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INPUT-OUTPUT MODELING OF THE WATER SYSTEM OF THE CITY OF FORT COLLINS

BY

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ABSTRACT

The present study reviews briefly the input-output modeling methodology and applies it to the Fort Collins water system. The final product is an input-output matrix of great resolution, showing the sources of supply, the distribution and collection network, the treatment facilities, and all the elements related to the operation of the system. The matrix can be utilized to develop and analyze future alternatives in the management and planning of the city's water system.

The matrix was displayed on a large magnetic board and provides a complete quantitative depiction of the overall water system. The quantitative data are documented by line diagrams of inputs and outputs of water to each respective component of the system. These diagrams provide not only the needed documentation but an organized format for ready reference.

The matrix display has the benefit of feasibility through visual means; it enables one to grasp the interactions of a large complex water system. The role of proposed projects and their perturbations on the rest of the system can be evaluated. The visual grasp of a complex water system facilitated by the matrix display and its simplicity can aid in explanations to members of the city council, administrators, and new personnel who will learn the system.

CONTRACTUAL BACKGROUND

The study which this report partially represents was initiated in February 1978 through a contract agreement between the City of Fort Collins and Colorado State University (CSU Project No. 31-1372-6942). The agreement provided for two studies: (1) development of an input-output depiction of the water system of the City of Fort Collins, and (2) the evaluation of alternative land use disposal schemes for the wastewater produced by the City. This report summarizes the results of the development of the input-output model for the water system of the City of Fort Collins. The study of the land use disposal alternatives is summarized in a separate companion report entitled, "Effluent Disposal Alternatives for the City of Fort Collins--An Input-Output Model Analysis," by John Blair, Environmental Engineering Technical Report No. 78-6942-01.

The two studies were supported by the CSU--City of Fort Collins contract, supplemented by additional support from the Colorado State University Experiment Station, Dr. Patrick Jordan, Director. The latter support was used to broaden the scope of the study to make the specific case study methodology and the report format more generally applicable to other situations. Under the direction of Dr. Norman Evans, the Colorado Water Resources Research Institute has also provided assistance in supporting the continuing development of the input-output methodology as applied to water planning. The final editing for the report was by Mr. Charles D. Turner. The final typing was done by Miss Camille Susemihl.

The project staffing for Colorado State University was as follows:

Principal Investigator:	D. W. Hendricks, Associate Professor of Civil Engineering
Staff Engineers:	Ventura Bengoechea, Research Assistant John R. Blair, Research Assistant

The administration of the contract in behalf of the City of Fort Collins was as follows:

Contract Officer:	Roger Krempel, Director, Water Utilities Department
Contract Administrator:	Tom Hayes, Assistant Director, Water Utilities Department
Contract Assistants:	Dennis Bode, Water Resources Engineer, Water Utilities Department

GLOSSARY

RAW WATER: water in its natural condition, as it is available at the sources of supply.

FILTERED WATER: water that has passed through a water treatment plant in order to meet the drinking water standards.

WASTEWATER: water collected after use in the sanitary sewer system with different concentrations of contaminants.

EFFLUENT FROM WASTEWATER TREATMENT PLANTS: the outflow from the plants that has to meet the effluent discharge standards.

WATER RIGHT: the legal right to use water under the appropriation doctrine. The water rights is defined in time of use, place of diversion, and quantity of lfow by judicial decree.

EXCHANGE: concept by which the owner of a water right temporarily allows his particular water to be used by another water user. In exchange the first may diver the particular waters of the other. District water organizations often exchange water rights.

NEW FOREIGN WATERS: waters recently imported from another hydrologically unconnected basin. Under Colorado Water Law, total consumptive use can be made of these waters.

OLD FOREIGN WATERS: waters imported in the past which historically have produced a return flow that is now being appropriated by junior users.

EXCHANGE BANK: pseudo-element of the input-output model that accounts for the exchanges of water between the city and other users.

REUSE BANK: pseudo-element of the model that accounts for the part of the reusable water that is actually reused.

CONVERSION FACTORS

Capacity

ac-ft	mg	m^3	hm^3
1	0.326	1,234	1.234×10^{-3}
3.07	1	402	4.02×10^{-4}
8.11×10^{-4}	2.64×10^{-4}	1	10^{-6}
811	264	10^6	1

Discharge

mgd	cfs	ℓ/s	m^3/s
1	1.547	43.806	43.8×10^{-3}
0.646	1	28.317	28.3×10^{-3}
2.28×10^{-2}	3.53×10^{-2}	1	10^{-3}
22.83	35.31	1000	1

ABBREVIATIONS

ac	acre
ac-ft	acre-feet
CBT	Colorado--Big Thompson Project
cfs	cubic feet per second
CLP	Cache La Poudre
CSU	Colorado State University
EEP	Environmental Engineeering Program
EPA	Environmental Protection Agency
ft	feet
gal	gallons
gpcd	gallons per capita per day
hm	hectometer (100 meters square)
hm^3	cubic hectometers
ℓ/s	litres per second
m^3	cubic meters
m^3/s	cubic meters per second
MCM	million cubic meters (hm^3)
mg.	million gallons
mgd	million gallons per day
PRPA	Platte Rîver Power Authority
psi	pounds per square inch
sq ft	square feet
STP	Wastewater (Sewage) Treatment Plant
USBR	US Bureau of Reclamation
WTP	Water Treatment Plant

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PREFACE

The City of Fort Collins is located along the foothills of north central Colorado's Front Range at an elevation of about 5,000 feet. Water in this area is scarce due to an annual average precipitation of less than 15 inches. The city is the major municipal entity in a fast growing metropolitan area. This growth is occurring through the urbanization of agricultural lands. These lands were originally developed for irrigation over one hundred years ago by means of an intricate system of ditches and irrigation canals. The physical complexity of this system is matched by the legal complexity of the appropriation doctrine, the basis for Colorado's water law. Under this doctrine, the time, place, and quantity of water diverted for use is controlled in accordance with a system of adjudicated water rights. Most of Fort Collins' water collection facilities are shared with other users, making their operation dependent upon external factors. In addition, by the year 1985, zero discharge of pollutants has to be achieved at the STP in order to meet the goals set up by the Federal Water Pollution Control Act Amendments of 1972.

Water right acquisition, raw water collection, treatment distribution, and wastewater collection and treatment all combine to make the operation of the Fort Collins water system very complex. The goal of this study is to help in the management of the system. The input-output model represents the whole water system in a matricial format, showing the water transfers between the elements and depicting at the same time the structure of the system. The matrix model has been for the City of Fort Collins as a management and design tool for city personnel and elected officials. The matrix enhances and simplifies the analysis of different operation alternatives and the study of new elements to meet future needs.

In order to construct the matrix, the main objective of the study, it is necessary to know the input-output modeling methodology and the Fort Collins water system. The principal aspects of these two areas are reviewed in the first part of this study. Detailed information and the data is referenced in the appendices.

I. INPUT-OUTPUT MODELING

The first input-output model was developed by Leontief in 1936 for the economic system of the United States. One of the important aspects of the model is that it can be applied to any system of components having transfers of "matter" between them. This "matter" can be money, water, chemical elements, cells in a reactor, or any other accountable substance limited only to human imagination.

1.1 Input-Output Modeling in Water Resources

The present application of the input-output model to depict a water system is based upon previous studies done by the Environmental Engineeering Program at Colorado State University since 1975. Hendricks and DeHaan demonstrated the ability of Leontief's economic model to represent water systems. Following that study came two others for the South Platte River basin (Hendricks et al., 1977), and the Cache La Poudre River basin (Reitano and Hendricks, 1978). The first was done for the Omaha District U. S. Army Corps of Engineers for "strategic" planning purposes, dealing with different hydrological and population projections for the years 1980, 2000, and 2020.

The study for the Cache La Poudre demonstrated the applicability of the model for "tactical" level planning when more resolution is needed. To illustrated this point, the model for the Cache La Poudre River, a tributary of the South Platte River, has 123 elements. The South Platte model has only 86. Any one part of an input-output matrix model can be expanded to provide the level of detail that is desired.

The present model developed for the City of Fort Collins water system has 78 elements. The level of resolution includes the treatment facilities, the distribution system, and different sectors of the city (commercial, industrial, sanitation basins). The model has sufficient detail to be functional at the operational level.

1.2 Methodology of Input-Output Modeling

A simple model basin is used to demonstrate the input-output model concept. Figure 1.1 (a) represents the schematic of a basin with different sectors which will be interconnected. Figure 1.1 (b) is a linear diagram representation of that basin.

The first step is to define the boundary of our system and to select the degree of aggregation or resolution that we will consider. There will be elements within the boundary which are call "internal components." The remaining elements are called "entries" or "exits" depending upon their mission. Entries bring water into the system and exits take it out. Figure 1.2 represents these ideas scehmatically.

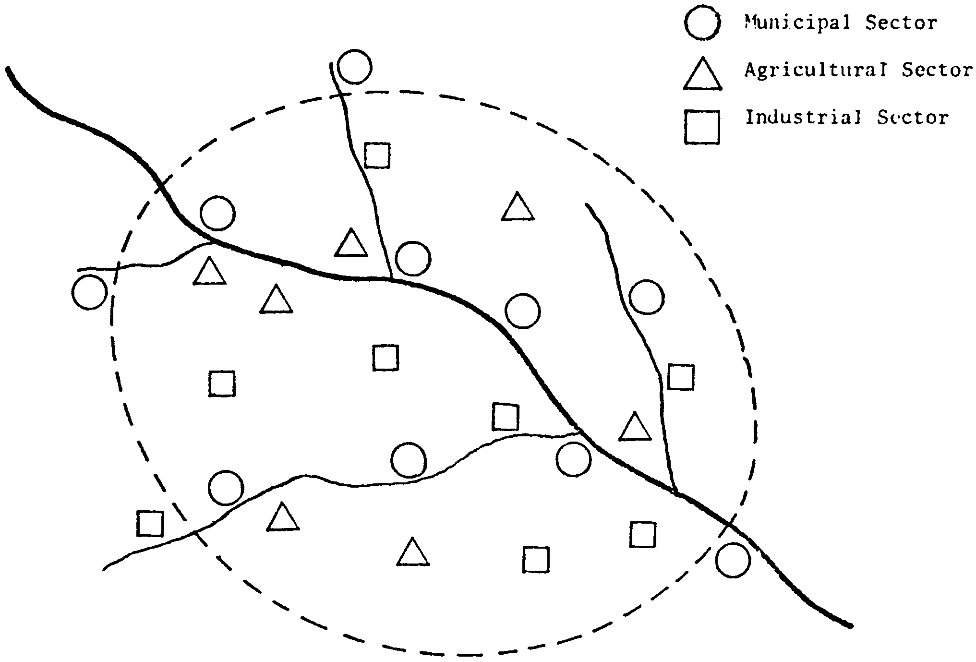


Fig. 1.1 (a) Schematic of a Basin.

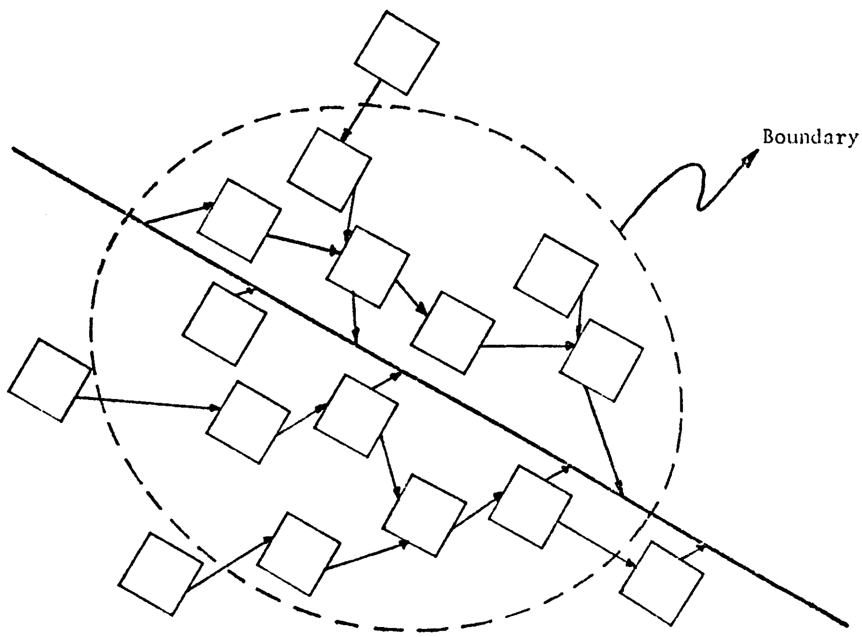


Fig. 1.1 (b) Linear Diagram Representation of a Basin.

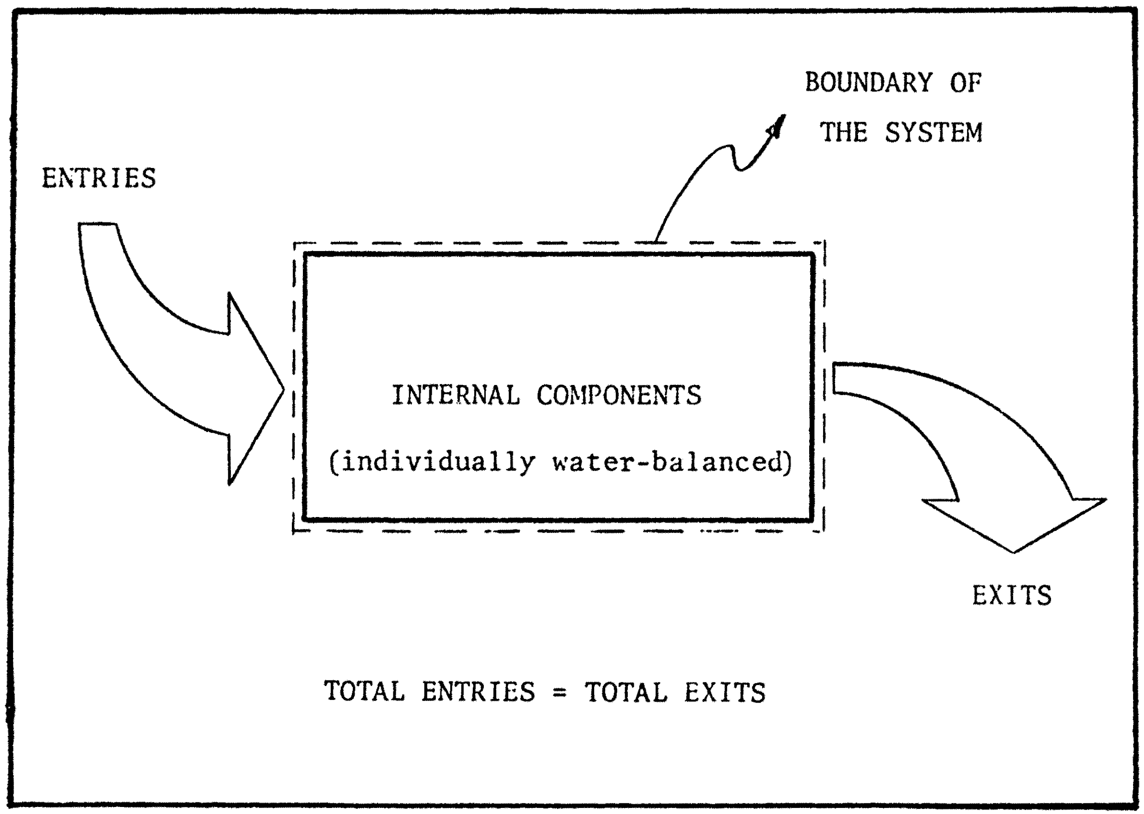


Figure 1.2 Principal Elements of the Input-output Model

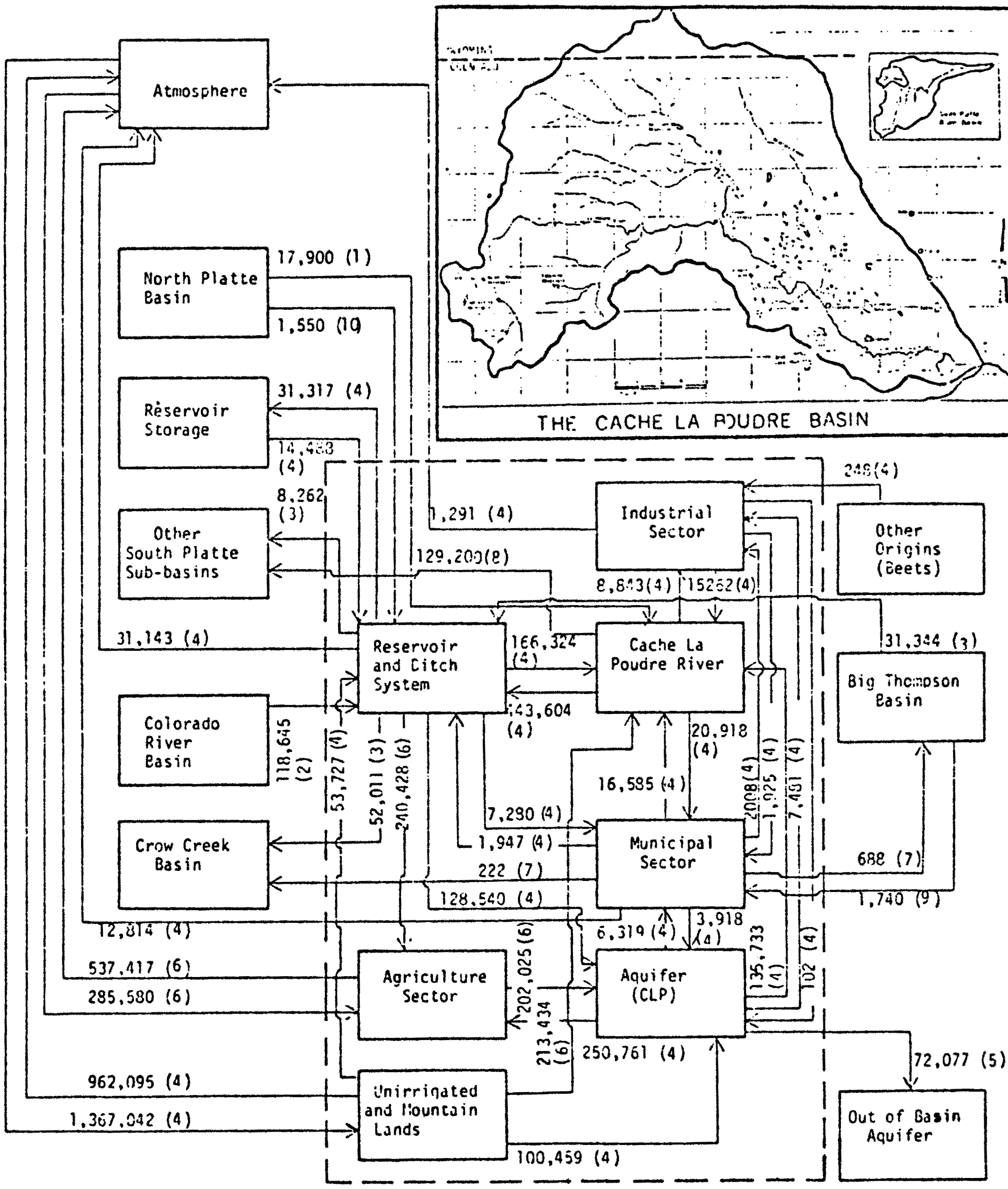
The fundamental principle of the input-output model is that it has to be mass balanced, in this case water balanced. The water cannot vanish, thus, for each internal component, the total amount of water received has to equal the total delivered. For the entire system, the total of entries must equal the total of exits.

When the number of components of the system increases, the linear diagram becomes a maze. As an example, let us consider an aggregated schematic of the Cache La Poudre River basin, Figure 1.3. This diagram with only 16 elements is rather confusing. Try to imagine the confusion when 123 elements are represented. It is obvious that another type of representation has to be utilized. Figure 1.4 represents the input-output matrix of the aggregated Cache La Poudre River basin. Although the entries and exits have been respectively embodied in single elements, the example is valid to show the simplicity of the input-output model.

Figure 1.5 shows an elemental input-output matrix, where the rows have been chosen as origins of water and the columns as destinations. Each intersection of row and column will represent a transfer of water from the row-element (origin) to the column-element (destination). The transfer will be an output from the first element and an input to the second. The entries are origins and thus are represented as rows. The exits, by the same token, will be destinations and represented as columns. The internal components present a dichotomy. Each component is both a destination and an origin of a water transfer.

To understand how the matrix operates, Figure 1.6 depicts the pathway of an ideal drop of water entering the system through C and leaving through Z, passing by the internal components 2, 4, and 7. With a coup d'oeil to the matrix we have all the transfers or possible transfers between the elements represented in a simple way. If the matrix has 100 elements, we could have 10,000 possible transfers.

Although the advantages of the matricial representation are evident, the structure of the system is better known with a linear diagram. In order to utilize this type of representation and at the same time avoid its unwieldiness in depicting large systems, each element of the system is represented individually. In this way, the advantages of both systems are realized. Figure 1.7 shows one element of the City of Fort Collins water system.



(1) Imports through Wilson Ditch and Laramie-Poudre Tunnel.
(2) Imports through Grand River Ditch and Colorado-Big Thompson Delivery System.
(3) Through irrigation ditches.
(4) Aggregated value of the exchanges between the related blocks.
(5) Computed through mass balance of the aquifer.
(6) See paragraph 5.4.3.
(7) See paragraph 5.2.3.
(8) Cache La Poudre discharge into South Platte River.
(9) See paragraph 5.2.2.
(10) Imports through Skyline Ditch.

Figure 1.3 Aggregated Scheme of the 1970 Water Transfers in Cache La Poudre Basin Water System (Reitano, 1978).

ORIGINS \ DESTINATION	TRANSBASIN DIVERSIONS	CACHE LA POUDR REACHES AND TRIBUTARIES	RESERVOIRS AND LAKES	DITCHES AND CANALS	MUNICIPAL SECTOR	INDUSTRIAL SECTOR	AGRICULTURE SECTOR AND OTHER LANDS	EXITS	OUTPUT TOTALS	USE TOTALS
ENTRIES	236,880	0	14,488	31,344	1,740	248	1,652,621	0	1,937,321	
TRANSBASIN DIVERSIONS	0	17,900	120,195	0	0	0	0	98,785	236,880	
CACHE LA POUDR REACHES AND TRIBUTARIES	0	926,948	33,655	409,949	20,918	8,843	0	134,537	1,529,513	8,843
RESERVOIRS AND LAKES (1)	0	230,229	9,785	206,965	6,319	7,481	220,699	134,537	816,015	232,081
DITCHES AND CANALS	0	71,828	277,607	45,443	7,280	0	233,163	60,273	695,594	233,163
MUNICIPAL SECTOR	0	16,585	3,972	1,893	80,849	20,008	0	13,724	119,031	28,206
INDUSTRIAL SECTOR	0	15,262	102	0	1,925	1,452	0	1,291	20,032	1,452
AGRICULTURE SECTOR AND OTHER LANDS	0	250,761	356,211	0	0	0	0	1,499,511	2,106,483	
INPUT TOTALS	236,880	1,529,513	816,015	695,594	119,031	20,032	2,106,483	1,937,321	7,460,669	503,745

(1) Aquifer is included among reservoirs.

Figure 1.4 Aggregated Matrix Representation of the Input-output Model of Cache La Poudre Basin Water System (Reitano,1978)

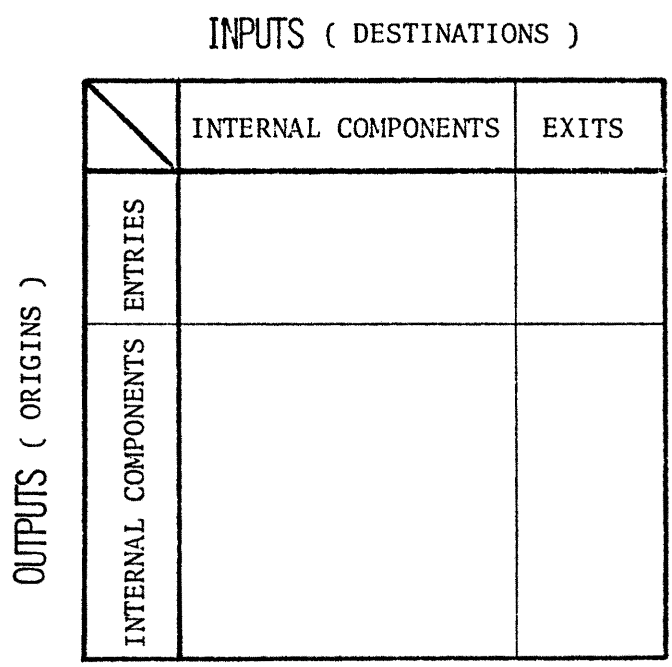


Figure 1.5 Representation of the Elements on the Matrix.

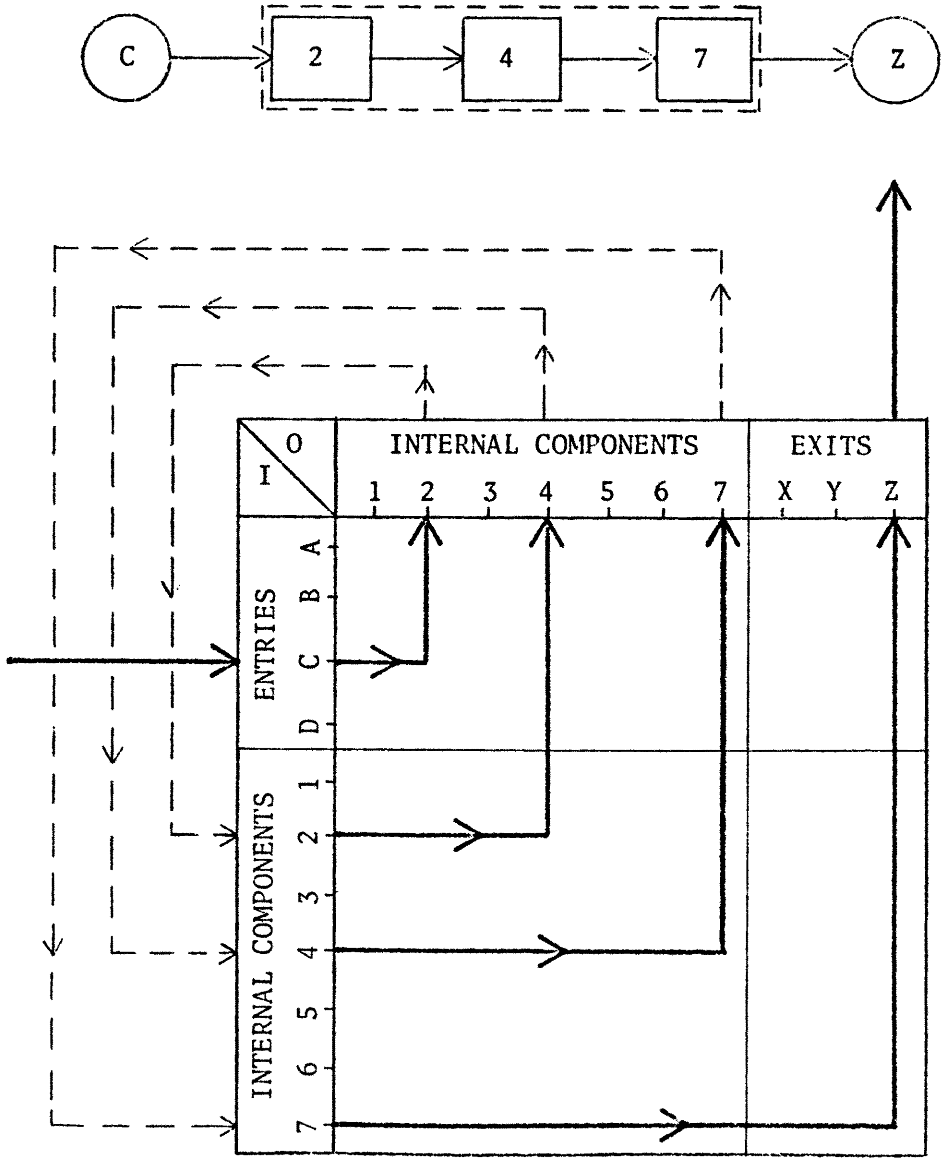
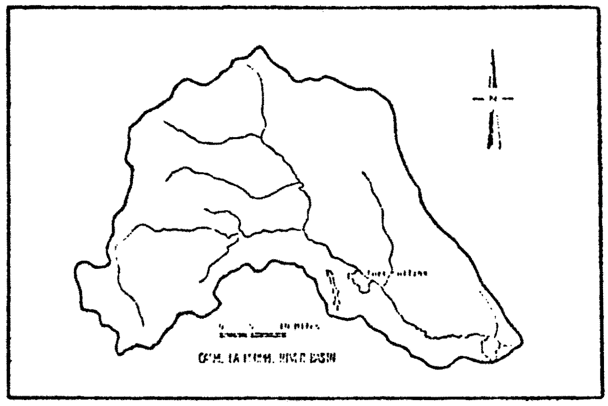


Figure 1.6 Schematic of Matrix Operation



Rights of Fort Collins
on CLP River
Direct Flow[1]

↓ 8,009[2]

Cache La Poudre River
(Source-mile 61)

[1] Table 4.1.

[2] Water balance at the water treatment plant No. 1.

Maximum Possible

15 cfs x 1.9835 ac-ft/cfs / day x 365 days/yr = 10,860 ac-ft/yr

4.93 cfs x 1.9835 ac-ft/cfs / day x 182 days/yr = 1,780 ac-ft/yr

TOTAL 12,640 ac-ft/yr
(15.6 MCM/yr)

Figure 1.7 Water Volumes Originated from Rights of Fort Collins on CLP River Direct Flow.

1.3 Display of the Input-Output Matrix

The matrix can be displayed in many different ways. For the final display, the Environmental Engineering Program at Colorado State University utilizes metallic magnetic boards attached to a wall. These boards measure eight feet by eight feet and have a one inch grid. Labels for the elements and numbers are made with three-quarters of an inch wide magnetic rubber strips. In order to give more resolution to the different subcategories, a color code is utilized. Letters and numbers are made with transfer lettering fixed to the colored strips. When the model was finished, several photographs were taken. After the photographs are taken, another alternative can be displayed by changing the appropriate magnetic strips.

The computer program IOPLOT was developed to display the South Platte River basin matrix. IOPLOT allows for a fast representation of the models for the various years with different hydrological conditions.

1.4 Input-Output Modeling of the City Water System

The application of the input-output model to a city water system has several points which must be emphasized in relation to the previous river basin applications.

First, the boundary needs to be defined. In the case of river basins, this component was chosen to coincide with the basin watershed. The present city model does not use the hydrologic basin as a boundary. Since the study is oriented towards operative purposes, the physical return of city water activities was selected as the boundary. All the elements where the city has control of operation are considered internal components. The elements bringing water to the system in a fixed or non-controllable amount are entries. Finally, the elements where the city discharges its water are the exits from the system.

Secondly, the "water" considered for the transfers on the previous models must be divided in different categories. There are four types: raw water, filtered water, wastewater, and the effluent of the wastewater treatment plants.

Finally, the local peculiarities of the system have significant influence in designing the model. All these points have been taken into account in the present study and are utilized in the construction of the model.

II. FORT COLLINS WATER SYSTEM

The most important points of the Fort Collins water system were briefly reviewed in the introduction. The system faces one of the highest population growth rates in the United States in a region with scarce water resources. The city is expanding over agricultural lands with a complex system of irrigation ditches and canals developed back at the turn of the century. In order to reach the zero discharge goal of the Federal Water Pollution Control Act of 1972, the wastewater treatment plants must be improved or alternative means of disposal must be found. At present, no large water-consuming industry exists in Fort Collins. Colorado State University was the largest water user in 1977. The University consumed 241 million gallons which represents about five percent of the total water distributed by the city. The remaining industries together consume less than the University. The city also serves water to other districts. These characteristics must be taken into account during the construction of the model. In order to make the system operative, only the water owned by the city is included in the model. This chapter describes the elements of the water system. More information can be found in the appendices.

2.1 Sources of Water

Under Colorado's "Appropriation Doctrine," the quantity of water available is regulated by water rights holdings. The city obtains most of its water from direct flow rights, shares of CBT water from the Northern Colorado Water Conservancy District, and shares of Water Supply and Storage Company and North Poudre Irrigation Company. Table 2.1 shows the values for 1977.

Besides these sources, the city owns shares in several irrigation companies, as presented in Table 2.2. Not all the water is useful for domestic purposes; some water can only be utilized for irrigation of parks and golf courses. This is indicated in the table. The water rights can be bought and sold similar to shares in the stock market. Therefore, the number of shares owned by the city is subject to change. In order to show the evolution of this market, two periods of time are shown on the table with the average yield per share.

The direct flow rights are utilized chiefly for domestic use and are diverted into the system at water treatment plant No. 1 "Poudre."

Table 2.1 Principal Sources of Raw Water for the City of Fort Collins, During 1977

--Direct Flow Rights

New Priority Number	Old Priority Number	Date of Appropriation	Amount (cfs)
14	1	6/1/1860	3.50 cfs
56	5	3/1/1862	2.15 *
58	6	3/15/1862	7.00
126	12	9/15/1864	2.78 *
140	14	5/1/1865	4.50
		Total	8,009 ac-ft

--Other Rights

--Colorado-Big Thompson Water	10,291 ac-ft
--Water Supply and Storage Company	893 ac-ft
--North Poudre Irrigation Company	4,031 ac-ft
Total	25,215 ac-ft

*Diversion limited to April 15 through October 15.

Table 2.2 Number of Shares, Average Yield and Expected Volume of Water Owned by the City of Fort Collins

	Number of Shares as of:		Average Yield	Volume
	Feb. 2, 1977	Apr. 20, 1978	ac-ft/share	Expected
Pleasant Valley and Lake Canal	78.750	100.0050	39.7	3,119
Larimer County Canal No. 2	17.2688	32.5022	42.7	737
New Mercer Ditch Company	13.6434	10.4670	30.2	412
North Poudre Irrigation Company	839.7500	839.7500	5.6	4,703
Taylor and Gill Ditch Company*	0.0625	0.0625	48.5	3
Dixon Lateral Ditch Company*	3.8000	4.8000	4.4	17
Harmony Lateral*	1.7500	1.7500	4.5	8
Warren Lake*	34.7166	36.3832	10.0	347
Sherwood Irrigation Company*	0.4375	0.4375	4.3	2
Water Supply and Storage Company	9.9170	10.4200	107.0	1,061
Arthur Irrigation Company	62.2242	57.1167	3.4	212
Horsetooth Reservoir (CBT)	10,291 units	10,292 units	0.78	8,027
Josh Ames	424 certificates	1,163 certificates	--	--
		Total		18,648

*Useful only for irrigation of parks, golf courses, and the like.

Waters from Horsetooth Reservoir are regulated by the Northern Colorado Water Conservancy District. The CBT system diverts water from the Colorado Riber basin at Grand Lake via the Adams Tunnel to Horsetooth and Carter Reservoirs for storage. During wet years, such as 1978, deliveries to CBT share holders are reduced to an average of 70 percent. The excess water is used to fill up the reservoir. Then in drought years, as 1977, water is delivered at 100 percent thereby offsetting the effect of the drought. Horsetooth Reservoir acts as a giant buffer for the Cache La Poudre System. The total reservoir capacity is divided into 310,000 units with a nominal value of one acre-foot. A policy exists for assessing different prices to the water utilized by lower-rate users (agriculture) or by higher-rate users (municipalities).

The city does not have storage rights at Horsetooth Reservoir. Therefore, the amount of water not withdrawn during any one year cannot be carried over to the next year. The city has storage capacity at Joe Wright Reservoir. The reservoir is located on Joe Wright Creek in the upper Cache La Poudre Basin close to Cameron Pass (Figure 2.1). This reservoir captures waters from the Cache La Poudre River watershed and waters imported through the Michigan Ditch. The foreign water (Michigan Ditch) is available for reuse. At the present time, work to enlarge Joe Wright Reservoir is being completed.

Waters owned in the other irrigation companies, are in general downstream from both water treatment plants and hence cannot be directly utilized. In order to resolve this problem, the waters owned by the city are exchanged for waters held upstream from the water treatment plants by another user. The exchanges are possible under proper flow conditions in the system. In general, the city arranges these exchanges with the irrigation companies, giving up some volume of water for possible losses and the exchange agreement. In the case of Water Supply and Storage Company, this amount is twenty percent.

