R. Longenbaugh

PROGRESS REPORT
ON
SENATE BILL NO. 407 STUDY

January 1, 1968

Morton W. Bittinger & Associates
Water Resources Engineers
P. O. Box 1592
Fort Collins, Colorado
Report No. 1-115-68

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INTRODUCTION

This report describes the area of study, basic premises, plan of work, status of work and results to date under a contract entered into with the Colorado Water Conservation Board, August 1, 1967. Said contract is pursuant to terms of Senate Bill 407, enacted by the 46th General Assembly of the State of Colorado, in which the Coordinator of Natural Resources was directed "to investigate relationships in the areas where intermingled surface and groundwater are commonly used in conjunction with each other on the same lands, or lands immediately adjoining, for the same purpose of irrigation; to determine the need for and content of legislation that would provide for integrated administration of all diversions and uses of water within the State, protect all vested water rights, conserve water resources for maximum beneficial use, and permit full utilization of all waters in the State; ..."

Area of Study

In preliminary meetings with the Director of the Colorado Water Conservation Board and the Coordinator of Natural Resources, it was suggested that this firm study the operations of particular ditch and reservoir systems in the Fort Morgan area of the South Platte River. Based upon this charge, two systems were chosen; (1) The Riverside Irrigation System, and (2) The Lower Platte and Beaver Irrigation System. As the study progressed it became apparent that, because of the interdependency of ditches and exchanges of water, information should be collected and analyzed for a larger area, such as the major ditch systems in Water District 1. Thus, the study was expanded to include ten ditch systems having points of diversion in Water District 1. Nine of these serve land in Water District 1, whereas the service area for the tenth is in Water District 64.

Additional suggestions by State Agency Personnel were (1) to utilize presently available data as fully as possible, spending a minimum of time and effort on field collection of data, (2) to consider a "water bank" or "basin account" approach, and (3) to make the study with the present situation, i.e., without the influence of the proposed Narrows Dam or other structures which may be constructed in the future.

Basic Premises

The problem at hand is complex and controversial from many standpoints--physical (hydraulic interrelationships), legal (protection of vested rights), customs (water-use practices), organizations and individuals (overlapping and competing), administration (multitude of points of diversion), etc. We believe, therefore, that we should make the starting point of this study clear to all by stating a few basic premises on which it is founded. These are:

1. That it is in the best interest of the State of Colorado and its water users to develop legislation which (a) will promote and allow an increasingly greater beneficial use of the total water supply, (b) will increase the dependability of supplies available to water users, and (c) will alleviate conflicts between water users.

2. That shutting off wells to satisfy senior surface rights is a negative approach which does not allow utilization of a reserve of stored water when it is most needed. Thus, if senior rights can be served by other means, strict adherence to the Prior Appropriation Doctrine in areas such as that under study is not in the best interest of the State of Colorado and its water users.

3. That (a) greater beneficial use, (b) better dependability of supply, and (c) an alleviation of conflicts between water users can be attained through planned integrated management and use of surface water and groundwater in the area of study. Such integrated management not only includes the planned utilization of groundwater, but also the planned manipulation of groundwater storage in conjunction with surface water storage and conveyance facilities.

4. That the science of groundwater hydraulics and hydrology is sufficiently advanced--and information on the alluvial aquifer is adequate--to develop sound and equitable groundwater management plans. This is not to say there is no need for continuing to gather and improve the available information, only that we have sufficient information to improve management over that now being accomplished.

5. That irrigation and plant sciences are sufficiently advanced to allow the determination of optimum irrigation requirements for the various combinations of crops, soils, topography, and climatic conditions encountered in the study area.

6. That each water user is (or should be) primarily concerned with having a dependable and reasonably priced water supply which provides him with:

   a. an adequate quantity,
   b. an adequate quality,
   c. at the proper times, and
   c. at his point of use

   regardless of whether it is furnished to him directly by closing down a junior right-holder or by compensation from an alternate source, such as groundwater.

7. That if it can be shown from a physical standpoint that a greater beneficial use, a better dependability of supply and an alleviation of conflicts between water users can be accomplished through planned interated management without infringing upon vested rights, the legal problems of implementing and operating such a program can be surmounted.

Plan of Work

From an engineering standpoint this study is one of "systems analysis" or "systems engineering." As in any system, whether it be mechanical, electrical or hydrogeological, we can consider it in three parts: (1) inputs and/or withdrawals of energy, matter, etc.; affecting (2) a system of interrelated and interacting elements to (3) produce responses which are of interest. In our hydrogeological system we have inputs and withdrawals of water which vary both in time and location, and are the results of both natural and man-made conditions. The predictability of the inputs and withdrawals is dependent upon many factors and must be considered in terms of a probability based upon historical experience rather than a set figure.

The pertinent elements of the system include hydraulic and geometric characteristics of the groundwater-surface water system which affect the location and movement of water in the system. Responses of the system which are of interest include changes in groundwater levels and interchange of water between the aquifer and the stream.

Although little more will be said in this report about the "systems" approach, the reader should realize that a wealth of experience and technology is available for the analysis and simulation of complex systems, and the optimization of such systems utilizing the techniques of "Operations Research." The groundwater-surface water system under consideration herein is admittedly complex, and has many interactions which cannot be fully quantitatively described at this time, but other accomplishments in the systems analysis and operations research fields give encouragement to what can be accomplished here.

The general plan of work for this study is outlined below:

1. Study and understand the organizational structure, priority situation and exchange and other features of current operations of the major ditch and reservoir systems in Water District 1.
2. Assemble and analyze hydrologic, geologic and other pertinent data available for the area in order to quantitatively evaluate such items as:
    a. the capabilities of the existing physical facilities (canals, surface water reservoirs, wells and groundwater reservoirs),

b. the historical inflows and outflows to and from the study area, and the historical supplies and beneficial use thereof within the area;

c. the irrigation requirements of the study area in relation to probability of supply under current methods of operation and administration;

d. the interrelationships of groundwater and surface water in the study area.

3. Develop an adequate model of the groundwater-surface water system and make preliminary operational studies of the integrated or coordinated use of the two sources of supply to meet irrigation requirements.

4. Develop general operational plans for the integrated management of groundwater and surface water with full consideration of existing vested rights.

5. Determine practical methods of administering and allocating costs of implementing and operating integrated management programs.

6. In conjunction with attorneys, prepare proposed legislation suitable for the implementation and operation of integrated management program as developed in items 4 and 5.

Sources of Data

The writers have utilized information and data from many sources, much of which is not published. U.S. Geological Survey Water Supply Papers have been utilized for groundwater and surface flow information and records, with some additional information from current U.S.G.S. studies. The U.S. Bureau of Reclamation, through the Colorado Water Conservation Board, has provided valuable information resulting from studies made in connection with the Narrows Dam Project. Other suppliers of published and unpublished data include Colorado State University, Office of the State Engineer, The Northern Colorado Water Conservancy District, many ditch and reservoir companies, and other consultants who have made previous studies in the area of study. The writers gratefully acknowledge these sources and the full cooperation which has been provided by all.

STATUS OF WORK AND RESULTS TO DATE

At the time of this writing (Dec., 1967) the most attention has been given to items 1 and 2 listed above under Plan of Work. Therefore, rather detailed results and findings are included in the following pages and the Appendix for these items.

A lesser amount of time and effort has gone into the remaining items under Plan of Work. Therefore, discussion of these items at this time must be limited to examples, alternative possibilities and tentative conclusions; with final conclusions and recommendations awaiting the outcome of further study.

Organization, Ownership and Priorities of Ditch and Reservoir Systems, Water District 1

Study and understanding of the organizational structure and the distribution of ownership of the individual ditch and reservoir systems[1] provides a clue to both the complexity and the flexibility of operations within Water District 1. Rights[2] in reservoirs such as Riverside and Jackson Lake are owned by many organizations and individuals, who may in turn lease these rights to other organizations and individuals

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[1]The ditch and reservoir systems within our larger study-area system should technically be referred to as subsystems (in fact our study area is just a subsystem of the entire South Platte Basin--which is a subsystem of ... etc.). However, the familiar terminology is "systems" and will be used herein rather than "subsystem."

[2]"Rights" as used here refers to the right to a portion of water handled by a company or district as obtained through ownership of shares in the company or tax-paying acres in the district. It is important to distinguish these "rights" from those rights held by a company or district for diversion from the river according to a priority date and obtained through administrative and ajudication procedures set forth in Colorado Statutes.

during certain years. The following sections and accompanying charts are an attempt to show the organizational structure, distribution of ownership, and exchange possibilities for several of the major systems.

The Riverside System

The Riverside System consists of two organizations (1) The Riverside Reservoir and Land Company and (2) The Riverside Irrigation District. Pertinent information on these organizations is listed below and is also presented schematically in Figure 1.

The Riverside Reservoir and Land Co. The Company is a mutual nonprofit organization which owns and controls:

1. The inlet canal
2. The Riverside reservoir
3. Four wells located immediately below the reservoir used to pump groundwater into the delivery canal.
4. Four storage decrees for the reservoir:
    a. A 1902 "measured in" decree for 16,070 acre-feet.
    b. A 1907 "measured in" decree for 41,437 acre-feet.
    c. A 1910 "rod" decree for storage to the 32.5 foot level on the reservoir staff gauge.
    d. A "refill" decree for about 57,000 acre-feet, with a 1929 priority date in common with many other reservoirs on the South Platte.

The Company has 2,505 outstanding shares or rights. Each right represents 1/2,505 part of the available water stored in the reservoir, or approximately 23 acre-feet for a full reservoir with no losses. Normally a Company right has a value of 12 to 16 acre-feet measured at the reservoir outlet, but it was as low as 3 acre-feet during the 1954-56 drouth period. Of the 2,505 outstanding rights:

1. 1895 3/4 are owned by the Riverside Irrigation District.

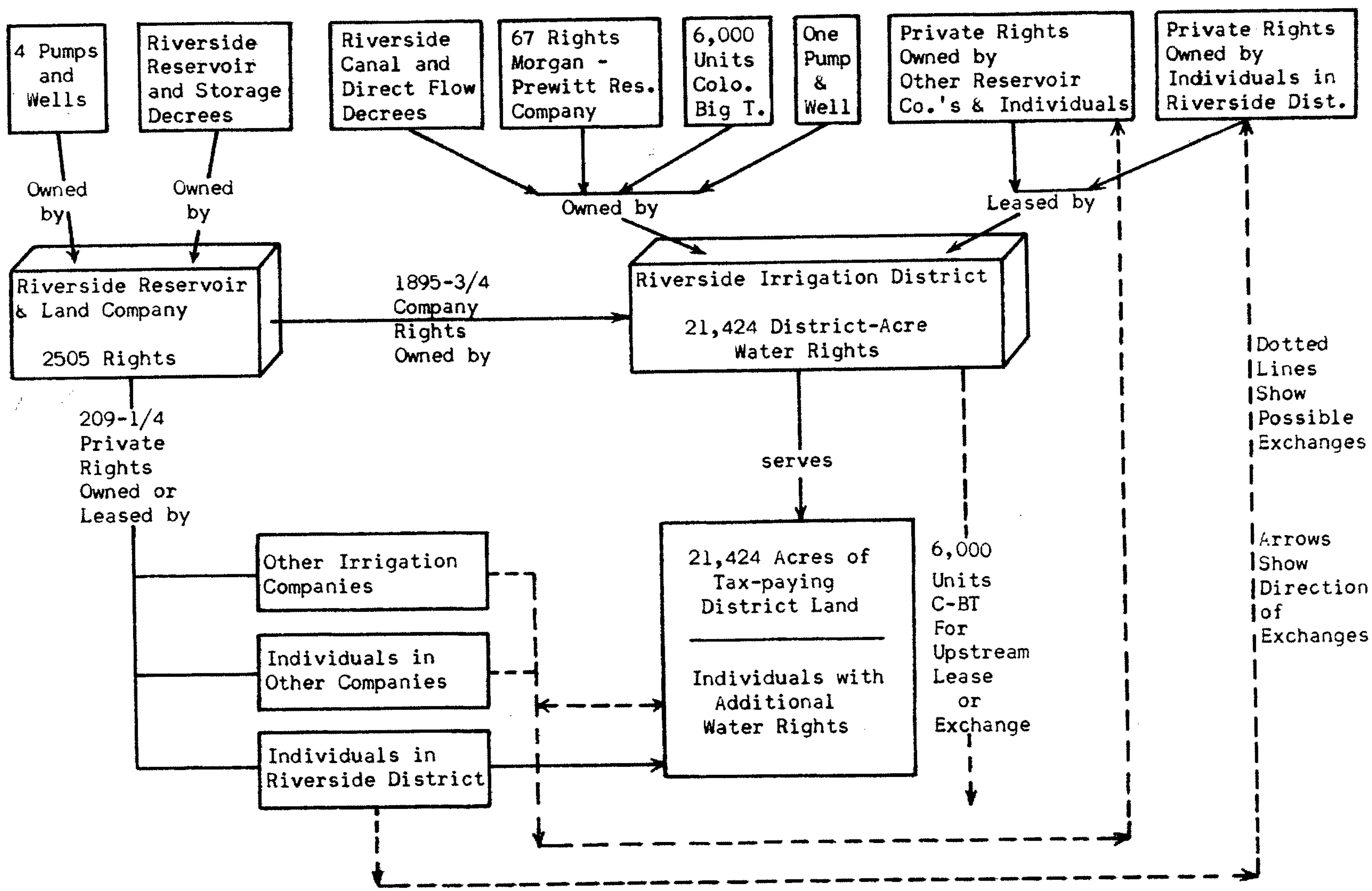

Figure 1. Diagram of Riverside System organization and ownership.

