2514
Engineer:	HRS Consulting Engineers
Operator:	Bill Condon
Analysis:	NCWCD
Return Flow Calcs:	Stream Depletion Factor
Site Description:	Pond and Ditch
Capacity:	20 ac-ft
Decree Date:	Admin. Date 1979 (Case W-8460-76)
Stream Depln. Factor:	133 days

Diversion Info:

Year	Recharged Water (ac-ft)
1981	1330
1982	2110
1983	2428
1984	2255
1985**	1295**
1986	1028
1987	890
1988	1058
1989	1114
1990	1417
1991	2287
1992	3829

**NOTE : Data prior to 1986 is NOT adjusted for evaporation

TABLE 9 (Continued)

Map Location No:	9I
Site Name:	Smart
ID Number (SEO):	2004
Water District:	64
Operator:	Carson Smart
Analysis:	NCWCD
Site Description:	4 Ponds
Capacity:	
Decree Date:	Admin. Date 1977 (Case W-8686-77)
Stream Depln. Factor:	370 days

Diversion Info:*

Year	Recharged Water (Ac-ft)
1988	177
1989	326
1990	100
1991	112
1992	523

*All of Smart's data has been adjusted for evaporation

Map Location No:	9J
Site Name:	Julesburg
ID Number (SEO):	2005
Water District:	64
Operator:	Lower S. Platte WCD
Site Description:	
Capacity:	
Decree Date:	
Stream Depln. Factor:	

Diversion Info:**

Year	Recharged Water (Ac-ft)
1991	381
1992	1322

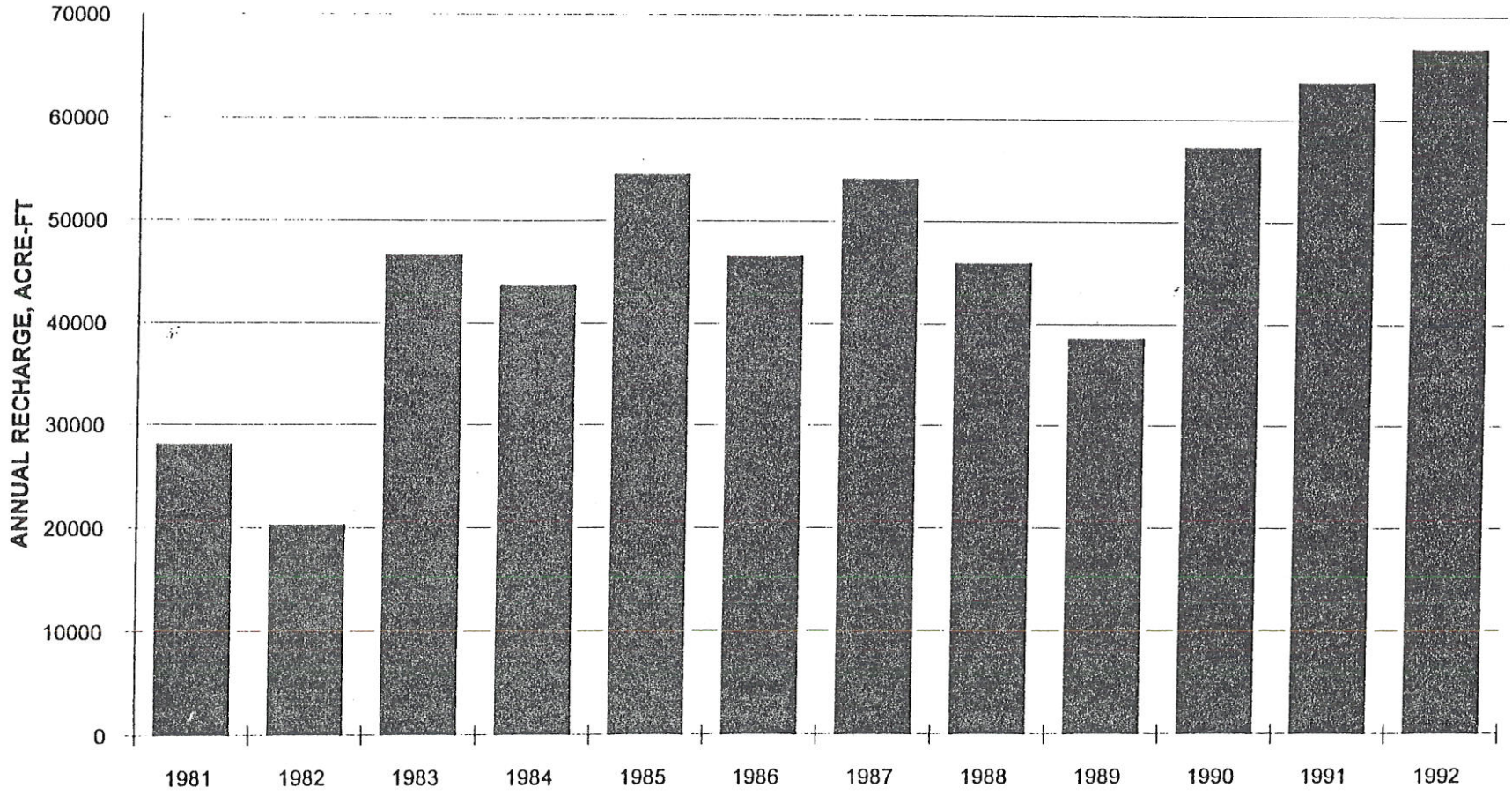
** None of Julesburg's data has been adjusted for evaporation