2.2 Water Treatment Distribution

The city has two water treatment plants. Plant No. 1 "Poudre" was constructed in 1904 and is located at river mile 61, about 11 miles northwest of the city. The capacity of the plant is 20 million gallons per day. Water treatment plant No. 2 is located below Soldier Canyon Dam and is fed with waters from Horsetooth Reservoir. The plant has been operating since 1970. In 1976 tube settlers were installed in the clarifiers and the filter media was changed. Capacity was increased from 16 to 24 mgd. At the present, the inlets to the plant are being enlarged to allow for future expansions. This will raise the present capacity of 32.8 cfs to 314 cfs or 203 mgd. At the present, the plant is operated to meet peak-demands. The plants require about 1 mgd of water for backwashing the filters. The backwash water is discharged into settling ponds and then recycled through the plant.

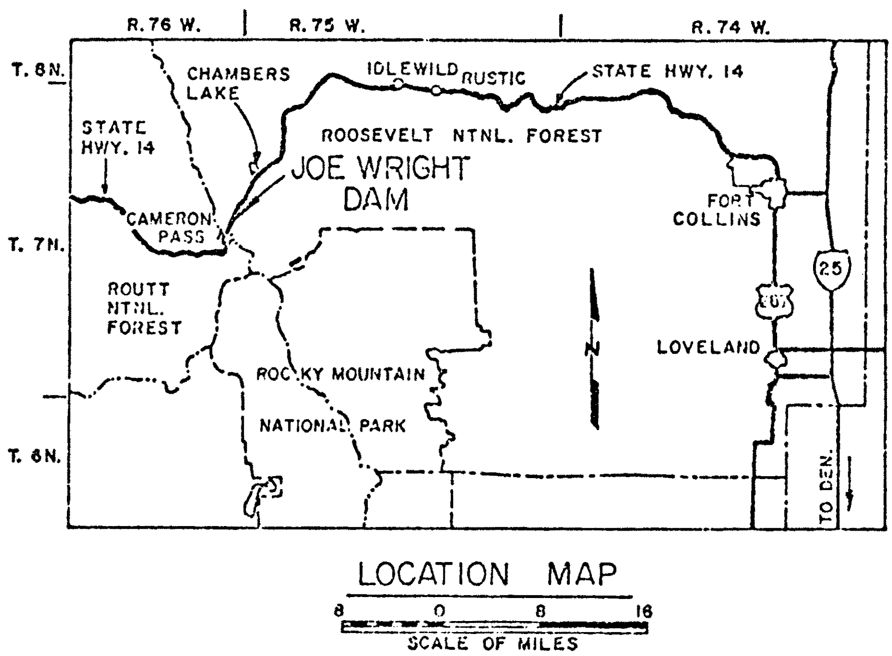


Figure 2.1 Location of Joe Wright Reservoir

Treated waters from both plants are temporarily stored for distribution in two water storage reservoirs at Bingham Hill and Soldier Canyon. The total capacity of the reseroivrs is about 40 million gallons. This volume is much lower than optional for Fort Collins' water supply system.

The distribution system is looped. The main diameters vary from 4 to 42 inches with pressures up to 100 psi. The pressure is checked by the fire department using the fire hydrants under two different conditions: static and flowing. These values are used as input data for computer design of the new mains and replacement of old ones. A schematic of the system is shown in Figure 2.2.

2.3 Wastewater Collection and Treatment

The sanitary sewer system collects the wastewater from eleven subbasins, from Laporte to south of Warren Lake (Figure 2.3). The diameters of the pipes range from 10 to 30 inches. The sewers discharge into two wastewater treatmtent plants which are connected by an interceptor. The sewer system has a high infiltration rate. During the summer, the infiltration rate can reach 50 percent of the total flow. During the winter, it is estimated at 10 percent.

The city has two wastewater treatment plants providing secondary treatment. The oldest, STP No. 2, was built in 1948 and is located just north of Highway 14 on the Cache La Poudre River. It consists of two settling basins and a trickling filter. Wastewater from Laporte Water and Sanitation District, Northwest Basin, Cherry Hills Basin, Mountain View Sanitation District, North Central Basin, and South Central Basin are collected at STP No. 1. The maximum capacity is fixed at 6 mgd. All sewage in excess of this value goes directly to the interceptor and onto STP No. 2. The treated effluent is discharged to the river.

Wastewater Treatment Plant No. 2 is located at Drake Road and the Cache La Poudre River between Fossil Creek Reservoir Inlet and Boxelder Ditch. The older part of this plant, which at the present time is not utilized became operative in 1968 with an average design flow of 4.5 mgd. THe old part consists of settling basins and an activated sludge process. A new plant was built just north of the first one for an average flow design of 12 mgd. The new facility began operations in January 1977. The plant consists of grit chamber, primary and final settling, activated sludge process and chlorine contact basins. The detention time at the aerators has been increased in order to take care of the nitrification. The plant treats wastewater from Spring Creek Basin, Drake Basin, Horsetooth Basin, Warren Lake Basin, and the interceptor from plant No. 1. The effluent is discharged either to Fossil Creek Reservoir Inlet Canal or by means of a syphon under this canal, to the Cache La Poudre River.

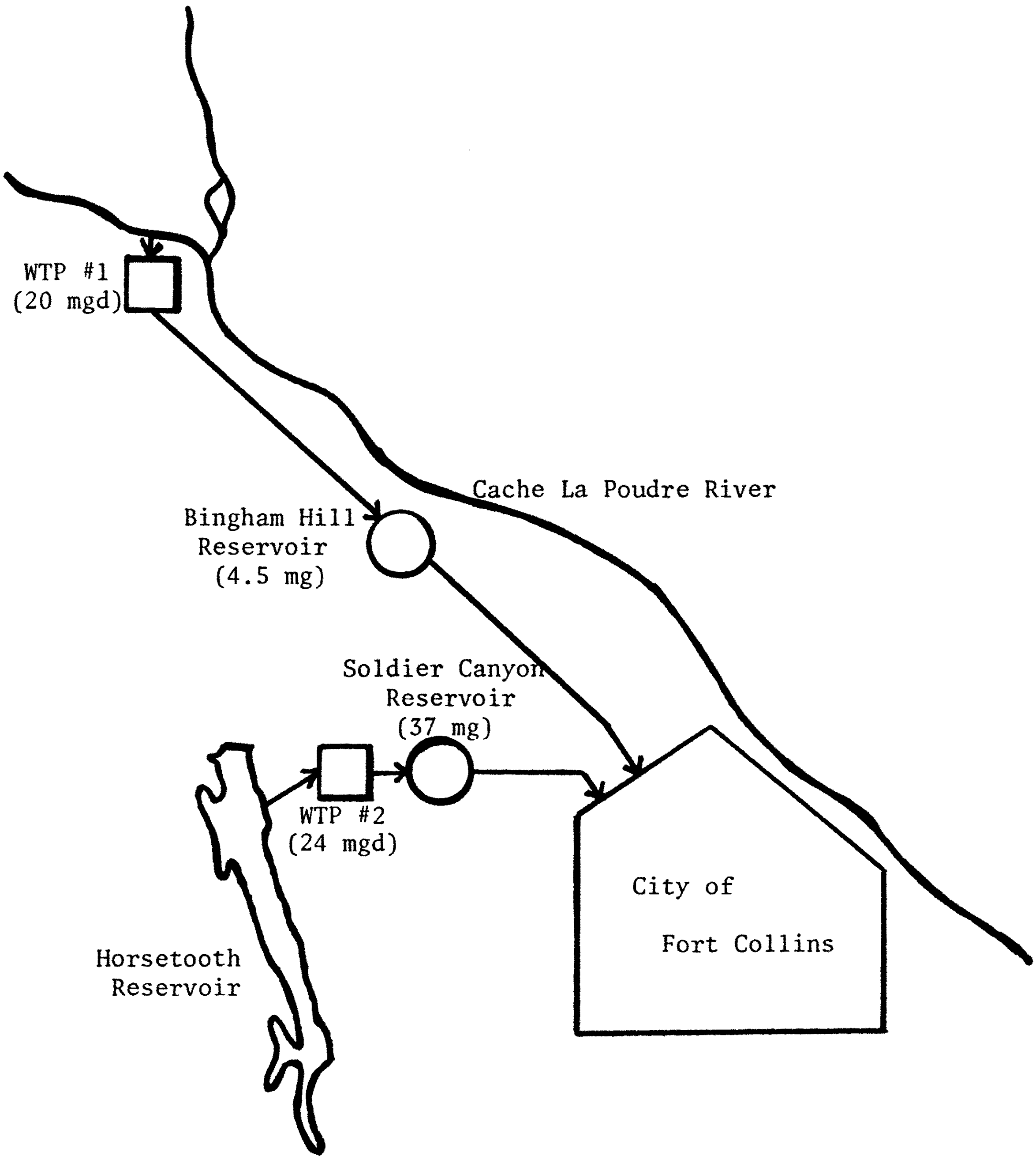


Figure 2.2 Schematic of Water Treatment Facilities

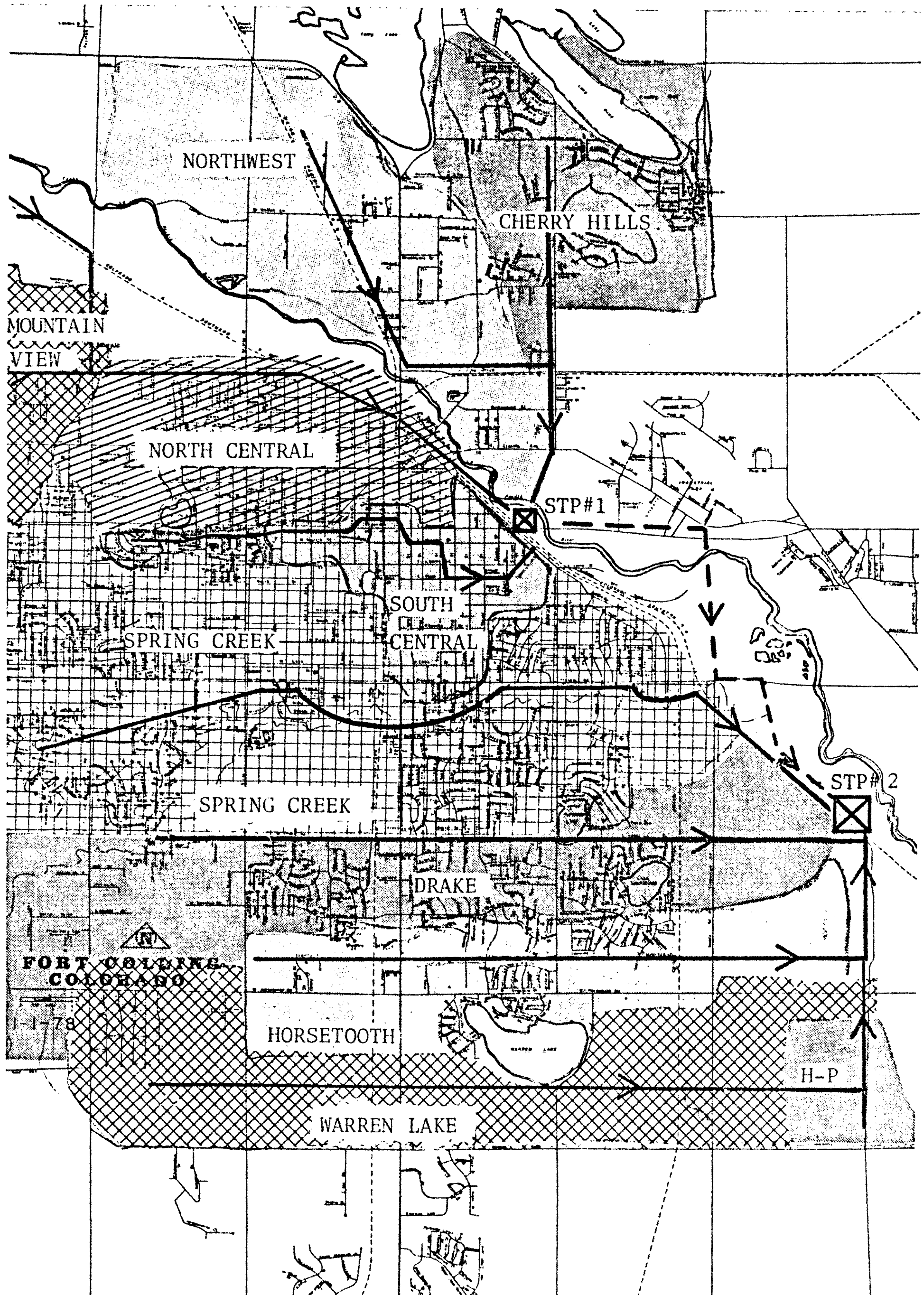


Figure 2.3 Sanitation Basins and Trunk Lines

2.4 Effluent Discharge

At the present the efflunet can be discharged directly from both plants to the Cache La Poudre River. Wastewater treatment plant No. 2 can also discharge Fossil Creek Reservoir Inlet and reservoir. A schematic of the whole system is shown in Figure 2-4.

2.5 Operation of the System

The Fort Collins water system has challenging operational problems because of water right's priorities and the systems interconnenction with the irrigation facilities. The operational characteristics of the system are reviewed in the following paragraphs.

2.5.1 *Distribution of Supply*

The waters owned by the City of Fort Collins are both "native" and "foreign." The native waters come from the Cache La Poudre River basin. The foreign water comes from the Colorado River basin, the Laramie River basin, and the North Platte River basin. The manner in which the native and foreign waters are mixed in the city water supply is not provided. The relative properties of each is a function of the amounts of foreign and native waters owned by the irrigation companies and the amount of CBT shares owned by the city.

When a direct flow right (vis a vis water available through CBT shares owned) is not high enough on the priority list to receive water, the entire rights is lost. This causes difficulties in forecasting water supply for the year. Water owned at the irrigation ditches may be forfeited even though it is physically available. Diversion of water at the time needed or at locations required may not be possible.

2.5.2 *Time Distribtuion of Demand*

Two different periods of time must be considered: annual period where the demand will be by months and a day period divided into hourly intervals. The annual demand period includes seasonal variations in water demand and determines the amount of raw water needed. There are two characteristics of annual water demand in Fort Collins: instanteous changes in the student population and the seasonal increase of water demand from May to September for water purposes. The student summer exodus, compensates in part for the lawn irrigation demand period (Figure 2.5).

Daily demands determine distribution system design. Peak-demand hours are critical. To meet daily demands, it is important to have adequate filtered water storage available in order to keep WTP output as steady as possible. Figure 2.6 presents a typical 24-hour demand ddistribution curve. Table 2.3 shows the maximum peak-demand day for the last eights years.

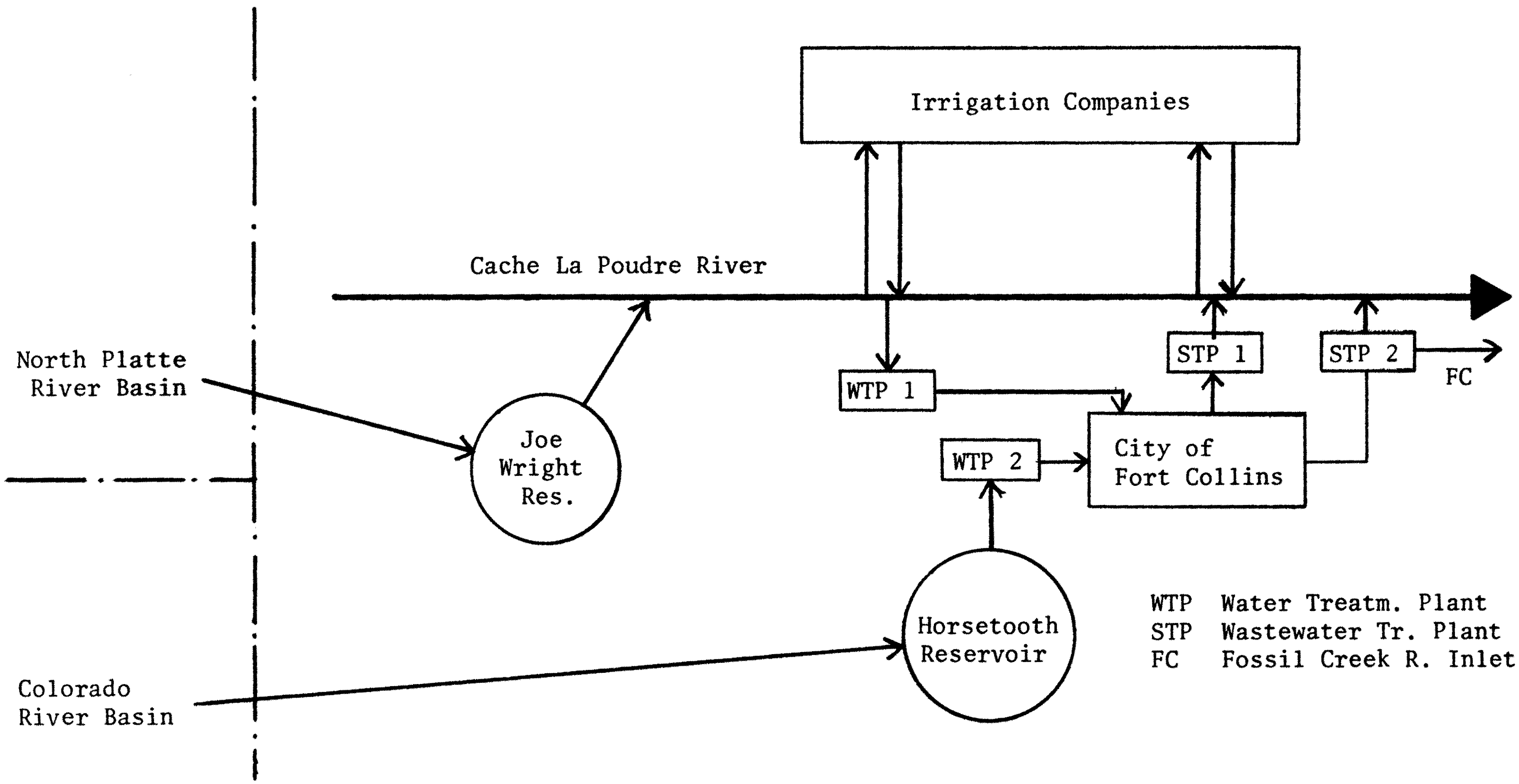


Figure 2.4. Schematic of Fort Collins Water System

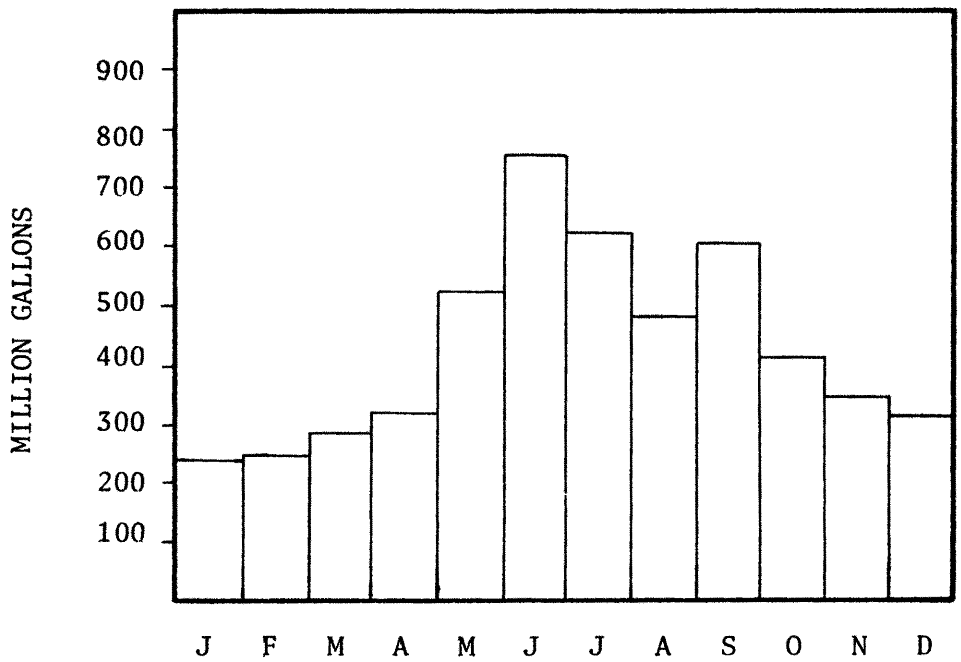


Figure 2.5 Water Demand for 1977 (Derived from records of the volume of water treated through both Water Treatment Plant No. 1 and Water Treatment Plant No. 2).

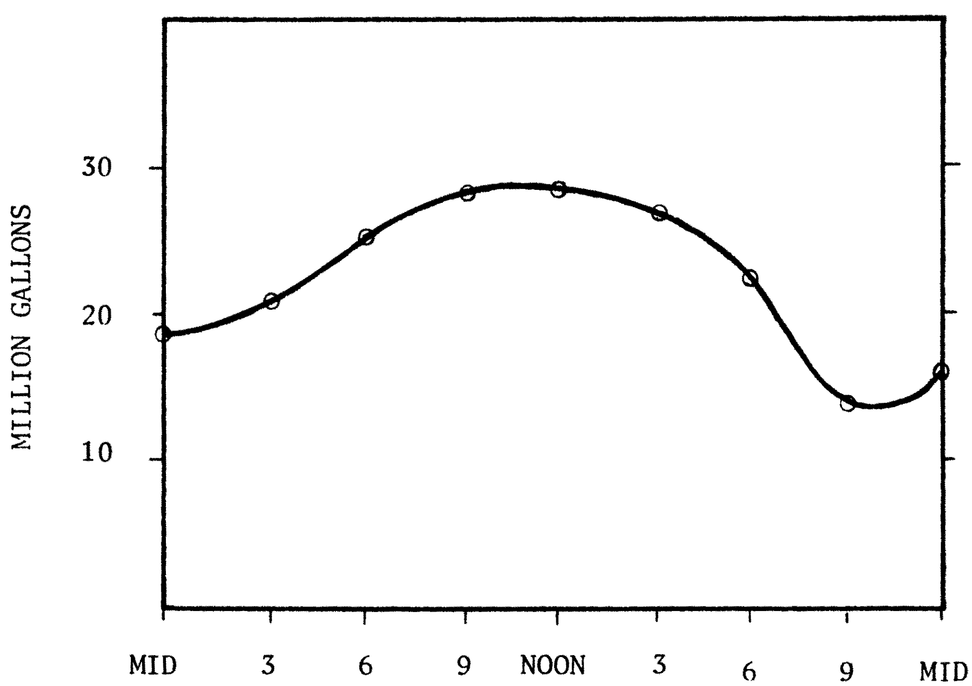


Figure 2.6. Demand Curve Corresponding to July 26, 1978, Fort Collins City Water System.

Table 2,3 Maximum Peak-Demand During a Day Fort Collins Water System

Year	Maximum Demand (MGD)
1970	27,08
1971	28,38
1972	27.67
1973	31,70
1974	34,30
1975	37.00
1976	35.60
1977	37,50

2.5.3 *Exchanges*

Special elements for the model are introduced here in order to deal with special characteristics of the system and/or system operation. The exchanges of water owned by the city with other users are included in a pseudo-element: "Exchange Bank." Figure 2.7 shows how the real volumes of water are flowing and the system exchanges of water rights. Exchanges are handled in the model through the Exchange Bank.

Although the input-output is an accounting model, it depicts indirectly the structure of the system. If the pseudo-element is not used, there are two alternatives: (1) to show the transfers as flowing directly from the shares owned on irrigation companies to the water treatment plant, or (2) to include the agricultural users as an internal component. By using the first alternative, the model loses its ability to depict the system. The second alternative contradicts the definition of internal components as elements over which the city has control.

For accounting purposes, the use of the pseudo-element is acceptable. A lack of "initial understanding" might be the only problem encountered. The other pseudo-element is the "Reuse Bank." The "Reuse Bank" works the same as the Exchange Bank. Volumes of reusable water utilized more than one time are taken into account within this element.

2.5.4 *Lease-Backs to Agriculture*

The city owns, under regular hydrological conditions, an amount of water above its annual demand. This excess of water cannot be stored because of legal restrictions and the lack of storage reservoirs. The excess water is sold in part to agricultural users and in part is forfeited. The city annually renews certain lease-back agreements. The lease-backs are with agriculural users, and a price break is given on renewal agreements. Most of these agreements expire at the beginning of 1980 while a few remain operative until January, 1983. Table 2.4 summarizes the lease-back agreements totaled for the irrigation companies in which the city has shares.

Table 2.4 Lease-Back Agreements as of December 1977

Origin of Water Utilized	Shares Leased	Average Volume of Water (ac-ft)
North Poudre-Irrigation Co.	348	1,949
Colorado-Big Thompson		274
Pleasant Va-ley and Lake Canal Company	4.6417	184
Larimer County Canal No. 2 Company	2.7123	116

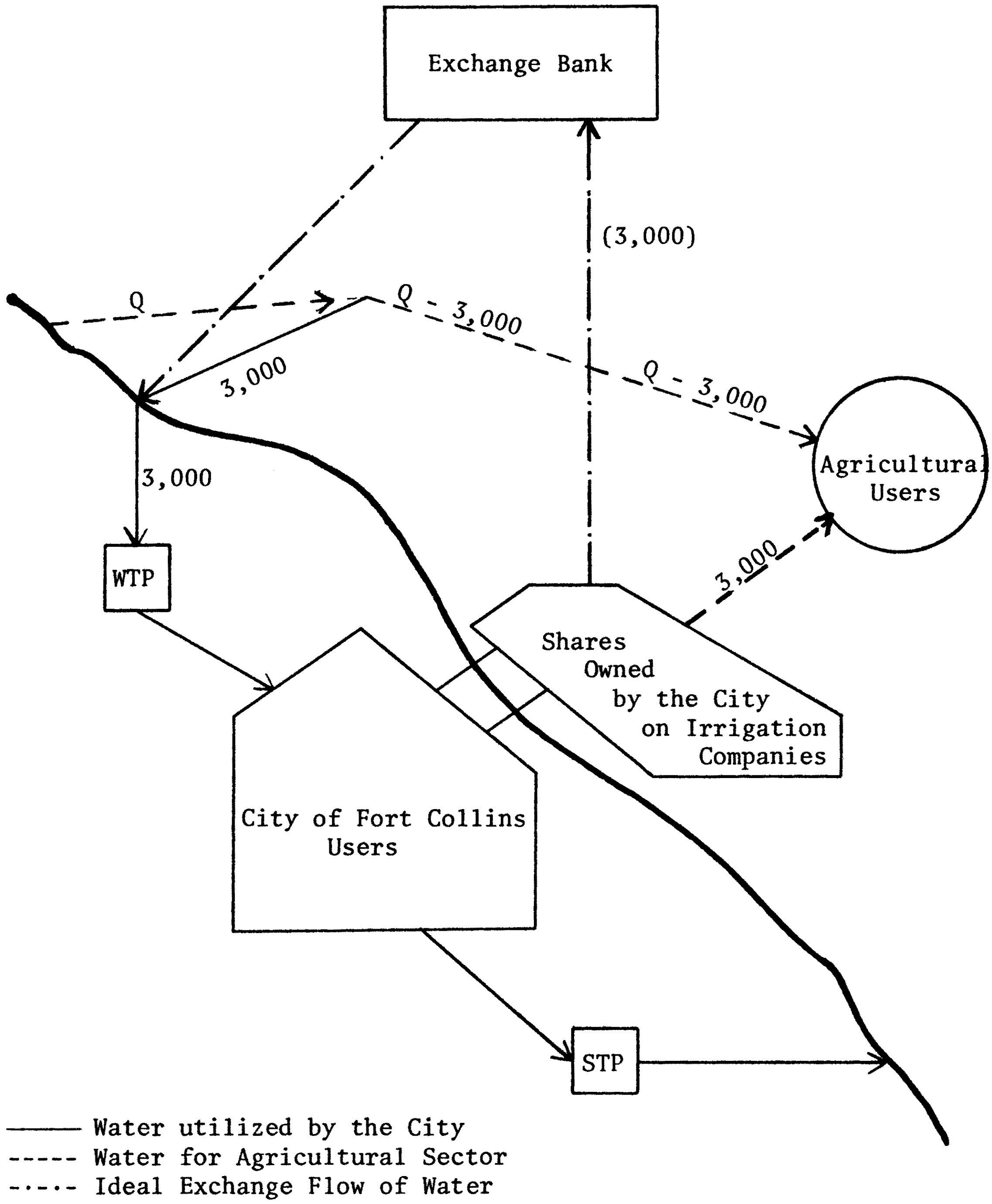


Figure 2.7. Schematic of Exchanges City - Agricultural Users

2.6 Alternatives for the Future

The model includes several future alternatives. Some of them are more feasible than others. The alternatives are clearly identified in the matrix with asterisks and in the linear diagrams with dashed lines. The information on the alternatives is contained in Appendix G.

III. CONSTRUCTION OF THE MODEL

The steps necessary to build the model are: (1) select the elements of the system; (2) find out the value of the transfers between the elements selcted; (3) display all this information on the input-output matrix. The values collected or assumed for the construction of the model are in Appendices A and H.

The aggregated Fort Collins Water System is used as an example of the model operation. A step by step alternative of reuse is presented to illustrate this operation.

3.1 Elements of the Model

Most model elements are shared between the city and other users. For the purpose of this study, it was necessary to decide between two alternatives: to include "all the water" or to consider only that part of the water owned by the city. The use of the first alternative introduces water not owned by the city into the model. In this way the model loses the desired operative qualities.

The use of the second option, considering only the part of the total water owned by the city, makes the model completely operative. According to our main objective, this alternative was chosen.

3.1.1 Boundary

Most of the internal components selected for this model (see Matrix of Appendix A) are circumscribed by a large circle around the city limits. Michigan Ditch and Joe Wright Reservoir are the most distant.

3.1.2 Entries

The water brought into the Fort Collins water system is subject to water rights holdings. Depending on the priority order, the right of appropriation can be lost sooner or later during adverse hydrological conditions. The entries have 10 elements in this model.

1. In-basin runoff. Under appropriation doctrine, the waters from runoff are appropriated. The only exception that can be considered is the right on "in-basin flood waters." These waters have not been historically used and therefore no return flows are expected. It is for this reason that Fort Collins attempts to make total consumptive use of flood waters. The only element of the system that can be benefited by these waters is Joe Wright Reservoir.

2. Imported Water. Imported or foreign water is classified into new and old. The new foreign water under Colorado Water Law can be total consumptively used. Appropriators on a stream have no vested right to a continuance of the importation of foreign water which another has brought into the watershed.

New foreign waters to Fort Collins are expected from Michigan Ditch and from Windy Gap Project. The first 1,000 acre-feet coming through Michigan Ditch and waters owned in different irrigation companies are considered to be old foreign waters.

3. River Direct Flow. The rights on the Cache La Poudre River are considered to be direct flow rights as shown in Table 2.1.

4. Water Rented. Fort Collins rents some waters to other users and to irrigation companies.

5. Raw Water Reservoir Storage. The only storage reservoir of the city is Joe Wright Reservoir near Cameron Pass.

6. Filtered Water Reservoir Storage. For the annual basin model, this element is not important.

7. Infiltration into the Sewer System. The superintendent of the wastewater treatment plants estimates that 10 percent of the total sewage flows during the winter months and 50 percent during the summer are due to infiltration.

8. Particular Elements. The city obtains some of its water from shares held in irrigation companies enumerated in Table 2.2 and from shares shares of CBT water which is administered by the Northern Colorado Water Conservancy District.

3.1.3 Internal Components

There are 55 internal components in the present model classified in the following subcategories:

1. Raw water transport and storage facilities
2. Water treatment plants
3. Filtered water reservoir storage
4. Filtered water distribution system
5. Users (divided into sectors)
6. Sewage trunk lines
7. Wastewater treatment facilities

3.1.4 Exits

There are 13 elements as follows:

1. Main diluting body. The Cache La Poudre River is the main diluting body and has been dividied in two reaches--from mile 61 (water treatment plant No. 1) to mile 47 (wastewater treatment plant No. 2); and from mile 47 to mile 00. The lower reach receives effluent from wastewater treatment plant No. 2 and indirectly from the effluent discharged to Fossil Creek Reservoir Inlet after it passes through the reservoir.

2. Groundwater. Most of the water comes from irrigation of parks and private lawns.

3. Atmosphere. The water is evaporated almost exclusively from the irrigation of lawns since the city's only reservoir, Joe Wright, is in the mountains.

4. Water Sold to Other Districts. The city sells water to West Fort Collins. Laporte, although outside of the city limits, receives the water as a regular city district.

5. Land Treatment. Land treatment is considered a potential treatment alternative.

6. Raw Water Storage. Joe Wright Reservoir is Fort Collins' only raw water storage facility.

7. Filtered Water Storage. As mentioned before, for an annual model, this element is not required.

8. Water Forfeited Without Use. This is important because the principal of beneficial use is attached to water rights; therefore, water not utilized can be lost after a determined period of time.

9. Particular Elements. This includes the water rented to agricultural users; the Fossil Creek Reservoir Inlet; the future Rawhide Project discussed in Appendix G; and the water forfeited in exchange agreements.

3.2 Example of Operation of the Model

This example is divided into two parts. The first displays the input-output matrix of an aggregated Fort Collins water system. The second shows the operational steps when the model is modified.

3.2.1 Display of the Model

In order to understand the matrix display and the isolation of elements from the linear diagram, an aggregated Fort Collins water system is used (Figure 3.1).

OUTPUTS \ INPUTS	MICHIGAN DITCH	JOE WRIGHT RES.	CLP (source-61)	HORSETOOTH RES.	IRRIGATION COMPANIES	EXCHANGE BANK	REUSE BANK	WTP NO.1	WTP NO.2	USERS	STP	GROUNDWATER	CLP (mile 47-00)	LAND TREATMENT	RENTED TO AGRIC.	REUSABLE WATER RESERVOIR STOR.	NONREUSABLE W. RESERVOIR STOR.	OUTPUT TOTALS
RIGHTS ON CLP DIRECT FLOW			14,000															14,000
RIGHTS ON NEW FOREIGN WATER	1,500																	1,500
RIGHTS ON CBT WATERS				10,000														10,000
REUSABLE WATER RESERVOIR STOR.		500																500
NONREUSABLE W. RESERVOIR STOR.																		0
MICHIGAN DITCH		1,500																1,500
JOE WRIGHT RES.			1,800													200		2,000
CLP (source-61)					4,000			11,800										15,800
HORSETOOTH RES.									9,400						3,600			13,000
IRRIGATION COMPANIES						3,000									1,000			4,000
EXCHANGE BANK				3,000														3,000
REUSE BANK																		0
WTP NO.1										11,800								11,800
WTP NO.2										9,400								9,400
USERS											15,500	5,700						21,200
STP													12,200	3,300				15,500
TOTAL INPUTS	1,500	2,000	15,800	13,000	4,000	3,000	0	11,800	9,400	21,200	15,500	5,700	12,200	3,300	4,600	200	0	123,200

Figure 3.1. Input-output Matrix of the Simplified Model of Fort Collins Water System.

3.2.2 *Operation*

This example explains the utilization of the matrix for an operational alternative. For this purpose the reuse alternative was selected. A 70 percent return flow from the city is used.

1. Amount of Reuse. The total amount of water available for reuse in the system is:

Entry of new foreign water	1,500 ac-ft
Reusable water at storage	500 ac-ft
Reusable water at the end of period	200 ac-ft

Total water available 1,500 + 500 - 200 = 1,800 ac-ft

assuming 30% consumptive use:

$$\frac{30}{100} \times 1{,}800 = 540 \text{ ac-ft}$$

thus water available for reuse 1,800 - 540 = 1,260 ac-ft

Use 1,200 ac-ft for this example.

2. Steps followed. A step by step process is followed for a clearer understanding. The final figures are shown in Figure 3.2.

a. The reuse water will be taken from the effluent of the wastewater treatment plant; therefore, it must be subtracted from the exits. Water discharged to the Cache La Poudre River must be reduced.

water discharged to CLP River	12,200 - 1,200
water sent to reuse	1,200

Note that the total water originating at the wastewater treatment plant remains constant.

b. In order to treat this water, it is necessary, following the methodology of the system, to exchange it with another user. Therefore, from the "Reuse Bank" the 1,200 acre-feet are sent to the "Exchange Bank." For simplification, let us assume that no exchange agreement is necessary.

c. The 1,200 acre-feet in excess at the Exchange Bank will be sent to Horsetooth Reservoir.

d. From Horsetooth Reservoir the extra 1,200 acre-feet are sent to WTP No. 2.

e. Once treated the water is delivered to the users.