2. 609¼ are called "Private Rights" and are owned by other irrigation companies and by individuals who are located both within and outside of the Riverside System service area. These Private Rights are often leased on a seasonal basis to the District, or to individuals.

Other features of the Company operation include:

1. Assessments for operation and maintenance, which have been $6.00 per right annually during recent years.
2. Farmers holding Private Rights in the Company or who lease or buy Private Rights from other reservoirs and who irrigate land under the Riverside system are charged with a conveyance loss of water from the reservoir to their farm headgates.
3. Farmers and ditch companies holding Private Rights in the Company reservoir and who irrigate from a canal other than the Riverside are supplied with water which is obtained by the Riverside Reservoir Company leasing private rights from other reservoirs, such as Prewitt or Jackson Lake. Thus, no Riverside Company reservoir water is released to the river for these so-called "Foreign Private Rights."
4. The Reservoir Company operates the inlet canal as a "carrier ditch" for the Illinois Ditch Company which has a decreed water right for 22 cfs. This water is delivered from the inlet canal upstream from the reservoir.
5. Water from the 4 wells is sold to individual farmers in the Riverside Irrigation District annually with a pump right being equal in value to a private water right in the Reservoir Company.

The Riverside Irrigation District. The District, a quasimunicipal entity formed under the 1905 Irrigation District Statute, owns, controls and operates:

1. The distribution canal for the irrigation of 21,424 acres on which District taxes are paid.
2. One well used to pump water into the distribution canal.
3. Direct river flow decrees for 16 cfs (11/29/86) and 417 cfs (5/31/07).
4. 6,000 units of Colo.-Big Thompson Project water. (This is usually leased by the District to upstream users or exchanged to other ditches for Riverside rights).

5. 1895-3/4 rights of the total outstanding 2505 rights in the Riverside Reservoir Company.
6. 67 rights in the Prewitt-Morgan Reservoir Company.
7. Riverside Reservoir Company Private Rights leased by the Company from individuals owning private rights.
8. Other water rights leased by the District from other reservoir companies or individuals owning private rights of other reservoir companies.

Other features of the District operation include:

1. At the beginning of each season the Superintendent makes an estimate of the total amount of water available to the District. A "District acre water right" amounts to 1/21,424 of this amount.
2. "District acre water rights" are leased on a seasonal basis only between farmers within the District.
3. The District purchases or leases additional Company Private Rights whenever possible. Recent prices have been in the neighborhood of $250 per right bought and $30 to $35 annually per leased right.

The Bijou System

The Bijou System also consists of two organizations. These are (1) The Bijou Irrigation Company and (2) The Bijou Irrigation District. These organizations are described below and are charted in Figure 2.

The Bijou Irrigation Company. The Company is a mutual nonprofit company which owns and controls:

1. Direct flow rights on the South Platte for
   a. 40 cfs - Priority date of October 1, 1871
   b. 16.32 cfs " " " April 20, 1873
   c. 10 cfs " " " April 1, 1880
   d. 30 cfs " " " April 26, 1882
   e. 450 cfs " " " October 1, 1888
   f. 50 cfs " " " April 1, 1900
2. The Bijou Canal.
3. The Bijou No. 2 Reservoir with storage right for 9,183 acre-feet, priority date January 15, 1909.
4. 1000 units of Colorado-Big Thompson Project Water. This water is usually leased by the Company to upstream users.

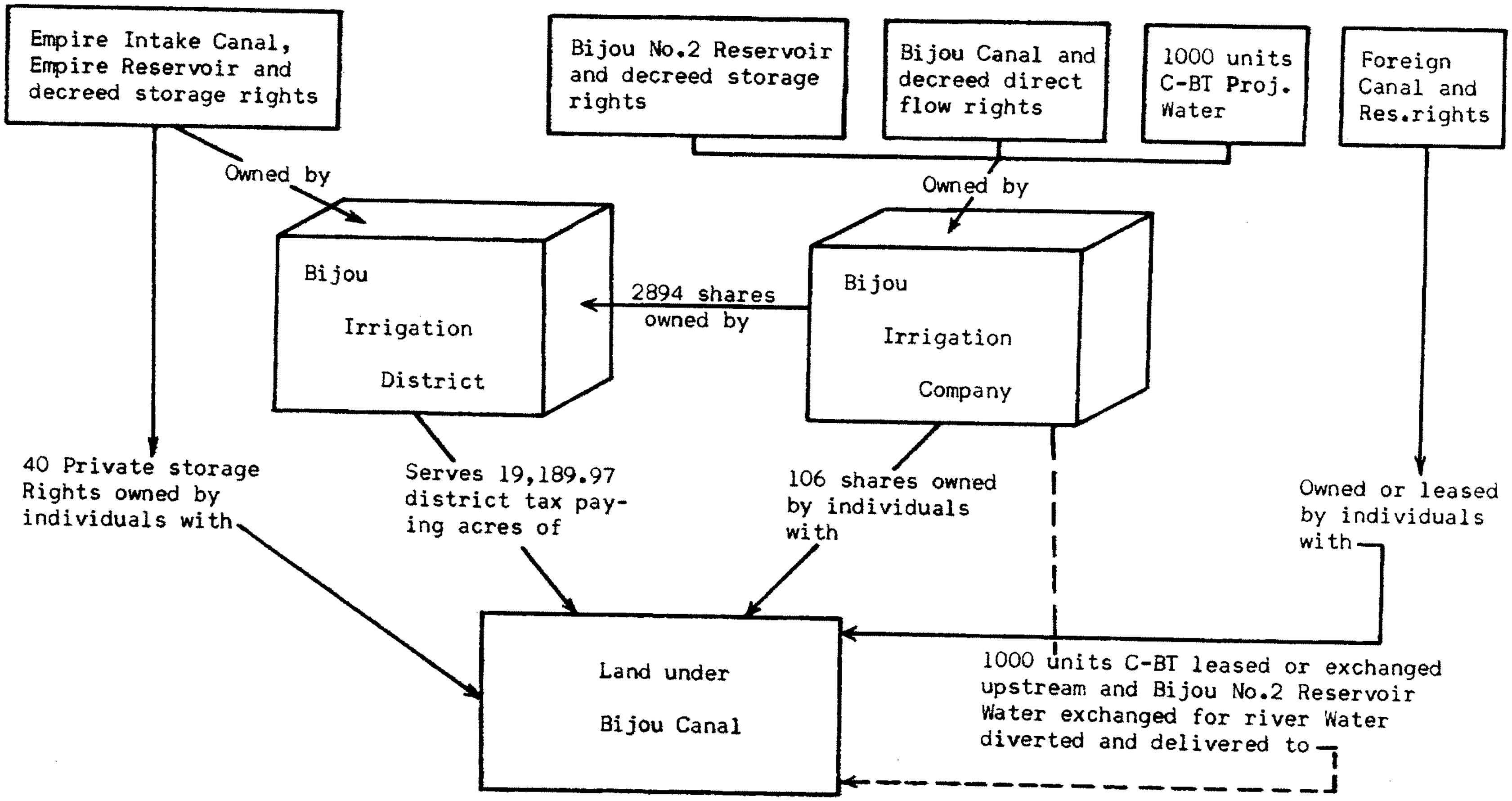

Figure 2. Diagram of Bijou System organization and ownership.

The Company has 4000 shares of outstanding stock of which 2894 are owned by the District. The remaining shares are owned by individuals under the Bijou Canal. Company stock may only be sold to the District or between individuals under the Bijou Canal. The Bijou Canal is used to convey not only water obtained from direct flow decrees, but also Bijou No. 2 Reservoir water obtained by exchange, District water stored in Empire Reservoir and water from other reservoirs for individuals who own or lease foreign private rights. Carrier charges are made for the latter two situations.

The Bijou Irrigation District. The District is a public irrigation district organized under the 1905 Statute and has 19,189.97 tax paying acres within its boundaries. The District owns and controls:

1. 2894 (72.35%) of the Company's 4000 shares of outstanding stock. Additional shares are purchased whenever possible.
2. The Empire Inlet Canal and Empire Reservoir.
3. Storage decree of 37,709 acre-feet with priority date of May 18, 1905.

The District stores its water in the Empire Reservoir and delivers via the Company's Bijou Canal. There are also 40 private reservoir rights in Empire Reservoir owned by individuals under the Bijou Canal. These rights have a maximum value of 10 acre-feet each when the reservoir is full.

The Fort Morgan Canal (and Jackson Lake Reservoir) System

Two organizations are involved in supplying water to land under the Fort Morgan Canal. These are the Fort Morgan Reservoir and Irrigation Company and the Jackson Lake and Reservoir Company.

The Fort Morgan Reservoir and Irrigation Company. The Fort Morgan Reservoir and Irrigation Company owns and controls:

1. The Fort Morgan Canal with a decree of 323 cfs of priority date October 18, 1882.
2. 1028 shares (66.6%) of the 1543 outstanding shares of the Jackson Lake and Reservoir Company.

The Fort Morgan Reservoir and Irrigation Company has 2840 outstanding shares. Sixteen shares are allotted to and supposedly supply each 80 acres with a flow of 1.5 cfs. Seasonal transfers of stock within the system are allowed but the Company does not permit seasonal transfers of foreign water into its system and it does not allow transfer of water out of its system. The Company does not allow its water users to individually lease or purchase water from the Jackson Lake Reservoir.

<u>The Jackson Lake Reservoir Company</u>. The Jackson Lake Reservoir Company is a mutual company which:

1. Owns and operates the Jackson Lake Reservoir and its inlet and outlet canals.
2. Holds a storage decree measured in terms of a rod or staff gauge reading of 30.0 feet having a priority date of May 18, 1901. Storage capacity is approximately 30,000 acre-feet.
3. Has 1,543 shares or rights, each of which represents 1/1543 of the water stored in the reservoir, or about 23 acre-feet at full stage and 100% efficiency. Ownership of shares or rights is currently as follows:
   a. 1028 (66.6%) by Fort Morgan Res. and Irr. Co.
   b. 194.5 (12.6%) by Hillrose Irrigation District.
   c. 29.5 (1.9%) by Lower Platte and Beaver Canal Co.
   d. 51.0 (3.3%) by individuals under the Lower Platte and Beaver Canal.
   e. 33.0 (2.1%) by Upper Platte and Beaver Canal Co.
   f. 165.5 (10.7%) by individuals under the Upper Platte and Beaver Canal.
   g. 15.0 (1.0%) by Deuel and Snyder Ditch and individuals under the ditch.
   h. 21.0 (1.4%) by Bijou Irrigation Co. and individuals under the Bijou Canal.
   i. 6.0 (0.4%) ownership unknown.

The 1028 Fort Morgan Reservoir and Irrigation Company rights are always used within that system, whereas the remaining 515 are subject to sale and lease to other companies or individuals.

The Lower Platte and Beaver System

Two organizations are principally concerned with the Lower Platte and Beaver System. These are The Lower Platte and Beaver Canal Company and The Hillrose Irrigation District, which are described below and presented schematically in Figure 3.

The Lower Platte and Beaver Canal Co. The Lower Platte and Beaver Canal Co. is a mutual irrigation company which:

1. Owns and operates the Lower Platte and Beaver Canal, serving approximately 15,000 acres.
2. Holds two direct river decrees: (a) 38 cfs, priority date September 4, 1882 and (b) 284 cfs, priority date April 15, 1888.
3. Owns 29 private rights in The Jackson Lake Reservoir Company and 124 private rights in The Riverside Reservoir and Land Company. These private rights are not leased outside of the area served by the Lower Platte and Beaver Canal.
4. Has individuals under the Canal who own private reservoir rights as follows:
    a. 51 private rights in Jackson Lake.
    b. 67 private rights in Riverside Reservoir.
    c. 45½ private rights in Prewitt Reservoir.

    These rights are frequently leased out to other parties because of the availability of groundwater to most water users under the Lower Platte and Beaver Canal.

The Hillrose Irrigation District. The Hillrose Irrigation District is a public district formed under the 1905 Statute which:

1. Has 11,400 acres of taxpaying land.
2. Owns no water diversion or storage facilities.
3. Was organized for the purpose of purchasing Jackson Lake Reservoir rights as a source of supplemental water land under the Lower Platte and Beaver Canal because of that canal's rather junior standing on the River.
4. Owns 194½ private rights in the Jackson Lake Reservoir Company.
5. Assesses district land owners to raise funds, most of which are used to pay the Lower Platte and Beaver carrier fees for conveyance of the Jackson Lake water.