TABLE 10 -- SUMMARY OF ARTIFICIAL RECHARGE ALONG THE SOUTH PLATTE
ACRE-FT OF RECHARGE *

OPERATOR	No. of Sites	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	TOTAL
Central CO Water Conservancy Dist.	8			3837	1899	2721	2294	4930	3963	6265	4883	4943	7274	43009
Henry Lyn	1	2532		1425	2358	3549	1749	5163	2746	2236	1640	2735	2403	28536
Bijou	9	3392	5185	8135	8205	17677	18242	17294	14665	10737	17932	20425	16372	158261
Ft. Morgan R&I	9	16662	4043	14091	12080	10997	10994	9666	7458	5136	10086	10128	9952	121293
Pioneer	5		3649	5535	4076	3664	4693	6930	5018	3886	3678	4563	4743	50435
Upper Platte and Beaver	5			3612	.2830	3680	1866	2304	4061	1214	2568	4325	4632	31092
Lower Platte and Beaver	5	726	460	533	1012	1084	2315	537	767	731	3411	1333	2336	15245
Riverside	3		1720	3324	5531	6953	991	2539	3421	3251	8153	8651	11578	56112
Condon	1	1330	2110	2428	2255	1295	1028	890	1058	1114	1417	2287	3829	21041
Individual	9	3515	3177	3755	3480	2978	2462	3962	2813	4085	3604	4626	3800	42257
TOTAL	55	28157	20344	46675	43726	54598	46634	54215	45970	38655	57372	64016	66919	567281

* Note : See individual project tables to determine if data listed here is adjusted for evaporation

FIGURE 7 -- ANNUAL RECHARGE ALONG THE SOUTH PLATTE RIVER



2.2.13. Analysis and Accounting

The Northern Colorado Water Conservancy District in Loveland, Colorado (Northern District), through its Augmentation/Recharge Accounting (ARA) program, provides the accounting and groundwater modeling that is required by Water Court decreed augmentation plans. The ARA program assembles the data, performs the accounting/modeling, and files the monthly reports with the Division Engineer of the Colorado State Engineer's Office. In addition, the ARA program helps manage the timing and location for recharge so that maximum groundwater return flows or accretions to the river are obtained. The Northern District is well suited to provide this program to its constituents throughout the lower South Platte River Basin because of its existing computer resources and regional weather station network.

An increasing role of the Northern District through its ARA program is educating entities that artificial recharge of the ground water aquifer is essential for the long term maintenance of adequate and reliable groundwater supplies. Managing recharge not only produces desired river returns but also maintains and enhances aquifer water levels and supplies. The ground water aquifer or reservoir will be the major water supply for future years of severe drought.

The Northern District has provided this accounting service to decreed augmentation plans within the Northern District boundaries since 1985. Currently the accounting is done for a total of 15 plans including major augmentation/recharge plans in the South Platte River Basin below Denver. Seven of these plans are associated with seven different irrigation companies while the other eight plans are for individual farmers. The two largest recharge projects were developed by the Fort Morgan Reservoir and Irrigation Company and the Bijou Irrigation Company. These irrigation companies developed their recharge programs to replace the depletions caused by their shareholders' irrigation wells. The Fort Morgan Reservoir and Irrigation Company's plan has 92 wells and the Bijou Irrigation Company's plan has 212 wells that are protected by their respective augmentation decrees. The Fort Morgan Plan is discussed in detail in Appendix B. Since irrigation companies have river diversion headgates and canal delivery systems in existence, it is very practical and economical for such companies to also divert water to recharge sites.

2.2.13.1 Accounting Procedure

Once each month, the Northern District's ARA program assembles and processes data collected by the augmentation plan operators and the Water Commissioners of the State Engineer's Office. Diversion flows to recharge sites are compiled by the Water Commissioners from recording measurement flumes and are reported as an average flowrate per day. Recharge sites are all surface basins or depressions such as canals, ponds, creeks, and/or draws. Seepage from irrigation canals can only be claimed as recharge when there are no deliveries being made for irrigation. The diversions for recharge from the South Platte River have junior priorities (i.e., 1970 or later) and are in priority mainly during spring runoff when there is plenty of water or during winter months when there is no irrigation demand.