OUTPUTS \ INPUTS	MICHIGAN DITCH	JOE WRIGHT RES.	CLP (source-61)	HORSETOOTH RES.	IRRIGATION COMPANIES	EXCHANGE BANK	REUSE BANK	WTP NO.1	WTP NO.2	USERS	STP	GROUNDWATER	CLP (mile 47-00)	LAND TREATMENT	RENTED TO AGRIC.	REUSABLE WATER RESERVOIR STOR.	NONREUSABLE W. RESERVOIR STOR.	OUTPUT TOTALS
RIGHTS ON CLP DIRECT FLOW			14,000															14,000
RIGHTS ON NEW FOREIGN WATER	1,500																	1,500
RIGHTS ON CBT WATERS				10,000														10,000
REUSABLE WATER RESERVOIR STOR.		500																500
NONREUSABLE W. RESERVOIR STOR.																		0
MICHIGAN DITCH		1,500																1,500
JOE WRIGHT RES.			1,800													200		2,000
CLP (source-61)					4,000			11,800										15,800
HORSETOOTH RES.									+1,200 9,400						3,600			+1,200 13,000
IRRIGATION COMPANIES						3,000									1,000			4,000
EXCHANGE BANK				+1,200 3,000														+1,200 3,000
REUSE BANK						+1,200												+1,200 0
WTP NO.1										11,800								11,800
WTP NO.2										+1,200 9,400								+1,200 9,400
USERS											+840 15,500	+360 5,700						+1,200 21,200
STP							+1,200						-1,200 12,200 +840	3,300				+840 15,500
TOTAL INPUTS	1,500	2,000	15,800	+1,200 13,000	4,000	+1,200 3,000	+1,200 0	11,800	+1,200 9,400	+1,200 21,200	+840 15,500	+360 5,700	-360 12,200	3,300	4,600	200	0	+6,840 123,200

Figure 3.2. Matrix of the Simplified Model after a Complete Loop for an Alternative of Reuse.

f. The users return 70 percent (840 ac-ft) to the sewers, but 30 percent (360 ac-ft) will be consumptively used being represented in this simplified model as an exit through groundwater.

g. The 840 acre-feet will arrive at the wastewater treatment plant and from there can be discharged to the river.

Note in Figure 3.2 that all the elements affected by this operational loop are again water balanced. After this operation another reuse cycle could be made.

The matrix can answer another question. If more water is needed for the users, the souces or supply are the two water treatment plants. At plant No. 2, the water supply source is Horsetooth Reservoir. Looking now at the Horsetooth column, water is received from the rights on BCT waters and from the Exchange Bank. CBT rights are fixed so in order to increase the amount of water, exchange should be increased. Another possibility is to look at the row of Horsetooth and see that the outputs flow to the water treatment plant No. 2 and to agricultural users. Hence, another possibility to increase the volume of water going to the plant is to reduce, in the same amount, the water leased to agriculural users.

3.3 Matrix of the System

The matrix of the whole system for the water year 1977 is shown in Figure 3.3. The matrix is complemented with the display of the individual elements in Appendix A.

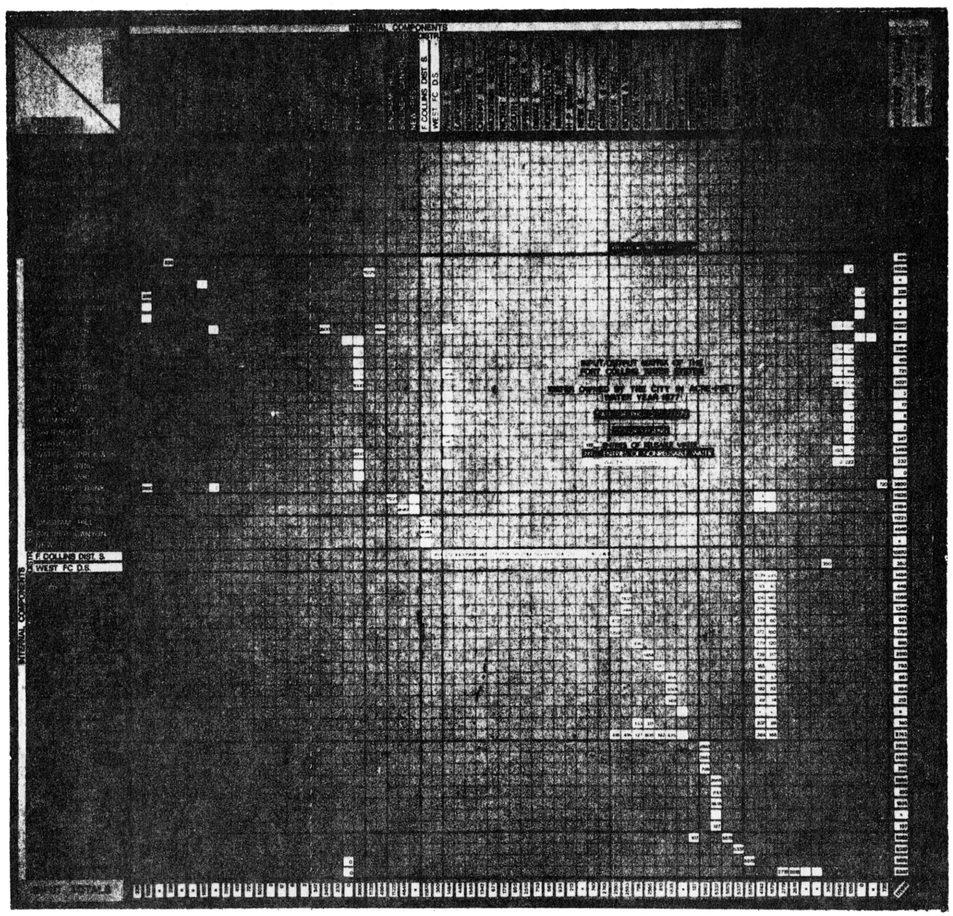


Figure 3.3 Input-output Matrix of the Fort Collins Water System for the Water Year 1977.

IV. CONCLUSIONS AND RECOMMENDATIONS

The 1977 input-output model constructed to depict the water system of the City of Fort Collins ties together the various components of the system, showing quantitative interactions. The matrix itself is complimented by the set of water balance diagrams for each component, shown in Appendix A, and the narrative text. Each of these parts-input/output matrix, the water balance diagrams, and the test-are necessary to each other. Together they provide a convenient reference document, facilitating easy access to either specific information about any one component of the system or about the interactions within the system.

The 1977 input-output model and the associated water balance diagrams provide a basic structure of information which can be updated easily to accommodate changes which are contemplated as well as those which actually occur. Further, as familiarity is gained with the input-output model and the component diagrams, improvements and changes may be desired by the users in order that they function in the most useful manner. To facilitate this it is recommended that the City purchase a magnetic board and construct their own matrix. The present matrix, for example, could be expanded to show the manner in which various ditch companies procure their water prior to delivery to the city. With such an expansion, the City could determine easily the supplies remaining in the ditch company, and then in the stream from which the company procures its water. In addition, the water balance diagrams can be updated in pencil as needed on a "change copy" of the report. Also the documentation of data given in these diagrams should be made more specific. Thre present report has this feature of providing a structure for such improvements and updating.

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APPENDICES

A. WATER BALANCE DIAGRAMS

A.1 Entries

The number of the element corresponds to the numbers given on the figures:

A.1 In-basin Flood Waters

A.2 Rights on Cache La Poudre Direct Flows

A.3 Rights on New Foreign Waters

A.4 Rights on Old Foreign Waters

A.5 Rights on Irrigation Companies

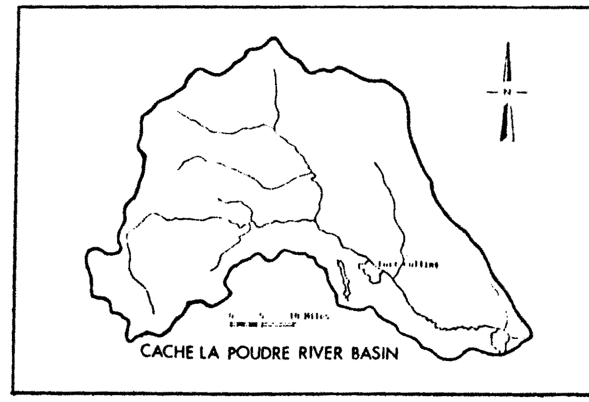
A.6 Rights on CBT Waters

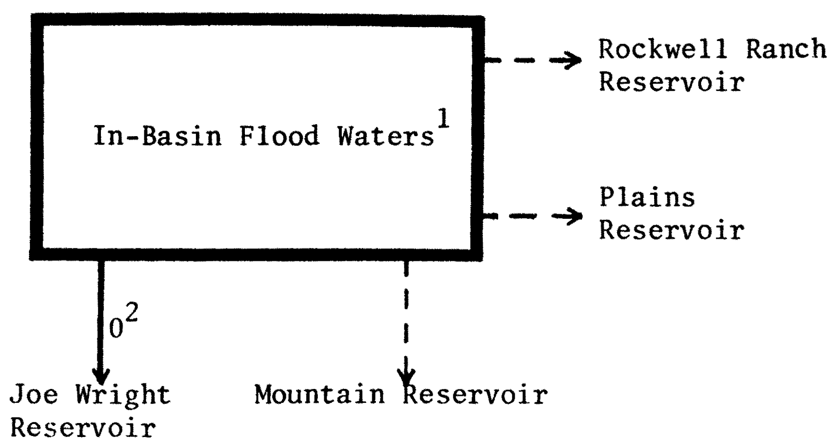
A.7 Water Leased from Other Right-holders

A.8 Reusable Water Reservoir Storage

A.9 Non-reusable Water Reservoir Storage

A.10 Infiltration into Sewer System



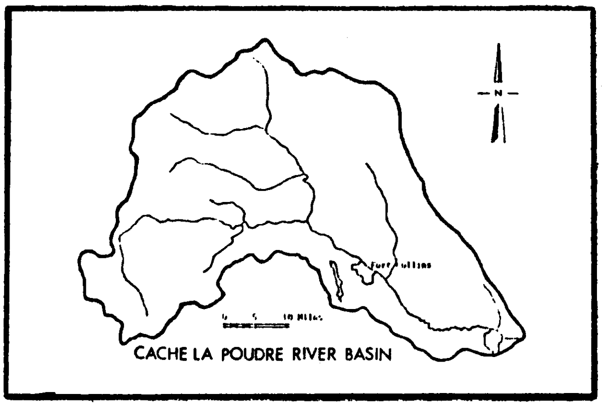


[1] These waters are considered reusable.

[2] This reservoir was being enlarged during 1977.

---Possible future alternatives.

Figure A.1. Water Volumes Originated from In-Basin Flood Waters.



Rights of Fort Collins
on CLP River
Direct Flow[1]

↓ 8,009[2]

Cache La Poudre River
(Source-mile 61)

[1] Table 4.1.

[2] Water balance at the water treatment plant No. 1.

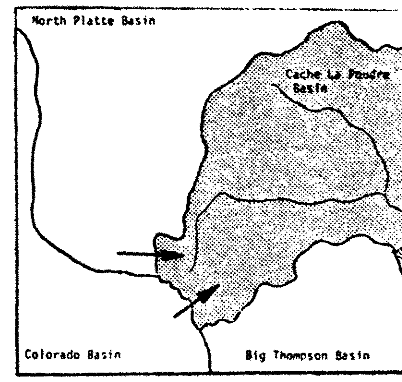
Maximum Possible

15 cfs x 1.9835 ac-ft/cfs / day x 365 days/yr = 10,860 ac-ft/yr

4.93 cfs x 1.9835 ac-ft/cfs / day x 182 days/yr = 1,780 ac-ft/yr

TOTAL 12,640 ac-ft/yr
(15.6 MCM/yr)

Figure A.2 Water Volumes Originated from Rights of Fort Collins on CLP River Direct Flow



Rights of Fort Collins
On New Foreign Water

0[1]

Michigan Ditch

Windy Gap
Project

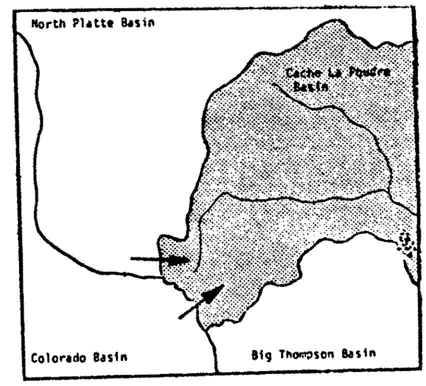
[1] Under improvement works

---Possible future alternative.

Total volume of water expected after completion:	3,000 ac-ft
Considered New Foreign Water:	1,000 ac-ft

From Windy Gap: originally was 8,100 ac-ft, actually this water has been transferred to the PRPA in connection with Rawhide Project.

Figure A.3. Water Volumes Originated from Rights of Fort Collins on New Foreign Water.



Rights of Fort Collins
on
Old Foreign Water

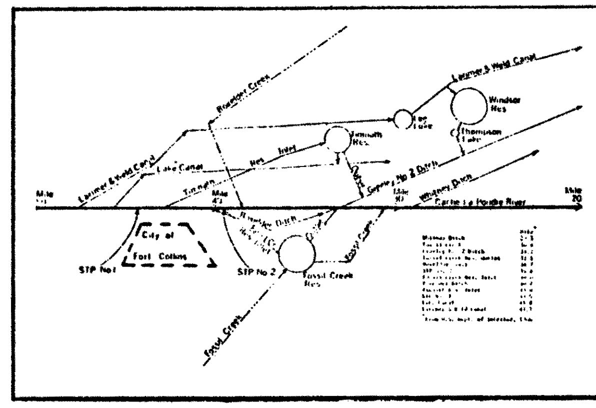
↓ 336[1]

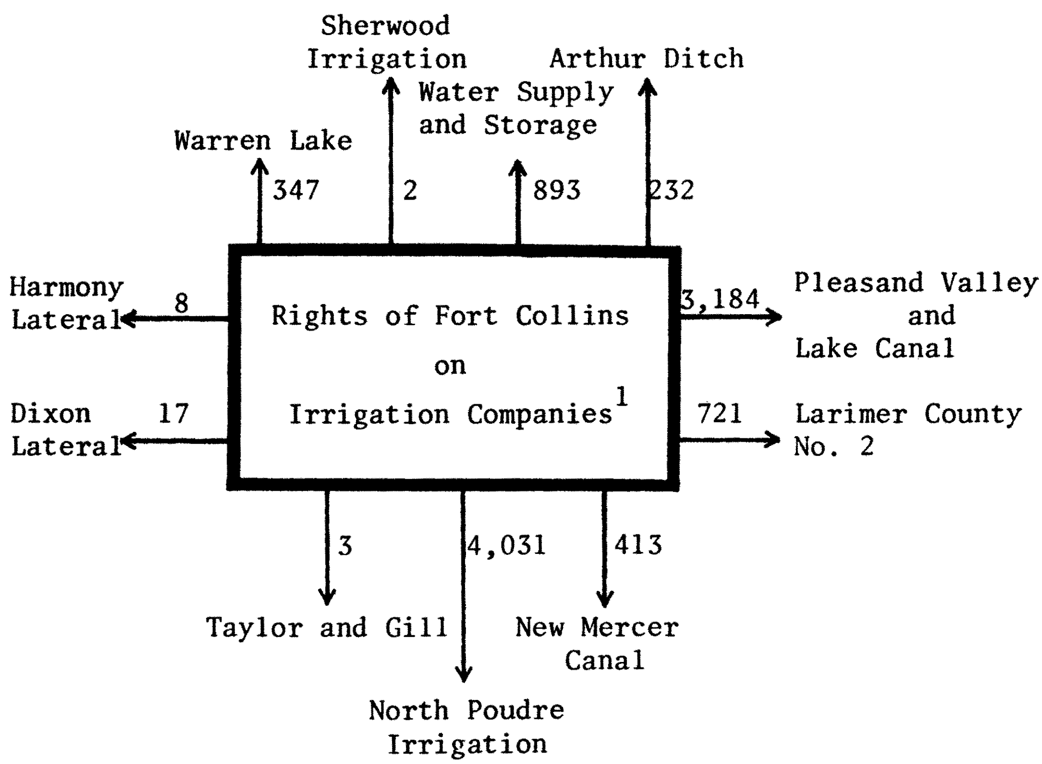
Michigan Ditch

[1] From the 1977 records at Water Utilities Department. The waters in excess of 1,000 ac-ft (123 MCM) will be considered New Foreign Water.

There is more old foreign water coming into the system, but it is included in the rights on irrigation companies. Figure A.5.

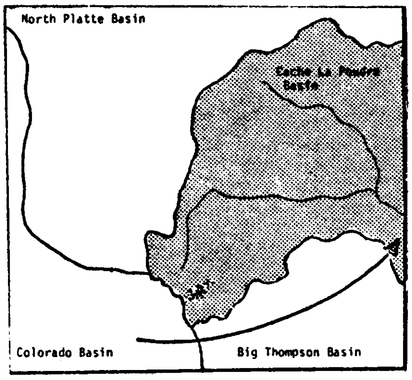
Figure A.4. Water Volumes Originated from Rights of Fort Collins on Old Foreign Water.

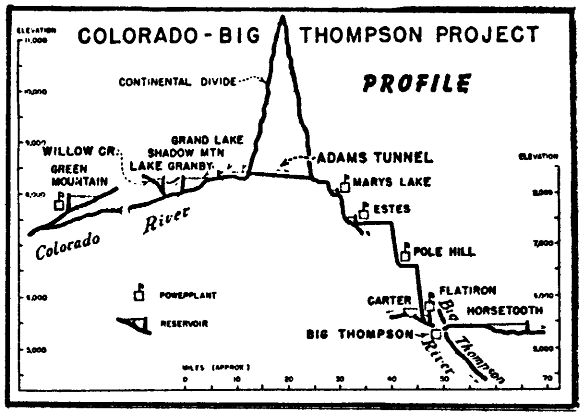




[1] These volumes were computed from Table 4.2. with the 1977 yield.

Figure A.5. Water Volumes Originated from Rights of Fort Collins on Irrigation Companies.





Rights of Fort Collins on CBT Waters

↓ 10,291[1]

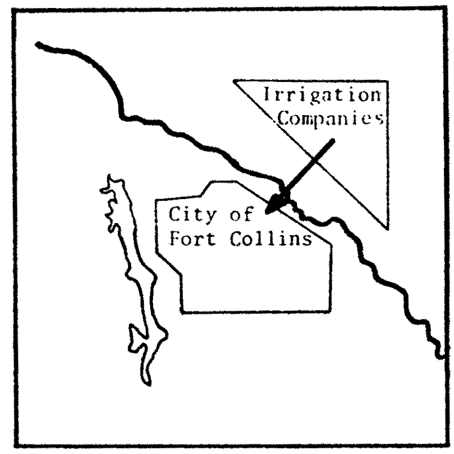
Horsetooth Reservoir

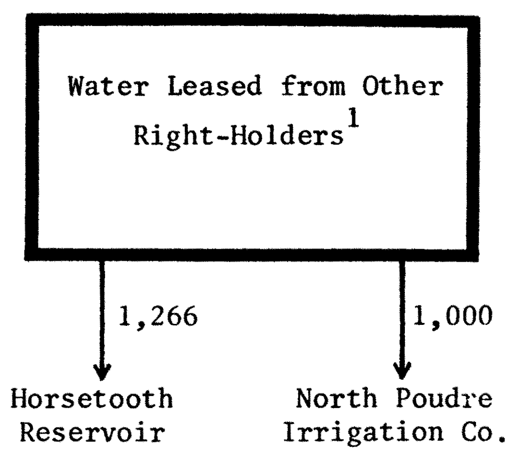
[1] 100% delivery during 1977.

Average delivery wet years	70%	7,204 ac-ft (8.9 MCM)
Delivery extremely dry years	100%	10,291 ac-ft (12.7 MCM)
Average last years	78%	8,027 ac-ft (9.9 MCM)

Total rights (units)	310,000
City owns (1977)	10,291
Percent	3.23%

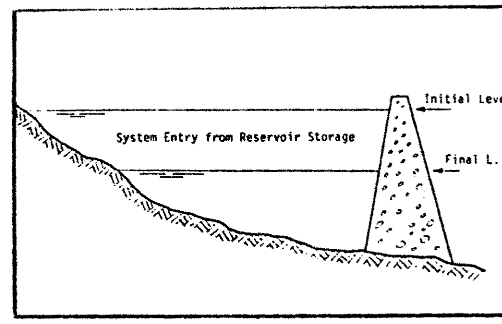
Figure A.6. Water Volumes Originated from Rights of Fort Collins on CBT Waters.

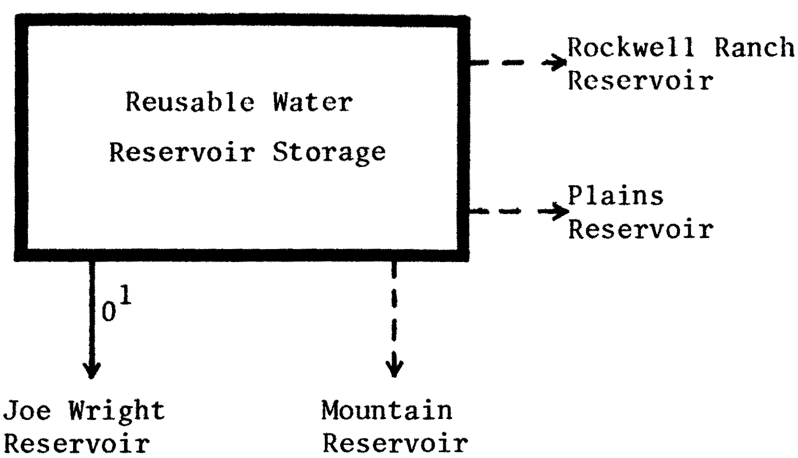




[1] Number varies from year to year

Figure A.7. Water Volumes Originated from Water Leased from Other Right-Holders.



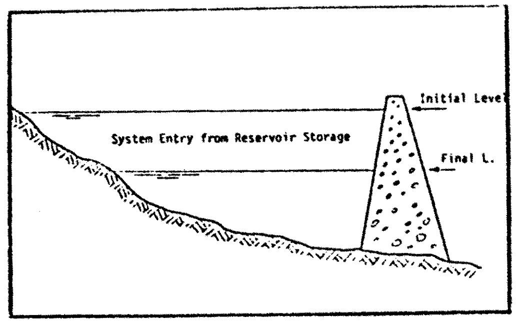


[1] Under construction.

---Possible future alternatives.

Joe Wright Reservoir future capacity 7,840 ac-ft (9.67 MCM)

Figure A.8. Water Volumes Originated from Reusable Water-Reservoir Storage.



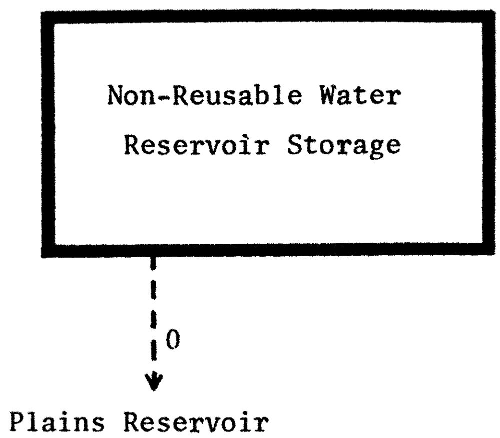
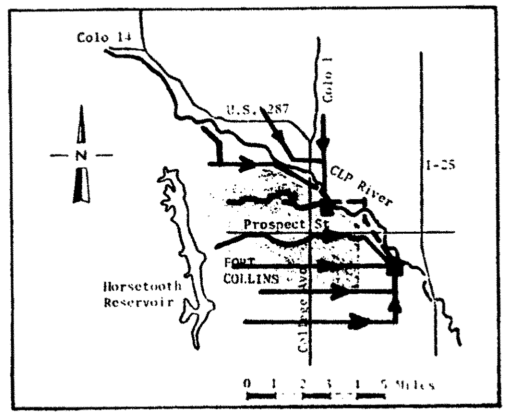
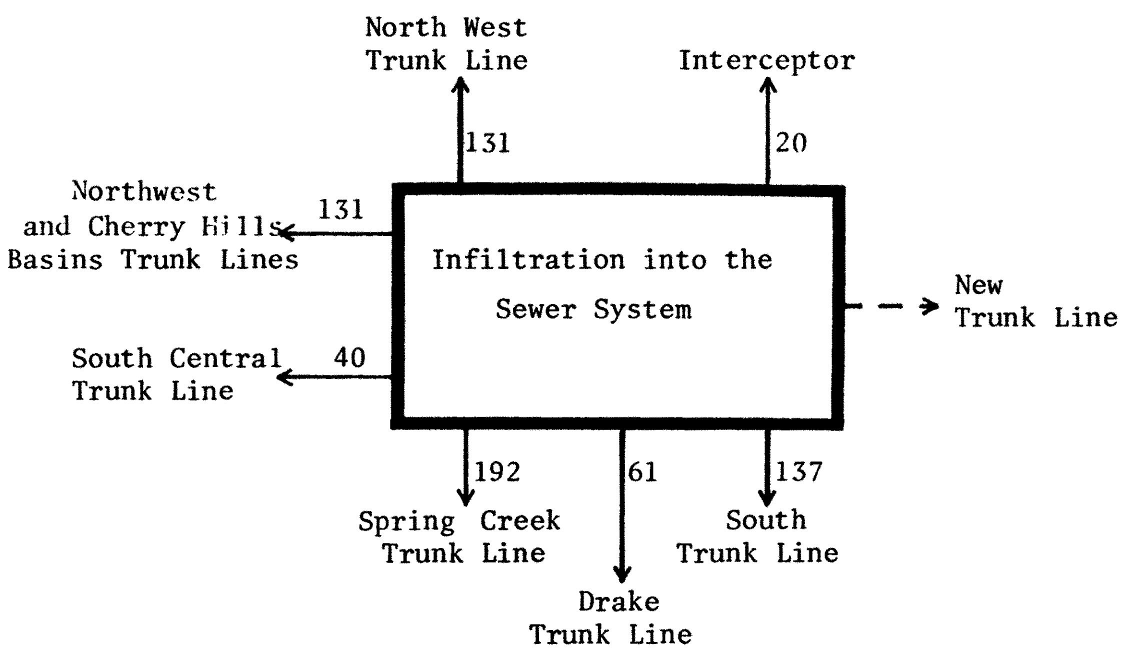


Figure A.9. Water Volumes Originated from Non-Reusable Water Reservoir Storage.





[1] Values estimated from an infiltration of 10% of total waste-water flow during winter months and 50% during summer months. See Table II.2.

---Possible future facilities.

Figure A.10. Water Volumes Originated from Infiltration into the Sewer System.

A.2 Internal Components

These elements are subdivided in the following groups, outlined on chapter three and shown on the matrix.

A.2.1 Raw Water Transport and Storage Facilities

A.11 Michigan Ditch

A.12 Cache La Poudre River (source-mile 61)

A.13 Windy Gap Project

A.14 Joe Wright Reservoir

A.15 Rockwell Ranch Reservoir

A.16 Mountain Reservoir

A.17 Horsetooth Reservoir

A.18 Plains Reservoir

A.19 Pleasant Valley and Lake Canal Irrigation Company

A.20 New Mercer Canal Irrigation Company

A.21 Larimer County Canal No. 2 Irrigation Company

A.22 North Poudre Irrigation Company

A.23 Taylor and Gill Ditch Company

A.24 Dixon Lateral Irrigation Company

A.25 Harmony Lateral Irrigation Company

A.26 Sherwood Lateral Irrigation Company

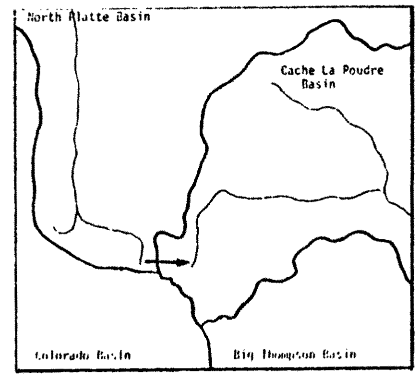
A.27 Warren Lake Irrigation Company

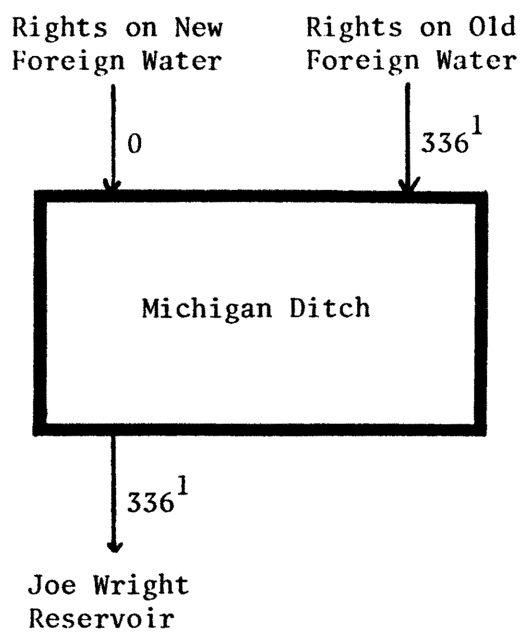
A.28 Water Supply and Storage Company

A.29 Arthur Irrigation Company

A.30 Reuse Bank

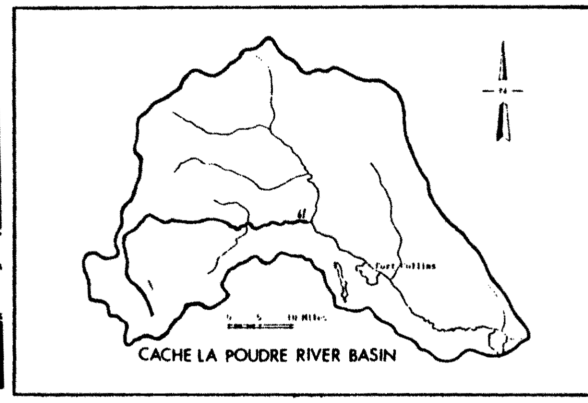
A.31 Exchange Bank

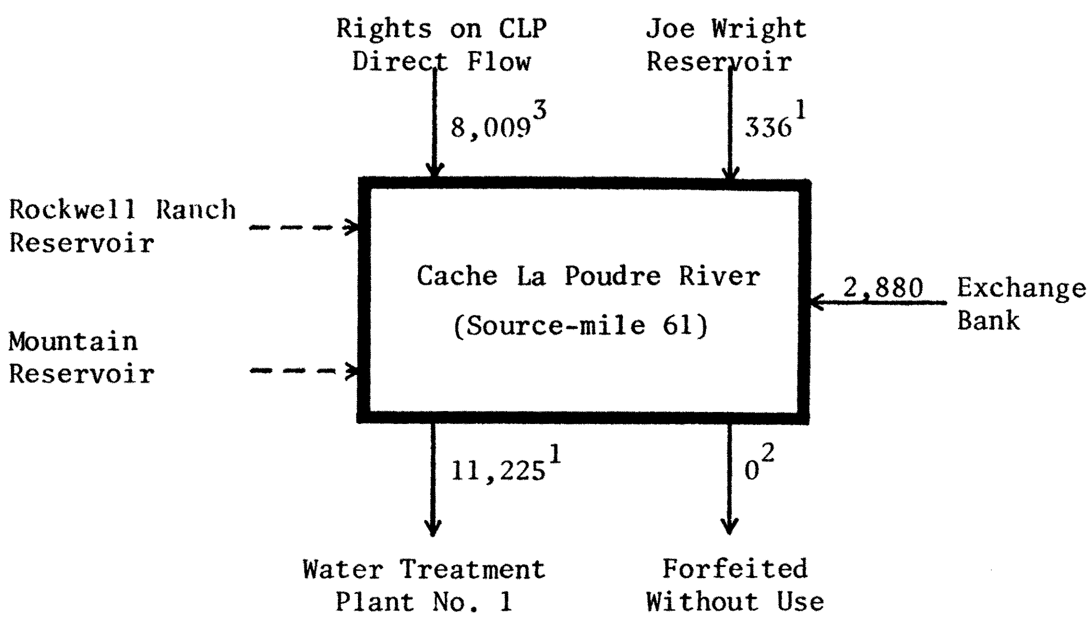




[1] Figure A.4.

Figure A.11. Water Balance of Michigan Ditch.





[1] From 1977's records at the Water Utilities Department.

[2] Assumed 0.

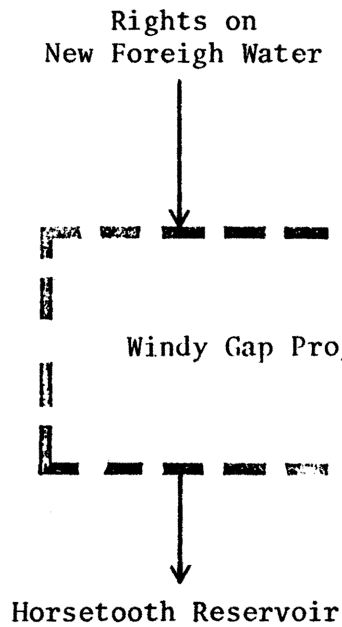
[3] Water balanced.

---Possible future alternatives.

Maximum water available from direct flow rights 12,640 ac-ft/yr (15.6 MCM/yr)

Average: 10,000 ac-ft/yr (12.3 MCM/yr)

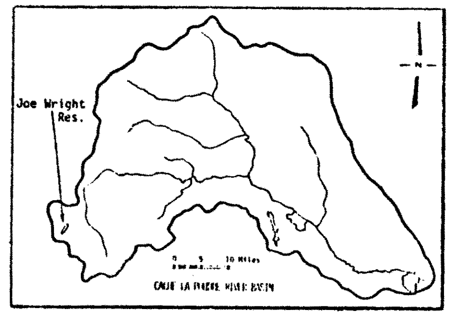
Figure A.12. Water Balance of the Cache La Poudre River.

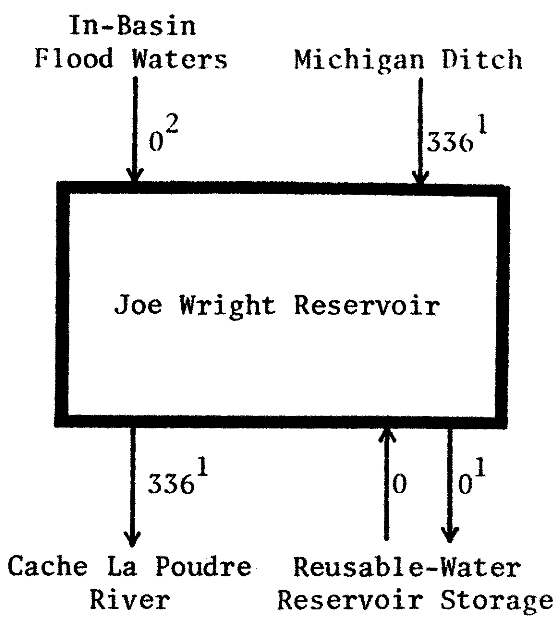


Total water expected 48,600 ac-ft

Water originally expected by the City of Fort Collins 8,100 a-ft
This water has actually been transferred to the PRPA in connection with Rawhide Project.

Figure A.13 Water Balance of the Windy Gap Project.



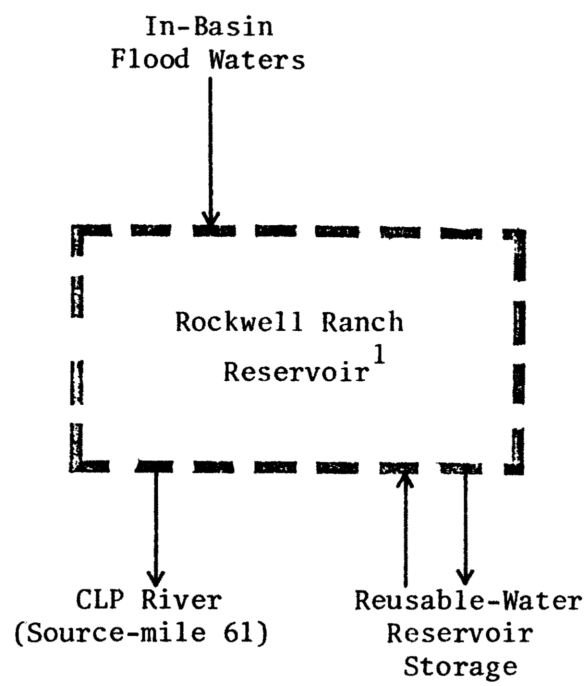


[1] Figure A.4.

[2] Under construction. No storage available yet.