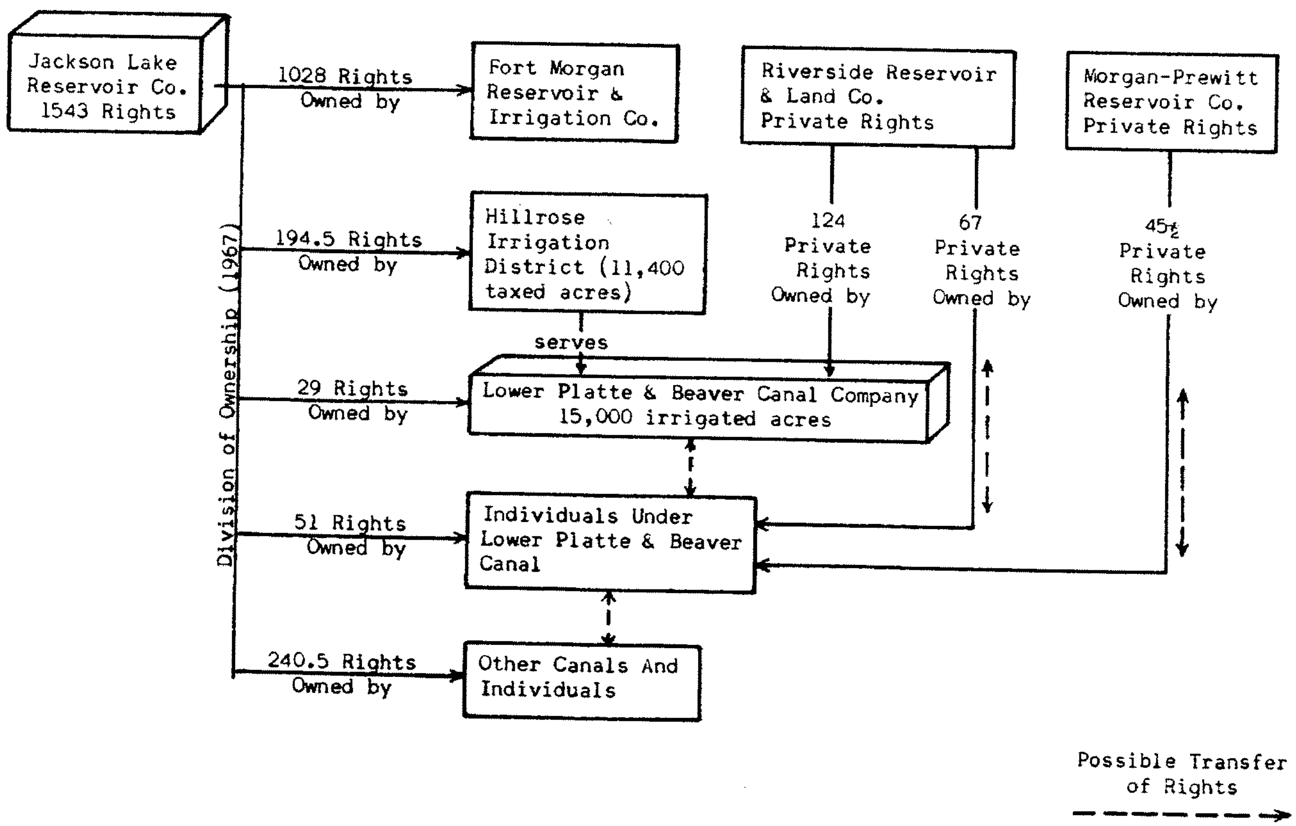

Figure 3. Diagram of Lower Platte and Beaver System (including Jackson Lake Reservoir Co.) organization and ownership.

Other Systems and Facilities

Other organizations in Water District 1 on which a lesser amount of information is available at this time include the Weldon Valley Ditch Company, The Deuel and Snyder Improvement Company and The Upper Platte and Beaver Canal Company. The first two serve about 9,000 acres of land on the north side of the South Platte River, all lying below the Riverside System. The Upper Platte and Beaver Canal serves about 15,000 acres south of the river, all lying below the Fort Morgan Canal. Each of these companies is a mutual nonprofit irrigation company. Each company holds direct flow rights in the South Platte, and also these companies, as well as individuals under their systems, own and lease foreign reservoir rights to supplement the direct water.

Another facility that should be mentioned is the Prewitt Reservoir located just below Water District 1 in Water District 64. This reservoir serves water users in both districts--those in Water District 1 by exchange. It currently plays an important role in river management, and most certainly would be of importance in any integrated management plan. The major difficulty lies in its rapid seepage rate, making its efficiency as a surface storage facility rather low.

Summary of Priorities

For reference purposes, tabulations of decreed rights for diversions from the South Platte River in Water District 1 are given below: Tables 1 and 2 show direct flow decrees listed in geographical and chronological order,respectively. Some interesting observations drawn from these tables include:

1. The more senior decrees, with two notable exceptions, are for flows of 50 cfs or less.
2. The two exceptions, Weldon Valley Ditch (165 cfs--1881) and Fort Morgan Canal (323 cfs--1882) represent the only direct flow decrees these two ditches hold.

Table 1. Direct flow decrees listed in geographical order, Water District 1[3].

River miles above Balzac	Ditch name	Date	Priority Amt. (cfs)	Accum. Amt.
73.7	Kersey gage	----	----	----
71.2	Hoover	2/21/84	23.00	
67.2	Riverside	1/1/76	22.00	45.00
		11/29/86	16.00	61.00
59.9	Bijou	10/1/71	40.00	101.00
		4/20/73	16.32	117.32
		4/1/80	10.00	127.32
		4/26/82	30.00	157.32
		10/1/88	450.00	608.32
40.8	Schultz[6]	4/1/88	21.00	628.32
47.4	Weldon Valley	10/26/81	165.00	793.32
37.3[4]	Ft. Morgan	10/18/82	323.00	1116.32
26.31	Deuel & Snyder	4/7/84	32.00	1148.32
		11/1/88	31.00	1179.32
25.2[4]	U.Platte & Beaver	4/20/68	15.00	1194.32
		5/15/69	5.17	1199.49
		6/20/82	50.00	1249.49
		4/15/88	164.00	1413.49
17.2[5]	L.Platte & Beaver	9/14/82	38.00	1451.49
		4/15/88	284.00	1735.49
13.2	Gill & Stevens[6]	9/3/89	23.00	1758.49
12.2[5]	Snyder	6/18/87	20.00	1778.49
2.2	Tetsel	11/15/74	17.00	1795.49
		7/1/82	20.00	1815.49
2.2	Johnson & Edwards	4/10/86	48.00	1863.49

[3]Decrees dated 1900 and later are omitted, as are several "Meadow Rights" totaling 187 cfs which are honored only between April 10th and July 10th.

[4]Since destruction of diversion works in the June 1965 flood, the Upper Platte & Beaver and the Deuel & Snyder Canals use the same diversion dam.

[5]Since the 1965 flood the Snyder Ditch diverts from same point as the Lower Platte & Beaver Canal.

[6]Diversions are reportedly no longer made by the Schultz and the Gill & Stevens Ditches.

3. The three large junior decrees are the 2nd, 4th and 5th decreed priorities of the Lower Platte and Beaver, Upper Platte and Beaver, and Bijou Canals, respectively. These three decrees amount to about one-half the pre-1900 direct flow decrees in the District.

Table 3 shows decreed rights for storage diversions out of the South Platte River in Water District 1. Two of the reservoirs (North Sterling and Prewitt) are located in Water District 64. All of the storage rights carry priority dates later than 1900.

Historic Surface Water Supplies

An evaluation of the water supplies which have been historically received and beneficially used in the study area is important in order to (1) establish bench marks under present administrative, management and exchange procedures, (2) determine where improvements are needed, and (3) evaluate the improvement that could be attained under new or different management techniques. Such an evaluation must go beyond that of determining simple average annual or seasonal supplies because of the variability inherent in stream flow and precipitation. Timing and dependability characteristics of the supply are often more important to a water user than the amount of supply.

Inflow-Outflow Characteristics

South Platte River gaging stations are located near Kersey (Station No. 6-7540) and Balzac (Station No. 6-7600) representing the surface inflow and outflow for Water District 1. Records on at least a monthly basis are available for Kersey since 1905 and for Balzac since 1916. A third gage, near Weldona (Station No. 6-7585) was established in 1952 in connection with the proposed Narrows Dam Project. The gages are maintained and rated by personnel of the Colorado State Engineer's Office and the records are published by the U.S. Geological Survey. Because of shifting control

Table 2. Direct flow decrees listed in order of priority date, Water District 1[7].

Ditch name	Date	Priority Amt. (cfs)	Accum. Amt.
U. Platte & Beaver	4/20/68	15.00	
U. Platte & Beaver	5/15/69	5.17	20.17
Bijou	10/1/71	40.00	60.17
Bijou	4/20/73	16.32	76.49
Tetsel	11/15/74	17.00	93.49
Riverside	1/1/76	22.00	115.49
Bijou	4/1/80	10.00	125.49
Weldon Valley	10/26/81	165.00	290.49
Bijou	4/26/82	30.00	320.49
U. Platte & Beaver	6/20/82	50.00	370.49
Tetsel	7/1/82	20.00	390.49
L. Platte & Beaver	9/14/82	38.00	428.49
Ft. Morgan	10/18/82	323.00	751.49
Hoover	2/21/84	23.00	774.49
Deuel & Snyder	4/7/84	32.00	806.49
Johnson & Edwards	4/10/86	48.00	854.49
Riverside	11/29/86	16.00	870.49
Snyder	6/18/87	20.00	890.49
Schultz	4/1/88	21.00	911.49
L. Platte & Beaver	4/15/88	284.00	1195.49
U. Platte & Beaver	4/15/88	164.00	1359.49
Bijou	10/1/88	450.00	1809.49
Deuel & Snyder	11/1/88	31.00	1840.49
Gill & Stevens	9/3/89	23.00	1863.49

[7] Decrees dated 1900 and later are omitted, as are several "Meadow Rights" totaling 187 cfs which are honored only between April 10th and July 10th.

Table 3. Summary of storage decrees for reservoirs obtaining supply from the South Platte River in Water District 1.[8]

Name of Reservoir	Priority Date	Priority Amount	Remarks
Empire	5/18/05	37,709 a.f.	Measured at lower end of inlet canal.
		G.H. of 30.0 ft.	"Rod" decree.
Riverside	4/1/02 8/1/07 10/25/10	16,070 a.f. 41,437 a.f. G.H. of 34.0 ft.	Measured at lower end of inlet canal. "Rod" decree.
Bijou No. 2	1/15/09	9,183 a.f.	
Jackson Lake	5/18/01	35,629 a.f.	
No. Sterling	6/15/08 8/1/15	69,446 a.f. Incr. to 81,400 a.f.	Source of supply also includes Springdale, Pawnee and Cedar Creeks.
Prewitt	5/25/10	32,300 a.f.	

[8]Not included is the Snyder Reservoir, a small reservoir under the Snyder Ditch which is no longer used.

the accuracy of records is sometimes poor, but they are generally classified as "good" by the U.S.G.S. (95% of records within 10% of true value). Also, as indicated by U.S.G.S.[9], the flow is heavily influenced by man's activities upstream:

For Kersey: "Natural flow of stream affected by transmountain and transbasin diversions, storage reservoirs, power developments, ground-water withdrawals and diversions for irrigation of about 888,000 acres, and return flow from irrigated acres."

For Balzac: "Natural flow of stream affected by transmountain diversions, storage reservoirs, power developments, ground-water withdrawals, diversions above station for irrigation of about 1,065,000 acres, and return flow from irrigated areas."

The average annual river flow at Kersey during the 50-year period 1917 through 1966 was about 516,700 acre-feet, with a range of 31% to 278% of the average for the extreme years. During the same period the average annual flow measured at Balzac was about 261,100 acre-feet, with a range of 23% to 394% of the average. The 255,600 acre-foot average difference represents an "apparent" average annual depletion or consumption of river water within the reach. To convert this to an "actual" average annual consumption of river water within the study area one must consider additional factors. These include:

1. Inflows

    a. Irrigation ditches from Water Districts 2 and 3 tailing water into the river within Water District 1.

    b. Surface runoff entering from tributaries such as Crow, Boxelder, Lost, Kiowa, Bijou, Badger, Beaver and Wildcat Creeks, in response to precipitation over their watersheds.

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[9] Water Resources Data for Colorado, 1966, Part 1. Surface Water Records. Published by the U.S. Geological Survey, Water Resources Division, in cooperation with the State of Colorado and with other agencies.

c. Direct runoff from land adjacent to the river, in response to locat precipitation.

2. Outflows

   a. Ditches diverting water in Water District 1 which is used in Water District 64. These are principally the North Sterling Inlet Canal and the Prewitt Inlet Canal.

3. Change in storage of water within the study area between the beginning and end of the 50-year period could also influence the determination of the actual consumption of water.

Most of these additional factors are unmeasured and must be estimated in order to obtain an "estimated actual" average annual river water consumption within the study area.