The net monthly recharge is the diversion to a recharge site minus evaporation and changes in storage in the recharge basin. Evaporation is computed from the water surface area of the site, days of inflow or evaporation during the month, and a monthly reference pan evaporation. Pan evaporation is computed from weather data derived from a network of 10 weather stations maintained by the Northern District.

The net groundwater extraction by the wells is assumed by the decrees to be that part of the crop consumptive water use (ET) supplied by the wells. It is computed as the total crop water use minus the portion supplied by surface water deliveries from a canal company. Total crop water use is computed from data obtained from the weather station network. Crop acreage, crop type, irrigation method (sprinkler or flood), and monthly surface water deliveries are reported to the ARA program and the accounting is done for each individual well. To obtain the portion of crop water use supplied by the surface water deliveries, surface deliveries to the farm are multiplied by an assumed application efficiency which is specified in the decree. As an alternative approach, some augmentation plan decrees allow the use of well flowmeters to get monthly volume pumped which is multiplied by the assumed application efficiency to get net groundwater extraction.

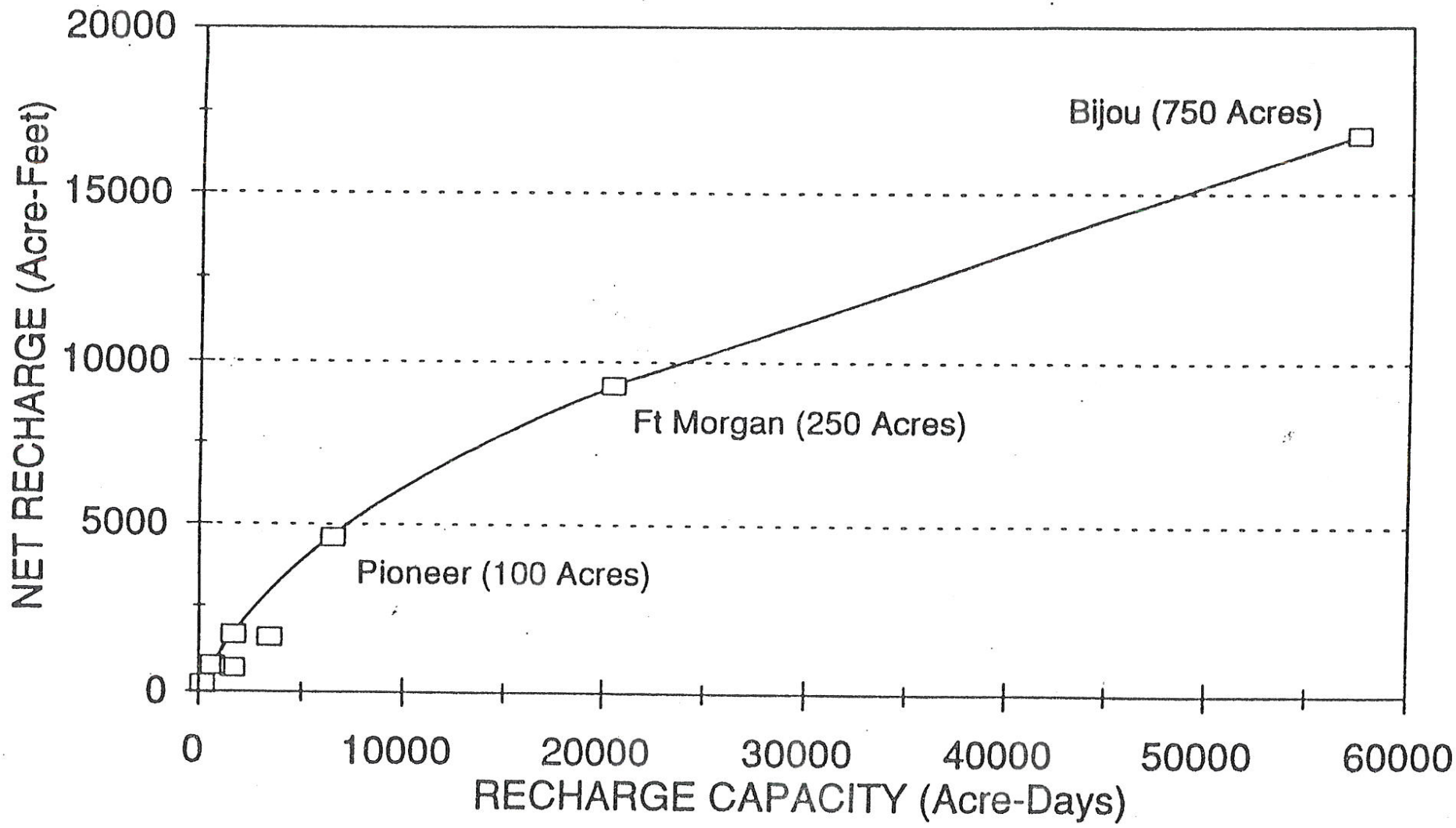
The computed net recharge and net groundwater extraction in ac-ft are used in groundwater flow models to determine the accretion or depletion effect at the river. The goal of augmentation plans is for the net effect at the river to be positive meaning there are more accretions than depletions. The ground water model specified by most decrees is the Stream Depletion Factor (SDF) method (see Section 2.3). Each well and recharge site is assigned an SDF value which characterizes the time lag between recharge or pumping and the respective resulting accretion or depletion effect at the river. The SDF value in days is computed from the perpendicular distance to the river from the well or recharge site and from the aquifer properties of specific yield and transmissivity. From the mathematical formulation, the SDF value is defined as the time when the volume of stream depletion or accretion is equal to 28 percent of the volume pumped or recharged. The SDF value for a recharge site or well can be obtained directly from contour maps of SDF values for the South Platte River basin (Figure 12) developed and calibrated by the U. S. Geological Survey (9). Recharge sites or wells that are one mile from the South Platte River typically have SDF values of around 100 days or less compared to recharge sites or wells on the fringe of the alluvial aquifer 6 miles from the river which have SDF values of around 5000 days.