Original capacity	800 ac-ft (1 MCM)
After enlargement	7,840 ac-ft (9.7 MCM)

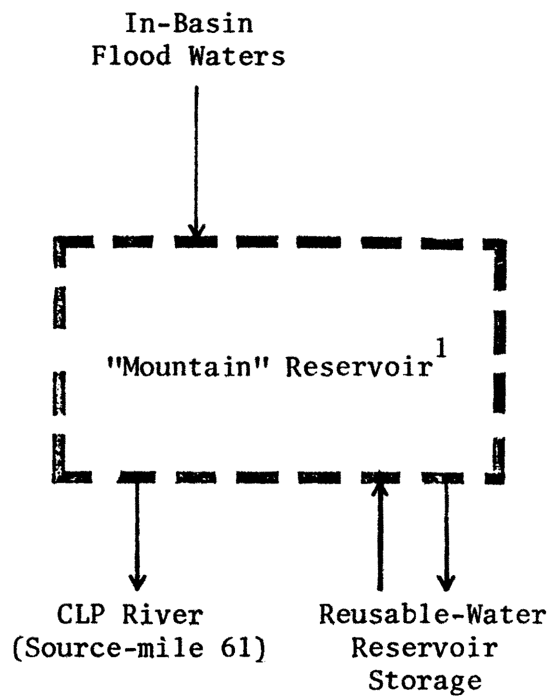
Figure A.14. Water Balance of Joe Wright Reservoir.



[1] Projected capacity 4,900 ac-ft (6 MCM).

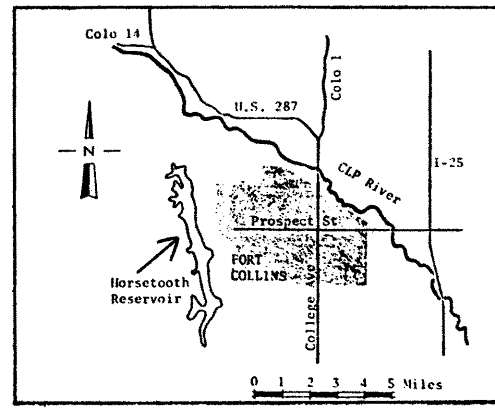
---Possible future alternative.

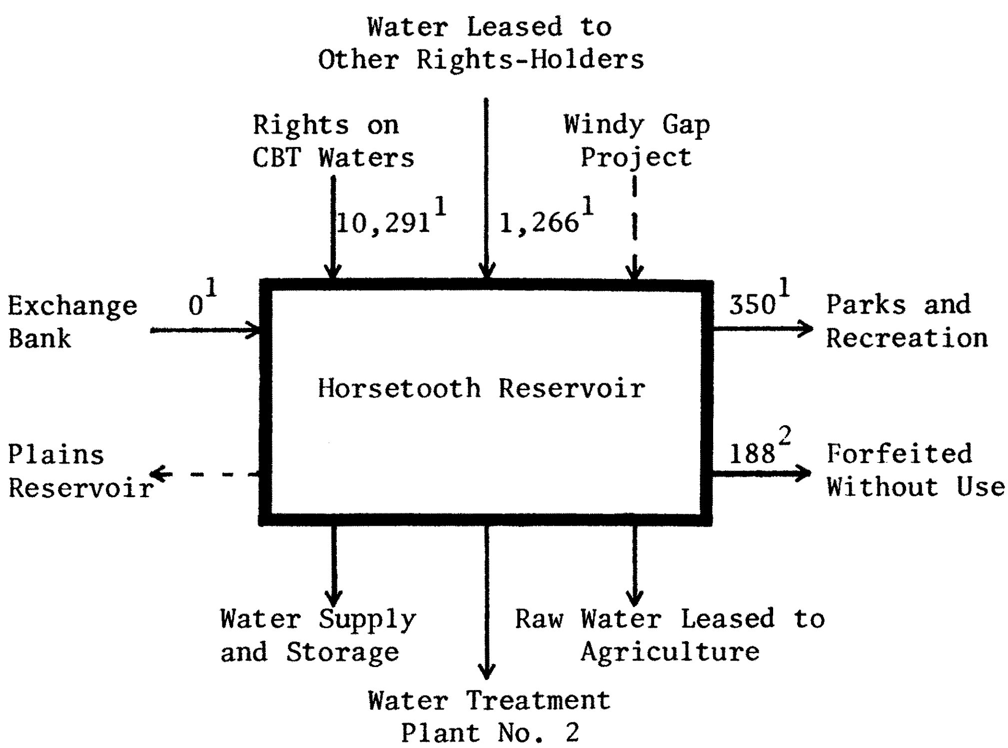
Figure A.15. Water Balance of the Rockwell Ranch Reservoir.



[1] This is a "generic" element, therefore there is no information.

Figure A.16. Water Balance of "Mountain" Reservoir.





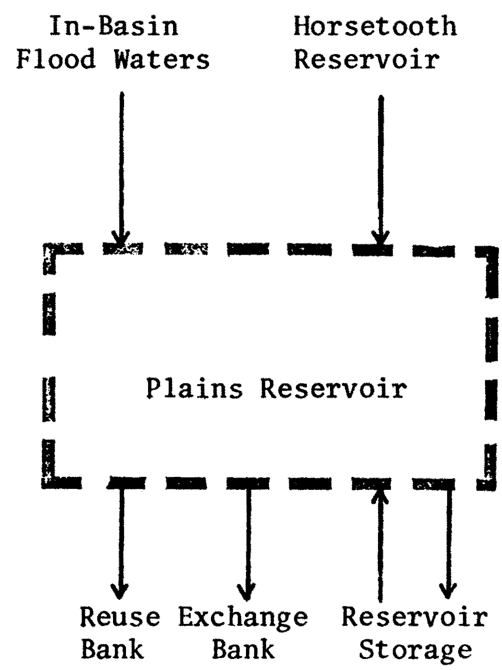
[1] From the Records at Water & Sewer Dept.

[2] Mass balanced.

---Possible future alternative.

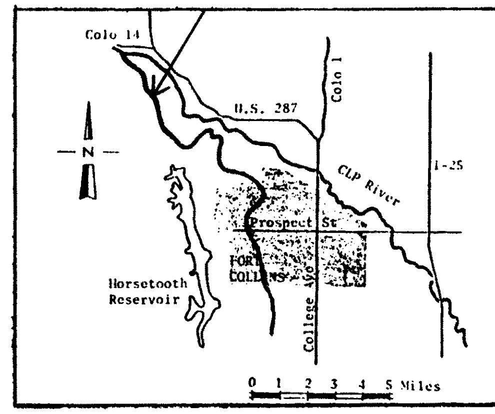
Total Capacity 151,800 acre-feet (187 MCM)

Figure A.17. Water Balance of Horsetooth Reservoir.



---Possible future alternative.

Figure A.18. Water Balance of Plains Reservoir.



Rights on
Irrigation Companies

3,184[1] ↓

Pleasant Valley and Lake Canal

→ 0[1] → Exchange Bank

↓ 3,158[1] → Raw Water Leased to Agriculture

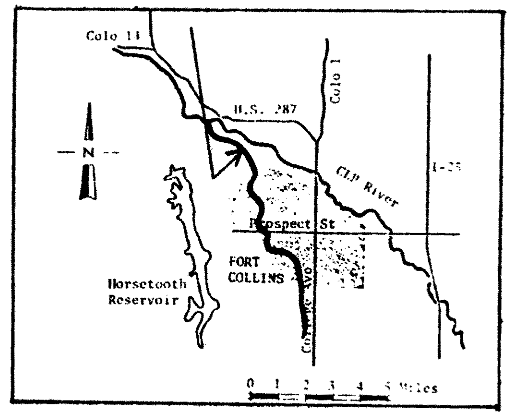
↓ 26[2] → Forfeited Without Use

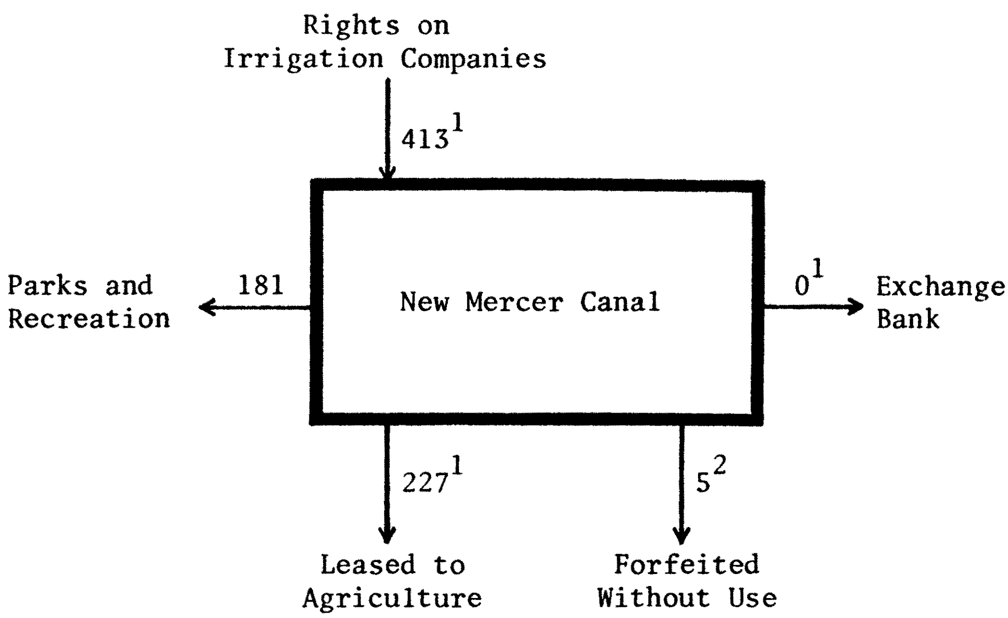
[1] From the Records at Water & Sewer Dept.

[2] Mass balanced.

Total shares:	256,000
Owned by City:	80,500 (31.45%)
Average yield:	39.7 ac-ft/share

Figure A.19. Water Balance of the Rights on Pleasant Valley and Lake Canal.



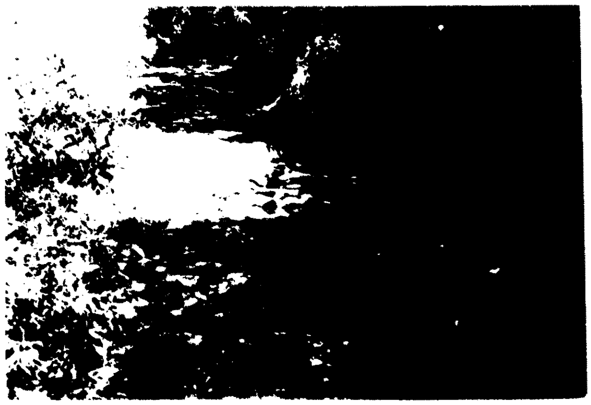


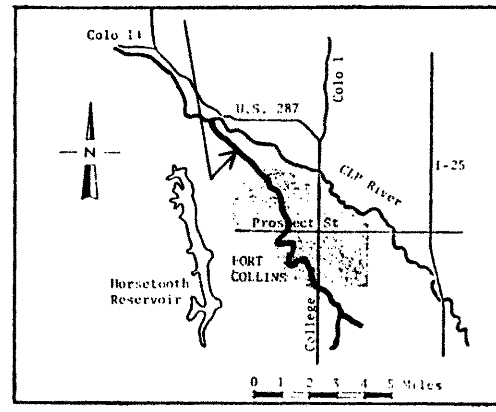
[1] From the Records at Water & Sewer Dept.

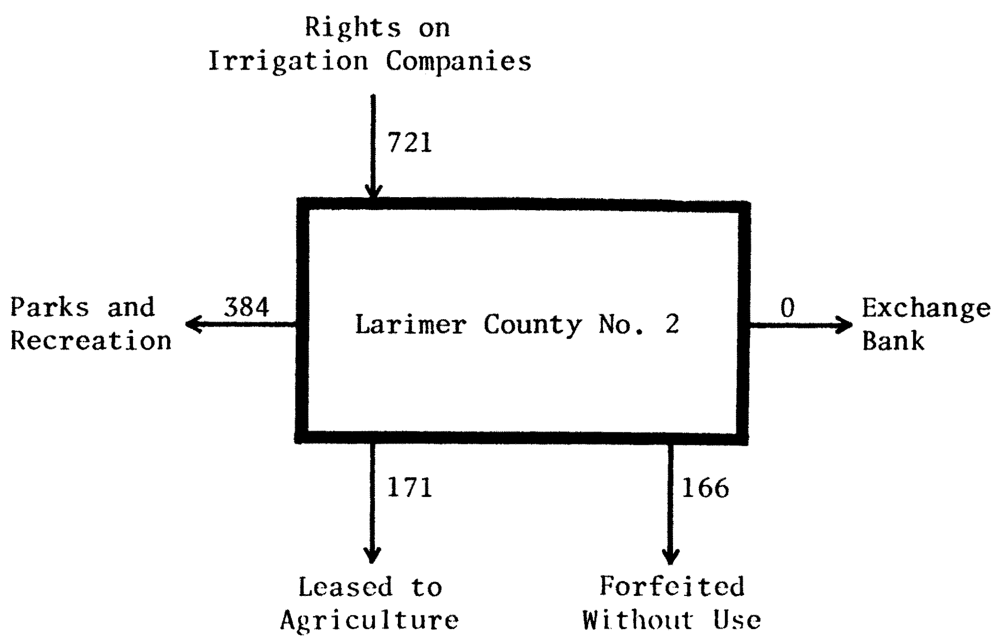
[2] Mass balanced.

Total shares:	148
Owned by City:	13.6434 (9.22%)
Average yield:	30.2 ac-ft/share

Figure A.20. Water Balance of the Rights on New Mercer Canal.





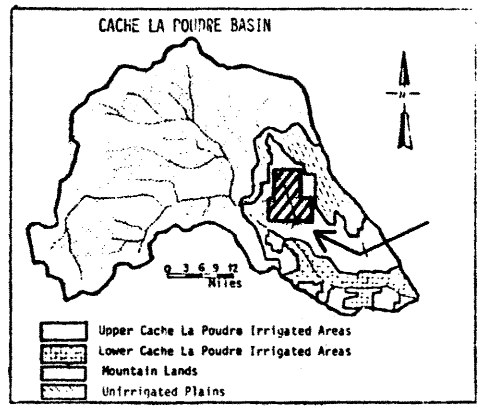


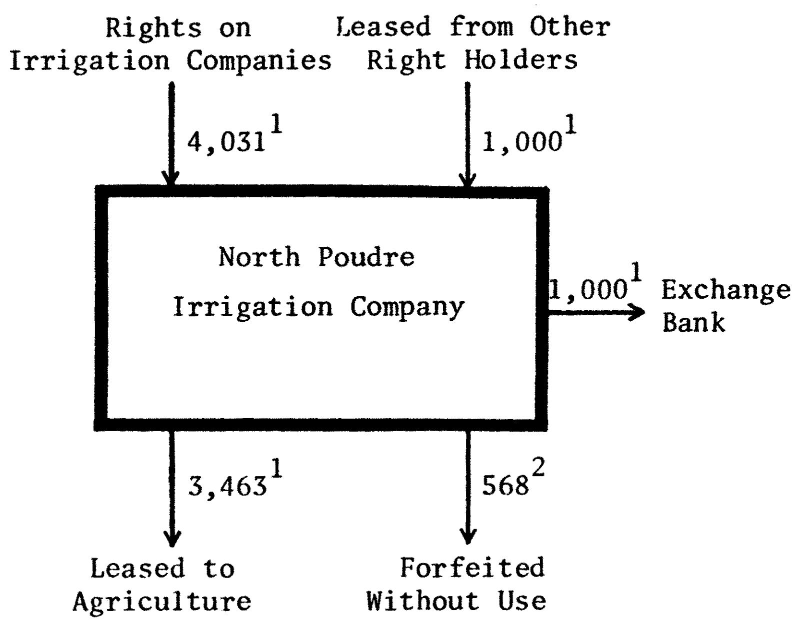
[1] From the Records at Water and Sewer Dept.

[2] Mass balanced.

Total shares:	157
Owned by City:	16.8938 (10.76%)
Average yield:	42.7 ac-ft/share

Figure A.21. Water Balance of the Rights on Larimer County No. 2.



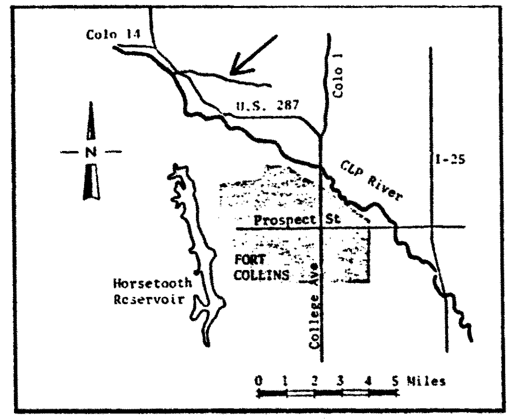


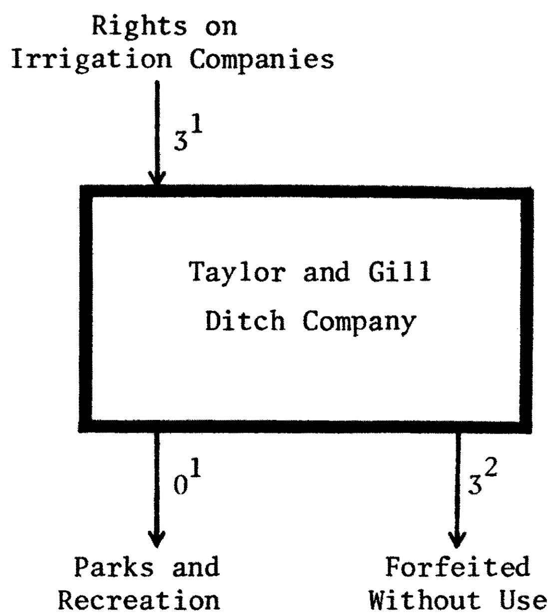
[1] From the Records at Water & Sewer Dept.

[2] Mass balanced.

Total Shares:	9,978
Owned by City:	839.75 (8.42%)
Average Yields:	5.57 ac-ft/share

Figure A.22. Water Balance of the Rights on North Poudre Irrigation Company.





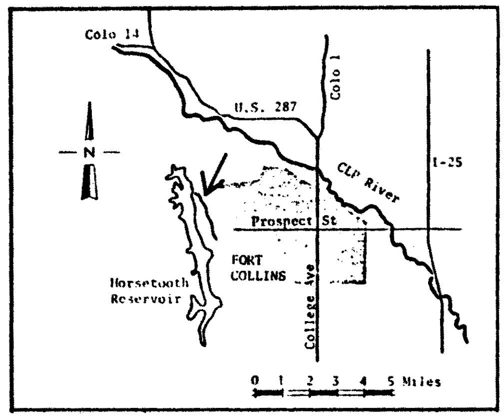
[1] From the Records at Water & Sewer Dept.

[2] Mass balanced.

Not for domestic use; only for irrigation of parks, golf courses, and the like.

Total Shares:	60
Owned by City:	0.0625 (0.1%)
Average Yield:	48.5 ac-ft/share

Figure A.23. Water Balance of the Rights on Taylor and Gill Ditch Company.



Rights on
Irrigation Companies

17[1]

Dixon Lateral

0[1]

17[2]

Parks and
Recreation

Forfeited
Without Use

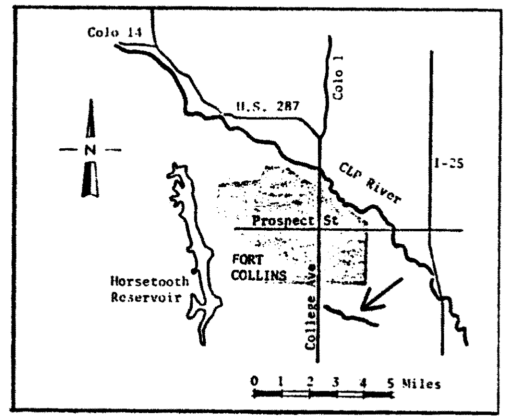
[1] From the Records at Water & Sewer Dept.

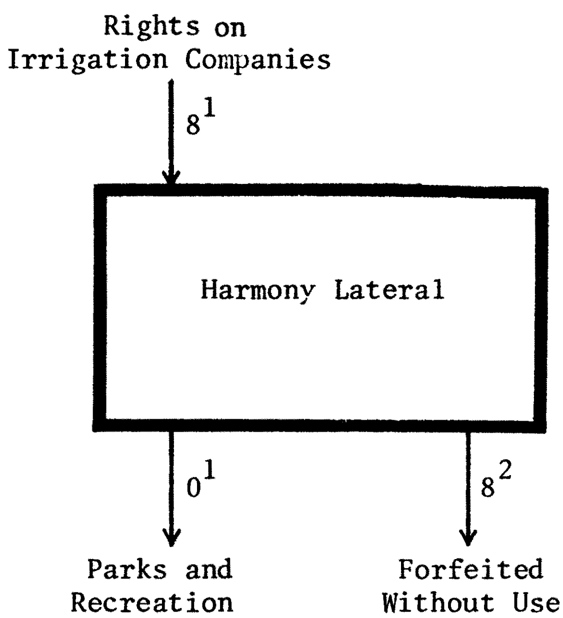
[2] Mass balanced.

Not for domestic use; only for irrigation of parks, golf courses, and the like.

Total Shares:	Not available
Owned by City:	3.8000
Average Yield:	4.4 ac-ft/share

Figure A.24. Water Balance of the Rights on Dixon Lateral.





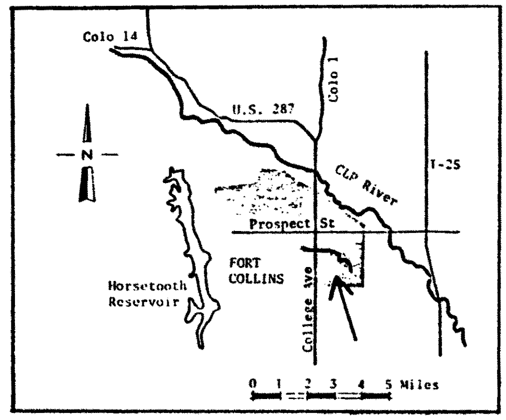
[1] From the Records at Water & Sewer Dept.

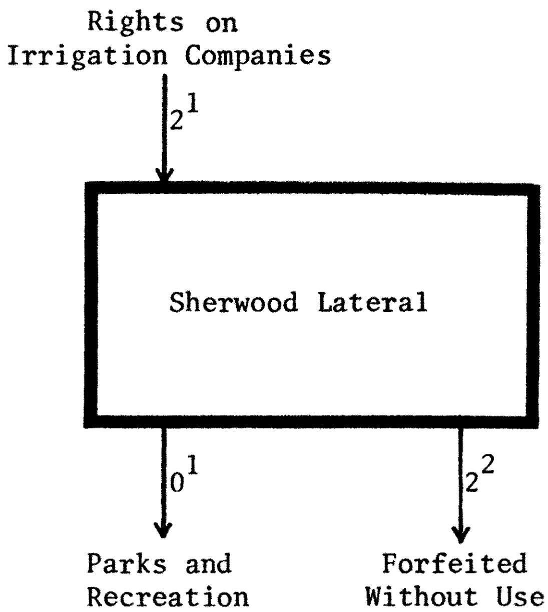
[2] Mass balanced.

Not for domestic use; only for irrigation of parks, golf courses, etc.

Total Shares:	Not Available
Owned by City:	1.7500
Average Yield:	4.5 ac-ft/share

Figure A.25. Water Balance of the Rights on Harmony Lateral.





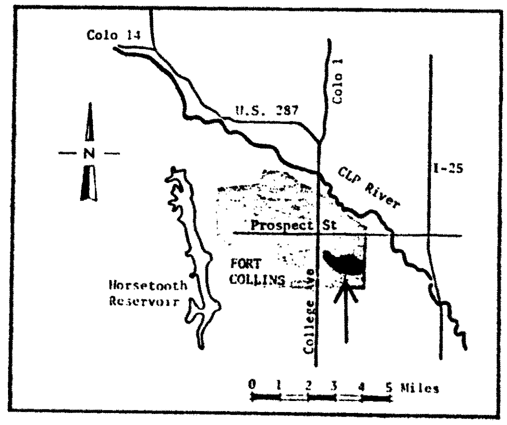
[1] From the Records at Water & Sewer Dept.

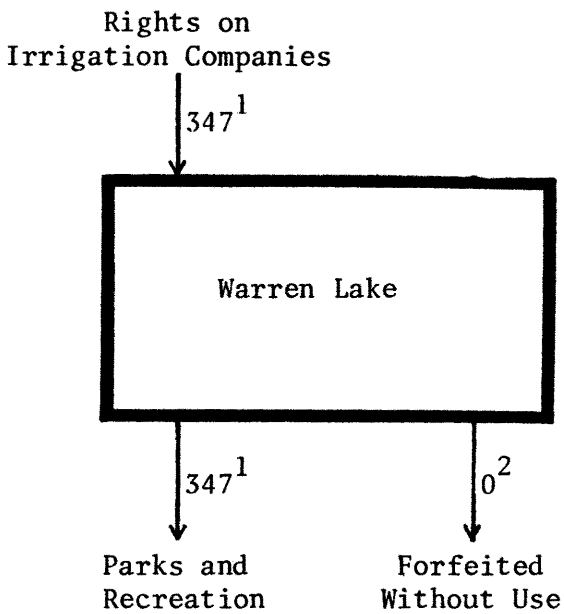
[2] Mass balanced.

Not for domestic use; only for irrigation of parks, golf courses, etc.

Total Shares:	Not Available
Owned by City:	0.4375
Average Yield:	4.3 ac-ft/share

Figure A.26. Water Balance of the Rights on Sherwood Lateral.





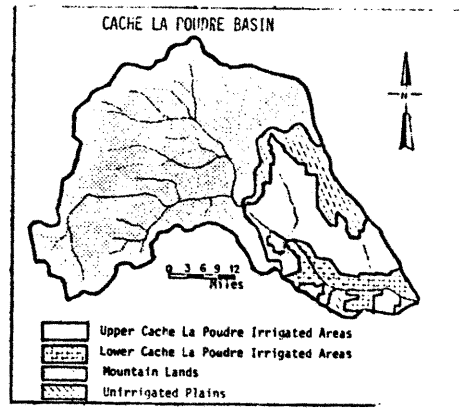
[1] From the Records at Water and Sewer Dept.

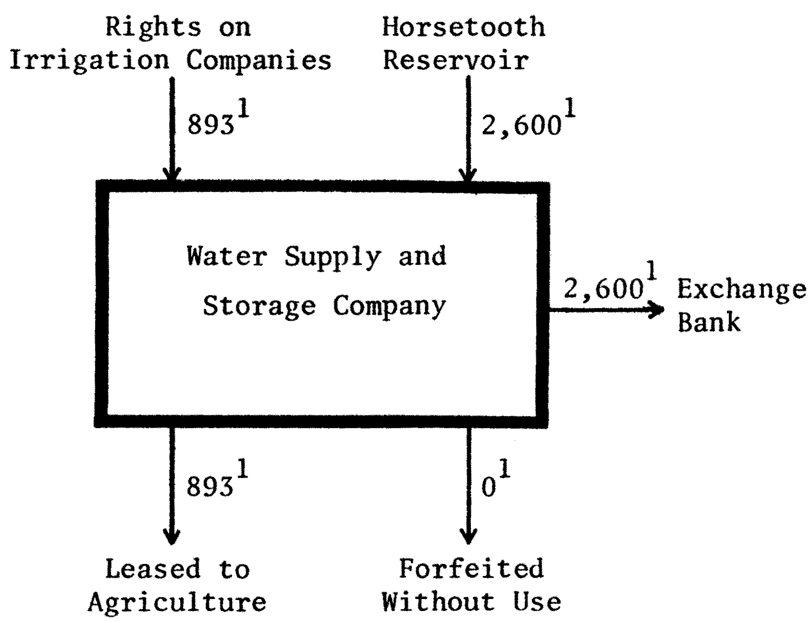
[2] Mass balanced.

Not for domestic use; only for irrigation of parks, golf courses, and the like.

Total Shares:	224
Owned by City:	34.7166 (15.5%)
Average Yield:	10.0 ac-ft/share

Figure A.27. Water Balance of Rights on Warren Lake.



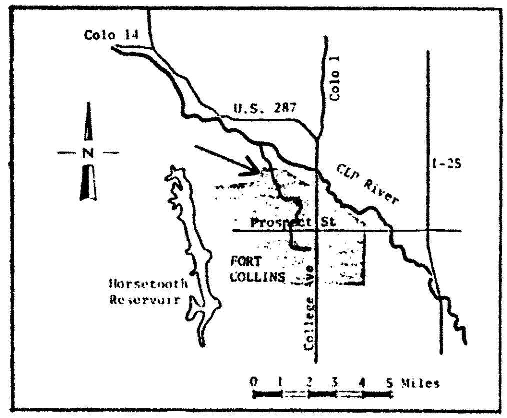


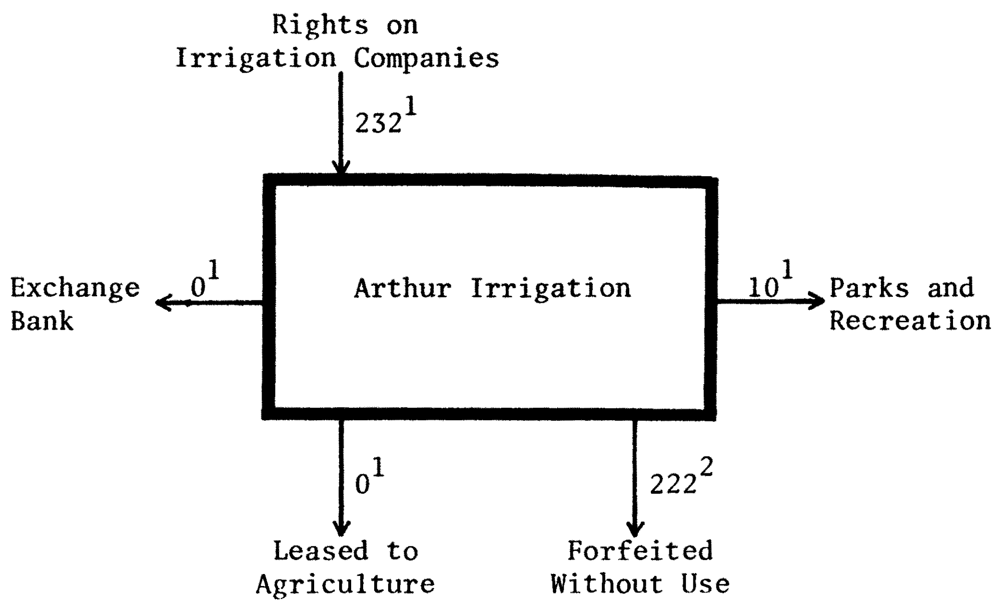
[1] From the Records at Water and Sewer Dept.

[2] Mass balanced.

Total Shares:	600
Owned by City:	9.9170 (1.65%)
Average Yield:	107 ac-ft/share

Figure A.28. Water Balance of the Rights on the Water Supply and Storage Company.



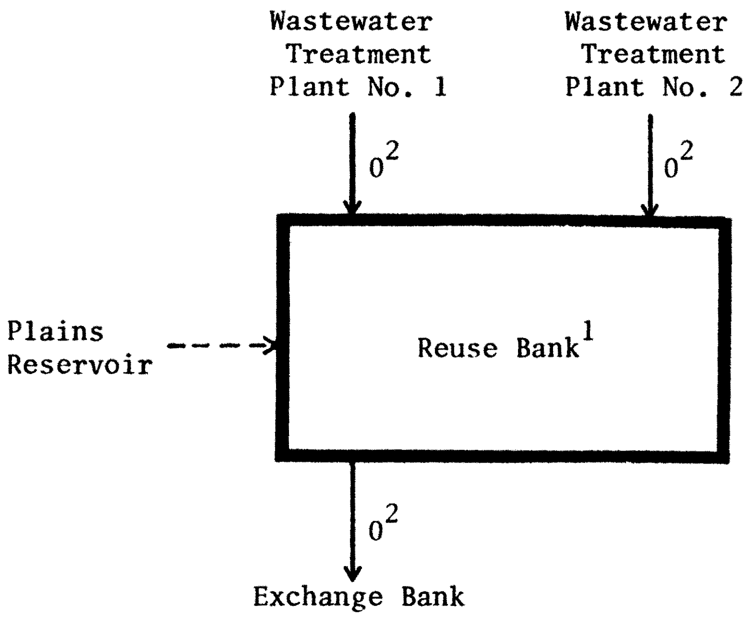


[1] From the Records at Water & Sewer Dept.

[2] Mass balanced.

Total Shares:	1,500
Owned by City:	68.2242 (4.55%)
Average Yield:	3.4 ac-ft/share

Figure A.29. Water Balance of the Rights on Arthur Irrigation.

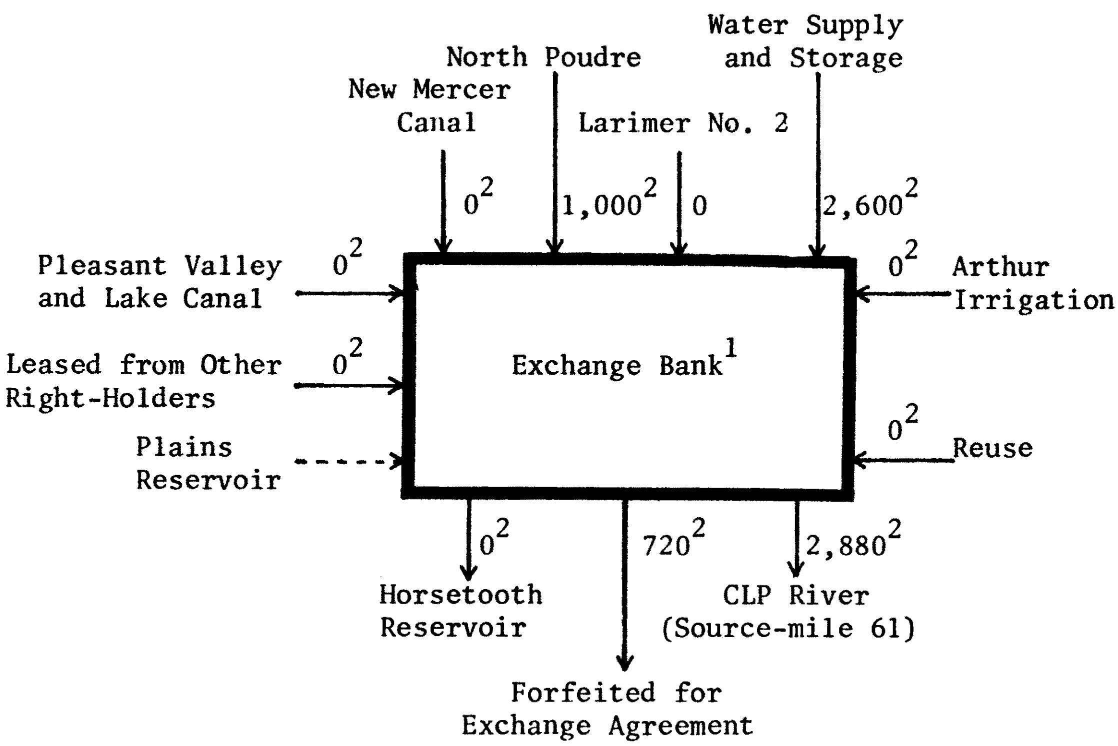


[1] This is a "pseudo-element" for the operation of the system.

[2] From the Records at the Water & Sewer Dept.

---Possible future alternatives

Figure A.30. Water Balance of Reuse.



[1] This is a "pseudo-element" necessary for the operation of the system.

[2] From the Records at the Water & Sewer Dept.

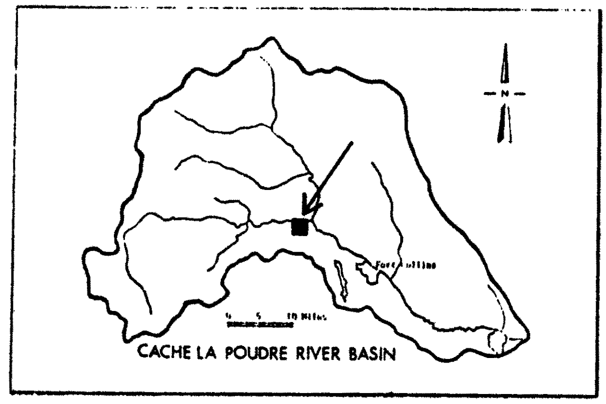
---Possible future alternative.