Tables 4 and 5 summarize the 50-year Kersey and Balzac data on a monthly basis. It can be seen from these tables that the variation of flows are much greater within months compared to years. For instance, the May discharge at Kersey varied from as low as 4% to as high as 700% of the 50-year average of 3180 acre-feet. The extremes at Balzac were noticeably larger in respect to the averages than those at Kersey, except for July, August and September.

Fifteen-Year Study Period

For water supply and other hydrologic studies it is normally desirable to analyze a long period of record. This is because we are usually interested in being able to predict the frequency with which particular extreme low or high values may occur in the future. This is difficult to do with a reasonable degree of accuracy from short-term records. The 50-year period for which Kersey and Balzac records are both available would serve our purposes here very well if (1) the other pertinent hydrologic factors were as well recorded, and (2) if the regimen of the river had remained nearly constant during the period. The latter cannot be assumed because of the well known increases in transmountain diversions, changes in character of use, increases in groundwater withdrawals and many other influences.

It is believed that a shorter period of record, using more recent and complete data, may be of greater value to this study. The U.S. Bureau of Reclamation chose a 15-year period, 1947 through 1961, for their study for the proposed Narrows Dam and Reservoir. This period as illustrated in Figure 1A, covers years of both extremely high and low flows at Kersey and Balzac. It is also a period during which major trans-mountain diversions (Colorado - Big Thompson and City of Denver) and major groundwater withdrawals took place. Comparisons made of this 15-year with two others and the full 50-year period are given in Table 6.

Table 6. Comparison of parameters of 50-year and 15-year periods of record for Kersey and Balzac.

	50-years 1917-1966	15 years 1917-1931	15 years 1932-1946	15 years 1947-1961
Average annual discharge at Kersey	516,700a.f.	611,100a.f.	414,300a.f.	537,200a.f.
Average annual dicharge at Balzac	261,100a.f.	325,700a.f.	208,100a.f.	250,000a.f.
Average annual difference, Kersey-Balzac	255,600a.f.	285,400a.f.	206,200a.f.	287,200a.f.
Average ratio Balzac/Kersey	0.51	0.53	0.50	0.46
Linear correlation coefficient[10]	0.93	0.94	0.89	0.94

[10] The linear correlation coefficient is a statistical index of how well the Kersey and Balzac annual discharge volumes are related to each other on a straight-line basis (0 = no relationship, 1 = perfect relationship). Statistical analyses of the 50-year period show that a good relationship between the two stations is given by the linear equation: Balzac ann. disch. = 0.7 (Kersey ann. disch.) - 100,000.

Table 4. Summary of monthly discharge volumes measured at Kersey, 1917 to 1966 inclusive.

Month	Average discharge (ac-ft)	Maximum discharge		Minimum discharge		Range (ac-ft)
		(ac-ft)	(% of av.)	(ac-ft)	(% of av.)	
Jan.	33,459	75,600	226	12,850	38	62,750
Feb.	31,611	82,370	261	10,120	32	72,250
Mar.	35,335	100,900	285	10,470	30	90,430
Apr.	42,689	302,900	709	4,880	11	298,020
May	78,997	553,100	700	3,180	4	549,920
Jun.	115,120	714,000	620	5,640	5	708,360
Jul.	28,556	140,900	493	5,180	18	135,720
Aug.	23,940	94,100	393	4,170	17	89,930
Sep.	21,505	164,800	766	4,580	21	160,220
Oct.	31,973	125,300	392	5,040	16	120,260
Nov.	36,614	136,000	371	5,180	14	130,820
Dec.	36,156	84,580	234	15,420	43	69,160

Table 5. Summary of monthly discharge volumes measured at Balzac, 1917 to 1966, inclusive.

Month	Average discharge (ac-ft)	Maximum discharge		Minimum discharge		Range (ac-ft)
		(ac-ft)	(% of av.)	(ac-ft)	(% of av.)	
Jan.	11,805	65,730	557	430	4	65,300
Feb.	14,221	68,560	482	450	3	68,110
Mar.	17,004	137,200	807	440	3	136,760
Apr.	20,742	199,700	963	860	4	198,840
May	42,288	460,500	1,089	2,670	6	457,830
Jun.	79,251	726,000	916	5,980	7	720,020
Jul.	17,392	78,670	452	6,310	36	72,360
Aug.	16,058	64,910	404	6,270	39	58,640
Sep.	15,313	89,410	584	4,920	32	84,490
Oct.	10,573	75,390	713	1,130	11	74,260
Nov.	7,979	120,000	1,504	520	6	119,480
Dec.	8,461	62,100	734	340	4	61,760

As can be seen from Table 6, the 1947-1961 period had Kersey and Balzac averages which fell between those of the other two 15-year periods and near the 50-year averages. Because of this, and for reasons given earlier, the 15-year period, 1947 through 1961, is utilized herein as a "study period."

Dependability of Surface Supply

Figure 2A in the Appendix is a frequency plot of the 15-year annual volumes of flow at Kersey and Balzac. Figure 3A is a similar plot for the 30-year period, 1937 through 1966. The frequency plot may be used to estimate the probability with which an annual discharge of less than (or more than) a given volume may be expected. For instance, assuming the 15-year data to be sound, the following probabilities can be determined from Figure 2A for Kersey:

1. 20% probability (3 years/15 years) of having an annual discharge of less than 190,000 acre-feet.
2. 20% probability of having an annual discharge exceeding 860,000 acre-feet.
3. 60% probability of having an annual discharge of between 190,000 and 860,000 acre-feet.

Other combinations of probabilities may be determined similarly. For example, the comparable 33-1/3% probabilities are about 260,000 and 770,000 acre-feet. Because of the short time period used discharge volumes for probabilities of less than 20% may be quite inaccurate.

The differences between annual discharge volumes at Kersey and Balzac are plotted in frequency form in Figure 4A. In order to obtain an approximate frequency of the annual volume of river flow consumed in Water District 1, diversions to North Sterling and Prewitt Reservoirs were subtracted from the upper curve of Figure 4A. This "net depletion" curve is not corrected for change in storage and other minor inflows and outflows. The net depletion or consumption of river flow within Water District 1 was between 60,000 and 200,000 acre-feet about 60% of the time. Variation in the net depletion from year to year is caused by variability of the supply, precipitation and other climatic factors and indirectly by unmeasured inflows from tributaries. The latter causes an error in the calculation of the depletion rather than a change in the actual consumption or depletion.

The four major surface reservoirs in the study area (Riverside, Jackson Lake, Empire and Bijou No. 2) have a total storage capacity of about 138,000 acre-feet. Storage in reservoirs is usually terminated by senior direct-flow calls early each irrigation season, so normally the reservoirs reach their maximum stage in April of each year. Figure 5A shows a frequency plot of storage volumes on May 1 of each year of the study period. Note that 20% of the time the storage was less than 105,000 acre-feet on May 1. However, the storage exceeded 128,000 acre-feet capacity 75% of the years on the May 1 date.

Groundwater Supplies and Facilities

The alluvial aquifer underlying the South Platte Valley in Water District 1 is large and productive. The saturated thickness of the alluvium, as reported in U.S.G.S. Water Supply Papers 1378 and 1658, ranges from zero to over 200 feet as shown in Figure 62A of the Appendix.

The aquifer is several miles in width in the central portion of the study area, and is continuous with several major tributary aquifers extending southward along the Kiowa, Bijou, Beaver and other valleys. The aquifer narrows in width towards the lower end of Water District 1 and probably also does so in the upper part. However, data are incomplete in the upper area and the full extent of the aquifer is undefined.

Groundwater Storage Capacity

Information presented in U.S.G.S. Water Supply Paper 1378 indicates that there is over three million acre-feet of groundwater in storage[11] in the South Platte main-stem alluvial aquifer of Water District 1. Investigations currently being conducted by the U.S. Geological Survey will result in refinement of this storage figure, but it will undoubtedly still be very large compared to the available surface storage. Figure 6A shows a comparison, for contrast purposes, of the storage capabilities below ground compared to those above. The writers are not advocating, of course, that the full groundwater storage capacity be used--but it does seem obvious that a planned use of a portion of this capacity as a long-term storage facility is vital to the full integration and beneficial use of the total water supply of the area.

Groundwater Development and Use

Irrigation well development and groundwater use have played an important role in the economy of the study area. It is estimated, from irrigation well registrations and other information sources, that there are at least 846 irrigation wells located between the highest ditches on both sides of the river in Water District 1. These are shown on Figure 61A in the Appendix. Most of the wells located under ditches are used to supplement surface water supplies, and thereby have provided those farmers who have been able to obtain wells an essentially insured 100% water supply every year. An approximate distribution of irrigation wells physically located under each ditch system is given in Table 7. Information is not available at this time as to the proportion of these wells which serve land not a part of an irrigation district or ditch system.

[11] Groundwater storage is computed by multiplying an estimated average specific yield by the total volume of saturated alluvium. It represents a volume of water which could only theoretically all be removed.

Table 7. Estimated number of irrigation wells under ditches in Water District 1.

Ditch	Number of irrigation wells
Riverside	151
Bijou	265
Weldon Valley	50
Ft. Morgan	91
Deuel & Snyder	18
U. Platte & Beaver	95
Tremont	14
L. Platte & Beaver	124[12]
Snyder	38
Total	846

[12] Approximately 18 additional irrigation wells are under the Lower Platte and Beaver Canal but across the line in Water District 64.

Water Table Fluctuations and Trends

Utilization of groundwater in the study area has been quite large at times, particularly during a sequence of low-runoff years such as the 1950-56 period. However, this amount of use has apparently not surpassed the recharge except on a short-term basis. Long-term observation well records collected and maintained by Colorado State University show a stable water table situation over the past 35 years. A typical annual cycle of fluctuation occurs in the study area in which the water table is generally at its highest in the fall and lowest in the spring. This type of pattern indicates that surface water additions to the groundwater from ditches, reservoirs and fields during the irrigation season exceed the net withdrawal of water through wells. During the winter, the river serves as a drain lowering the water built up during the previous season. Looking at it from a reservoir standpoint, we have tremendous storage facility which is being kept full and overflowing, therefore being used to a very minor extent as a functioning reservoir.

Groundwater Quality

Quality of groundwater in the alluvial aquifer in Water District 1 (main stem) is generally satisfactory for irrigation. However, consideration and prediction of how it might deteriorate with implementation and operation of any integrated management program is an essential part of the planning of such programs. Water quality can become a serious problem in the area, and already is in terms of domestic uses and well incrustations.

Farm Headgate Requirements and Supply

The nine ditches, (1) Riverside, (2) Bijou, (3) Weldon Valley, (4) Ft. Morgan, (5) Deuel and Snyder, (6) Upper Platte and Beaver, (7) Tremont, (8) Lower Platte and Beaver, and (9) Snyder, serve approximately 97,250 acres of land in Water District 1. It is desirable to evaluate the adequacy and dependability of supplies which have been available to water users under these ditches from both surface water and groundwater sources. To make such an evaluation, it is necessary to estimate the amount of groundwater pumped and the portions of surface water diversions and reservoir releases which have been available at the farm headgates. A general lack of information on leases and exchanges, on losses from ditches and reservoirs, on nonbeneficial consumption of water and on the volume of water pumped from wells make accurate estimates difficult.

Such estimates have been made for the 15-year study period by U.S. Bureau of Reclamation personnel to determine irrigation water shortages in connection with the proposed Narrows Dam. Information contained in the U.S.B.R. "Farm Water Utilization Study" is used extensively in this section of this report because it appears to be the best available. The writers believe that the figures are reasonable, although no field or office checks have been made. As is usually the situation with figures of this type, there is always room for modification through professional judgment or additional information made available at a later date.

Irrigation Requirements

To evaluate the adequacy of a water supply one must first determine the requirements or needs. Irrigation requirements vary with the crop, the stage of growth, soil, precipitation and other climatic factors such as temperature, wind, humidity and solar radiation. Several empirical methods are used for estimating consumptive use requirements of crops. For the "Farm Water Utilization Study" U.S.B.R. personnel used the "Lowry-Johnson Method," a technique developed within the Bureau. The consumptive use requirement was modified into an irrigation requirement by adjusting for effective precipitation and irrigation application efficiency (60% assumed). Irrigation requirements developed for each month of the 15-year study period are shown in Table 8.

Combined Supply During Study Period

According to the U.S.B.R. study, an average of 183,600 acre-feet was available at farm headgates under the nine ditch systems, or 1.89 acre-feet per acre. Utilizing power consumption records and estimates of average lift and efficiency, the U.S.B.R. personnel estimated an annual average groundwater withdrawal of 110,200 acre-feet, or 1.14 acre-feet per acre. The annual values of these supplies are compared with the annual irrigation requirements in Table 9. Notice that except for very minor deficiencies in 1954 and 1955, the gross seasonal supply under the nine ditch systems from combined surface water and groundwater sources exceeded the irrigation requirements.

Table 9 represents an ideal distribution of water over the 97,250 acres of land served by the nine ditches. Of course this ideal distribution did not exist, but the figures do indicate the historical availability of an adequate total

Table 8. Monthly and seasonal irrigation requirements for 15-year study period as calculated by U.S.B.R.