Figure 8 illustrates the average annual net recharge from the period of 1985 to 1992 for different recharge projects in the lower South Platte River Basin as a function of the project's recharge capacity expressed as total average annual acre-days. Acre-days of a recharge site is the maximum surface area in acres multiplied by the days of inflow to the site. Total acre-days is the sum of acre-days for all recharge sites of a given project.

2.2.13.2 Recharge Management

An important recharge management decision is the timing of deliveries to the various recharge sites. The April through October diversion period for senior surface water rights is when well depletions to the surface stream must be replaced. The ARA program utilizes groundwater models to develop operational strategies for recharging that maximize the river

FIGURE 8
NET RECHARGE vs. RECHARGE CAPACITY
1985-1992 Average Annual Values for South Platte Recharge Projects



[Recharge Project Name and Acres of Recharge Sites]

accretions during this critical period.

These operational strategies consider the recharge sites' SDF factors and what range or combination of values is available. Recharge at sites with low SDF values (100 to 300 days) results in most of the return flows at the river occurring mainly in the 2 to 3 months following the diversion to the recharge site. Recharge sites with large SDF values provide small but constant return flow rates or accretions to the river--diversions to these sites are developing a "long term bank account" that will provide return flows many years into the future.

If there is a limited water supply for diversion to recharge sites during the spring runoff months of April, May, and June, then it is best to put the supply in recharge sites close to the river with low SDF values so that river accretions are available in that same year. Diversions for recharge from a plentiful spring runoff or winter time river flows should be spread among sites with medium to large SDF values. By such "groundwater reservoir banking," wells can continue pumping in future years of drought even though the surface water supplies of those drought years will limit the amount of recharging that can be accomplished in those years.

By increased operations and improved management, the larger recharge projects have become so extensive that there are now considerable excess return flows or accretion credits at the river for others to purchase. The Ground Water Appropriators of the South Platte (GASP) and the Central Colorado Water Conservancy District are two water user organizations that purchase these excess accretion credits as one of their sources of water to augment the stream for mitigation of the depletions of their members' wells.

2.3 Methods for Calculation of Return Flows

Return flow calculations estimate the amount of water from an 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 describing stream depletion due to a nearby pumping well (10), and the Stream Depletion Factor method (11). 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 (10) as:

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

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

$$\mathrm{erf}(z) = \frac{2}{\sqrt{\Pi}} \int_0^z e^{-z^2} dz \qquad (2)$$

The error function is very common in groundwater hydrology and extensive tables can be easily found (12).

Equation (1) is commonly written as

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

where

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

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 (i.e. a well).

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

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

where

V_S = volume of water depleted from the stream since pumping was started.

$Q * t$ = Volume of pumping and $z = \frac{a}{\sqrt{4tT/S}}$

This is equivalent to Hantush (13)

$$\frac{V_s}{Q \cdot t} = 4i^2\text{erfc}(z) \qquad (7)$$

where

$i^2\text{erfc}(z)$ = 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 (see reference (11)):

$$\frac{V_s}{Q \cdot t} = (2z^2 + 1) \cdot \text{erfc}(z) - z\frac{2}{\sqrt{\pi}} e^{-z^2} \qquad (8)$$

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, Glover's 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 course 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 has used the Glover's solution in the calculation of return flow to the river.

The following example is presented to illustrate the 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 from t = 10 days will be shown.

$$z = \frac{a}{\sqrt{4tT/S}} = \frac{2000}{\sqrt{(4)(10)(30000)/0.20}} = 0.82$$

From Table 7.1 in Abramowitz and Stegun (12) then erf (0.82) = 0.754.

Substitution into equation (1) yields

$Q_S = Q(1\text{-erf}(z)) = 5(1 - .754)$

$Qs = 1.23$ 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 9.