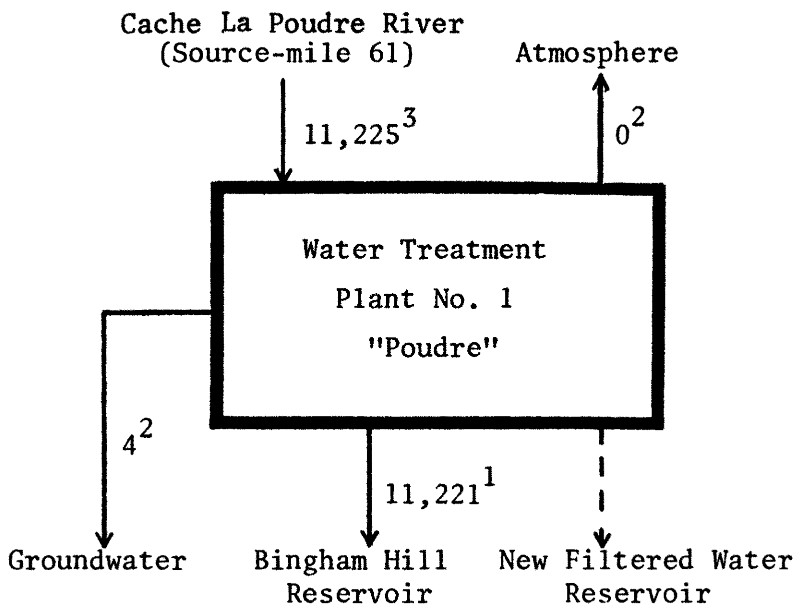
Figure A.31. Water Balance of the Exchange Bank.

A.2.2 Water Treatment Plants

A.32 Water Treatment Plant No. 1 "Poudre"

A.33 Water Treatment Plant No. 2 "Horsetooth"



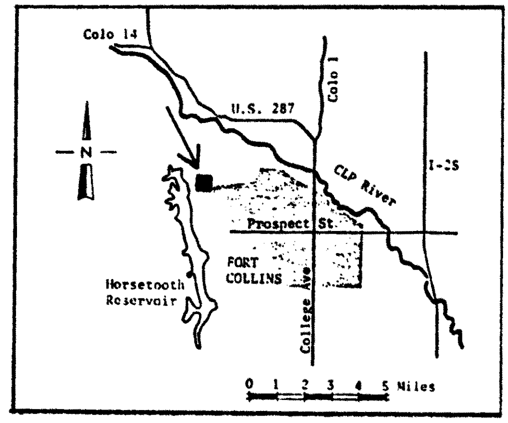


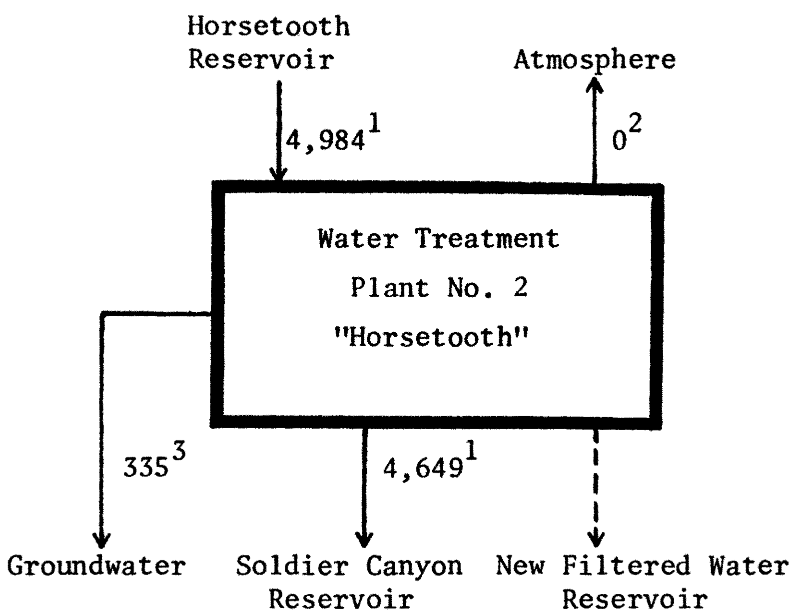
[1] Table H.5

[2] Value assumed.

[3] Mass balanced.

Figure A.32. Water Balance of Water Treatment Plant No. 1.





[1] Table H.5

[2] Value assumed.

[3] Mass balanced.

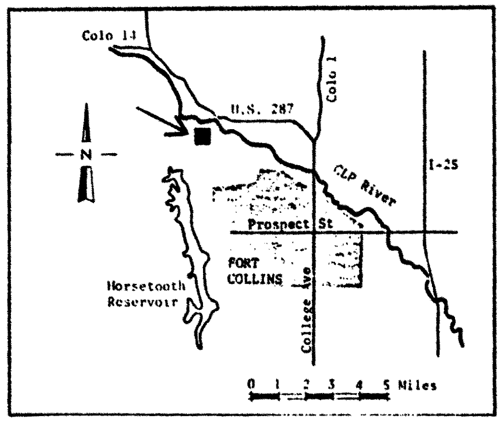
Figure A.33. Water Balance of Water Treatment Plant No. 2.

A.2.3 Filtered Water Storage

A.34 Bingham Hill Reservoir

A.35 Soldier Canyon Reservoir

A.36 New Filtered Water Reservoir



Water Treatment Plant No. 1

↓ 11,221[1]

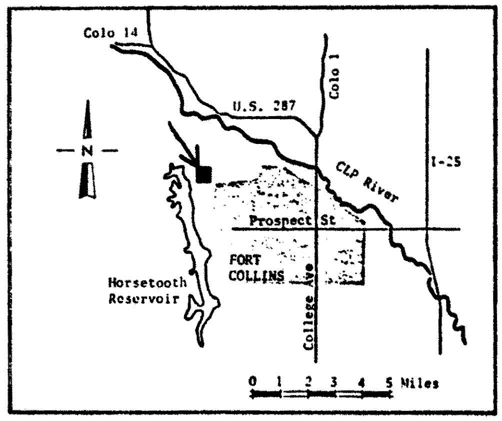
Bingham Hill Filtered Water Reservoir

↓ 11,221

Fort Collins Distribution System

[1] Table H.5

Figure A.34. Water Balance of Bingham Hill Filtered Water Reservoir.



Water Treatment Plant No. 2

↓ 4,649[1]

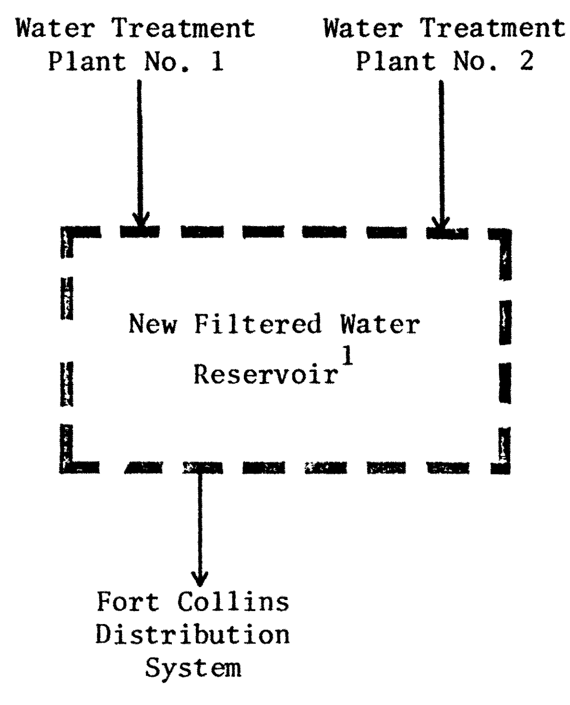
Soldier Canyon Filtered Water Reservoir

↓ 4,649

Fort Collins Distribution System

[1] Table H.5

Figure A.35. Water Balance of Soldier Canyon Filtered Water Reservoir.



[1] This is a generic element and therefore can be interconnected with both treatment plants.

Figure A.36. Water Balance of a New Filtered Water Reservoir.

A.2.4 Distribution System

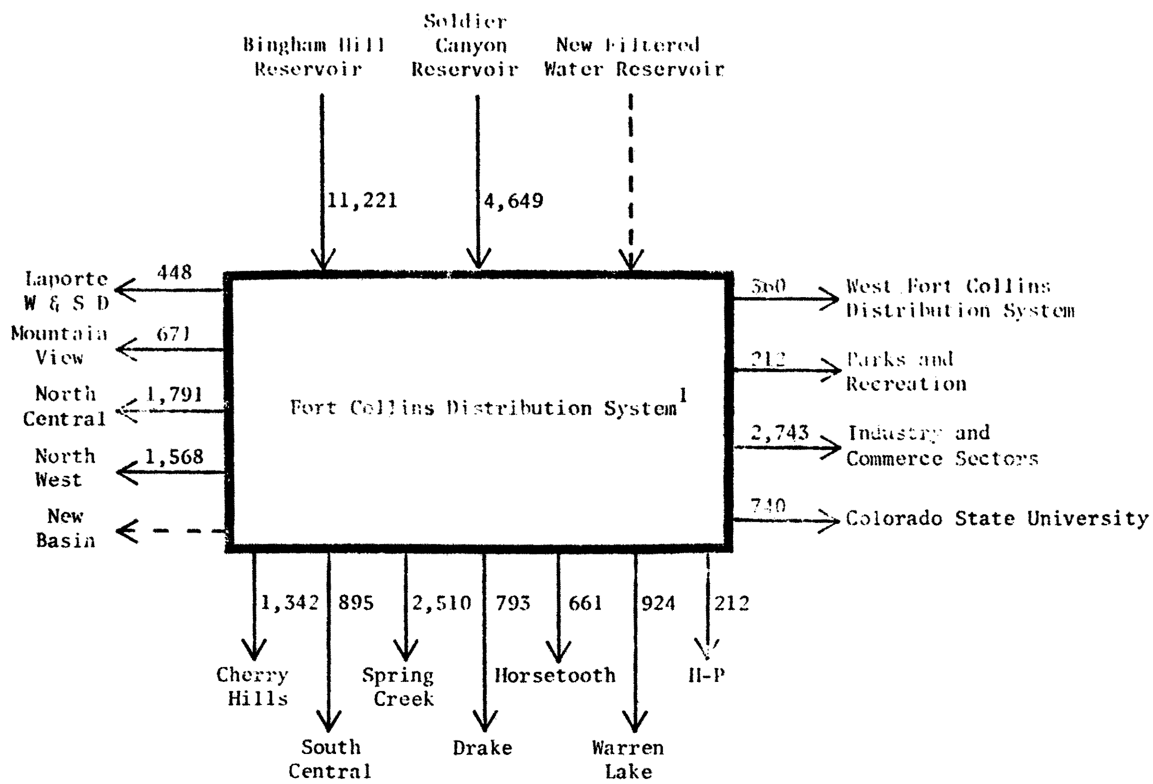
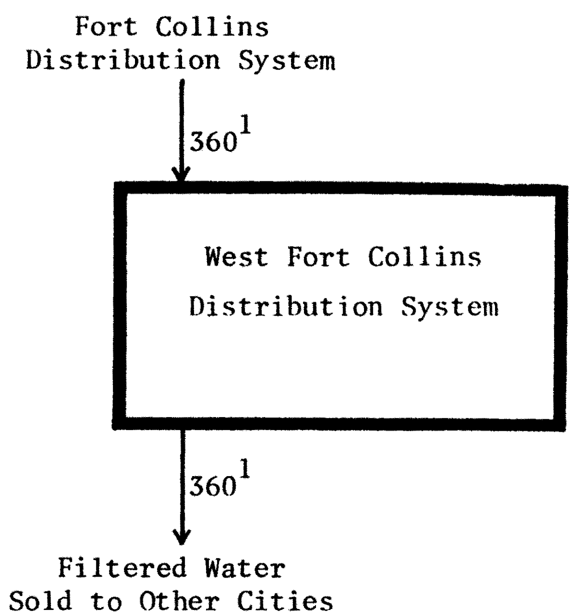


Figure A.37 Water Balance of Fort Collins Distribution System



[1] From the Records at the Water & Sewer Dept.

Figure A.38. Water Balance of West Fort Collins Distribution System.

A.2.5 Users

A.39 Parks and Recreation

A.40 Laporte Water and Sanitation District

A.41 Northwest Basin

A.42 Cherry Hills Basin

A.43 Mountain View Basin

A.44 North Central Basin

A.45 South Central Basin

A.46 Spring Creek Basin

A.47 Drake Basin

A.48 Horsetooth Basin

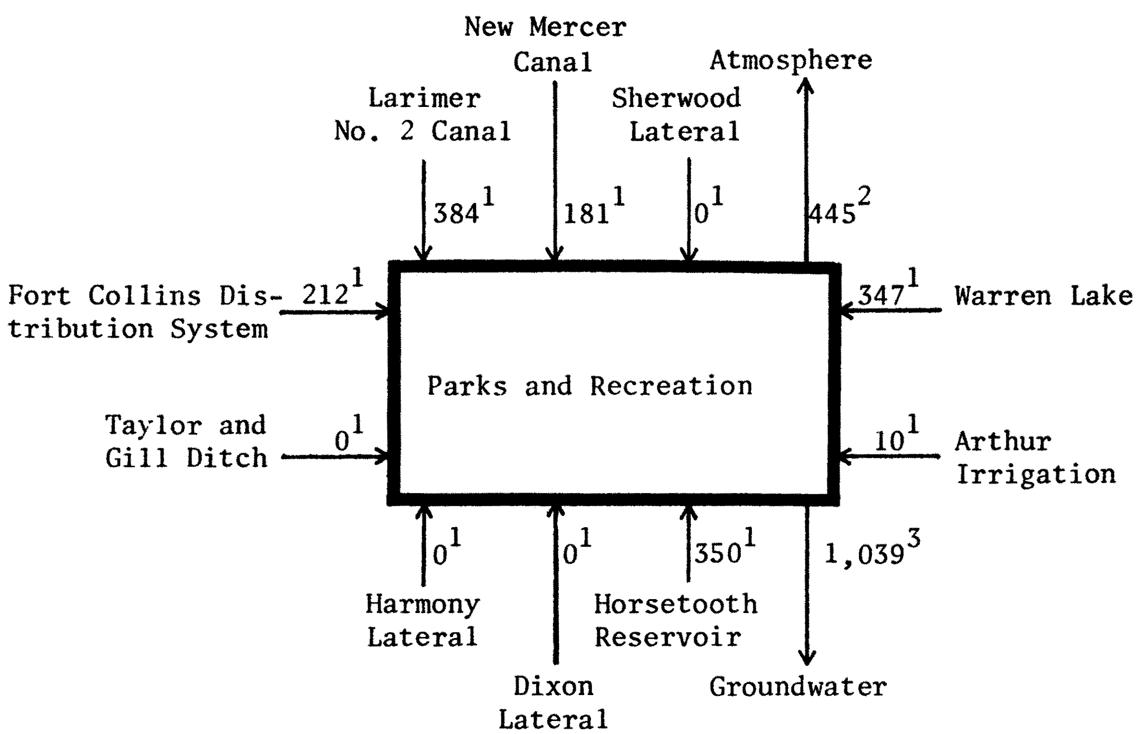
A.49 Warren Lake Basin

A.50 H-P Basin

A.51 New Basin

A.52 Colorado State University

A.53 Industrial and Commercial Sectors

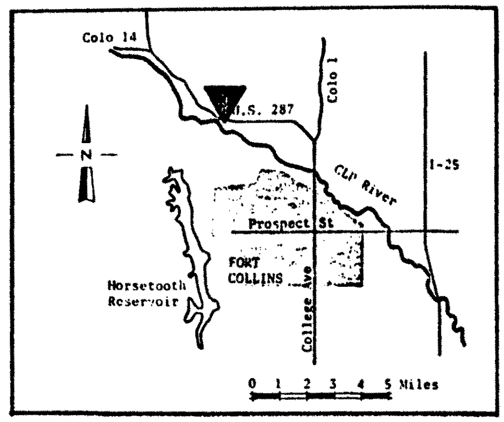


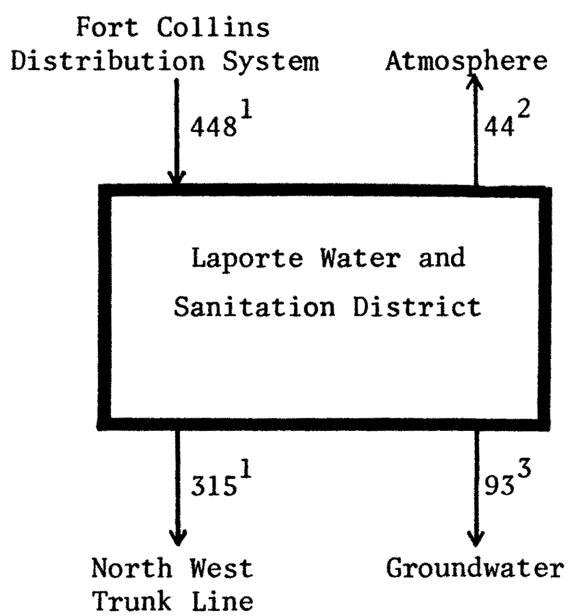
[1] From the Records at the Water & Sewer Dept.

[2] Assuming 30% of total consumptive use.

[3] Mass balanced.

Figure A.39. Water Balance of Parks and Recreation.



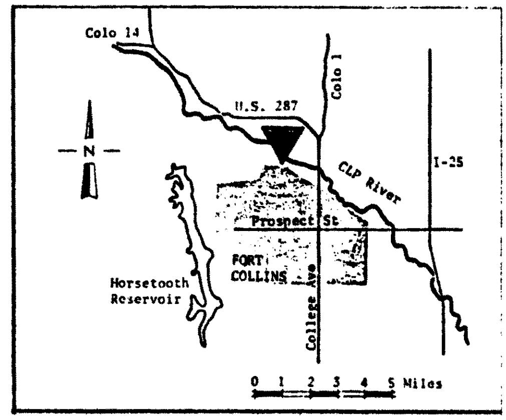


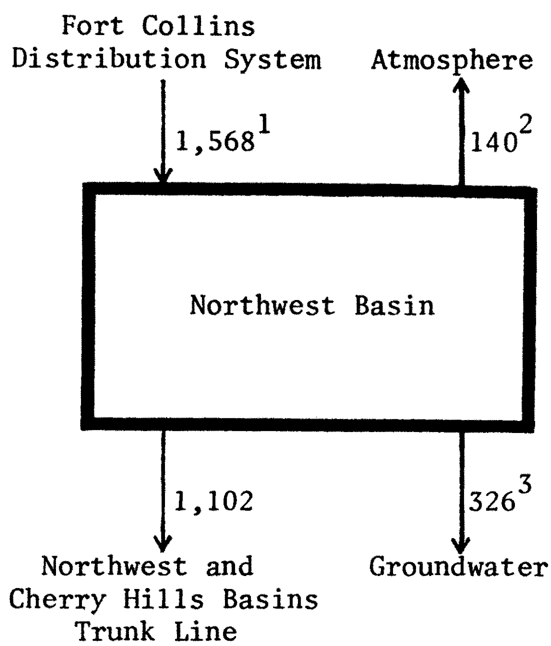
[1] Table H. 2.

[2] Assumed a 30% of total consumptive use.

[3] Mass balanced.

Figure A.40. Water Balance of Laporte Water and Sanitation District.



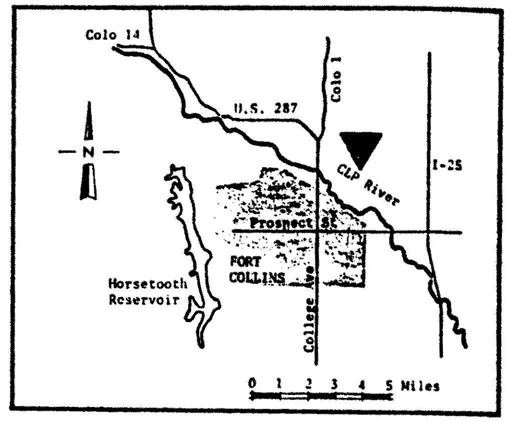


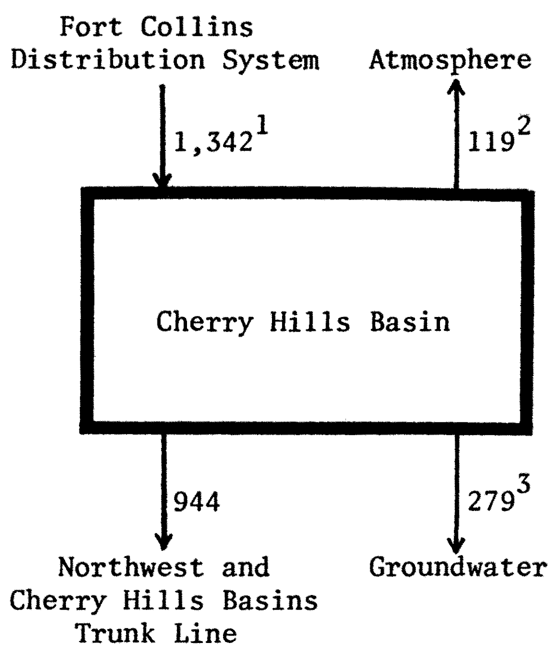
1 Table H. 2.

2 Assumed a 30% of total consumptive use.

3 Mass balanced.

Figure A.41. Water Balance of Northwest Basin.



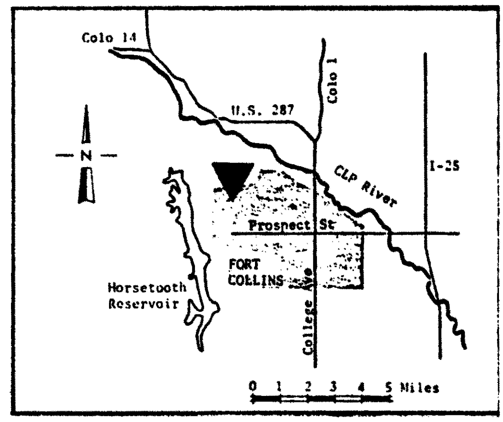


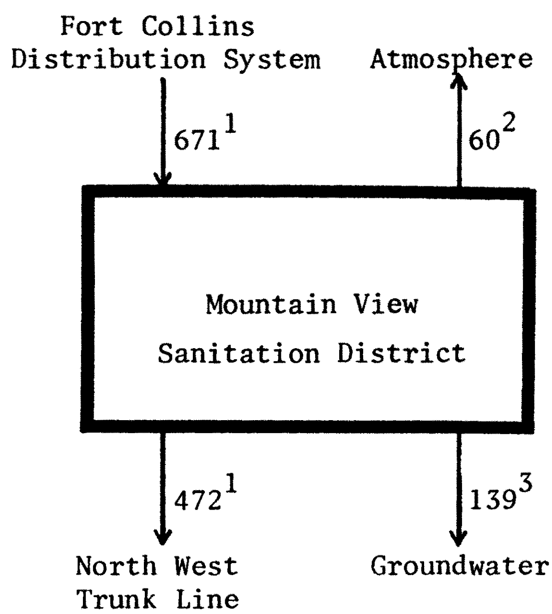
[1] Table H. 2.

[2] Assumed a 30% of total consumptive use.

[3] Mass balanced.

Figure A.42. Water Balance of Cherry Hills Basin.



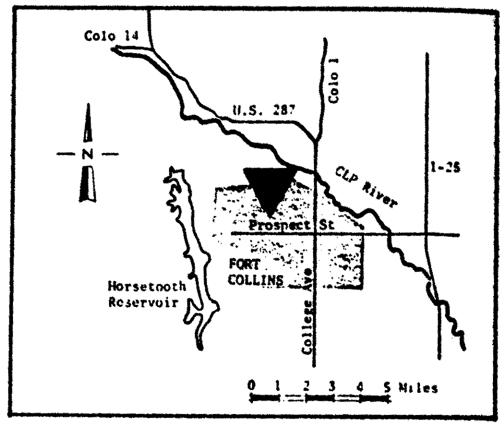


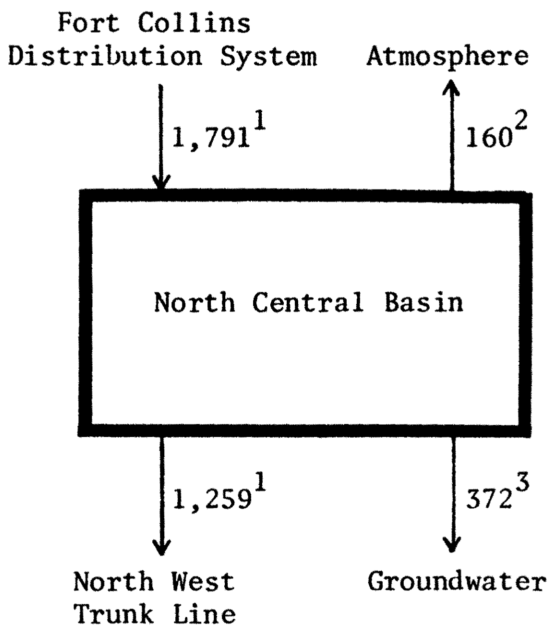
[1] Table H.2.

[2] Assumed a 30% of total consumptive use.

[3] Mass balanced.

Figure A.43. Water Balance of Mountain View Sanitation District.



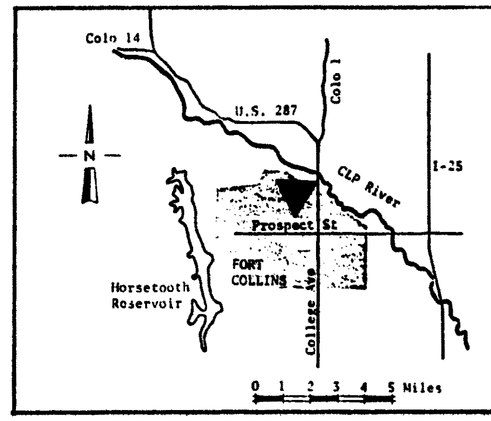


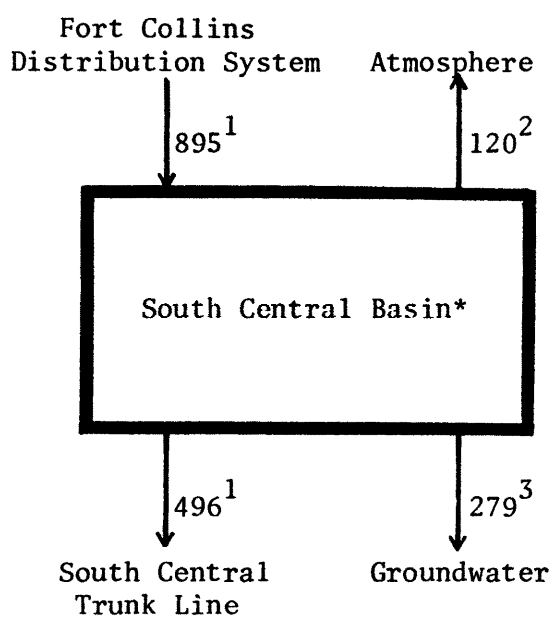
[1] Table H. 2.

[2] Assumed a 30% of total consumptive use.

[3] Mass balanced.

Figure A.44. Water Balance of North Central Basin.





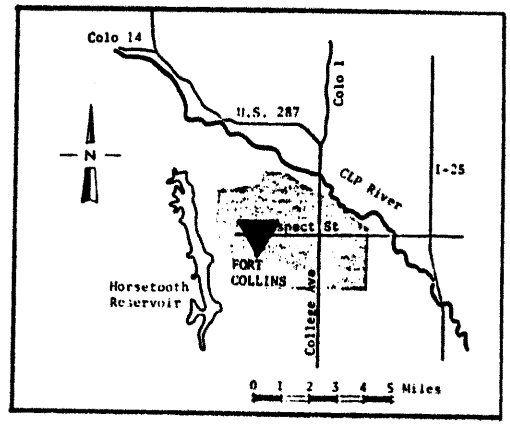
[1] Table H. 2.

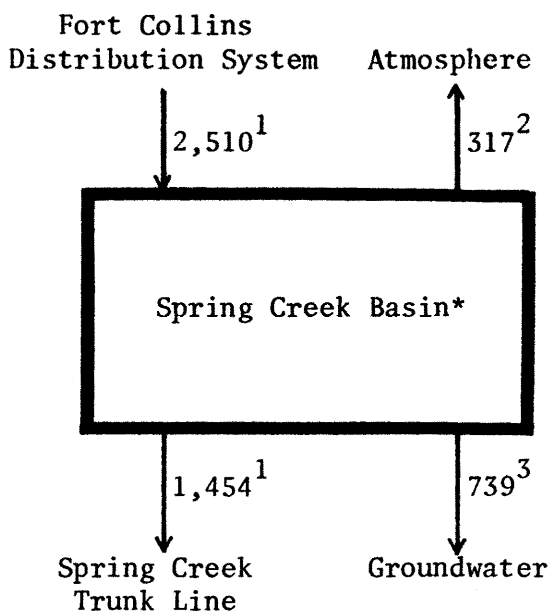
[2] Assumed a 30% of total consumptive use.

[3] Mass balanced.

* Excluding CSU

Figure A.45. Water Balance of South Central Basin.





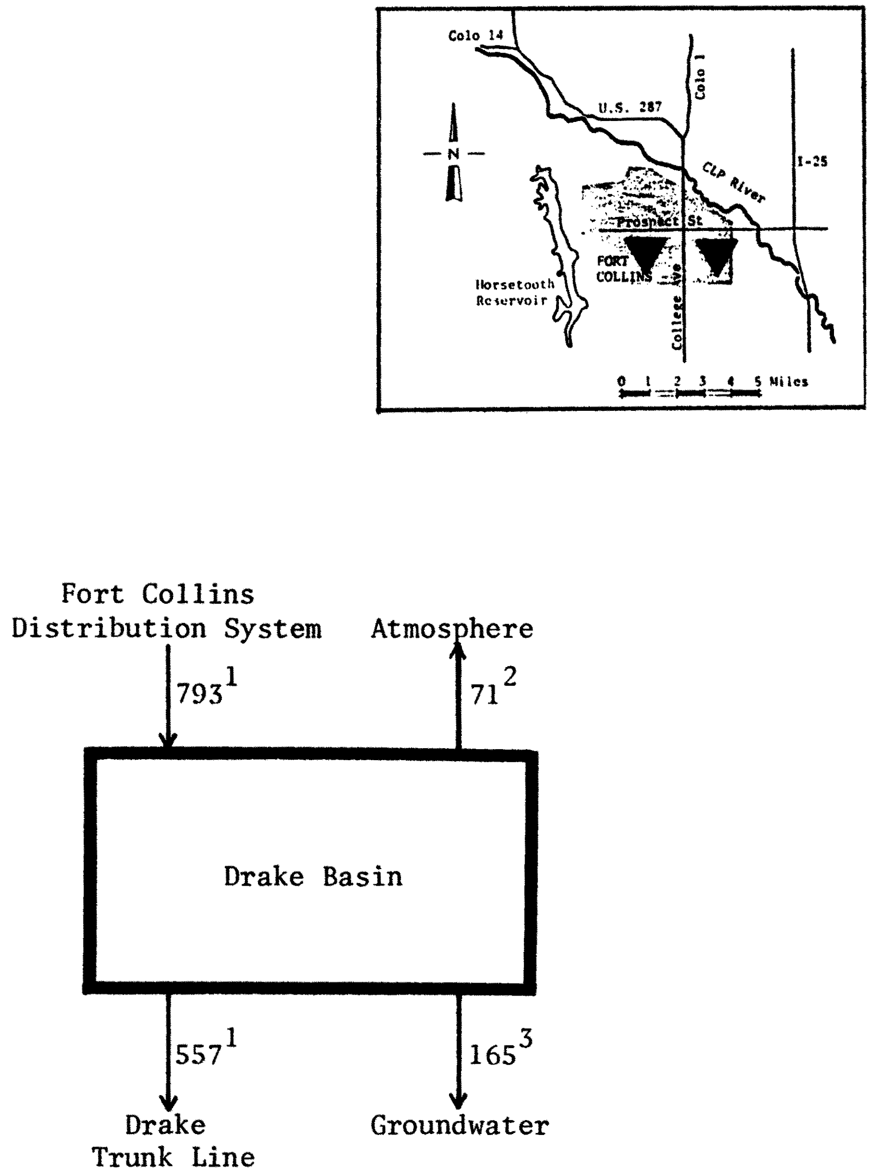
[1] Table H.2.

[2] Assumed a 30% of total consumptive use

[3] Mass balanced.

* Excluding CSU

Figure A.46. Water Balance of Spring Creek Basin.

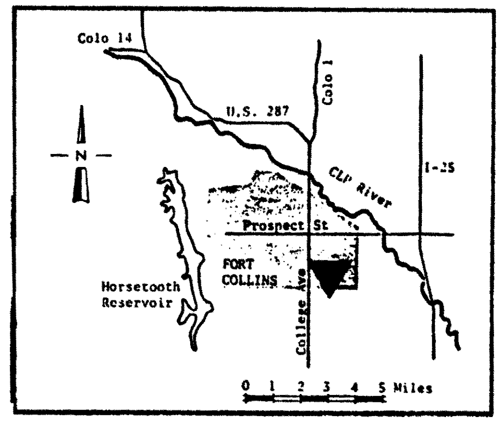


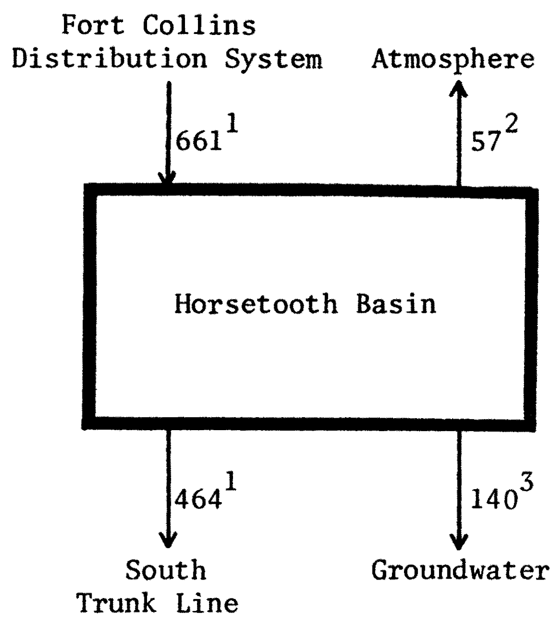
[1] Table H.2.

[2] Assumed a 30% of total consumptive use.

[3] Mass balanced.

Figure A.47. Water Balance of Drake Basin.



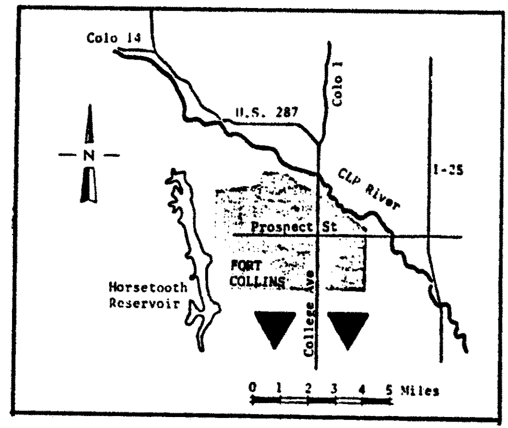


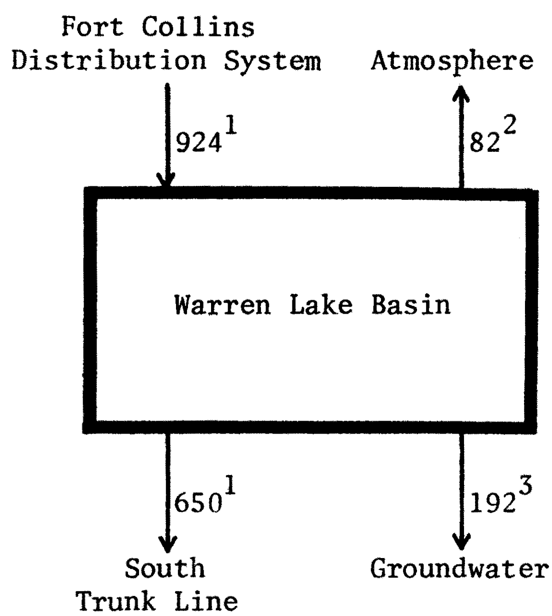
[1] Table H.2.

[2] Assumed a 30% of total consumptive use.

[3] Mass balanced.

Figure A.48. Water Balance of Horsetooth Basin.