Year	April	May	June	July	Aug.	Sept.	Oct.	Season
				(acre-feet/acre)				
1947	0.032	0.107	0.330	0.636	0.715	0.418	0.0	2.238
1948	0.158	0.176	0.418	0.738	0.599	0.432	0.209	2.730
1949	0.111	0.060	0.260	0.696	0.604	0.385	0.093	2.209
1950	0.042	0.125	0.511	0.655	0.655	0.339	0.209	2.536
1951	0.0	0.079	0.404	0.506	0.525	0.316	0.037	1.867
1952	0.028	0.028	0.636	0.776	0.566	0.418	0.209	2.661
1953	0.005	0.204	0.478	0.576	0.608	0.469	0.204	2.544
1954	0.195	0.283	0.599	0.627	0.478	0.320	0.209	2.711
1955	0.227	0.125	0.353	0.687	0.557	0.260	0.209	2.418
1956	0.162	0.292	0.474	0.381	0.423	0.446	0.232	2.410
1957	0.0	0.0	0.423	0.627	0.539	0.395	0.088	2.072
1958	0.0	0.084	0.302	0.580	0.618	0.279	0.200	2.063
1959	0.093	0.014	0.539	0.678	0.641	0.246	0.0	2.211
1960	0.084	0.223	0.608	0.701	0.757	0.362	0.028	2.763
1961	0.130	0.0	0.390	0.404	0.469	0.079	0.167	1.639
Ave.	0.084	0.120	0.448	0.618	0.584	0.344	0.140	2.338

Table 9. Summary of annual canal and pump supplies compared with irrigation requirements.

Year	Water at farm			Irrigation Requirement	Surplus or Shortage(-)
	Canal	Pump	Total		
	(acre-feet per acre)				
1947	2.70	.63	3.33	2.24	1.09
1948	2.52	.69	3.21	2.73	0.48
1949	2.52	.86	3.38	2.21	1.17
1950	1.80	1.01	2.81	2.54	0.27
1951	2.13	.98	3.11	1.87	1.24
1952	2.54	1.16	3.70	2.66	1.04
1953	1.66	1.06	2.72	2.54	0.18
1954	.98	1.67	2.65	2.71	-0.06
1955	.72	1.53	2.25	2.42	-0.17
1956	.62	1.88	2.50	2.41	0.09
1957	2.54	.82	3.36	2.07	1.29
1958	2.07	1.01	3.08	2.06	1.02
1959	1.55	1.24	2.79	2.21	0.58
1960	1.96	1.46	3.42	2.76	0.66
1961	2.04	1.08	3.12	1.64	1.48
Ave.	1.89	1.14	3.03	2.34	0.69

supply. Table 10 shows a tabulation of annual irrigation water shortages under each ditch, assuming ideal distribution of the annual total amount of water available at the farm headgates. On this basis, two ditches of the nine had major shortages during about one-third of the study period. Figures for the North Sterling Ditch are also included in Table 10, showing that it had major shortages nearly every year.

Table 10 is also idealized in that it assumes an optimum distribution of the available water during each season. Normally, the ditches have more water than needed during May and June and are short during July and August. By contrast, Table 11 lists the actual shortages calculated to have been experienced by water users under these ditch systems because of uneven distribution between ditches and poor distribution during the season. On this basis, every ditch showed some shortage nearly every year. Thus an average shortage of 26,100 acre-feet existed per year under the nine ditches, and another 25,600 acre-feet of shortage existed under the North Sterling Ditch. The annual shortages calculated in this way (summation of monthly shortages) are shown graphically in Figure 4. From this figure it is noticeable that the shortages under the North Sterling Ditch are approximately the same as the total of shortages under the nine ditches studied in Water District 1.

Operational Losses

In the months during which canal supply plus groundwater withdrawals exceeded the irrigation requirement, the difference between total supply and requirement was called "operational loss" by the U.S.B.R. study. These operational losses are tabulated by years and ditches in Table 12. It is interesting to note that these losses were often quite large and occurred nearly every year under all but three of the ten ditches. It is not entirely correct to call these "losses", for a portion of the excess water either percolates to

Table 10. Farm irrigation shortages experienced during 15-year study period, annual basis. (Excess of annual irrigation requirements over annual water supply)

Year	River-side	Bijou	Weldon Valley	Fort Morgan	Deuel& Snyder	U.P.& Beaver	Tremont	L.P.& Beaver	Snyder	Total	North Sterling	Total
					(Thousands of acre-feet)							
1947	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.4	14.4
1948	2.1	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	2.3	6.1	8.4
1949	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.6	9.6
1950	30.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.3	29.8	60.1
1951	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	3.2
1952	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.7	18.7
1953	19.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.2	24.1	45.3
1954	31.6	2.7	0.0	0.0	0.0	0.0	0.0	1.0	0.0	35.3	42.7	78.0
1955	31.0	9.2	0.0	0.0	0.5	0.0	0.0	0.0	0.0	40.7	74.4	115.1
1956	31.9	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.0	45.3	80.3
1957	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1958	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.9	0.0	0.9
1959	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.7	15.7
1960	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.7	25.7
1961	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	3.5
Av.	9.73	1.15	0.0	0.0	0.11	0.0	0.0	0.07	0.0	11.05	20.88	31.92

Table 11. Farm irrigation shortages, monthly basis. (Summation of monthly shortages within each year)

Year	River-side	Bijou	Weldon Valley	Fort Morgan	Deuel& Snyder	U.P.& Beaver	Tremont	L.P.& Beaver	Snyder	Total	North Sterling	Total
					(Thousands of acre-feet)							
1947	4.6	1.4	0.2	0.0	0.8	0.0	0.1	0.0	0.4	7.5	20.6	28.1
1948	8.8	3.1	0.0	1.2	1.0	1.8	0.4	0.9	0.0	17.2	16.2	33.4
1949	2.4	2.7	0.7	0.4	0.5	1.2	0.2	2.1	0.4	10.6	14.8	25.4
1950	30.3	9.4	0.0	0.0	0.8	0.2	0.1	2.0	0.7	43.5	32.7	76.2
1951	6.1	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.2	7.8	11.4	19.2
1952	10.9	0.8	0.5	0.0	0.4	0.3	0.2	3.0	0.4	16.5	22.7	39.2
1953	26.3	5.6	0.1	0.1	0.1	1.2	0.3	2.4	0.7	36.8	24.1	60.9
1954	31.6	11.2	0.0	9.9	0.7	2.2	0.3	5.7	0.6	62.2	42.7	104.9
1955	37.8	14.9	1.9	4.3	1.0	2.2	0.1	5.3	0.3	67.8	74.5	142.3
1956	31.9	15.3	0.1	4.0	0.2	2.8	0.1	2.0	0.3	56.7	45.3	102.0
1957	0.0	0.0	0.3	0.2	0.0	0.8	0.0	0.0	0.3	1.6	5.7	7.3
1958	0.0	1.2	0.0	1.5	1.1	1.0	0.1	0.6	0.1	5.6	14.1	19.7
1959	8.6	3.9	0.6	5.5	0.5	2.2	0.2	4.9	0.4	26.8	17.8	44.6
1960	5.5	1.2	0.0	0.9	0.2	0.9	0.2	2.2	0.3	11.4	27.9	39.3
1961	2.8	6.0	1.4	2.4	0.5	1.9	0.5	3.4	0.9	19.8	14.1	33.9
Av.	13.84	5.21	0.39	2.03	0.52	1.25	0.19	2.30	0.40	26.12	25.64	51.76

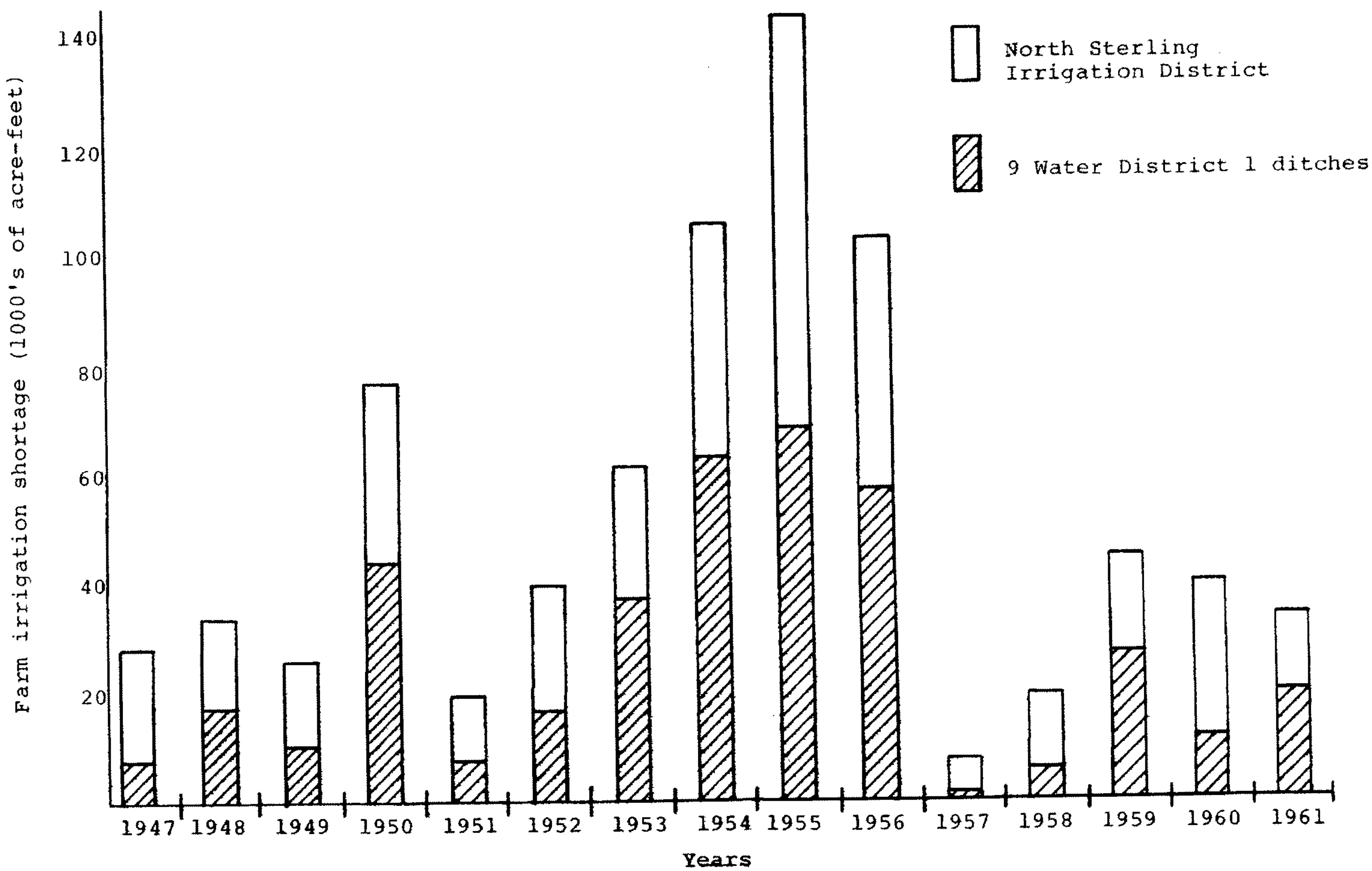

Figure 4. Farm irrigation shortages, 1947-1961. (Summation of monthly shortages within each year).

Table 12. Operational losses as calculated in the U.S.B.R. 15-year farm water utilization study. (Summation of monthly operational losses within each year)

Year	River-side	Bijou	Weldon Valley	Fort Morgan	Deuel& Snyder	U.P.& Beaver	Tremont	L.P.& Beaver	Snyder	Total	North Sterling	Total
					(Thousands of acre-feet)							
1947	3.7	28.8	12.9	32.0	0.1	11.1	1.3	18.7	0.5	109.1	0.0	109.1
1948	0.0	13.5	13.6	11.1	0.0	7.0	0.0	10.7	0.8	56.7	0.0	56.7
1949	13.4	30.5	11.6	33.9	0.4	11.5	0.6	14.3	0.6	116.8	0.0	116.8
1950	0.0	0.8	17.3	17.5	0.5	14.7	1.0	9.0	0.3	61.1	0.0	61.1
1951	2.5	34.7	19.9	32.4	3.3	14.2	1.4	17.4	1.7	127.5	0.0	127.5
1952	4.7	24.7	20.1	28.3	1.0	14.5	1.4	9.0	1.9	105.6	0.0	105.6
1953	0.0	0.0	14.3	17.3	0.6	6.0	0.2	3.4	1.3	43.1	0.0	43.1
1954	0.0	0.0	18.0	3.5	0.0	8.6	1.1	0.0	1.8	33.0	0.0	33.0
1955	0.0	0.0	11.0	4.4	0.0	6.7	1.8	1.9	1.9	27.7	0.0	27.7
1956	0.0	0.0	18.0	6.9	2.2	9.5	1.9	6.5	3.2	48.2	0.0	48.2
1957	23.8	36.8	18.7	21.7	3.5	5.0	1.9	14.9	1.8	128.1	3.3	131.4
1958	19.5	25.8	17.6	14.7	0.0	8.9	1.1	14.6	3.3	105.5	0.1	105.6
1959	0.9	11.5	16.8	12.8	0.6	9.4	0.6	2.0	1.3	55.9	0.0	55.9
1960	3.6	10.8	17.9	14.6	0.9	6.9	0.4	8.9	2.4	66.4	0.0	66.4
1961	22.3	39.0	19.7	30.6	1.9	15.8	0.7	9.3	0.8	140.1	0.0	140.1
Av.	6.29	17.13	16.49	18.78	1.00	9.99	1.03	9.37	1.57	81.65	0.27	81.88

the groundwater and provides "return flow" or supplies down-slope irrigation wells, or it runs over the surface directly to the river to become part of a downstream surface supply. It should also be noted that the operational losses do not include the 40% of the irrigation requirement which also is lost to crop use through deep percolation and runoff, because of the assumed 60% irrigation application efficiency.