The volume of water returned to the river at any specified time is the area under the curve in Figure 9, 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 ten days will be shown. From before t = 10 days, then z = 0.82. Substitution into Equation (8) yields

$$\frac{V_s}{Q \cdot t} = \{(2)(0.82)^2 + 1\}\{1 - \text{erf}(0.82)\} - 0.82\frac{2}{\sqrt{\pi}}e^{-(0.82)^2}$$

From before erf (0.82) = 0.754 and

$$\frac{V_s}{Q \cdot t} = 0.57 - 0.472 = 0.105$$

or

$$V_S = \frac{(0.105)(5)(86400)(10)}{43{,}560} = 10.4 \text{ ac-ft.}$$

The ratio of volume of return flow to the river to the volume recharged at other times are shown on Figure 10.

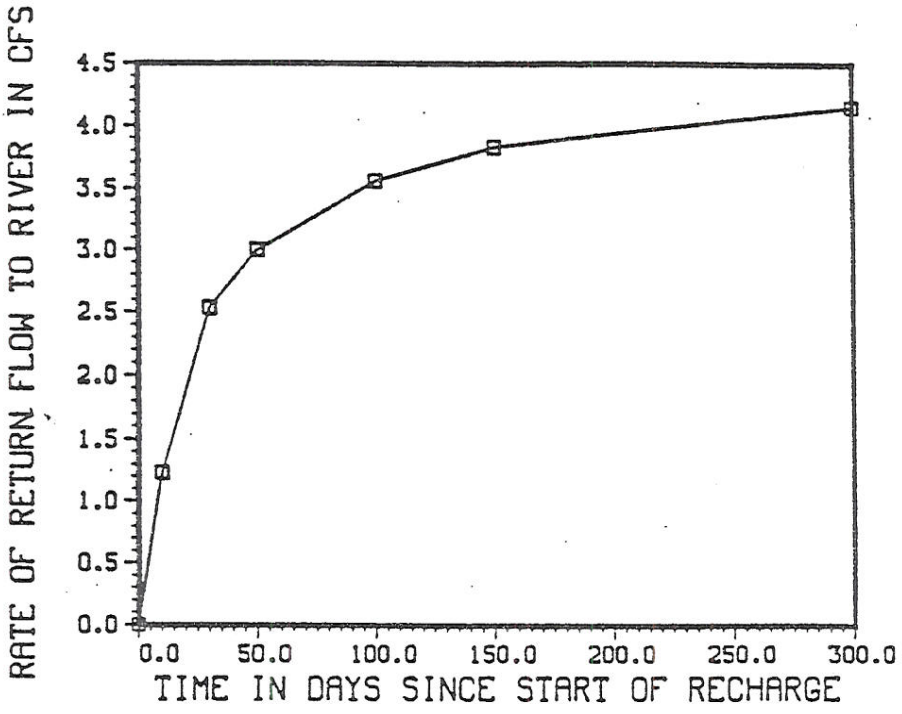


Figure 9 — Plot of Return Flow to River versus Time for Glover's Solution Example Problem

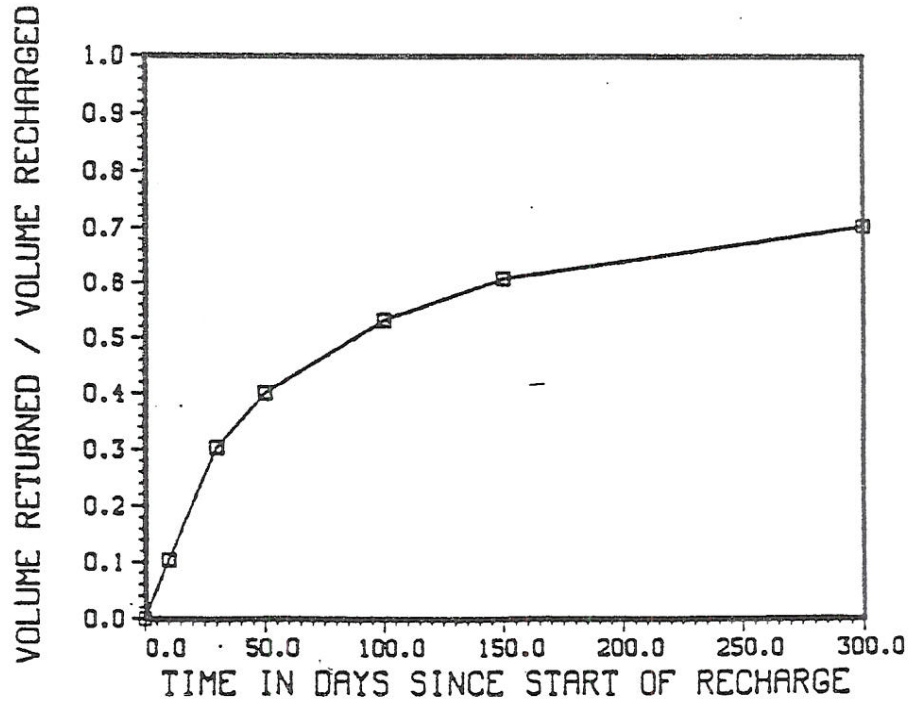


Figure 10 — Plot of Cumulative Volume of Return Flow to River versus time for Glover's Solution Example Problem