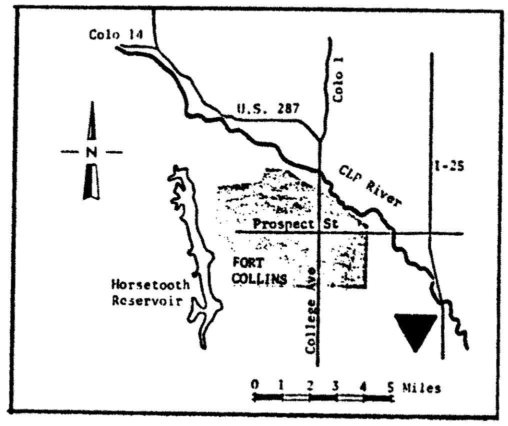


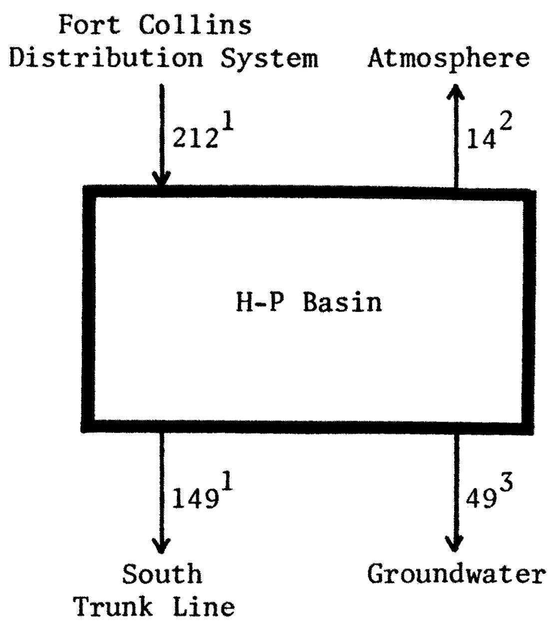
[1] Table H.2.

[2] Assumed a 30% of total consumptive use.

[3] Mass balanced.

Figure A.49. Water Balance of Warren Lake Basin.



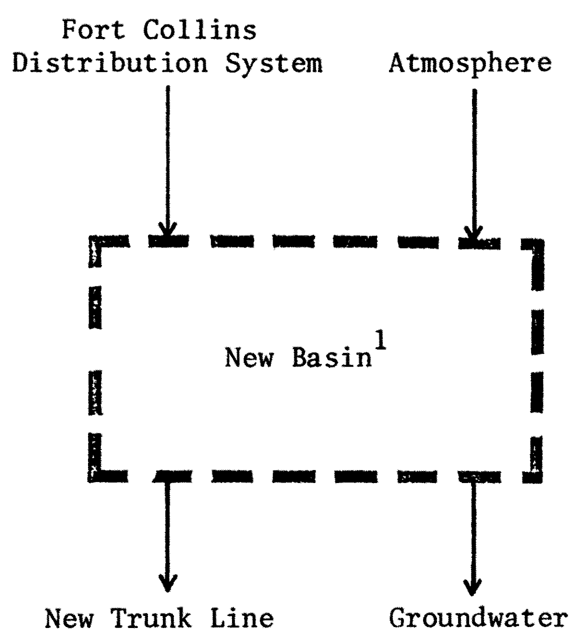


[1] Table H.2.

[2] Assumed a 30% of total consumptive use.

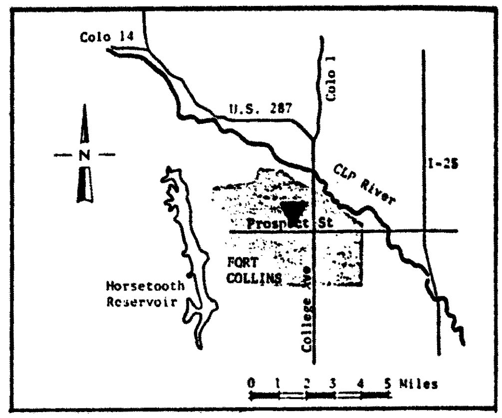
[3] Mass balanced.

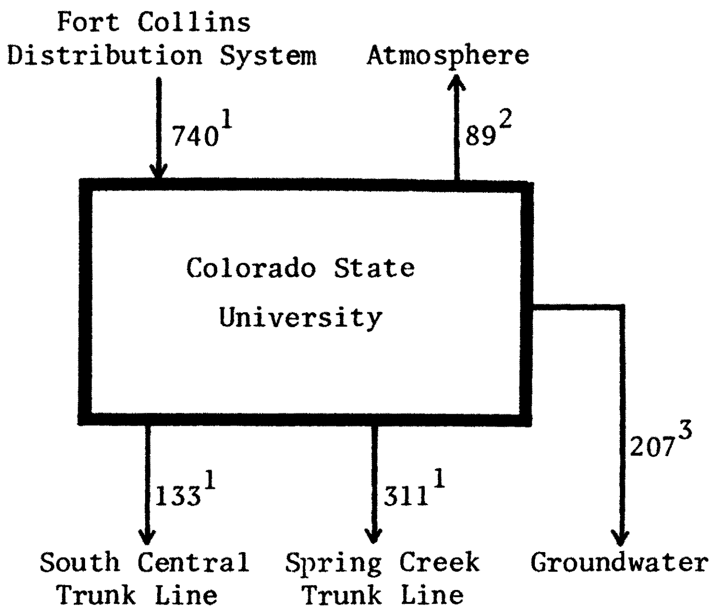
Figure A.50. Water Balance of H-P Basin.



[1] This is a "generic" element.

Figure A.51. Water Balance of New Basin.



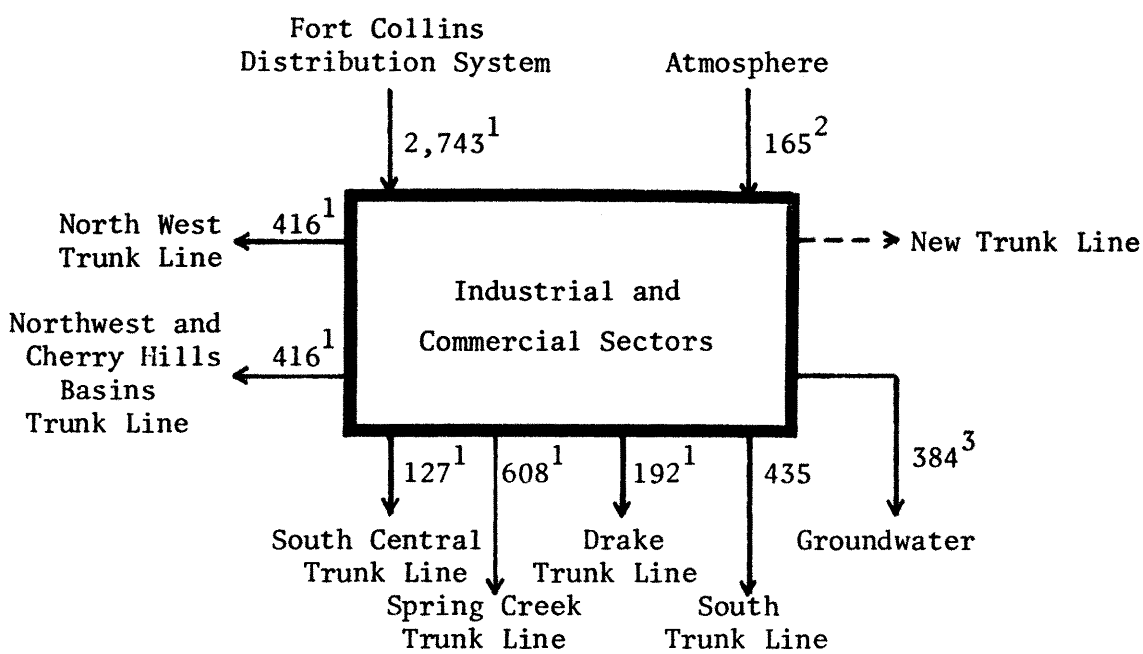


[1] Table H.2.

[2] Assumed a 30% of total consumptive use.

[3] Mass balanced.

Figure A.52. Water Balance of Colorado State University.



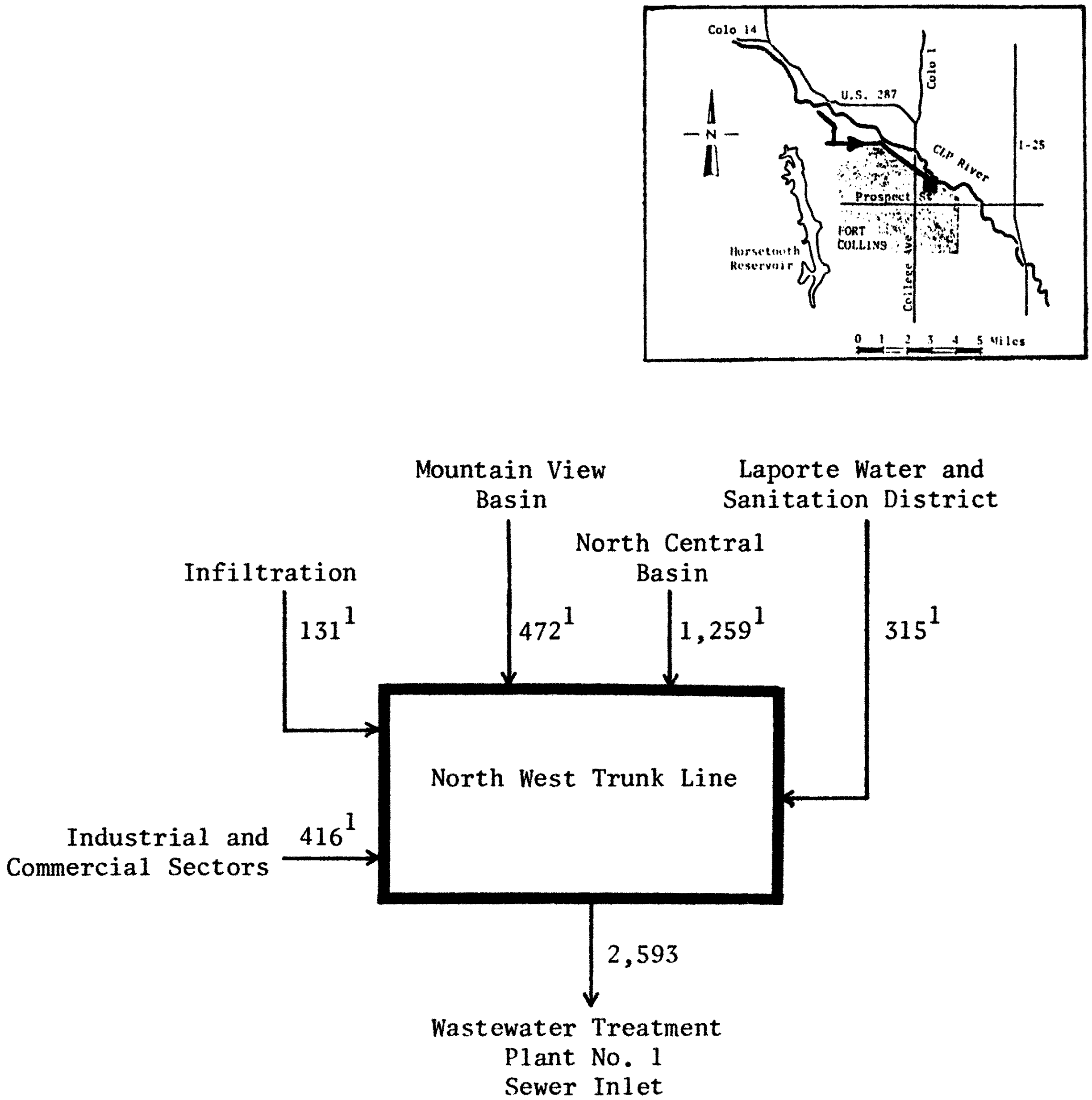
[1] Table H.2.

[2] Assumed a 30% of total consumptive use.

[3] Mass balanced.

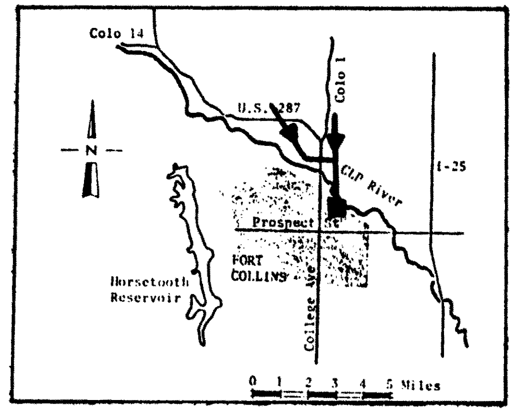
Figure A.53. Water Balance for Industrial and Commercial Sectors.

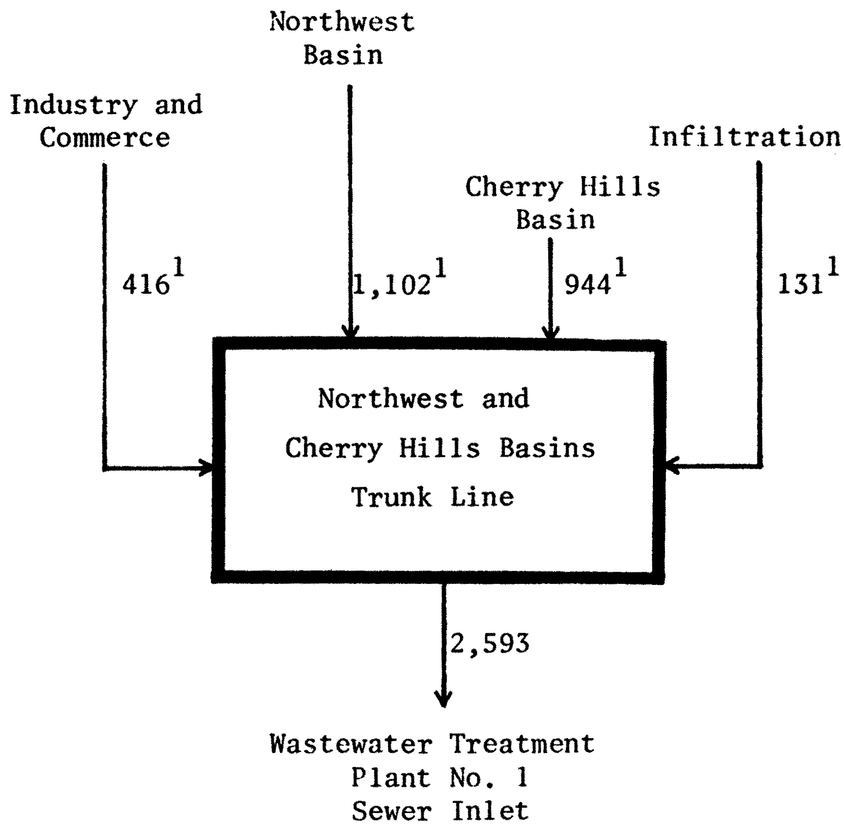
A.2.6 Sewage Trunk Lines



[1] Table H.2.

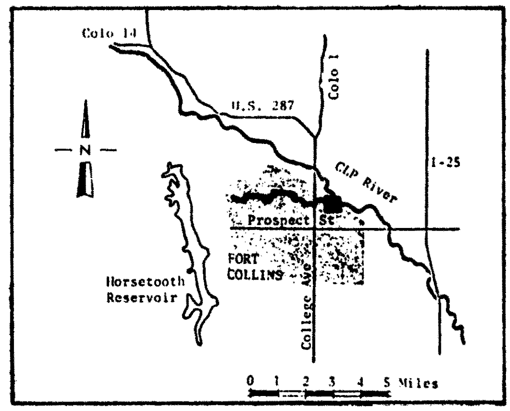
Figure A.54. Water Balance of North West Trunk Line.

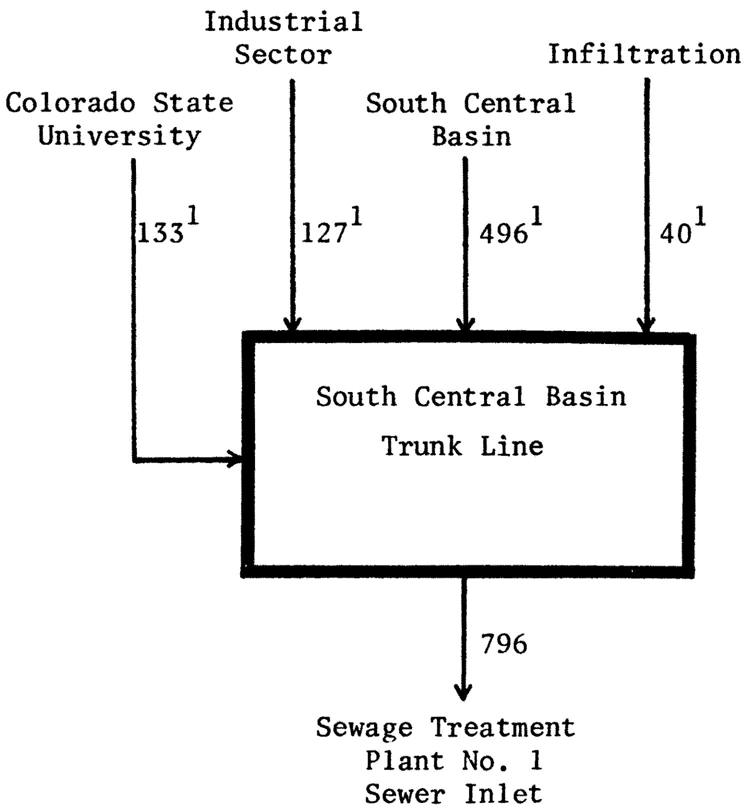




[1] Table H.2.

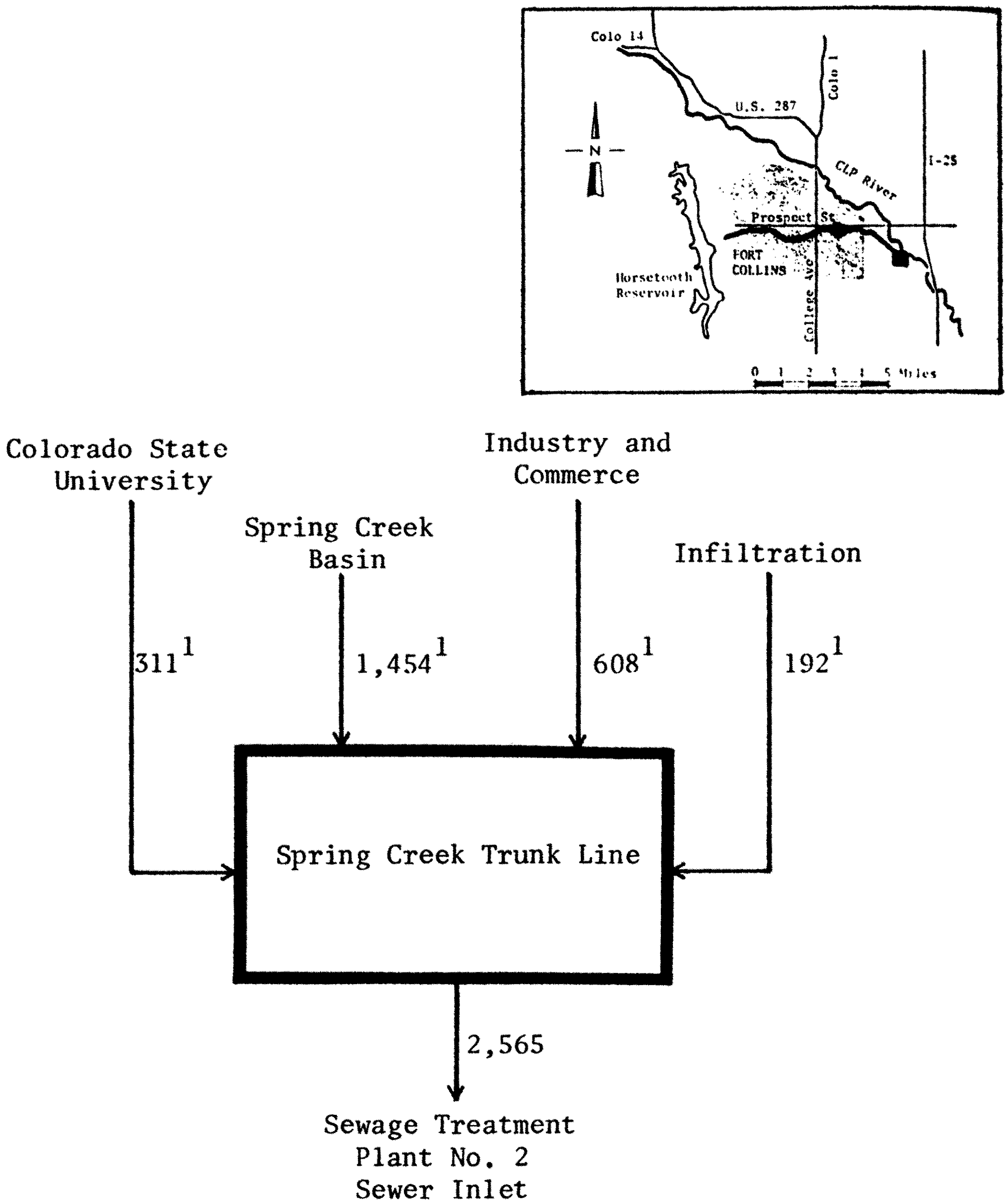
Figure A.55. Water Balance of Northwest and Cherry Hills Basins Trunk Line.





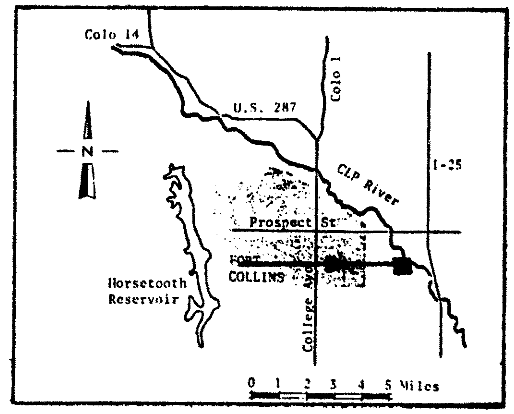
[1] Table H.2.

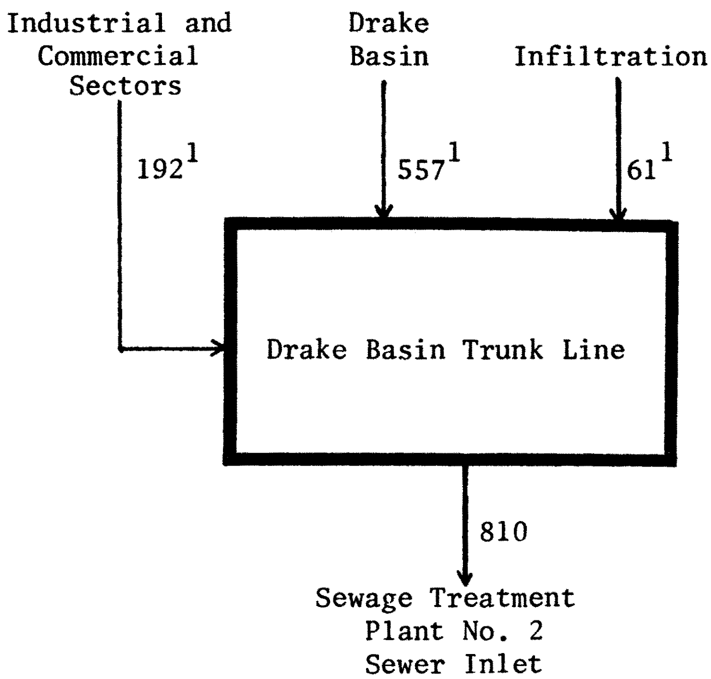
Figure A.56. Water Balance of South Central Basin Trunk Line.



[1] Table H.2.

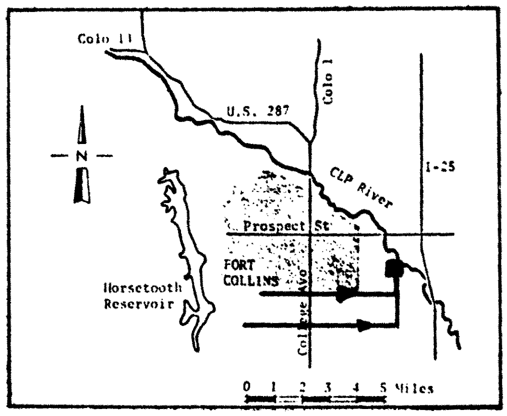
Figure A.57. Water Balance of Spring Creek Trunk Line.

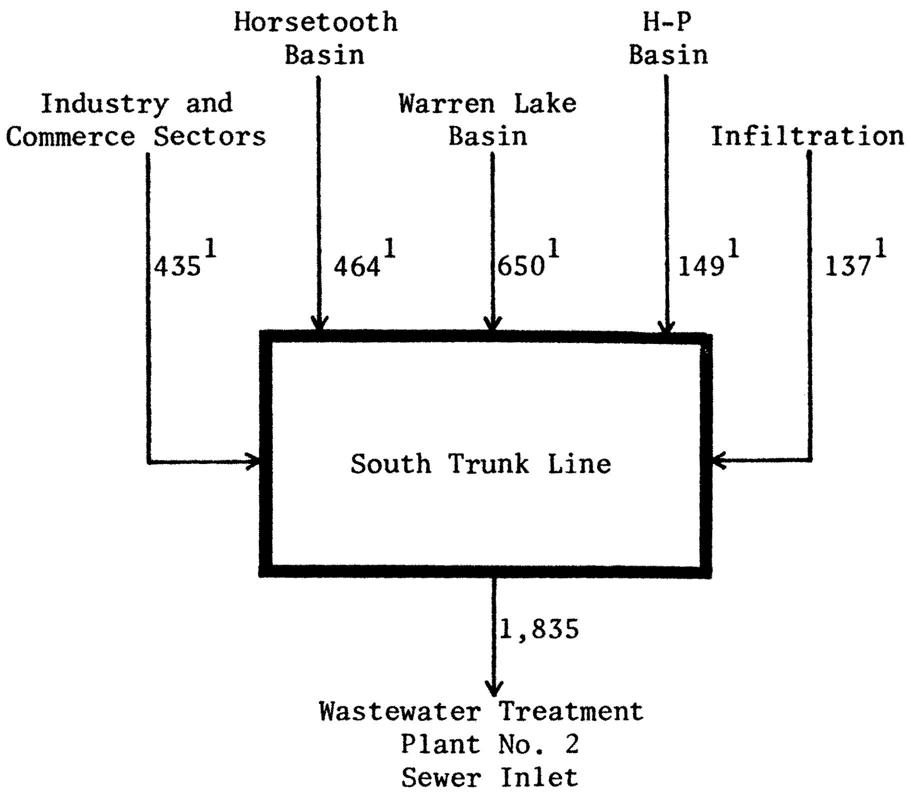




[1] Table H.2.

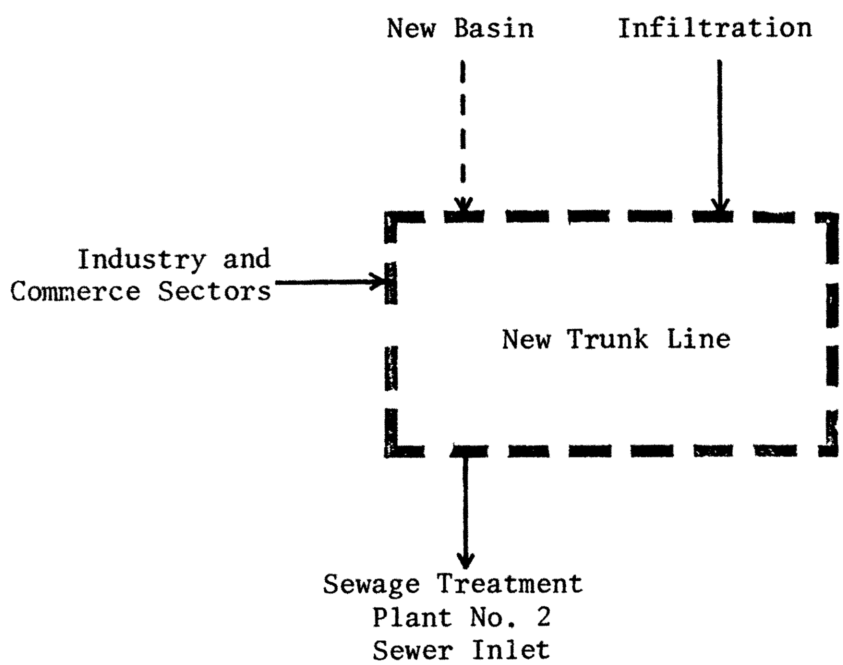
Figure A.58. Water Balance of Drake Basin Trunk Line.





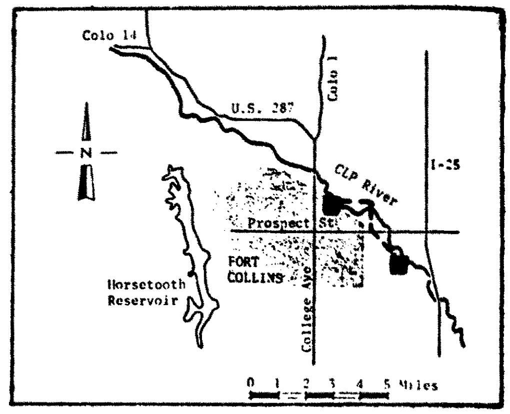
[1] Table H.2.

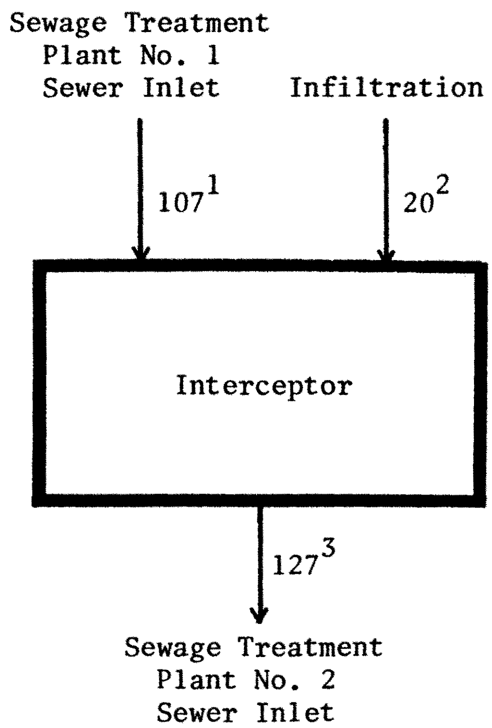
Figure A.59. Water Balance of South Trunk Line.



[1] This is a "generic" element.

Figure A.60. Water Balance of New Trunk Line.





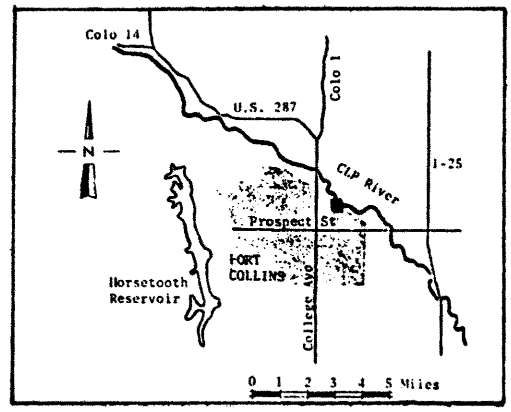
[1] Estimated by superintendent of wastewater treatment plants in 30-40 mgd.

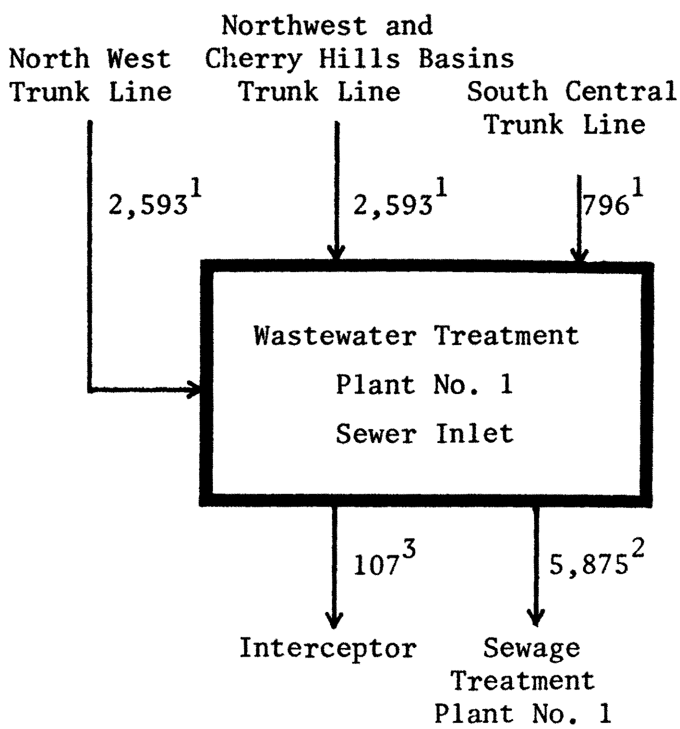
[2] Estimated proportional to the surface

[3] Mass balanced.

Figure A.61. Water Balance of Interceptor.

A.2.7 Wastewater Treatment Plant



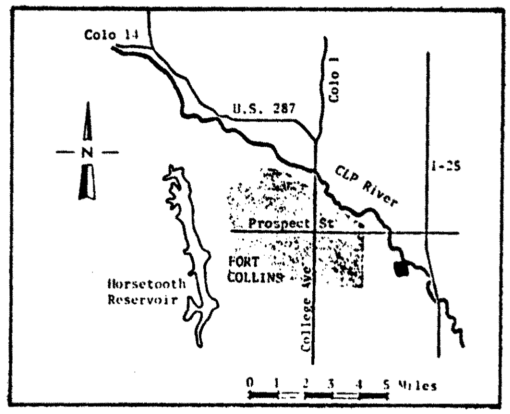


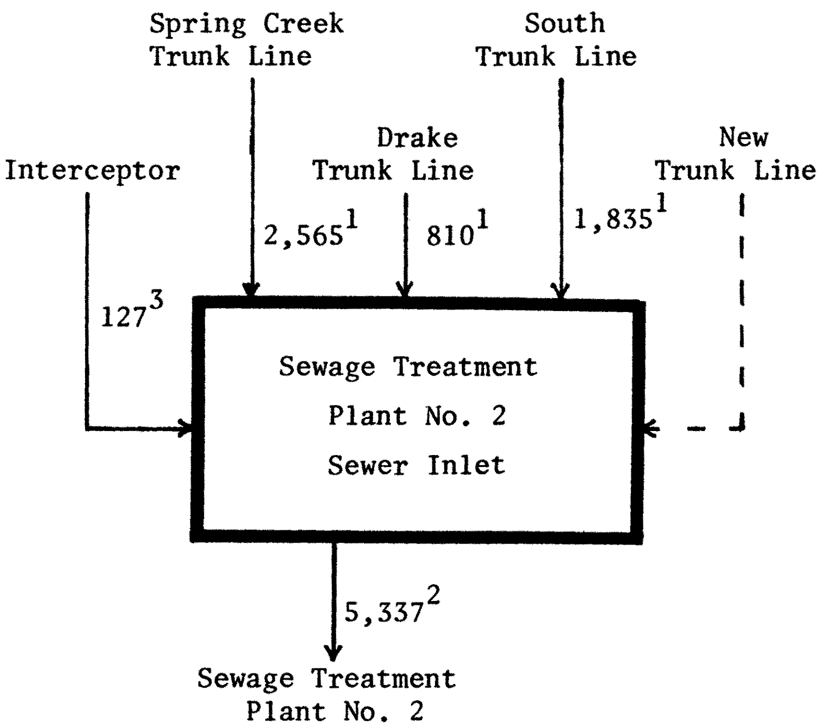
1 Figures A.54, A.55, and A.56

2 Table H.6

3 Mass balanced.

Figure A.62. Water Balance of Wastewater Treatment Plant No. 1 Sewer Inlet.



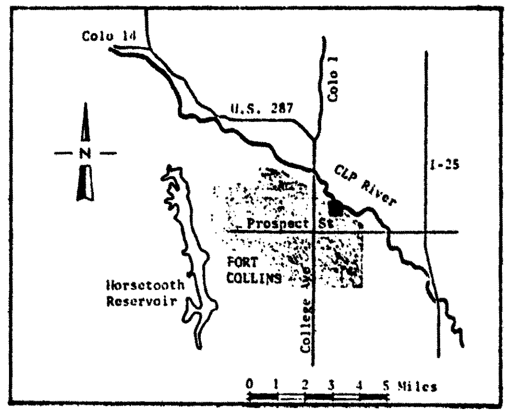


[1] Figures A.57, A.58, and A.59

[2] Table H.6

[3] Mass balanced.

Figure A.63. Water Balance of Sewage Treatment Plant No. 2 Sewer Inlet.