Frequency of Shortages and Surpluses

Frequency graphs have been prepared which show the shortage and surplus situation under several of the Water District 1 ditch systems. Annual and monthly frequency graphs for the Riverside, Bijou, Weldon Valley, Fort Morgan, Upper Platte and Beaver and Lower Platte and Beaver are shown in Appendix Figures 7A through 48A. The following paragraphs briefly point out pertinent features of these graphs.

Riverside System. The annual frequency chart for the Riverside Canal (Fig. 7A) shows that the canal and reservoir supply provided less than the irrigation requirement during 80% of the study period. It provided less than 50% of the irrigation requirement one-third of the time. Irrigation well development is rather limited, but was sufficient to bring the total supply above the irrigation requirement 75% of the time compared to only 20% of the time by the canal alone. The third (upper) line on this and the following frequency graphs represents the potential water supply available from existing wells plus the canal. The potential groundwater supply was based upon the maximum amount of water pumped by wells under each ditch during the 15-year study period.

Bijou Canal. The farm headgate supply delivered to water users under the Bijou Canal was adequate to meet the irrigation requirements during six of the 15-years, as shown in Figure 14A. Groundwater pumping added to the ditch supply brought the combined supply above the 100% line 11 years out of 15, and pumping capacity is apparently available to make the full requirement available 13 out of the 15 years. The two remaining years were very near the 100% amount. Similar patterns exist for individual months of the growing season, as can be seen from Figures 15A through 20A.

Weldon Valley Ditch. According to the U.S.B.R. Farm Water Utilization Study, the Weldon Valley Ditch provided its water users with over 100% of their irrigation requirements during 14 of the 15 years (Figure 21A). Groundwater withdrawals added to the canal supply brought the combined supply to over 150% of the requirements during every year of the study period. Distribution of water on a monthly basis was generally adequate, although the April chart (Figure 22A) shows considerable percentage of deficiency. Because water requirements are low in April, these deficiencies do not amount to a large amount of water.

Ft. Morgan Canal. Canal supplies alone were sufficient to furnish Ft. Morgan Canal water users with 100% of their seasonal requirements 10 years out of 15 (Figure 28A). Withdrawals from wells supplemented the canal supply to the extent that water users had a full supply every year. However, as shown in the monthly frequency charts (Figures 29A through 34A), some shortages occurred because of suboptimum distribution of the supply during the growing season.

Upper Platte and Beaver Canal. The development of groundwater supplies has apparently made the difference between a poor supply and an adequate supply for water users under the Upper Platte and Beaver Canal. According to the U.S.B.R. study, the canal supply alone would have been adequate only one year out of the 15, and it just barely so (Figure 35A). However, groundwater withdrawals brought the combined supply above the 100% requirement all 15 years of the study period. Distribution of water during the season has generally been good, with some minor deficiencies in June (Figure 38A).

Lower Platte and Beaver Canal. Groundwater development has also greatly benefited water users under the Lower Platte and Beaver Canal, as shown in Figure 42A. The "canal supply only" line in Figure 42A indicates a canal supply of less than 75% of the irrigation requirement during nine of the 15 years. This line is probably somewhat lower than it would have been if wells were not available; in that it is the prevailing practice for water users under the Lower Platte and Beaver Canal to lease out their reservoir rights to water users under other systems, particularly the Riverside, and to pump their own supply from wells. This is a form of groundwater-surface water integration that has already taken place, motivated by economics and convenience, which has tended to provide a better distribution and use of water in Water District 1.

North Sterling Irrigation District. The annual frequency graph for the North Sterling Irrigation District (Figure 49A) presents quite a contrast to those ditch systems presented above, in that groundwater pumping plays a very minor role in its total water supply. Deliveries by ditch were less than the requirements during 13 years out of the 15-year study period. Very little well development is possible because of poor aquifer conditions, thus the water users under this system are almost entirely at the mercy of the river runoff and return flow conditions.

Water District Ditches. The frequency with which water was available to meet irrigation requirements under 10 major ditch and reservoir systems diverting in Water District 1 is shown in Figure 50A. This graph includes the North Sterling Irrigation District. Canal supplies were adequate for irrigation requirements six years out of 15. Adding the groundwater withdrawals brought the supply up to or above the 100% requirement eleven years out of 15.

Figures 51A through 57A show annual and monthly frequency plots for the nine Water District Ditches listed at the beginning of this section, (do not include the North Sterling District). Figure 51A shows, as did Table 9, that the gross amount of water available on the farms was more than the total irrigation requirements 13 out of the 15 years, with rather minor deficiencies the other two years. The monthly charts show that the shortages were generally in April, June and July, with the larger surpluses occurring in May. August and September gross supplies were generally adequate, thanks to the use of groundwater.

Maximum Groundwater Withdrawal

During the 15-year study period, the U.S.B.R. records show that the maximum groundwater withdrawal was made during August 1956. A summary of their estimate of groundwater pumping under the nine major Water District 1 ditch systems is given in Table 13. Note that the pumping capacity under seven of these ditches exceeded 0.6 acre-feet per acre, the average irrigation requirement for the month of August. The present pumping capacity is not known, but probably is greater than the 42,500 acre-feet per month (approximately 700 cfs) indicated in Table 13, because of wells which have been drilled since 1956, and because it is likely that not all wells were pumped 100% of the time in August of 1956. It seems reasonable that the discharge from the 846 wells mentioned in Table 7 should average 1½ to 2 cfs, giving a total potential of 1250 to 1700 cfs.

Table 13. Estimated amount of groundwater withdrawn during August of 1956 under Water District 1 ditch systems.

Ditch	Approximate acreage under ditch	Estimated groundwater withdrawn, Aug. 1956 (acre-feet)	(acre-feet/acre)
Riverside	21,500	4,600	0.21
Bijou	26,300	1,300	0.05
Weldon Valley	7,000	4,500	0.64
Ft. Morgan	11,900	7,900	0.66
Deuel & Snyder	2,050	1,400	0.68
U.P. & Beaver	12,000	9,300	0.76
Tremont	1,000	1,100	1.10
L.P. & Beaver	13,500	10,100	0.75
Snyder	2,000	2,300	1.15
Total	97,250	42,500	0.44

Modeling the System

In order to be able to operate a complex system in an optimum way it is generally desirable to model the system such that the model can be used to predict the prototype responses to various input conditions. In this way, the field system can be "pre-operated" or tested and administrative and management decisions made based on the predicted responses obtained from the model.

The writers believe that a model or models simulating the groundwater-surface water interrelationships of the South Platte Basin are not only necessary to make the desired operational studies for the efficient management of the total water supplies therein, but also is of importance in determining benefits derived by water users from changes in management.

The first modeling of the system will necessarily be crude because of poorly defined inputs and hydraulic relationships, but as time goes on and more data become available, the modeling can be refined and results improved.

To show what can be done with existing information an example is given in this section of a mathematical model solved by digital computer for an area near the Riverside Reservoir.

This model represents a one-dimensional cross-section from the reservoir to the river and then across the other side of the valley through the Bijou and the Empire Intake Canals in the general direction of the maximum water table slope. For convenience one can think of the model as having unit (1 foot) thickness. Inputs and withdrawals included seepage from the reservoir and canals, deep percolation of precipitation, seepage from the reservoir and canals, deep percolation of precipitation, pumping of groundwater along the Riverside Canal and evapotranspiration from low-lying high water table areas. Response calculations were made over a 3½ year period of groundwater levels and groundwater flow into the South Platte. Stage of the reservoir was fluctuated according to the historical records for the period, and precipitation effect and evapotranspiration were estimated from local climatological data. Water table elevations and reservoir inflow and river outflow amounts were calculated every 10 days.

Figure 58A in the Appendix shows the calculated and observed water tables in an observation well located between two of the Riverside pumped wells and measured periodically by Riverside personnel. The match between calculated and observed is quite good and illustrates what can be accomplished with a model.

The middle set of curves in Figure 58A represents the calculated reservoir losses and the return flow into the river as a function of time. It should be noted that the return flow is not merely a routing of the reservoir losses through the aquifer, but it is also influenced by the pumping, precipitation and evapotranspiration factors.

The lower curve on Figure 58A represents the amount of water in storage in the aquifer with time. A percent scale on the right side of the graph shows that for the 1300 days of analysis, the maximum change in storage was only about 8% of the total storage volume.

A sample of computer output for this model is given in Figure 59A. This shows calculated water table elevations for the period 480 to 490 days at each of 48 points (called grids) along the model. Grid No. 1 represents the reservoir water level, No. 10 the grid from which there is groundwater withdrawals taking place by the Riverside wells, Nos. 22 through 33 represent the lowland and river area, No. 44 the Bijou Canal, and No. 47 the Empire Intake Canal.

One-dimensional models as just described can provide a great deal of information and insight to the physical situation at various points along the river. Ultimately, however, these should be merged into a two-dimensional model of the entire system, or at least to a time-linked series of one-dimensional models. Going to two-dimensional models increases the computer time and storage requirements, and it is likely that the South Platte Basin would need to be separated into several overlapping two-dimensional models.

Alternative Degrees of Integrated Management[13]

It is clear that a certain degree of integrated management of groundwater and surface water supplies is already taking place in Water District 1, although generally unplanned and haphazard. During years of low surface water supplies, the groundwater reservoir is being utilized to a heavier extent than during years of surplus surface water. During more favorable years the surplus surface water is diverted and applied to land with a portion of that supply serving as a replenishment of groundwater pumped out in other years. The principal problem lies in the fact that these activities are not coordinated to the extent that they need to be in order to assure that some vested water rights are not being injured by such operations. In addition, it results in waste and does not provide optimum beneficial use of the water. Several degrees of intensity of integrated management of groundwater and surface water supplies may be possible and practical. In the following sections, alternative degrees or levels of intensity are described and discussed.

Alternative Number 1

Alternative number one, the lowest degree of integrated management of groundwater and surface water, is defined herein as basically continuing with the present law under which we are now operating, but adding certain voluntary operational agreements such as are now being developed between water users in Water Districts 64 and 1. We feel that the current discussions and tentative agreements between these water users are efforts in the proper direction to achieve the desired goals. In brief, the agreements include the following:

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[13] This section has been prepared in consultation with Mr. John Barnard, Jr., Attorney at Law, Boulder, Colorado.

1. Direct flow ditches and reservoir systems above Balzac in District Number 1 will voluntarily curtail diversions from the river after October 15th of each year in order to allow downstream reservoirs to begin their winter fill.

2. Beginning in the spring of 1968, all ditches and reservoir systems in both districts will voluntarily, where possible, use other means (wells or reservoir water) to obtain their early irrigation water in order to allow maximum reservoir filling and also to assure those ditches, which because of inadequate aquifers below their land cannot pump their early irrigation water supplies, an adequate direct flow river diversion.

3. After April 15, reservoirs will not make a call on the river during the irrigation season, and direct flow ditches will make every attempt to obtain decreed priorities of water through whatever means is available; and if the ditch is yet short of water it will first contact the office of the Water Users Protective Association of Water District Number 64 and will allow a period of 5 days for the voluntary agreement to function through informal exchange of water within and between Water Districts Number 1 and 64, and that a formal call will not be invoked until the persons administering the voluntary agreement shall have had a chance to obtain the necessary water.

4. The South Platte River will be administered under the appropriation system, under adjudicated priorities, if all efforts to provide the necessary water fail.

This agreement, if not broken, can do much to provide for a better distribution of the available water during any particular year. The plan would tend to reduce diversions of surface water for direct use during the early months of April and May, allowing more of this water to be retained in storage for use later in the season than is now being accomplished. The plan has shortcomings, the most obvious being the lack of assurance that all parties involved will hold to the above agreements, particularly in a year of low surface water supplies. It is quite likely that in a year in whcih the snowpack measurements predict a meager supply of surface water, or in case of a dry spring with low precipitation during the months of March or April, that one or more ditch companies will decide that they should take what they are legally entitled to from the river early in the season, and rely upon their pumps late in the season--essentially the way they have operated previously. With no legal status to do anything but operate in the way they have in the past, the voluntary plan could deteriorate to no value in a very short time. During dry years there may be no means by which direct flow ditches or the Water Users Protective Association could obtain water to satisfy decreed priorities. Unfortunately, the voluntary arrangement, no matter how well conceived, is most likely to fail at the time it is needed most. Some portions of the plan might be rendered legally enforceable under the exchange agreement provisions of Article 148-6, 1963 CRS, but such agreements could not, in all probability, be completely covered by these statutory provisions. In addition, the preparation, execution and enforcement of such agreements would be awkward and cumbersome.