2.3.2 Stream Depletion Factor Method

The Stream Depletion Factor (SDF) method is the predominant method used to co[illegible]ate effects on river return flows due to well pumping and recharge. The 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 (11) developed the SDF method in which a numerical model is used to simulate the irregular boundary conditions and heterogeneous 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

$$z = \frac{a}{\sqrt{4tT/s}} = 0.5 \qquad (9)$$

or when

$$\frac{a^2 S}{Tt} = 1.0 \qquad (10)$$

Jenkins defined the SDF as

$$SDF = \frac{a^2 S}{T} \qquad (11)$$

The relationship between z and the SDF is

$$SDF = 4tz^2 \qquad (12)$$

From equations (8) and (12) when z = 0.5 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 11). Curve A is a plot of Q_s/Q_w versus t/SDF. This curve is obtained from the solution of Equation (1). Curve B is a plot of V_s/Q^*t 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)

$$SDF = \frac{a^2 S}{T} = \frac{(2000)^2 (0.2)}{30,000} = 26.67 \text{ days}$$

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

$$Q_s/Q_w = 2/5 = 0.4$$

From Figure 11, curve A, when $Q_s/Q_w = .4$ then t/SDF = 0.7, thus

$$t = (0.7)\ (26.67) = 18.7 \text{ days.}$$

which is the time when the return flow to the river is 2 cfs. For $V_s/Q^*t = 0.5$ from Figure 11, curve B, then t/SDF = 3.2. Thus

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

which is the time when the volume of return flow is 50 percent of volume recharged. The use of Figure 11 simplifies the calculations in that it is not necessary to go to tables for the error function or interpolate between tabular 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 is 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 $V_s/Q^*t = 0.28$ and t/SDF = 1. The time in the model at which 28 percent of