Wastewater Treatment
Plant No. 1
Sewer Inlet

↓ 5,875[1]

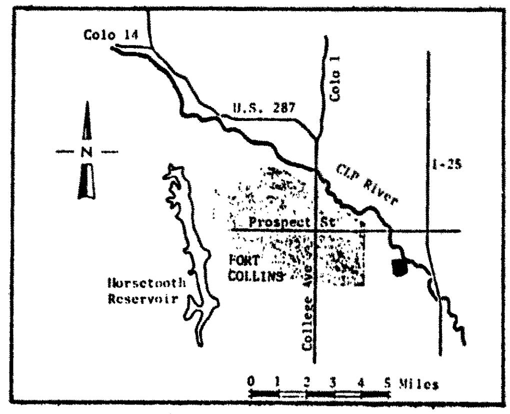
Wastewater Treatment Plant No. 1

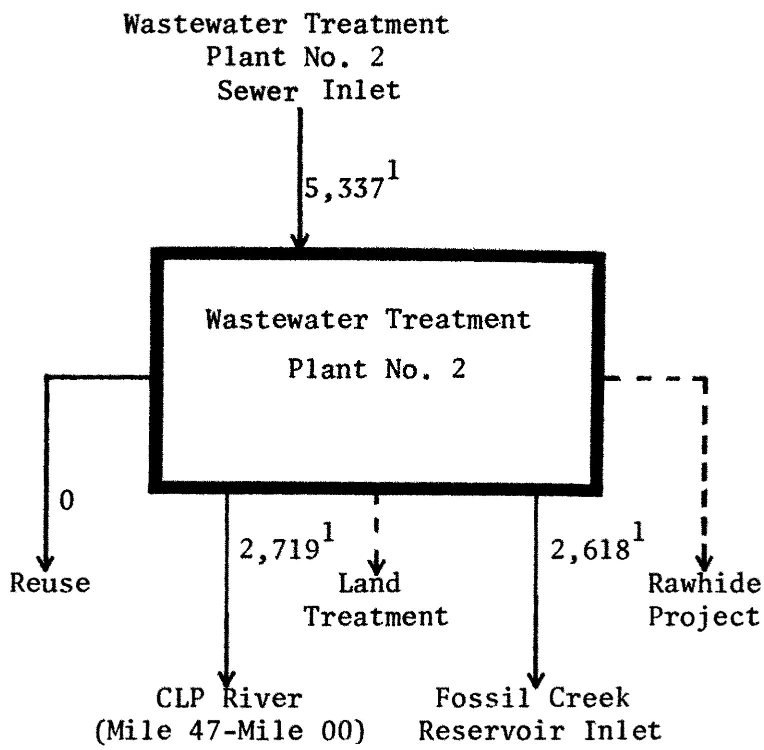
↓ 5,875[1] → CLP River (Mile 61-Mile 47)

↓ 0[1] → Reuse Bank

[1] Table H.6

Figure A.64. Water Balance for Wastewater Treatment Plant No. 1.





[1] Table H.6

Figure A.65. Water Balance for Wastewater Treatment Plant No. 2.

A.3 Exits

A.66 Cache La Poudre River (Mile 61-Mile 47)

A.67 Groundwater

A.68 Atmosphere

A.69 Cache La Poudre Reservoir Inlet

A.70 Fossil Creek Reservoir Inlet

A.71 Land Treatment

A.72 Rawhide Project

A.73 Filtered Water Sold to Other Districts

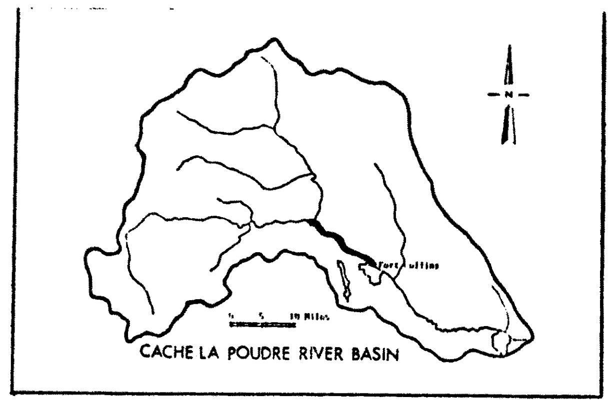
A.74 Raw Water Leased to Agricultural Users

A.75 Forfeited Without Use

A.76 Reusable Water Reservoir Storage

A.77 Non-reusable Water Reservoir Storage

A.78 Forfeited for Exchange Agreement



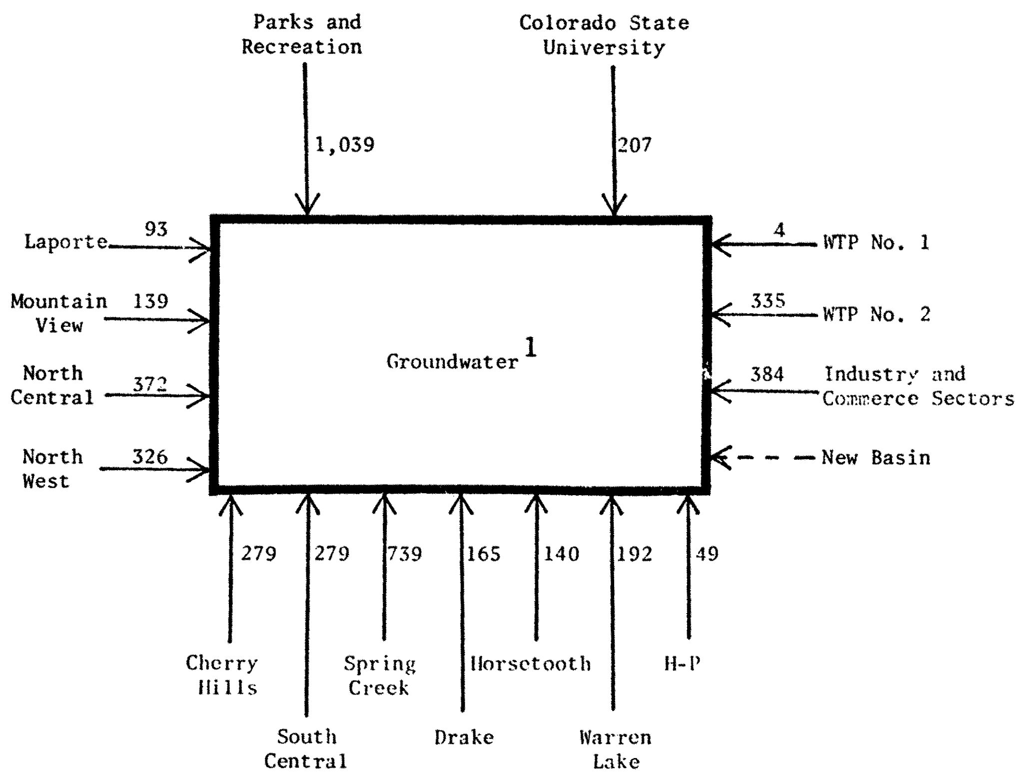
Wastewater Treatment
Plant No. 1

↓ 5,785[1]

Cache La Poudre River
(Mile 61-Mile 47)

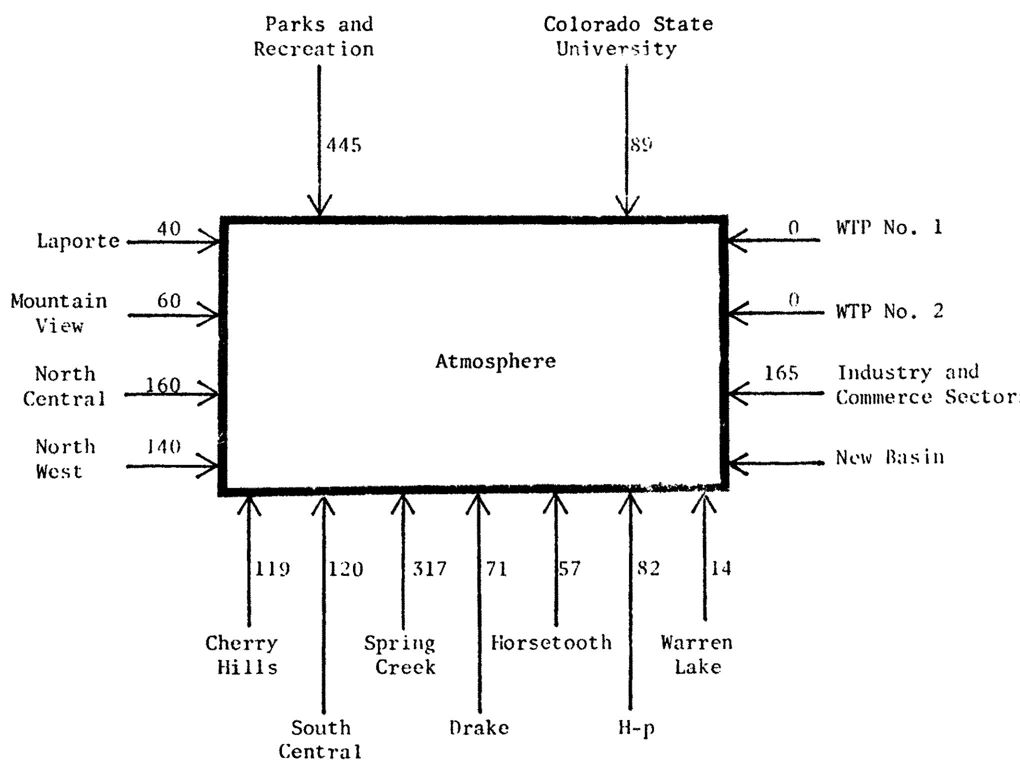
[1] Figure A.64.

Figure A.66. Effluent Discharged into the Cache La Poudre River (Mile 61-Mile 47).



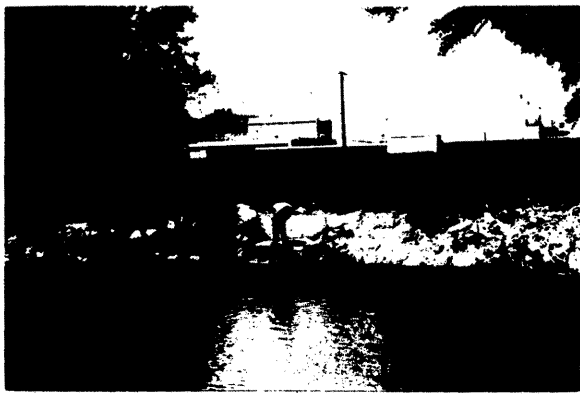
[1] From the mass balance of the different basins.

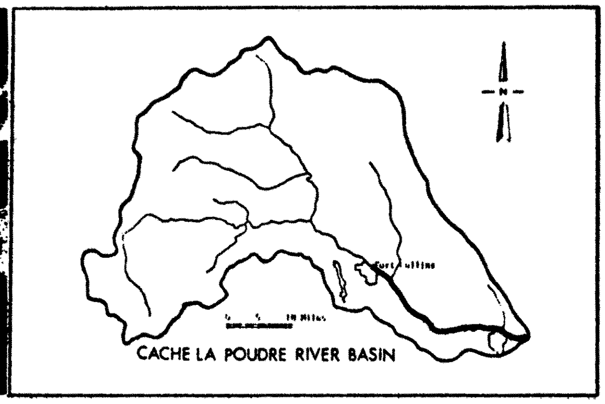
Figure A.67 Water percolating to Groundwater



[1] From the mass balance of the different basins.

Figure A.68 Water Evaporated to the Atmosphere





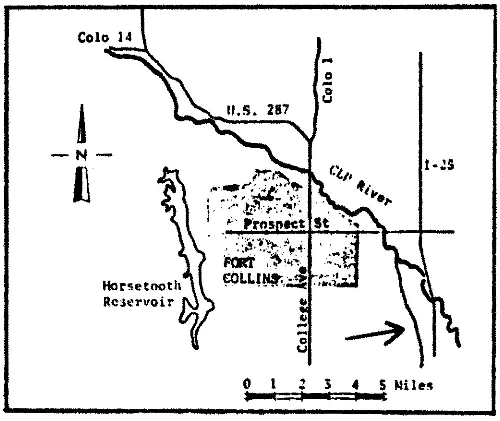
Wastewater Treatment
Plant No. 2

2,719[1]

Cache La Poudre River
(Mile 47-Mile 00)

[1] Figure A.65

Figure A.69. Effluent Discharged into the Cache La Poudre River (Mile 45-Mile 00).



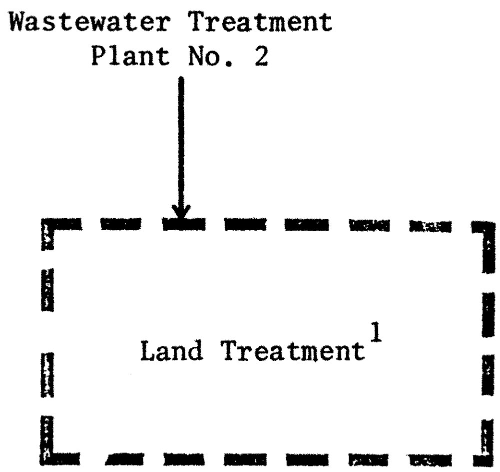
Wastewater Treatment
Plant No. 2

↓ 2,618[1]

Fossil Creek Reservoir
Inlet

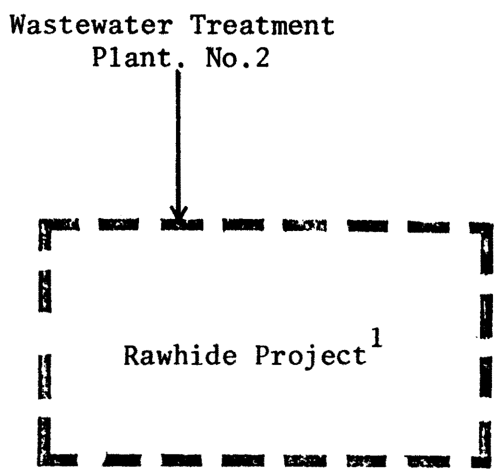
[1] Figure A.65.

Figure A.70. Effluent Discharged into Fossil Creek Reservoir Inlet.



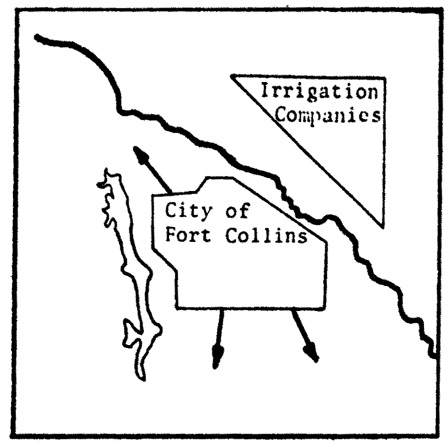
[1] This element is an alternative for the future.

Figure A.71. Effluent Sent to Land Treatment.



[1] This element is an alternative for the future.

Figure A.72. Effluent Sent to the Rawhide Project.



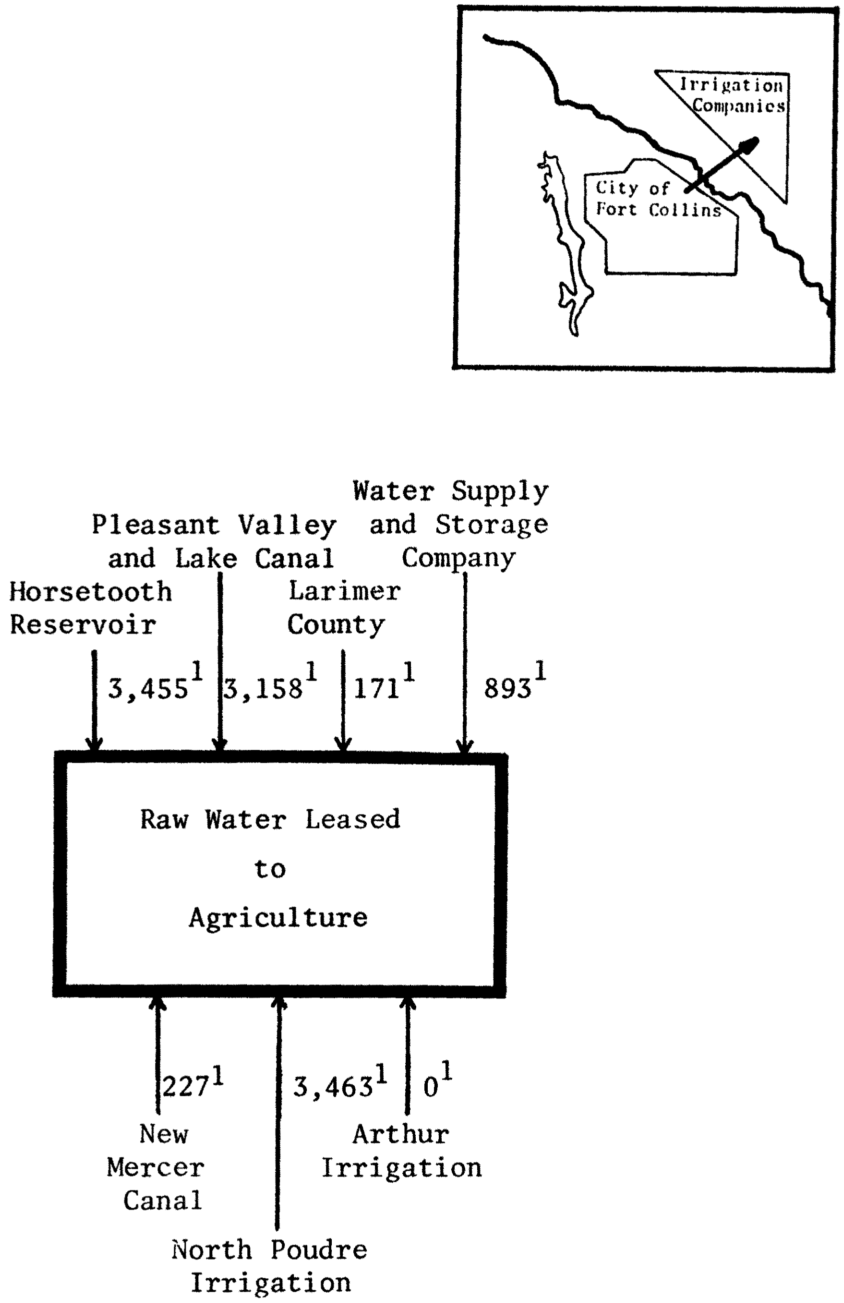
West Fort Collins Distribution System

360[1]

Filtered Water Sold to Other Districts

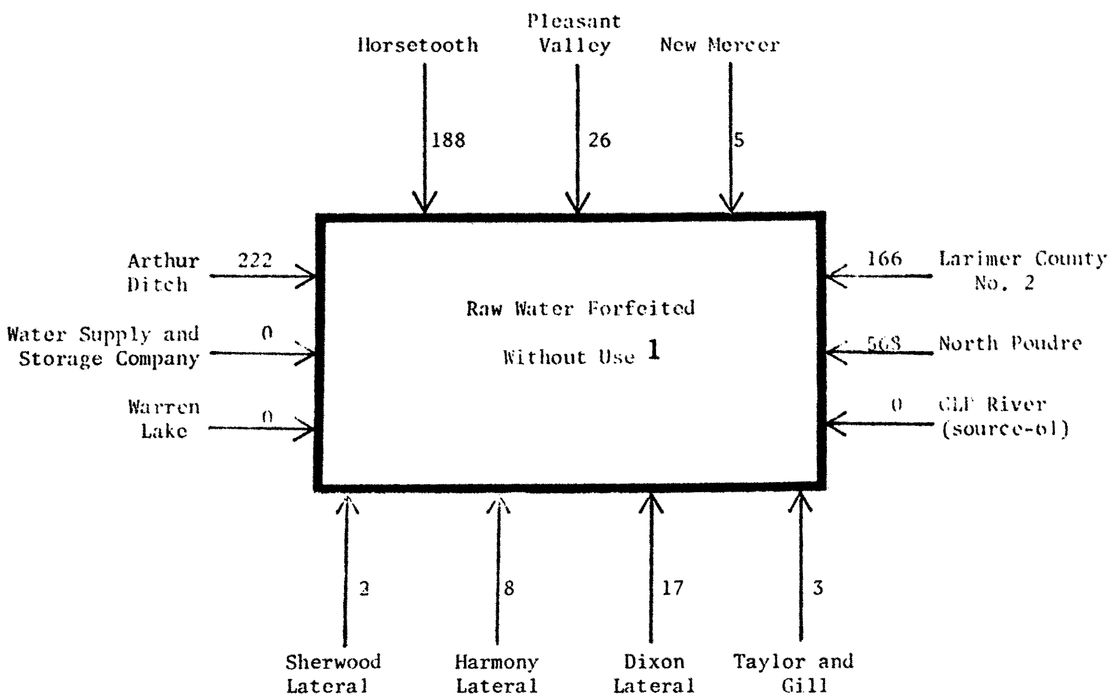
[1] From the Records at the Water & Sewer Dept.

Figure A.73. Volume of Filtered Water Sold to Other Districts.



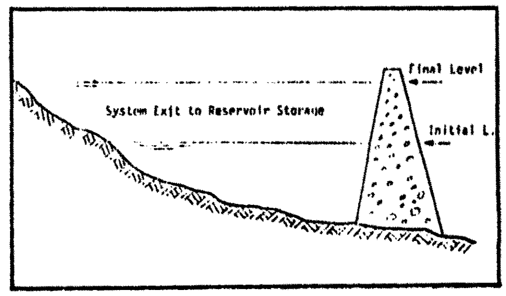
[1] From the Records at the Water & Sewer Dept.

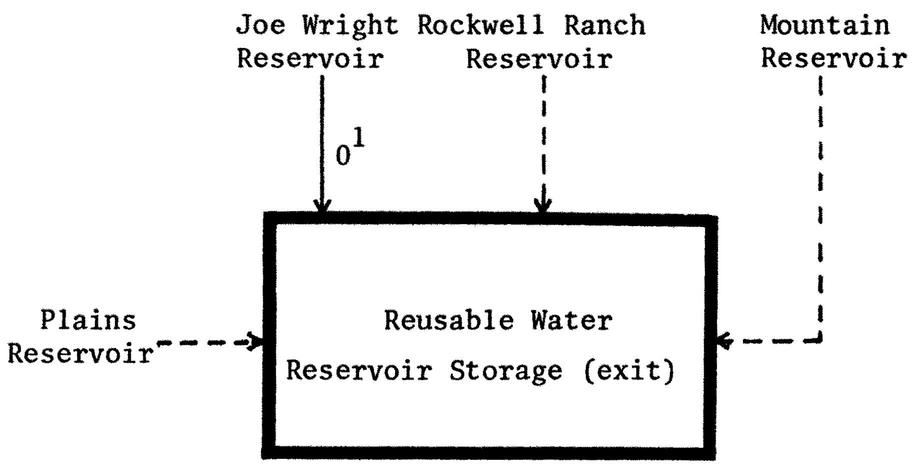
Figure A.74. Volume of Raw Water Leased to Agriculture



1 From the mass balance of the respective elements.

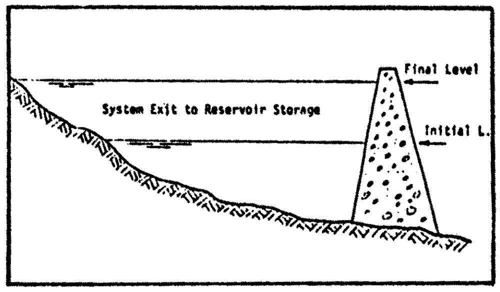
Figure A.75 Total Volume of Water Forfeited Without Use





[1] Storage not available because of enlargement works.

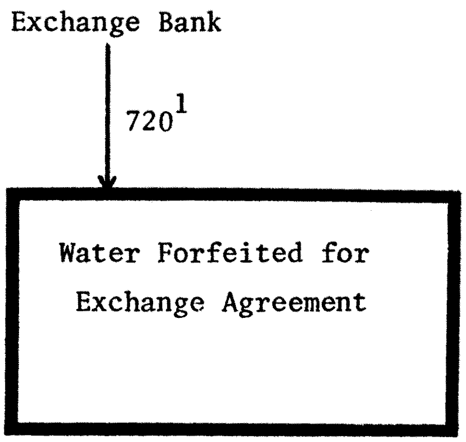
Figure A.76. Volume of Reusable Water Left at Reusable Reservoir Storage.



Plains Reservoir

Nonreusable Raw Water
Reservoir Storage

Figure A.77. Water Stored at the End of the period at Nonreusable Water Reservoir Storage.



[1] From the Records at the Water & Sewer Dept.

Figure A.78. Volume of Water Forfeited for Exchange Agreement.

B. HISTORICAL DEVELOPMENT OF THE FORT COLLINS WATER SYSTEM

The first development of the Cache La Poudre water resources was for agricultural uses. The New Mercer Colony arrived in the late 1860's, and the Union Colony settled in the early 1870's. Both colonies began to look for solutions to atleviate the effects of the scarce rainfall. Irrigation was the answer. The construction of canals and ditches is attributed (M. Thompson, 1927) to two factors: (1) the expenses to build canals were small, and (2) it was thought that the heavy black alluvial soil of lands further from the river were by far richer than the light sandy soil along the river. The first hypothesis was a mistake. The projected cost for the canals, Greeley No. 2 and No. 3, Loveland and Greeley, Larimer and Weld Counties was $20,000. The actual cost was $387,000.

The lands with rich soil and further from the river were the first occupied forcing any new settlers to the free lands closer to the river. This had a great importance in the distribution of water because the new settlers were at the banks of the river and hence could utilize river water easier than the first arrivals. The disputes were increasing and reached a peak during the drought of 1874. Water was not available for the irrigated bottom lands and there was danger that even the trees, small fruits and lawns of Greeley would be ruined. Irrigators using the Cache La Poudre met and quarreled. In the end some water was released saving the most valuable flora in Greeley. A late summer rain storm also provided relief from the drought.

Although most of the flora was saved, people felt laws were necessary to avoid repetition of the same problem. A delegation was sent to the Constitutional Convention held in Denver in December 1875, and the philosophy of appropriation was adopted in Article XVI, Sections 5 to 8 of Colorado's State Constitution.

In order to increase the amount of water available for irrigation, the people began to think about the construction of reservoirs in 1890. There were many differences among the farmers; but the in end, the engineering logic prevailed as can be noted by the large number of reservoirs in the area. The development was accomplished, however, on a piecemeal basis without systems approach. The next step in water resources development was the construction of transbasin diversions to import water into the Cache La Poudre River basin.

Continued irrigation development made it necessary to improve diversion dams, measurement facilities, and the like. This development was associated with the research program at the Agricultural College (later Colorado State University). While at Colorado State University, Ralph Parshall, faculty member, developed his world renowned Parshall flumes.

The third part of the water system is the treatment facilities. The summary of facility construction in chronological order is as follows:

--1904 construction of WTP No. 1 "Poudre"
--1948 construction of STP No. 1 off Mulberry
--1968 construction of the old STP No. 2 at Drake
--1970 construction of WTP No. 2 "Horsetooth"
--1976 improvements on WTP No. 2
--1977 operation of STP No. 2 at Drake

C. WATER LAW WATER RIGHTS

The two main water law doctrines in the United States are riparian and appropriation. The riparian doctrine has its origin in Roman Water Law. Its philosophy is: "water, like air and sunshine, is one of the gifts of the nature and therefore is free to all alike." This doctrine was applied in the eastern part of the country where water was abundant. The philosophy of this doctrine is not strictly applied today even in the humid regions. It was necessary to modify the riparian doctrine thereby creating the "American Rule of Reasonable Use."

The appropriation doctrine was created soon after the first settlements in California upon the discovery of gold in 1848. Its first application was in connection with mining operations where water was idispensable Mining use frequently involved the diversion of water to distant points. Often times the diverted water could not be returned or if returned, the quality was seriously deteriorated. These losses in quantity and quality made the riparian doctrine inapplicable.

Moreover, at that time, the West belonged almost entirely to the public domain and there were no riparian proprietors. The settlers were free to adopt rules governing the use water for mining and other purposes.

The mining industry was regulated at an early date according to certain customs and rules adopted by the miners. The essential principle of their ruels and regulations was the the right to a mining claim could be acquired only by prior discovery and appropriation and could be retained only by actual work and development. The extension of this rule to water use is rather evident, creating the appropriation doctrine which was soon recognized and sanctioned by the state courts and included in the Constitution.

The basin principles found in all jurisdictions applying this doctrine are:

1. Beneficial use of water. In order to avoid a pure economic meaning for beneficial, a clear explanation is extracted from Radosevich and Daines (1975): "Though the use to which the water is put must be beneficial, the manner in which it is used must be reasonable."

2. Defined amount. The right is valid for a determined value; the state engineer fixes the amount necessary for a particular land according to the soil and other characteristics.

3. Priority instead of equality. This is the main spirit of this doctrine; thus during drought periods, the last water rights begin to be cancelled in inverse order to their accession, guaranteeing a firm supply to the senior appropriators.

4. Perpetuity. Water rights are perpetual whenever they are exercised in proper accordance to the laws.

5. Not fixed to the land. This makes them available in a kind of stock market. For the legal aspects of heritage, taxation, and so on, water rights are considered as real property instead of personal property.

6. Loss of rights. They can be lost by means of (a) abandonment--when the right is not used for a statutory period of time, after being proved, and is intended not to use it; (b) forfeiture--when exists a non-use of all or a part of the water owned with the right, this part can be extinguished; (c) adverse possession--when someone openly uses the water of another person, and no reclamation is made, after a certain period the new user can claim the right as his own; this point leads to many court cases; (d) condemnation--this rights is exercised by preferred users that have to give an amount for compensation. The right of the municipalities to condemn agricultural water is a controversial issue in Colorado.

C.1 Water Rights and Water Administration in the Cache La Poudre Area

As a result of the adoption of the appropriation doctrine, the office of State Hydraulic Engineers was created in 1881, and water divisions and districts are formed. The Cache La Poudre River basin closely coincides with the Water District No. 3. The first steps to obtain definite information on Colorado water supplies were initiated during this early period. The office was also in charge of collecting data on snowbanks for predicting porbable runoff to the rivers. The control of the public water supplies of the state was given to the State Engineer.

Any person who desires a water right must file an application with the water clerk, setting forth facts supporting the ruling sought. Opposition, if any exists, must be filed by the last day of the second month following application. Rulings on applications and opposition will be made within sixty days of filing of opposition arguments by the referee of the water district. The rulings may be appealed to the distrct water judge.

The water of the basin can originate within its boundaries or be brought into the basin from another unconnected river basin by a transbasin diversion. Water from another basin is called "imported" or "foreign water" and has great importance for the city water system since it can be reused. The State of Colorado's first statutory provision concerning this property is contained in Senate Bill 81:

> 148-26 Right of reuse of imported water--whenever an appropriator has heretofore, or shall hereafter lawfully introduce foreign water into a stream system from an unconnected stream system, such appropriator may make a succession of uses of such water by exchange or otherwise to the extent that its value can be distinguished from the value of the streams into which it is introduced. Nothing herein can be construed to impair or diminish any water right which has become vested.

The law has always been, and continues to be, that waters originating within a basin can be used only once for the purpose of appropriation and must then, after use, be allowed to return to the river for subsequent use by junior appropriators. There was a continuing dispute among the legal profession as to whether this rule ever applied to foreign waters. Decisions of the Colorado Supreme Court can be cited in support of either view. Finally, in the case of the City and County of Denver vs. Fulton Irrigation Ditch Company, decided June 19, 1972, the Supreme Court said: "Even without the Statute (SB#81 quoted above), we think that Denver had the right to reuse, successive use and disposition of foreign water..."

The Colorado River waters imported through the Colorad-Big Thompson project (CBT), which are administered by the Northern Colorado Water Conservancy District, are an exception to this rule. CBT water cannot be reused. At the time the Colorado Big Thompson project was built, the United States, by contract with the district, reserved all of the return flows for the benefit of all downstream appropriators. This contractual provision effectively prevents any allottee of the district from making more than one use of his allotted water.

The 1974 revised tabulation of Colorado Water Rights lists about 370 absolute and conditional direct flow rights decreed to the surface water runoff of the Cache La Poudre's drainage area. Water from the mainstem of the Cache La Poudre River is decreed to 144 ditch rights and 13 pipeline rights. Thirty-one ditch rights are decreed to waters of the North Fork. A list of the existing direct diversion rights is given in Table C.1.

Twenty-two reservoirs with a combined capacity of 50,511 acre-feet are located in the mountains of the Cache La Poudre basin. These range in size from the 69 acre-feet Bellaires Lakes to the 10,128 acre-feet Halligan Reservoir (USBR, 1966). Most survivors are owned by irrigation companies but some are owned by the cities of Greeley and Fort Collins (Joe Wright Reservoir).

Horsetooth Reservoir does not have absolutely decreed storage rights for the surface flows of the Cache La Poudre River sub-basin. It does, however, have a conditional storage appropriation for 96,000 acre-feet of water from Soldier Creek. The appropriation date, of the right, is October 15, 1935 (Wilkinson, 1974). Horsetooth Reservoir was built to store imported CBT water. There are over 90 reservoirs in the plains portion of the Cache La Poudre basin.

The Cache La Poudre River basin had more land suitable for irrigation than available water to supply it. Ignoring the contribution of the Colorado-Big Thompson water which started in 1951, it was the above conditions which caused the evolvement of a puzzling exchange system.

The Cache La Poudre sub-basin, of all the sub-basins in the Souht Platte River basin, has the most intricately developed "exchanges" among users. All of the canals and most of the reservoirs are tied together in a complex network of ditches and pipelines that permit the exchange of

Table C.1 List of Water Rights by Irrigation Companies (after Skogerboe, Radosevich and Vlachos, 1973)

Canal Name	Priorities	Amount (cfs)	Date (1800's)
Ames Canal (Cap. 20 cfs)	25	17.97	10-1-67
Arthur Ditch (Cap. 110 cfs)	2	0.72	6-1-61
	19	2.165	7-1-66
	29	2.165	6-1-68
	32	1.67	6-1-69
	38	31.67	4-1-71
	52	18.33	7-20-72
	66	52.28	4-1-73
B.H. Eaton (Cap. 40 cfs)	9	29.10	4-1-64
	18	3.33	6-1-66
	53	9.27	7-25-72
Boxelder (Cap. 60 cfs)	15	32.5	3-1-66
	23	5.33	5-25-67
	30	11.93	7-1-68
Greeley #3 (Cap. 185 cfs)	35	52.0	4-1-70
	46	41.0	10-1-71
	50	63.13	7-15-72
	59	16.66	5-15-73
Chaffee (Cap. 22 cfs)	49	22.38	3-10-72
Coy (Cap. 32 cfs)	13	31.63	4-10-65
Jackson (Cap. 60 cfs)	3	11.67	6-10-61
	36	14.42	10-21-70
	67	12.13	9-15-73
Jackson	91	12.70	7-15-79
Ft. Collins Pipeline (Cap. 28 cfs)	1	3.5	6-1-60
	5	2.5	3-1-62
	6	7.0	3-15-62
	12	2.78	9-15-64
	14	4.5	5-1-65
Greeley Pipeline (Cap. 30 cfs)	6	5.0	8-1-62
	65	7.5	
Jones Ditch (Cap. 25 cfs)	24	15.52	9-1-62
Lake (Cap. 165 cfs)	54	158.35	3-1-62
Larimer County Canal (Cap. 500 cfs)	5	10.77	3-1-62
	12	13.89	9-15-64
	28	4.66	3-15-68
	56	4.0	3-20-73
	84	7.23	4-1-78
	100	463.0	4-25-81
Larimer County #2 (Cap. 180 cfs)	14	3.5	5-1-65
	57	175.0	4-1-73
Larimer & Weld (Cap. 850 cfs)	10	3.0	6-1-64
	16	1.47	4-1-66
	21	16.67	4-1-67
	45	75.0	9-20-71

Canal Name	Priorities	Amount (cfs)	Date (1800's)
Larimer & Weld (Continued)	73	54.33	1-15-75
	88	571.0	9-18-78
Little Cache La Poudre (Cap. 125 cfs)	31	62.03	
	58	20.42	
Munroe Canal - North Poudre (Cap. 250 cfs)	199	250.0	
Greeley #2 (Cap. 600 cfs)	37	110.0	10-25-70
	44	170.0	9-15-71
	72	184.0	11-10-74
	83	121.0	9-15-77
New Mercer (Cap. 105 cfs)	25	7.03	10-1-67
	33	4.17	9-3-69
	47	8.33	10-10-71
	49	15.0	7-1-72
	98	136.0	2-15-80
North Poudre Canal (Cap. 125 cfs)	2	.72	7-20-72
	17	4.75	8-15-73
	19	2.165	5-15-74
	29	2.165	2-1-80
	40	4.0	3-1-83
	52	15.0	10-1-84
	60	7.2	10-1-88
	61	9.28	2-20-90
	63	3.32	5-1-94
			Date (1900's)
	66	11.0	4-30-00
	69	3.32	8-1-01
	77	6.72	5-15-03
	79	6.72	11-1-04
	80	6.72	11-2-04
	82	2.85	12-31-24
North Poudre Canal	97	307.0	
Ogilvy (Cap. 70 cfs)	122	91.0	7-1-81
Pleasant Valley & Lake (Cap. 138 cfs)	4	10.97	9-1-61
	11	29.63	6-10-64
	51	16.50	7-10-72
	92	80.83	8-18-79
	102C	-----	10-10-81
Poudre Valley Canal (Cap. 450 cfs)	--		
Taylor & Gill (Cap. 20 cfs)	17	12.17	4-15-66
Whitney Ditch (Cap. 70 cfs)	7	48.23	9-10-71
	43	12.95	

water between any two parties that wish to do so. For example, Fort Collins can transfer some of its CBT water in Horsetooth Reservoir "up to" its storage facility in the mountains, Joe Wright Reservoir. An irrigation company, however, may divert out of priority to upstream lands by replacing it with stored water at lower elevations to satisfy the senior appropriator who has "call" on the river. In both cases, of course, compensation for carriage losses over the distance of the exchange is made so as not to injure a third party.