The writers consider this level of integrated management to be interim in nature only while more far reaching plans and necessary legislation are being developed.

<u>Alternative Number 2</u>

An intermediate degree of integrated management of groundwater and surface water could be similar to the principle which was involved in Senate Bill 3 of the 46th General Assembly, submitted by Senators Gill and Hahn. This bill provided for the use of water from all sources before a call could be made on other appropriators by

1. Requiring every appropriator of water to use such methods and equipment as ditches, dams, headgates, wasteways, pumps, wells, measuring devices and supplemental points of diversion in existence and where necessary to capture such appropriator's full decree before placing a call on junior appropriators.

2. Require that the diversions by any appropriator be limited to no more water than the total amount in his decreed water rights except at times when all other decreed water rights are satisfied and have released their call on the river.

It appears that the intent of this proposed legislation was to incorporate the wells located under each ditch system into the decreed diversion rights of the ditch. On the surface, this seems to have considerable merit, but many questions remain unanswered. For instance, the following factors should be given consideration:

1. Well owners who have sold their ditch stock (or who never have owned ditch stock) but who are located under and benefit from one or more ditch systems should be considered. The limitations and operating rules imposed should not be an undue burden on those who are associated with a ditch system compared to those who are not.

2. The equities between well owners and non-well owners under the same ditch should be considered. Provisions should be made for recognizing investments in wells and pumps which under the proposed operation would no longer be under the complete control of the owner.

3. Large junior ditch decrees which have had little or no value in terms of water delivered to the land should be considered in terms of need and historical use. Allowing an increase in use beyond needs would certainly not meet the purposes of the proposed legislation.

4. Consideration must be given to what authority a mutual company or an irrigation district can have to force its stockholders or taxpayers to obtain water from wells rather than the ditch (and vice versa) at particular times, and to limit the amount withdrawn.

5. Further consideration should be given to the type of limit on "total decreed rights" which could be imposed and administered. A limit in terms of flow rate would be almost impossible to administer, but a limit on monthly or seasonal volumes may be possible. In either case, continuous measuring devices on each pump discharge would be necessary.

The philosophy of Senate Bill 3 may be carried a step further to that of requiring additional facilities (such as wells and pumping plants) to be installed and utilized by a senior ditch in order for it to obtain its decreed rights. The question of whether the financial burden of the construction, operation and maintenance of such facilities is properly that of the senior ditch is of importance here.

The general rule is commonly accepted that surface water diversions have no right to the maintenance of stream levels or rates of flow from which the appropriator had made his initial appropriation, so long as the required quantity of water is available in the stream at the point of diversion--in other words, that an appropriation by inefficient diversion works would not justify requiring that a greater volume of water be left in the river in order to permit the continued use of such inefficient diversion works. The language of the Colorado Supreme Court in the City of Colorado Springs, *et al*. v. Bender, 148 Colo. 458; 336 p. 2d 552, would seem to require a modification of this rule for groundwater appropriators, but the principle is similar. In that case, the Court said:

> "A determination of these questions is necessary. The court must determine what, if anything, the plaintiffs should be required to do to make more efficient the facilities at their point of diversion, due regard being given to the purposes for which the appropriation had been made, and the "economic reach" of plaintiffs. The plaintiffs cannot reasonably "command the whole" source of supply merely to facilitate the taking by them of the fraction of the entire flow to which their senior appropriation entitles them. On the other hand, plaintiffs cannot be required to improve their extraction facilities beyond their economic reach, upon a consideration of all the factors involved."

Thus, acceptance of alternative number 2 would be to impose, by additional legislation or judicial action, similar requirements on users of both ground and surface water in the study area. Logically, this would result in the requirement that groundwater would be used, where available, to provide the required water where such use is within the physical and economic ability of the user, rather than permit such a user to call water away from a junior that is not so fortunately situated.

The administrative problems that would be presented by such an approach are, to say the least, manifold and difficult. In addition to determinations of amounts and occurrence of available groundwater, determinations of economic capability of each user would probably be required, and possibly determinations of which uses are feasible, and which are of such marginal nature as to require that they be denied protection as opposed to uses of higher economic productivity. Unless unanimous agreement was obtained among the principal parties involved, it would appear that the making of the determinations mentioned above in order to arrive at an equitable cost allocation, and provisions for the collection of such costs, virtually require a more formal organization and level of integrated management as contemplated under alternative 3 below.

Alternative Number 3

The third, and seemingly most desirable level, is a fully integrated management program designed to achieve the optimum use of the total water supply. Such a plan would not only contemplate the integration of groundwater and surface water use within individual ditch and reservoir systems but also would include the planned integrated management and operation among ditch systems on a basin basis, and a planned manipulation of groundwater storage as a functioning component of the entire water supply, storage, and conveyance facilities of the area. Of necessity, this higher level of integrated management must include overall authority centered in existing agencies or organizations or in new agencies or organizations. Under this plan it would be the purpose and duty of such an agency or organization (which we will hereafter refer to as the "basin authority") to provide the various ditches and water users the amount of water required to meet their needs at the proper times and places. The plan would be oriented towards an alleviation of shortages and a stabilization of water supplies for all water users. In order to accomplish this it is envisioned that the "basin authority" would need to:

1. Provide water by means of groundwater pumping at predetermined locations, times and rates depending upon the natural surface water supplies.
2. Provide for recharge facilities and operation to replenish groundwater supplies during periods of abundant surface water.
3. Determine and establish a maximum volume allowable for each ditch for beneficial use from combined surface water and groundwater sources.
4. Allocate costs of the management program according to benefits received.

The design of specific physical facilities for the implementation of a planned integrated management program must await detailed operational studies. However, in order to provide the reader with the concept of what may be accomplished in Water District 1, the following example is offered.

Of the ditch systems studied, the one with the poorest water supply and also the one which may have suffered the most from reduction of return flows caused by groundwater pumping, is the North Sterling Irrigation Company. This system is heavily dependent upon obtaining a full or near full reservoir by the beginning of each irrigation season. Storage is strongly influenced by return flows available from the previous irrigation season. Furthermore, only a few farmers under the system are fortunate enough to have a sufficiently productive aquifer under their lands to be able to supplement their supplies with groundwater.

Two possible solutions, or combinations thereof, are apparent. If sufficient aquifer and property are available along the first few miles of the North Sterling Inlet Canal to develop a well-field, with delivery directly to their canal, this may be the least expensive and most satisfactory solution for providing decreed water plus an insured supply of water. The actual feasibility, design and location of such a well-field must take into consideration many factors[14] which cannot be treated here. An attractive feature of the well-field approach is the possibility of stage construction rather than having one large initial investment tied to a facility of fixed size.

If the geologic conditions near the diversion works and initial few miles of the North Sterling Inlet Canal are such that none or only part of the above program could be achieved, an alternative would be needed. One such alternative worthy of study would be the location of a well-field in the vicinity of the Bijou No. 2 Reservoir and Bijou Creek which could be used to supply part of the Bijou System requirements in exchange for water left in the river to be diverted by the North Sterling. The Bijou No. 2 Reservoir and Bijou Creek stream bed could be used during high runoff years as recharge facilities. The same type of operation as described for the Bijou System could also be worked out for the Riverside System, with (if economically feasible) enough capacity designed in the 3-way exchange system to insure a full water supply every year to the North Sterling, Bijou and Riverside water users.

As noted earlier, the Riverside has already initiated a well-field supplying 25 cfs of water to its ditch. This would fit into the overall scheme as outlined above--but of most importance is that all such facilities are planned on a basin rather than an individual go-your-own-way basis. Detailed operation studies which utilize an adequate model of the entire system should be conducted to develop the optimal operation procedure and determine the facilities necessary. The same model can be utilized to compare costs and to determine the benefits to water users in order to make an equitable allocation of costs.

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[14] Not the least of importance is consideration of the affect such a well-field may have on decreed rights of downstream water users.

Cost allocation of such a management program should be made on the basis of benefits received. Figure 5 shows, in principle how this might work for a system like the North Sterling. The center line on the figure is a reproduction of the frequency graph given in Figure 49A based upon the 15-year farm water utilization water study made by the U.S. Bureau of Reclamation. The lower line hypothetically represents a frequency of water supply which might occur if upstream pumping were allowed to continue and the North Sterling Ditch were not allowed to call for surface water because of the inefficient delivery conditions. The upper line hypothetically represents a possible attainment of water supply frequency utilizing a planned integrated management program utilizing one or more well fields and recharge facilities. Under the principle which we propose that should apply here, the proportion of the costs of new facilities to be carried by the North Sterling System is represented by the distance between the middle and upper line, i.e., the benefit above and beyond the deliveries which historically have been obtained by operating under the priority doctrine. The proportion of the installation and operation cost which should be underwritten by the well owners upstream who may otherwise have been shut off in order to provide the historical diversion amount is represented by the distance between the middle line and the lower line.

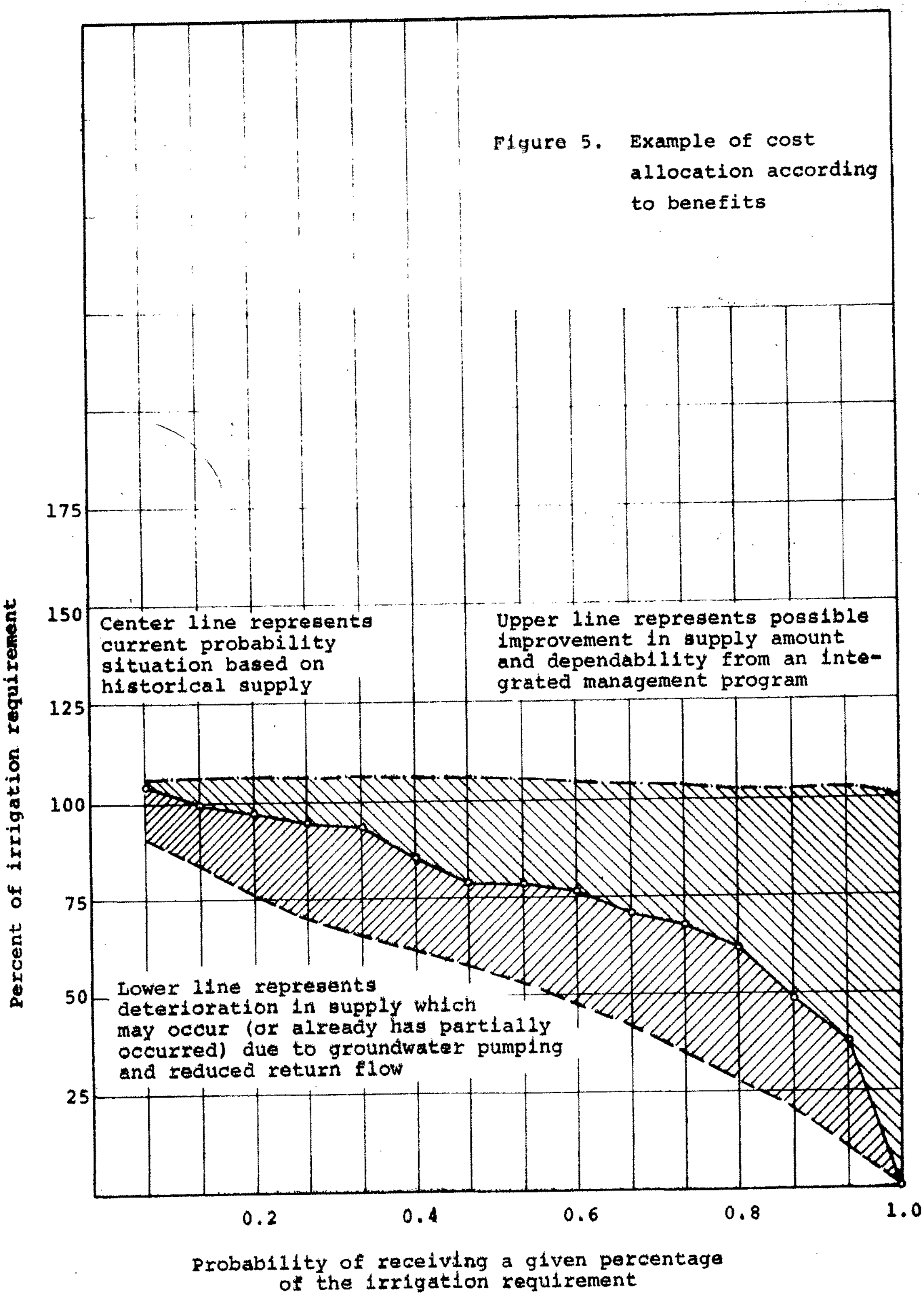
Figure 5. Example of cost allocation according to benefits
175
150
125
100
75
50
25
Percent of irrigation requirement
0.2
0.4
0.6
0.8
1.0
Probability of receiving a given percentage of the irrigation requirement
Center line represents current probability situation based on historical supply
Upper line represents possible improvement in supply amount and dependability from an integrated management program
Lower line represents deterioration in supply which may occur (or already has partially occurred) due to groundwater pumping and reduced return flow

Thoughts on Organizational and Legislative Needs[15]

The implementation and operation of a successful integrated management program will require a carefully planned and competently staffed organization. It seems preferable that such an organization have jurisdiction over an entire basin, however, it is possible that basins can be divided into logical geohydrologic units for integrated management. In the South Platte Basin a logical subdivision occurs in the vicinity of the Kersey gage. The irrigated areas above this point principally derive their supplies from the Rocky Mountains and from supplemental well development along the main stem between Denver and Greeley and in the Cache la Poudre drainage area. Below Kersey irrigation ditches are heavily dependent upon return flows from the irrigation activities in the upper region and upon groundwater development, but there is a noticeable break in groundwater development just below Kersey. A third subdivision which could operate quite independent from, but with specific obligations to the rest of the South Platte System, is the Cache la Poudre drainage basin above its confluence with the South Platte River near Greeley.