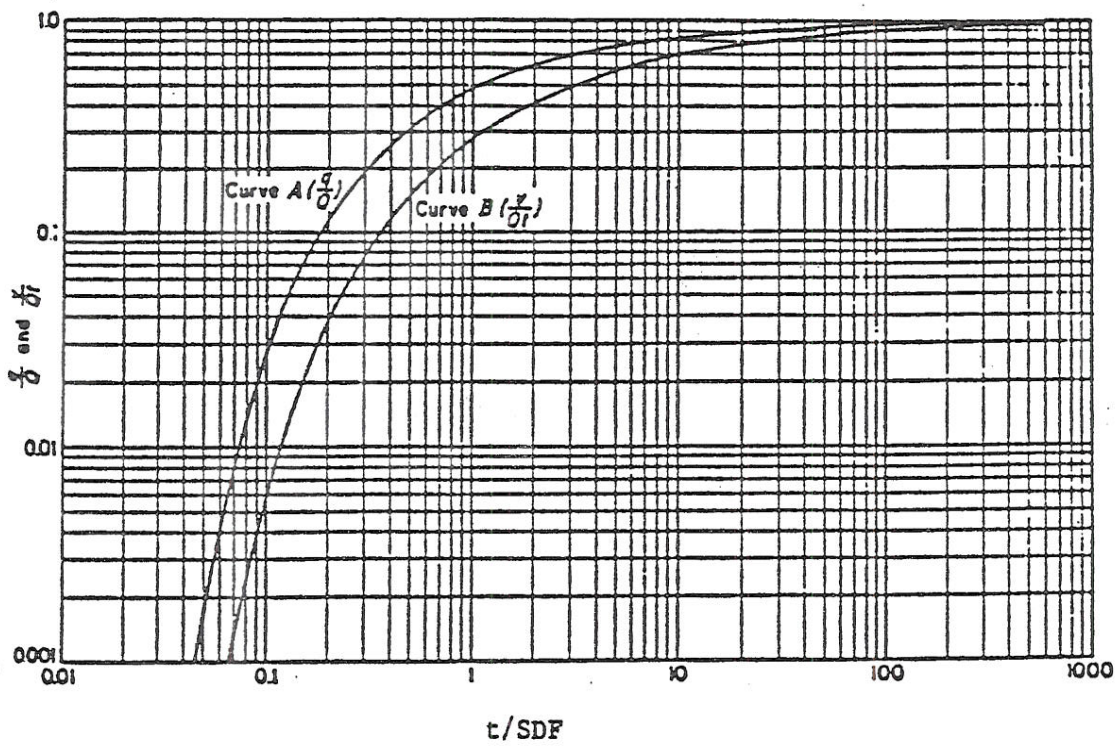


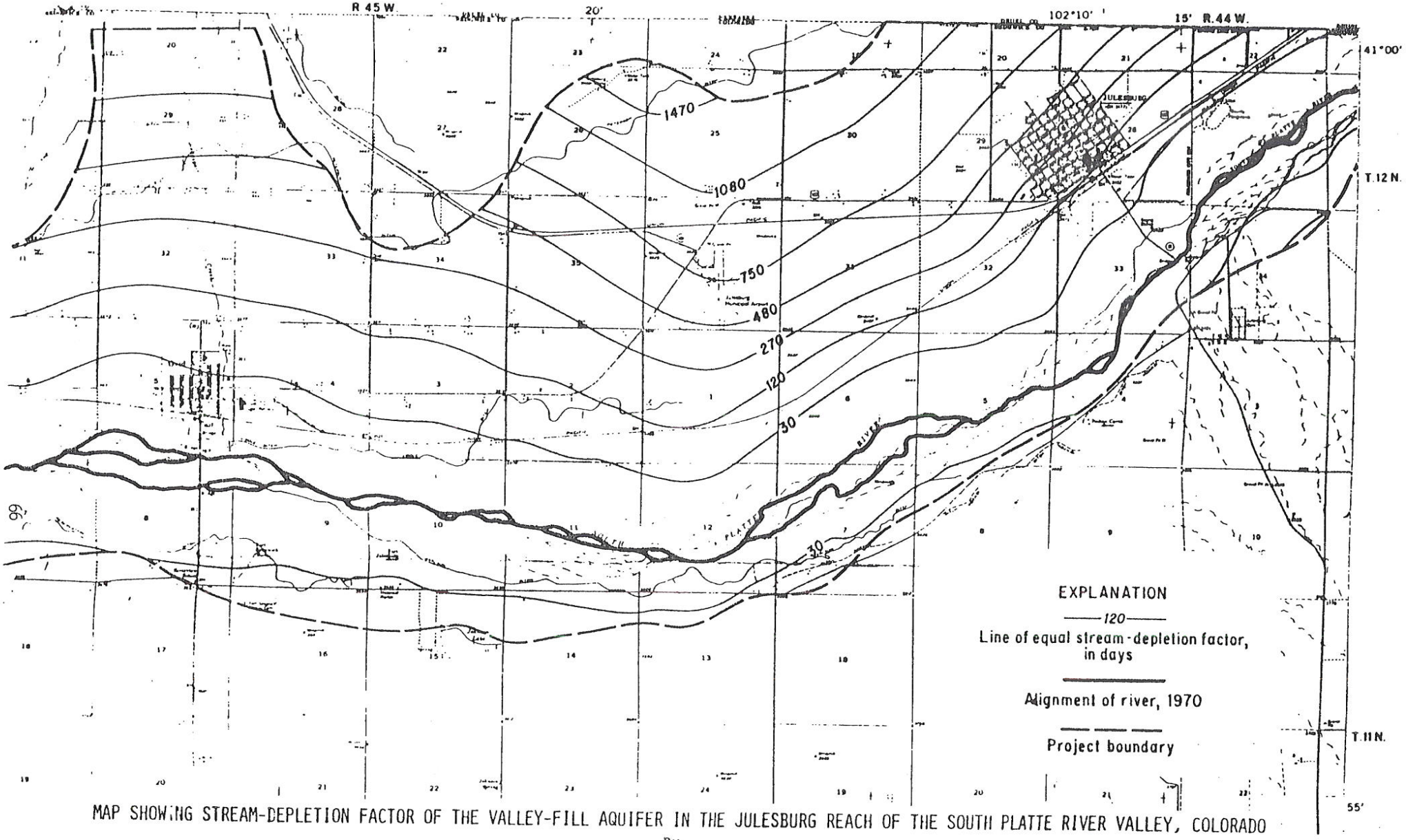
Figure II — Graphical Plot of Glover's Solution Used in Stream Depletion Factor Method

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 11) 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 (9) and widely used. Figure 12 is a reproduction of one of the USGS SDF maps for the South Platte River. 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).

Figure 13 graphically represents the effect to the river of different values for the SDF with a recharge of 100 ac-ft. For an SDF of 30 days, the water returns to the river very quickly, while for an SDF of 1000 days a much longer time is required for the recharged water to return to the river.

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 (i.e. a 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 analysis could result in either over estimations or underestimation of return flow to the river. Colorado State University research is investigating these questions.