Authority Needed by Management Organization or Agency

For successful implementation and operation of an integrated management program there are several specific powers or authorities which would be required by the "basin authority" whatever the organization may be. These are listed below with brief comment providing the reasoning behind the specific items where it seems desirable.

1. Authority to determine and establish water requirements. As discussed elsewhere in the report, waste of water must be reduced and converted to beneficial uses because of the increasing demand upon the total

[15] This section has been prepared in consultation with Mr. John Barnard, Jr., Attorney at Law, Boulder, Colorado.

water supply. The "basin authority" should have the power to set a limit on water used based upon scientific evaluation of soils, crops, water quality, topography and climate.

2. Authority to determine benefits derived from integrated management activities. The entire purpose of the proposed integrated management program is to decrease deficiencies and increase dependability of water supplies without infringing upon vested rights. As described and discussed elsewhere in this report, when an adequate model of the physical system is developed, it not only will be valuable as a tool for determining the optimum method of operation, but will also be useful in determining the amount of benefit derived by water users from the changes in management. Such a means of evaluating the benefits is necessary in order to assure an equitable distribution of costs resulting from the integrated management program.

3. Authority to make and collect assessments or levy taxes according to benefits derived. The cost of the integrated management program should be distributed in proportion to the benefits derived therefrom. The "basin authority" should also have ad valorem taxing authority as well in order to recognize general basin wide benefits and cover basic administration expenses, but the major capital and operating costs related to delivery of water should be according to benefits derived.

4. The authority to construct and operate physical facilities. As described earlier the "basin authority" as envisioned would need to construct and operate wells and pumping plants, conveyance facilities, recharge facilities and other works in order to carry out an integrated management program.

5. Power of eminent domain. The power of eminent domain is not only desirable in order to acquire land and rights-of-way for wells, conveyance facilities, recharge facilities and other works, but also for the acquisition of water rights. It is quite likely that in order to achieve an optimum flexibility of operation, the "basin authority" should have certain water rights under its control. In addition, in some areas it may be desirable to acquire water rights for which compensatory water is not economically feasible and to retire marginal agricultural land from irrigation in order to make better use of a limited water supply. Lastly, the existence of such power would seem to remove Constitutional objections based on injury of vested rights, since any taking of vested

> rights can be compensated for, and the question becomes one of economics rather than Constitutionality.

The above itemization of authority of powers which should be allotted to a "basin authority" is not exhaustive or all inclusive. Those items mentioned, however, would be necessary in order to achieve the full integration of groundwater and surface water supplies under one management and administration.

The "Basin Authority"

At least three alternatives could be considered for the proper organization or agency in which the responsibility for integrated management of groundwater and surface water could be vested. Since administration of surface water rights is a responsibility of the State Engineer, it would seem reasonable that one alternative would be to vest in the office of the State Engineer the responsibility of initiating and administering the integrated management program described previously. Certain objections can be raised to this alternative, the principle one being the desire of the water users to have a more direct voice in the operation of their systems. Another objection would be based on the creation of a dual function in that office which might well result in a conflict of functions. A second alternative is to utilize the presently organized conservancy districts as the organizations to implement and operate integrated management programs. The third alternative is to establish an entirely new public district specifically designed to carry out the integrated management activities within an entire basin. The writers favor the second alternative rather than establishing another governmental unit with the associated duplication of facilities and efforts.

A full evaluation of the advantages and disadvantages of the second alternative, that of utilizing presently existing conservancy districts, has not been made as yet. However, a few comments can be made in this regard. Although ground water is not specifically mentioned in the conservancy district enabling act and subsequent amendments, the general purposes and policy of conservancy districts are very compatible with the objective of an integrated management program. Powers given to conservancy districts are broad and extensive and could probably be construed to include most of the powers itemized in the above section. However, more study is needed to fully evaluate existing grants of power and make specific recommendations for amendments to the conservancy district statutes to make certain that such districts possess the necessary powers for implementation and operation of integrated management programs.

Certain deficiencies are apparent in the use of alternative number 2. A very apparent problem that would need to be solved is that of gaps between conservancy districts and overlapping of conservancy districts. Figure 6 shows the approximate boundaries of the three conservancy districts now existing in the plains area of the South Platte Basin. It will be noted from this map that there are gaps and overlaps in boundaries. In addition, the first Designated Groundwater Basin established under the 1965 Colorado Ground Water Management Act borders and overlaps a portion of the Northern Colorado Water Conservancy District. A second question which must be answered is the existence or nonexistence of power of present conservancy districts to contract with neighboring conservancy districts or to deliver water outside of district boundaries. As envisioned under the integrated management plan, the various conservancy districts would negotiate with adjacent districts to establish water delivery schedules at their common boundaries, thus providing a more predictable supply than if on a strict priority call basis. Such activity would result in obvious benefits to the water users in the affected districts, and utilize the considerable experience of those districts in water management to resolve the problems of combined ground and surface water management. The writers are hopeful that the board members and staffs of the presently

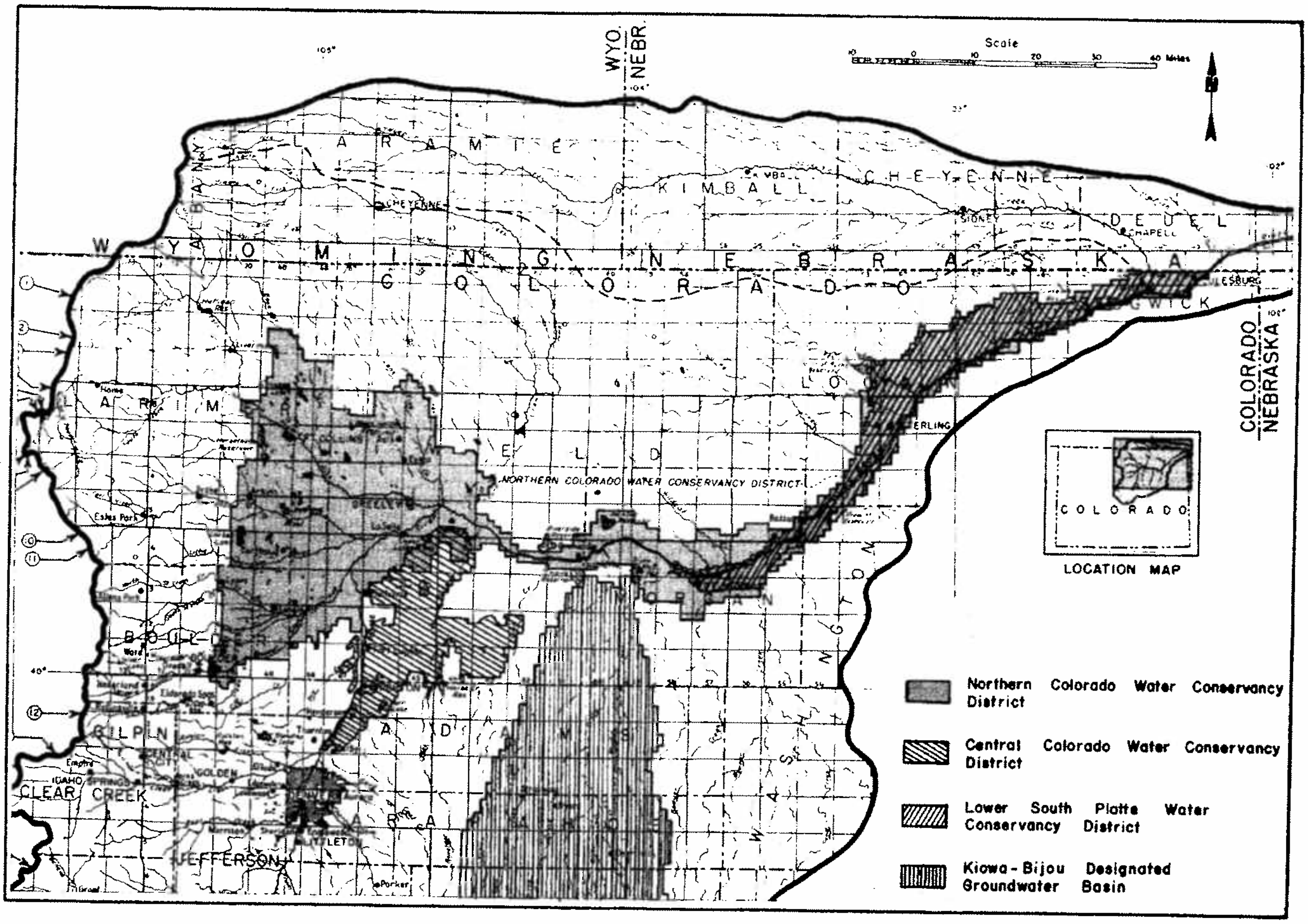

Figure 6. Approximate boundaries of organized districts in the Plains area of the South Platte River Basin.

organized water conservancy districts would willingly accept the added responsibilities involved in an integrated managment program, but have made no inquiries along these lines.

SUMMARY AND CONCLUSIONS

The following statements briefly summarize findings and conclusions to date:

1. The average annual historical supply of surface water available to users in Water District 1 is adequate for irrigation requirements.

2. The variability of the surface supply, ranging to less than 10 percent of the average during some months, makes sole dependence upon this source very unsatisfactory.

3. Surface storage facilities have reduced some of the uncertainty of supply by providing a better distribution of water through the season. The surface storage facilities, however, are quite inefficient, and of little value for long-term storage bridging a series of low runoff years.

4. Groundwater development and use has removed much of the uncertainty of supply for those water users fortunately situated. Subsequent exchanges and leasing of reservoir shares by ditches and individuals changing to greater groundwater use has tended to stabilize supplies even for those who have not been able to develop groundwater supplies.

5. The development of groundwater, and the subsequent exchanges and leasing of water, has come about haphazardly and without coordination on a basin basis. Although the development has improved the distribution and availability of water to most users, there has been no assurance that some parties have not been adversely affected. In addition, with little or no overall planning or coordination, the possibilities of achieving maximum beneficial use and minimum waste are nil.

6. The large alluvial aquifer underlying most of the irrigated land along the South Platte in Water District 1 can serve as a very efficient long-term storage facility with which, assuming economic feasibility, all uncertainties and inequities of supply can be virtually eliminated. The planned utilization and manipulation of groundwater storage in conjunction with surface water supplies, storage and conveyance facilities is referred to as integrated management of groundwater and surface water.

7. Full integrated management of groundwater and surface water should be planned for the entire basin, not just the area involved in this study, in order to achieve maximum benefits.

8. Full integrated management of the large and complex groundwater-surface water system of the South Platte Basin can be facilitated with computer model studies. These computer studies can help in the design and location of facilities, in the management decisions associated with operations and in determining benefits from the integrated management program.

9. Responsibilities for implementing and administering an integrated management program could probably best be handled by existing water conservancy districts. Certain problems in this regard need further study before legislation is proposed.

RECOMMENDATIONS FOR FURTHER WORK

It is recommended that work continue on uncompleted items under Plan of Work, pages 4 and 5, with emphasis on:

1. Basin operation studies.
2. Development of guidelines for establishing irrigation requirements under the various ditch systems.
3. Development of guidelines for cost allocation and administration procedures under proposed operations.
4. Preparation of proposed legislation.

Additional work and activities, not directly a part of this study, which the writers consider desirable include:

1. Well planned and conducted educational and informational programs should be held throughout the areas concerned with the groundwater-surface water problem. The problem is complex and the concepts are somewhat new to many. It is human nature to be skeptical of changes which are not understood.
2. Studies should be made leading to the improvement and automation of data collection, storage and retrieval. As the value of water increases, value of good and accessible records cannot be over estimated. Automatic data processing machines and techniques available today offer many possibilities of improvement over procedures presently being followed.