MAP SHOWING STREAM-DEPLETION FACTOR OF THE VALLEY-FILL AQUIFER IN THE JULESBURG REACH OF THE SOUTH PLATTE RIVER VALLEY, COLORADO

By

Donald R. Albin and R. Theodore Hurr

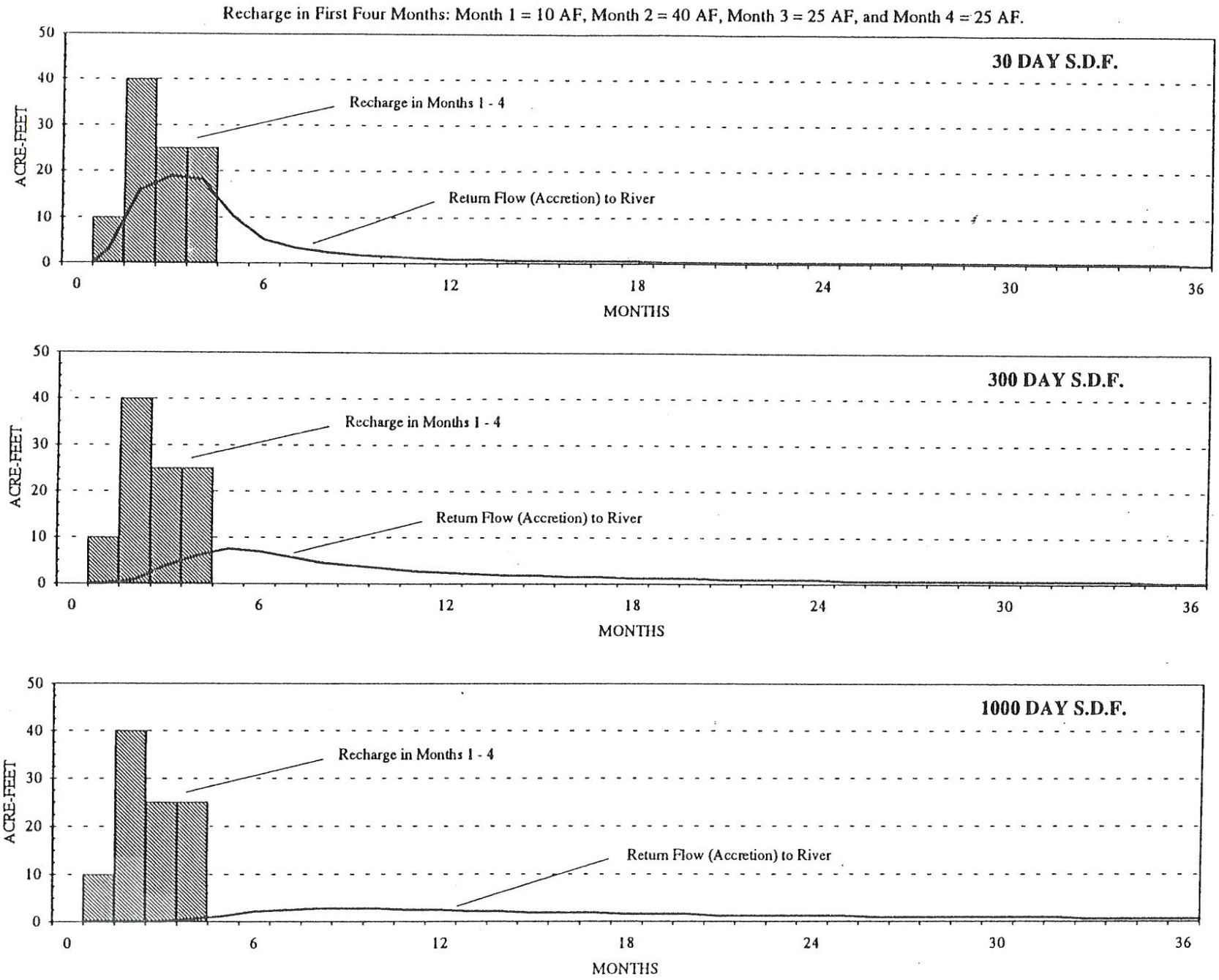
1972

0 1 2 3 MILES

0 1 2 3 KILOMETERS

FIGURE 12. Example USGS Stream Depletion Factor Map

FIGURE 13: Return Flow to River From 100 AF of Recharge for Various S.D.F. Values



III. CONCLUSION

This report represents an up-to-date comprehensive documentation of the augmentation/recharge projects in the South Platte River Basin. These augmentation/recharge projects are continuing to develop as an essential part of the water management practices of the South Platte River Basin. The purpose of nearly 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.

This study has compiled data on the number, location and total annual recharge for these projects. In the South Platte River Basin there are about 60 recharge/augmentation projects. This represents about three-fourths of all the recharge projects in the State of Colorado. Total annual recharge in the South Platte River Basin has increased from about 20,000 ac-ft in the early 1980's to about 67,000 ac-ft in 1992. Most of the current recharge operations are being conducted by irrigation companies. 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. Local 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 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. The SDF method is the predominantly used method. 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 by comparison to numerical groundwater models.

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. They view these recharge projects as an essential element of the overall water management effort in the South Platte River Basin to develop an adequate and reliable water supply.

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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 senior 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 withdrawal 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 substantiated 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.

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 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

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

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

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Forrest Leaf, Water Resources Engineer

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