Anderson (1963) has stated that the existing exchange system for this area was possible for three major reasons: (1) company ownership of water rights; (2) development of private and corporate storage reservoirs; and (3) the contribution of the Colorado-Big Thompson Project (CBT).

Company ownership of waters removes the restriction that a water right is appurtenant to a specified tract of land and allows the water to be moved between several parcels of land. The reservoir system made possible a dependable water supply late in the summer. The CBT, under its charter, can easily transfer water anywhere within the Northern Colorado Water Conservancy District (NCWCD) from any one use to any other use.

There are three basin types of transfers which have evolved along the Cache La Poudre River: (1) exchanges between stockholders in a company; (2) exchanges between companies; and (3) exchanges of CBT water. Transfers involving persons belonging to a ditch company are handled by the company office. The large companies often maintain a service to facilitate the "rentals" by having a list of those who have surpluses and how much water is surplus. When any stockholder requests additional water, the company can effect the transfer with a minimum of difficulty. Many companies set a fixed rate of exchange while others leave the price up to the seller.

Municipalities and industries have competed for any CBT water shares being sold. The demand for CBT water has raised the price to a point where, if a farmer no longer wants CBT water, the person will invariably sell to a municipality because agriculture cannot afford the high price. Although the municipal and domestic water distriacts have acquired almost 23 percent of the CBT water, the loss to agriculture is not as great as it would seem at first glance for three reasons: (1) the cities have expanded and taken over land previously used for agriculture; (2) there are larger return flows from cities than from a corresponding agricultural area, even though the same amount is approximately needed on a per acre basis for both uses; and (3) at the present time, the cities have surplus water and are "renting" it to agricultural and industrial users.

A very important element in relation to the future conditions is the United States Reserved Rights Claims. United State Reserved Rights could have an important impact on imported waters.

The United State, in 1969, filed its application in various courts in Colorado. The United States is seeking an adjudication of certain water rights, including its rights to the waters in North Park. Its claim is based not on the Colorado water laws but rather upon the theory that the United States has always owned and has reserved substantial portions of the waters of Colorado's streams. These waters originate on federal lands such as national forests. States Supreme Court decisions back up these rights.

The present claims of the United States are those arising by virtue of United States ownership of the national forests and other public lands in North Park. These claims are in conflict with the rights of the City of Fort Collins. The United States is claiming rights which, if granted, could have substantial effect on the Michigan Ditch. The Michigan Ditch, though located primarily outside the forest, obtains a substantial portion of its flow from the forest above. More specifically, the United States' claim is"

> The United States of America hereby claims certain quantities of the surface, ground and underground waters, both tributary and nontributary, which were unappropriated as of the reservations dates, and which are or will become reasonably necessary to fulfill the present and future purpose of purposes for which said reservations were created . . . The United States calims direct water rights, storage water rights, transportation rights and well rights for purposes, including, but not limited to, the following: growth, management and production of a continuous supply of timer; recreation; domestic uses; municipal and administrative site uses; agriculture and irrigation; stock grazing and watering; the development, conservation and management of resident and migratory wildlife and wildlife resources, the terms 'wildlife' and 'wildlife resources,' including birds, fishes, mammals, and all other classes of wild animals, and all types of aquatic and land vegetation upon which wildlife is dependent; fire fighting and prevention; forest improvement and protection; commercial, drinking and sanitary uses; road watering; watershed proteciton and management, and the securing of favorable conditions of water flows; wilderness preservation; flood, soil and erosion control; preservation of scenic, aesthetic, and other public values; and fish culture, conservation, habitat protection and management.

The rights of the United States, as seen by it, are not limited to the amount of water used on the requested appropriation date. The quantity is instead indefinite and subject to enlargement.

Recognizing the commonelity of interest of all appropriators of the water of North Park, the City of Fort Collins is participating in the defense of its water rights with the Jackson County Water Conservancy District (representing the residents of North Park) and the Water Supply and Storage Company. The Water Supply and Storage Company owns the Cameron Pass ditch and diverts water to the Poudre from the Michigan Rover headwaters.

D. GEOGRAPHICAL AND CLIMATOLOGICAL CHARACTERISTICS

The City of Fort Collins is located along the foothills of north central Colorado's Front Range at an elevation of 5,004 feet. The Cache La Poudre River crosses the City in a northwest southwest direction.

The number of clear days during the year averages 300. The average number of frost-free days is 144, from June through September. The total annual average precipitation is 14.94 inches. The monthly records of precipitation, temperature, and humidity are summarized in Table D.1.

The regional winds blow predominantly from the northwest. The average velocity is 5 miles per hour. The average maximum velocity is 80 miles per hour.

E. POPULATION CHARACTERISTICS

The City of Fort Collins, since its origins in the 1860's, has been characterized by a high population growth rate. Table E.1 shows the population census from 1860 through 1976. Several population projections are studied in Appendix G and plotted in Figure G.7.

F. ADMINISTRATIVE STRUCTURE OF THE CITY OF FORT COLLINS

The town of Fort Collins was incorporated by an order of the Board of County Commissioners of Larimer County, Colorado, on February 3, 1873. The town became a city of the second class on February 2, 1883. The first charter, establishing a commission form of government, was adopted by the electorate of the city on October 5, 1954. See the schematic on Figure F.1.

The high post-war population growth of Fort Collins made it necessary to expand the city water system. The expansion was the origin of many problems between city interests and those of the irrigators. Two court cases resulting from misuse and misappropriation of city water in the 1950's precipitated the formation of the Water Board (Jones-San Filippo, 1973).

The Board was established by ordinance to advise the city on its water needs and the acquisition of additional water supplies. In 1967 the Water Board was established in the city charter as an advisory board to the city council with the following duties and functions:

1. To advise the council on all matters pertaining to acquisition, control, and disposition of water rights;

2. To advise the council on all matters pertaining to the municipal water works system;

3. To perform such other duties and functions and have other powers as may be provided by ordinance of the city council.

Therefore, although the Water Board could have executive power, it has never been delegated by the city council. The Water Board is limited to an advisory function. In general the Water Board is composed of water specialists and other people representing different community interests.

Table D.1 Climatic Characteristics of Fort Collins

	Precipit (Inches)	Max Temp	Mean Temp	Min Temp	Ave Relat Humidity
January	0.45	40.3	26.2	11.9	43%
February	0.43	42.5	28.6	14.6	
March	1.04	49.7	36.0	22.2	
April	1.82	60.1	46.1	32.1	
May	2.90	68.0	54.4	40.8	
June	2.14	78.4	63.7	48.9	30%
July	1.47	84.4	69.4	54.4	30%
August	1.55	83.2	68.0	52.7	
September	0.96	75.6	59.7	43.8	
October	1.28	64.3	48.6	32.8	
November	0.54	51.1	36.4	21.6	
December	0.36	42.3	28.3	14.3	43%

Table E.1 Population Census, Fort Collins-Larimer County

Census of	Town or City	County
1870	---	838
1975	400-500?	---
1880	1,356	4,844
1890	2,011	9,712
1900	3,053	12,168
1910	8,210	25,270
1920	8,755	27,872
1930	11,489	33,137
1940	12,251	35,539
1950	14,937	43,554
1960	25,027	53,343
1970	43,377	89,900
1973	55,375	114,000
1976 (est)	65,400	137,500

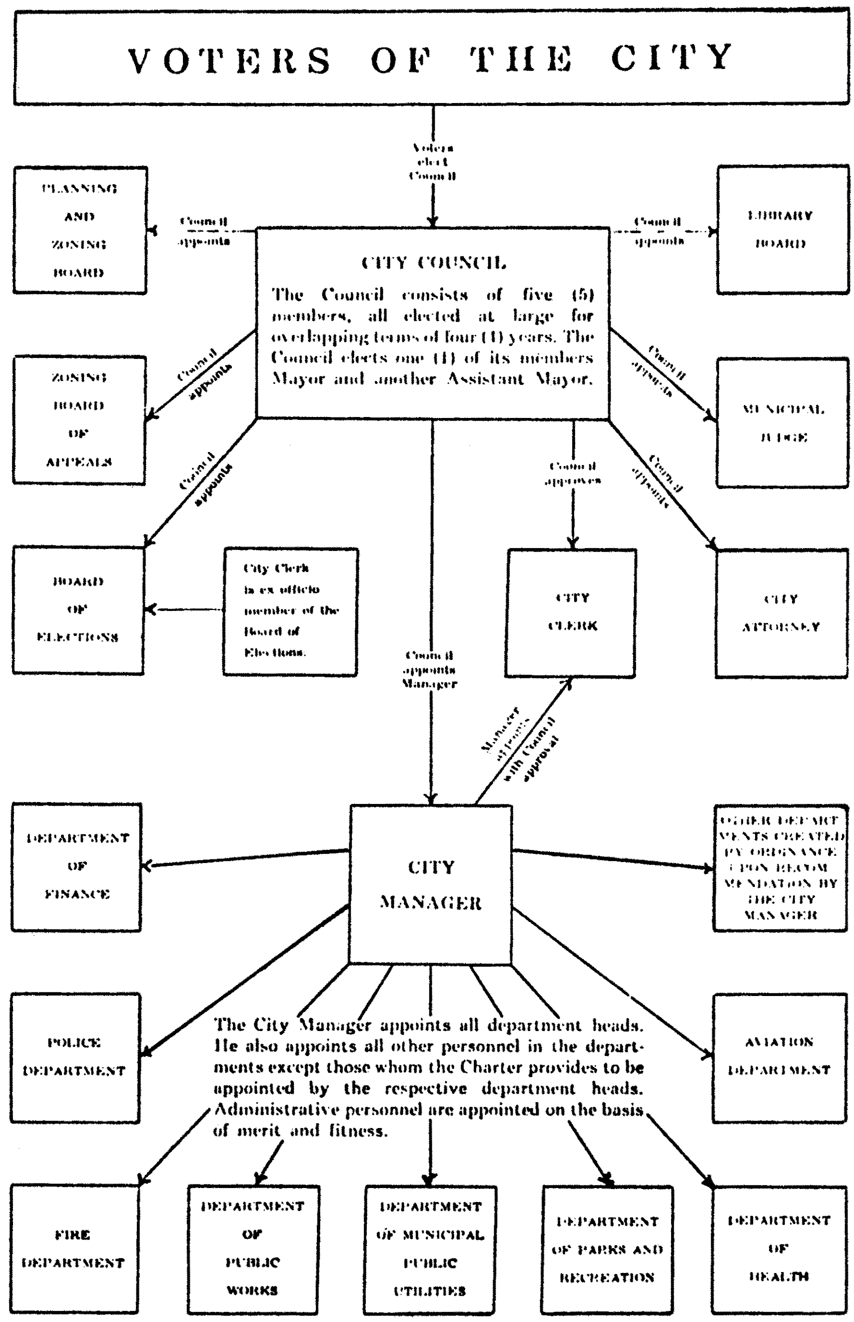


Figure F.1 Diagram of the Government of the City of Fort Collins (Extracted from the City's Code).

G. ALTERNATIVES FOR THE FUTURE

G.1 Windy Gap Project

The idea of the Windy Gap Project came out in the 1960's led by representatives of Fort Collins (Tom Coffey and Ward Fisher). In 1968 the "Six Cities Water Committee" was formed with members from Fort Collins, Loveland, Estes Park, Boulder, Longmont and Greeley in order to study the feasibility of the project. A report from Engineering Consultants, Inc. was submitted to the committee in March 1970.

The proposed Windy Gap Project would be located on the Colorado River below Lake Granby and immediately downstream from the junction of the Colorado River with the Fraser River (Figure G.1). The idea is to use this project in connection with the Colorado-Big Thompson for the transportation of the waters collected there to the eastern slope. (Figure G.1).

The original study contemplated a possible two-stage development. The first stage included a diversion weir diverting water to a pumping plant and from thence to the toe of Granby Reservoir. Part of the flow was to be used to provide the required fish flows at the toe of Granby Dam--to all ow capture within Granby Dam--and part was to be pumped directly into Granby Reservoir. The waters would then be pumped in the same manner as CBT waters to Grand Lake for diversion through the Adams Tunnel. This could produce 25,000 acre-feet of water per year with a cost of $13.50 per acre-foot.

The second stage would involve the construction of a storage reservoir at Windy Gap. The waters produced would be 58,000 acre-feet at a cost of $32.80 per acre-foot plus carriage costs.

The most important difficulties are the legal aspects due to conflicts between eastern and western slope interests. At the present, the legal process is in its final stage with optimistic perspectives for the completion of the project.

G.2 Storage Reservoirs

Following the "build mountain reservoir" policy, the city acquired Joe Wright Reservoir from North Poudre Irrigation Company in 1971. The original capacity was 800 acre-feet. Work to enlarge its capacity to 7,840 acre-feet is nearing completion. Other possible sights have been considered. Rockwell Ranch site was jointly studied with the City of Greeley and the lands were bought. The possible dam site is situated about eight miles above the mouth of the Sourth Fort of the Cache La Poudre River and about 1,000 feet below the junction of the South Fork with the Little Beaver Creek. The first feasiblity studies were done in 1960.

Another site close to Rockwell Ranch was considered as a better alternative in a place known as Poverty Flats. Both projects have been

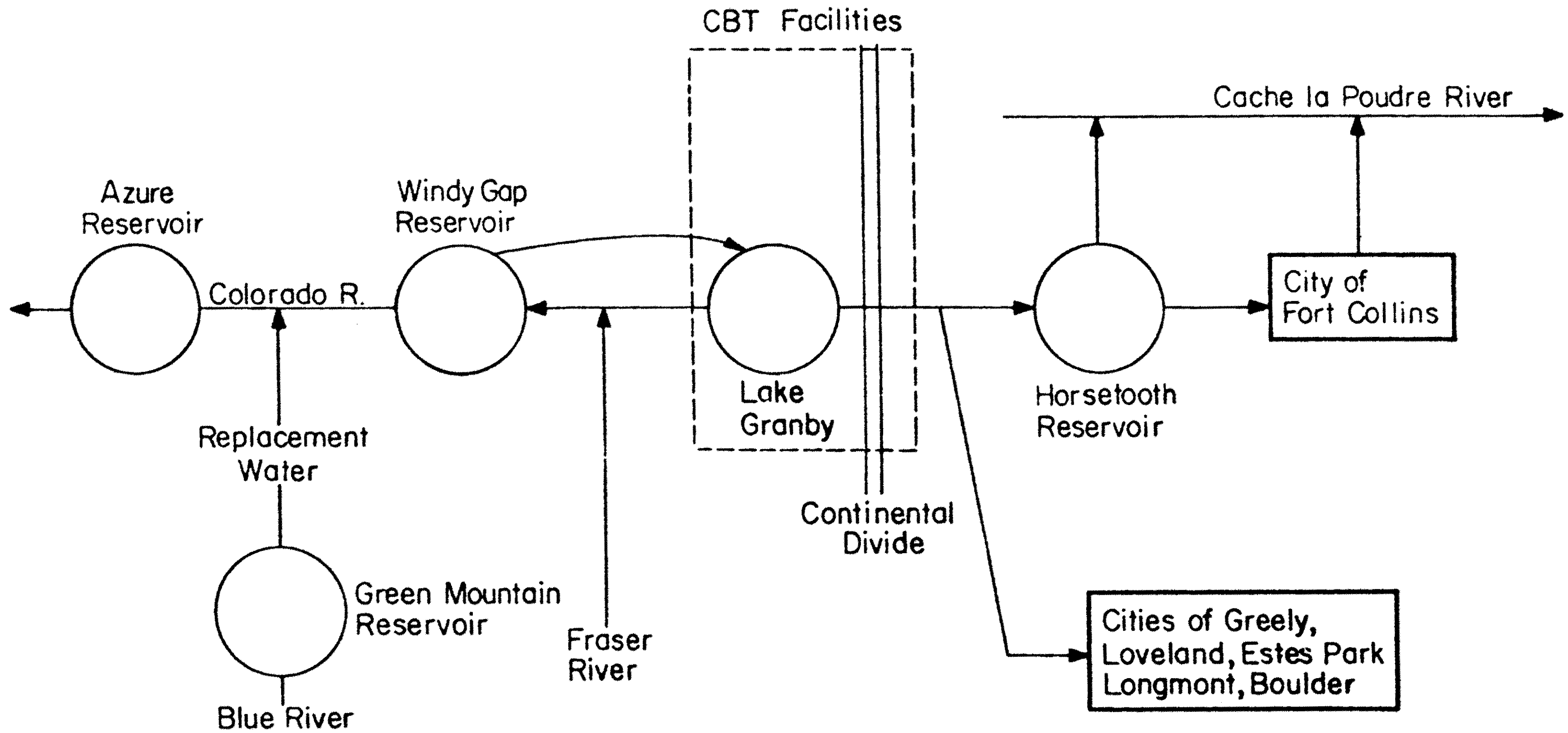


Figure G.1 Schematic of Windy Gap Project (derived from Deredec, 1972) temporarily filed because of the acquisition of Joe Wright. Arguments against these reservoirs came from possible environmental impacts. Reservoirs on the plains, even though less effective, cannot be neglected. The large number of these reservoirs surrounding the Fort Collins area makes it possible to buy an existing reservoir. Another alternative is to buy storage rights. This solution always present difficulties of operation because of the sharing of interests.

Some studies have been done in relation to Windsor and Fossil Creek Reservoir. The importance of these facilities may be increased in the near future if they are used to store the effluent of the wastewater treatment plants for future land treatment.

G.3 Reuse

The average wastewater return flow from the city is approximately 70 percent. Bittinger Eng. in their study on the Rawhide Project estimate the consumptive use as 45 percent. For their reuse study both return flows are considered, 70 percent and 55 percent.

Maximum reuse. This theoretical maximum is reached after an infinite number of reuses. The value will be given by the sum of the infinite terms geometric series:

$$\Sigma = a + ar + ar^2 + ar^3 + \ldots = \frac{a}{1-r}$$

where: a = initial volume considered
r = return flow rate

Considering a unit of reusable water, i.e. a = 1, for the two return flows considered we obtain:

$$r = 0.7 \qquad \Sigma = \frac{1}{1-0.7} = 3.333$$

$$r = 0.55 \qquad \Sigma = \frac{1}{1-0.55} = 2.222$$

Feasible Reuse. If a limited number of reuse cycles is analyzed, the total potential reuse volume is smaller. The sum of the finite terms geometric series will be:

$$\Sigma = a + ar + ar^2 + \ldots + ar^{n-1} = \frac{a(1-r^n)}{1-r}$$

where: a = initial reusable volume
r = return flow rate
n = number of terms

This known mathematical expression can be modified to fit with the usual speaking expressions. When we talk about a reuse of water, we mean a second use, hence the expression of the sum will be:

$$\Sigma = \frac{a(1-r^{n+1})}{1-r}$$

where n is now the number of reuses of the initial unit of water.

When this number is increased, the sum of the series will tend asymptotically to the maximum theoretical value already obtained. The values for several reuse cycles and the two return flows considered are given in Table G.1.

Table G.1 Number of Times Utilized a Unit of Water (Factor α)

Number of Reuse Cycles	Return Flow 70%	Return Flow 55%
1	1.70	1.55
2	2.19	1.85
3	2.53	2.02
4	2.77	2.11
5	2.94	2.16
6	3.06	2.19
7	3.14	2.20
8	3.20	2.21

Calling α the sum of the series, which indicates the number of times that a unit of water is utilized, the available volume of water after the reuse alternative will be:

$$V_n = \alpha V$$

where: V_n = volume available after n reuses
α = coefficient obtained from Table G.1
V = initial volume of reusable water

The values obtained in Table G.1 are represented graphically in Figure G.2

In order to complete a cycle of reuse, it is necessary to raise the water upstream from the effluent of the wastewater treatment plants to the inlets of the water treatment plants. One solution would be to pump it. The particular characteristics of the system make it more interesting at this time to use exchange agreements. In the exchange case the values from reuse should be lowered to the extent that agreements with the agricultural sector reduce reuse potential by 20 percent.

Reuse of Fort Collins' wastewater will be made in connection with the Rawhide Project. This alternative is studied in G.7.2.

G.4 New Demand Sectors

The average annaul per capita consumption of water has been decreasing during recent years from values of 300 gallons per capita per day in the mid 1950's to almost 200 at the present time, as shown in Figure G.3. Estimating a future demand of 210 gpcd and using the population growth projection utilized by the Water Utilities Department (Figure G.4) the demand curve shown in Figure G.5 is derived. Both drought and wet water year supplies were considered. The drought periods present a periodical frequency of 20 to 24 years. Therefore, another dry cycle is expected by the end of this century.

The parks and golf courses in the city use primarily raw water. Raw water use does not affect the capacity of the water treatment plants. The Scotts Professional Turf Manual, 1976, indicates that to maintain the health, growth, and color of grass, shrubs, flowers, and trees in developed parks, the irrigation should amount to 1.5 inches per week. Therefore for the 26 week season, 1.5 x 26 = 39 inches = 3.25 feet are needed. Therefore it is necessary to consider a demand of 3.25 acre-feet per year for each acre of new parks and golf courses.

A new demand sector for the future is the Rawhide Project. The project will utilize effluent water from the city that comes from a foreign basin import source.

G.5 Alternatives in Patterns of Use

G.5.1 The Ditch System. Most of the ditches of the Fort collins water system were built during the last quarter of the past century. There have been few modifications since that time. The seepage of these unlined ditches averages 25 percent. During the late 1960's there were several studies about consolidation of ditches. Huszar, et al., (1969) concluded in their report that the consolidation of New Mercer Canal and Larimer County No. 2 had a benefit-dost ratio greater than one (Figure G.6). These two ditches are a clear example of the characteristics of the system. Both ditches have the same point of diversion, and they circulate in parallel paths over 12 miles with a maximum separation of one-half mile and a minimum of nine feet. The consolidation of these two ditches would reduce the seepage by reducing the wetted perimeter. The city could save money on bridges and their maintenance. At that time, the City of Fort Collins was not interested in the project but the conditions can change in the near future. The city is presently interested in the possibility of using the ditches as storm drains.

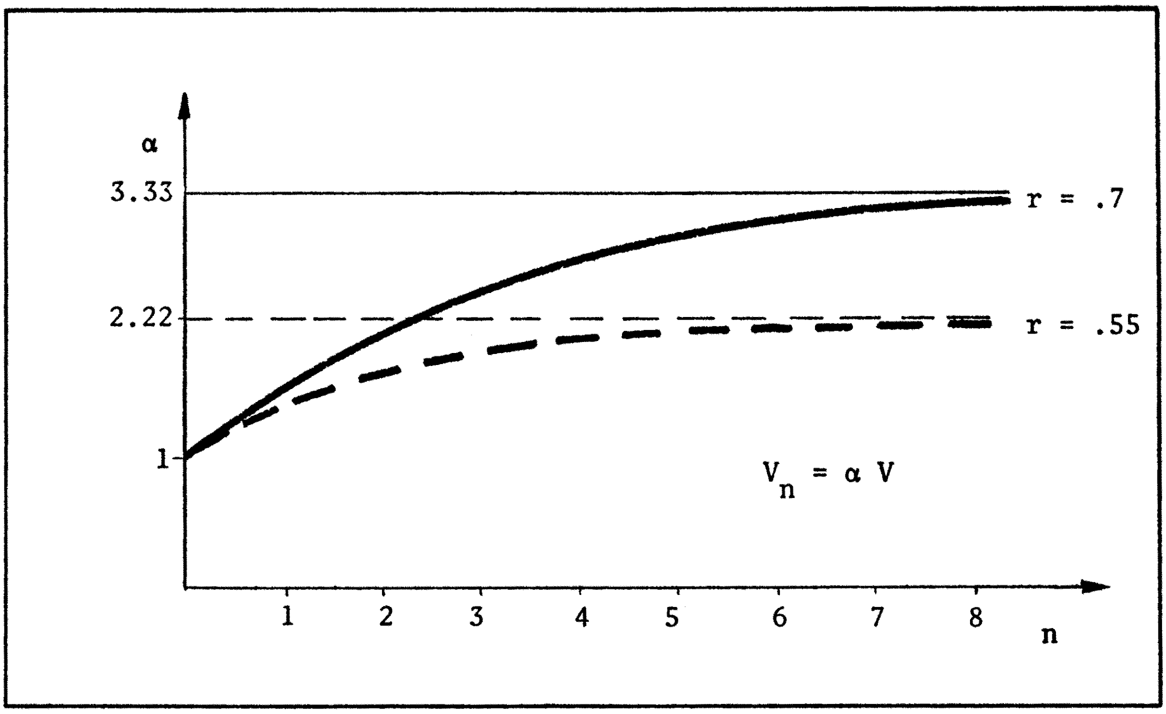


Figure G.2 Graphical Representation of Table G.1

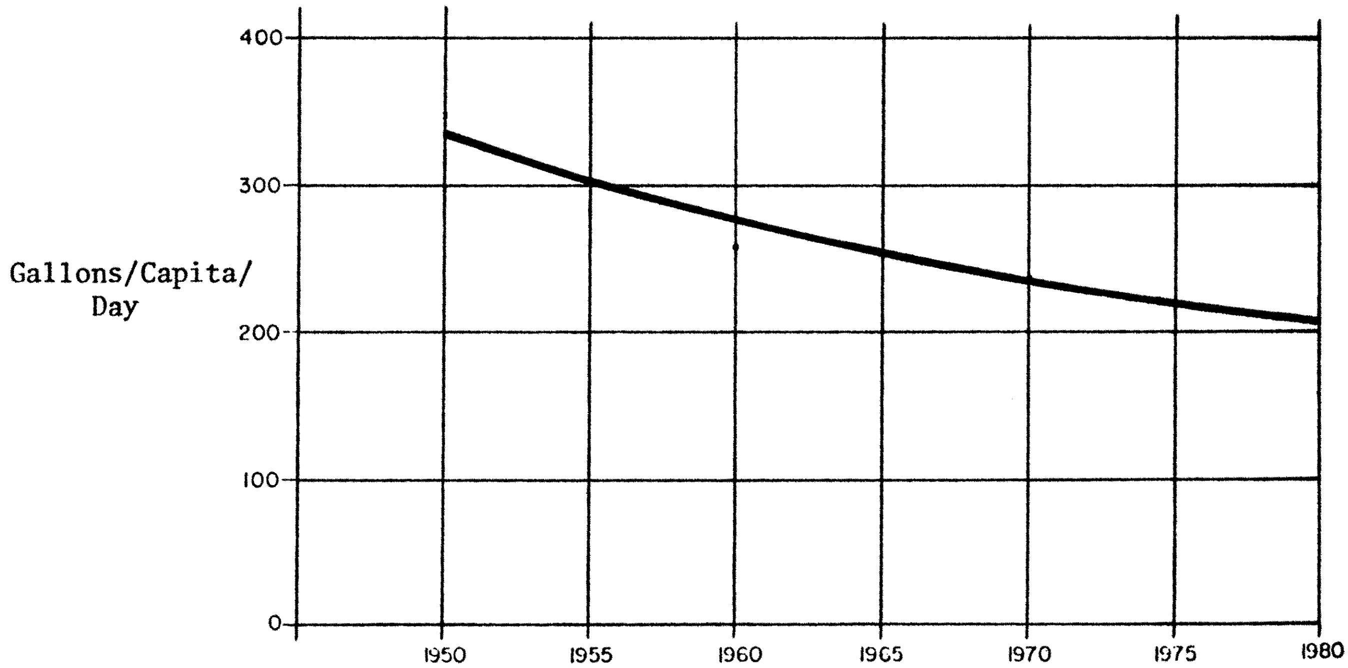


Figure G.3 Average annual per Capita Consumption
(after Water and Sewer Department).

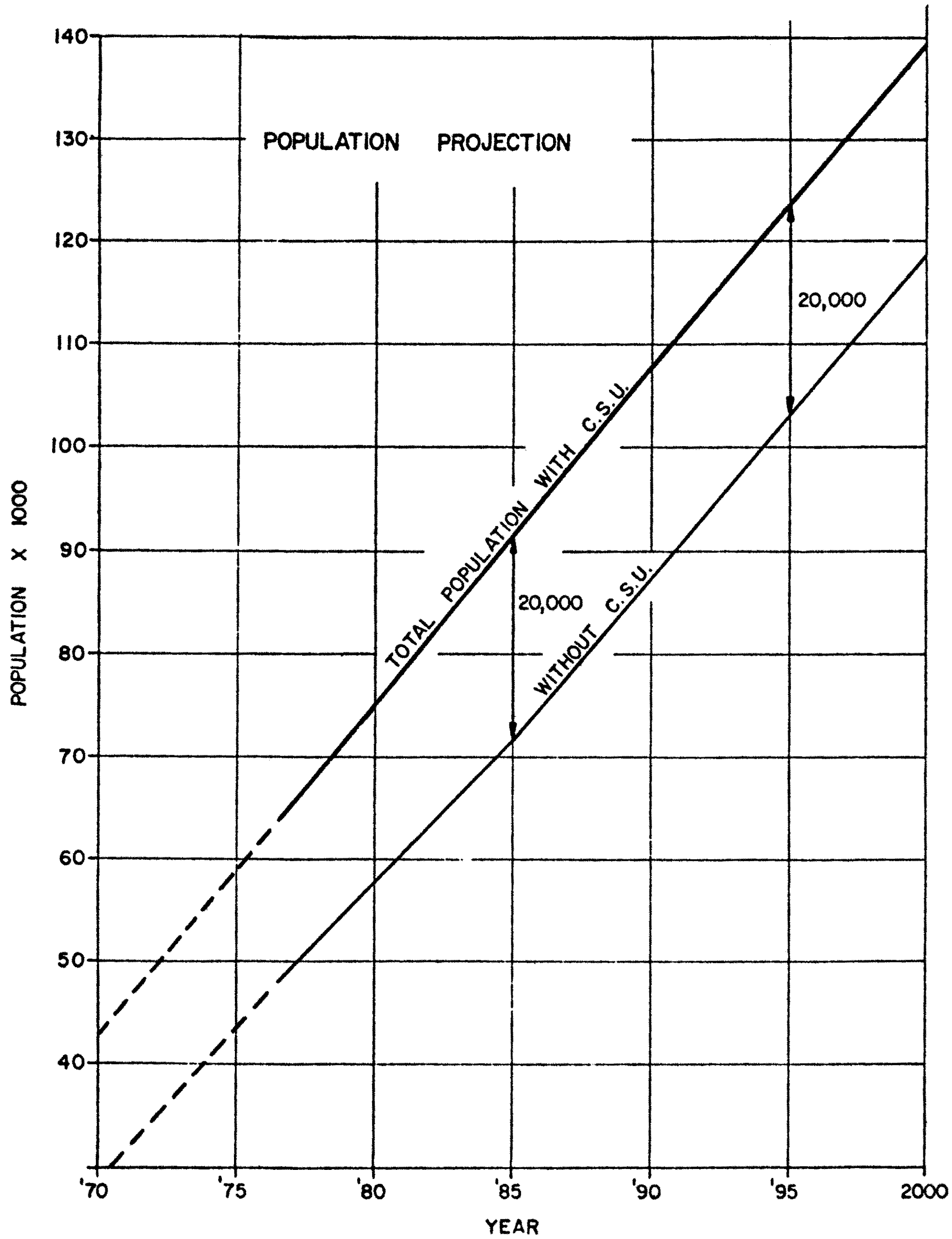


Figure G.4 Fort Collins Growth Projection (after Water and Sewer Department).

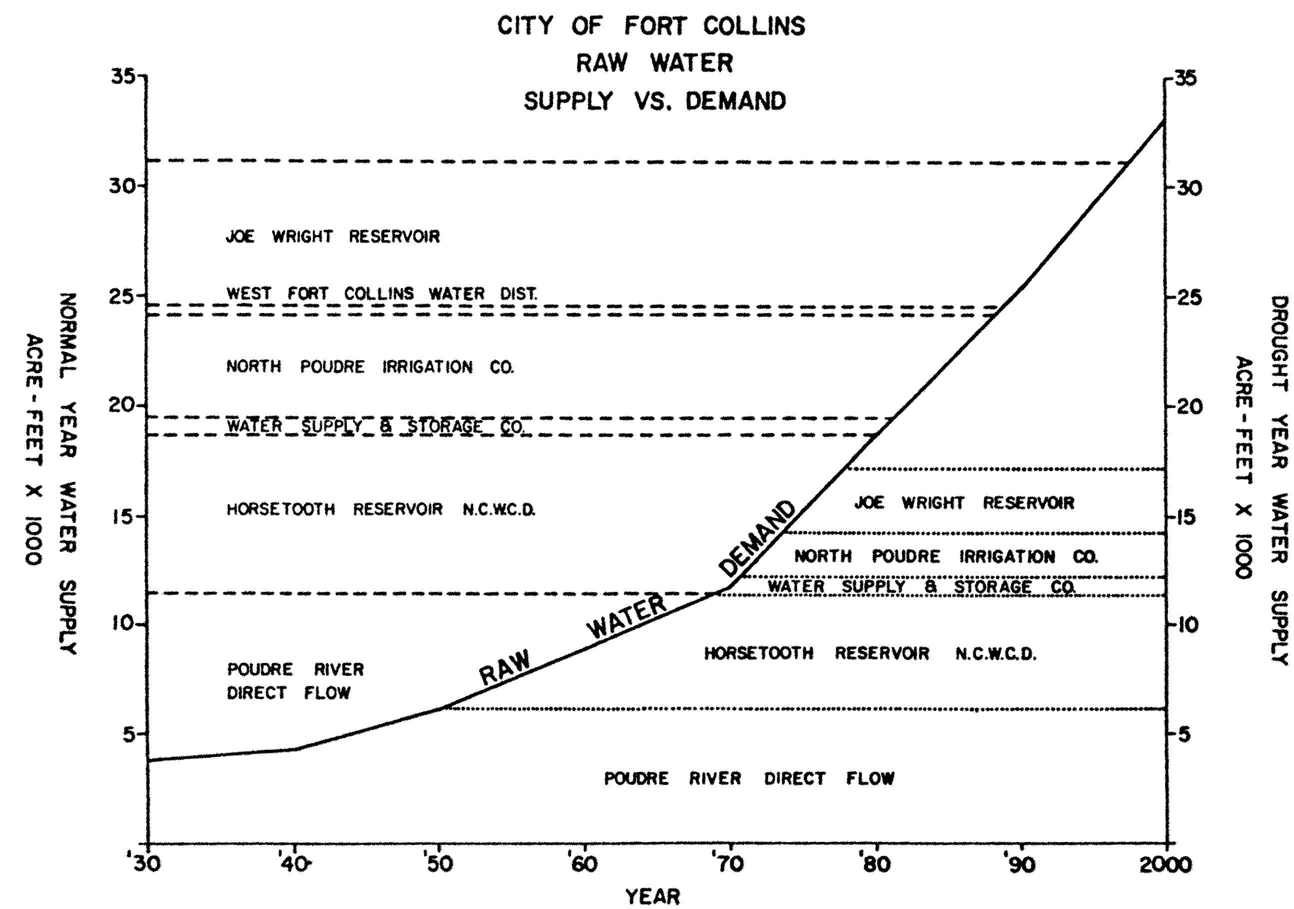


Figure G.5 Supply vs. Demand for two Hydrological Characteristics (after Water and Sewer Department).

G.5.2 Water Meters. From the 5,171.37 million gallons treated during 1977, only 1,440.76 were delivered to metered users, which represents 28 percent of the total. The rest of the water was sold on a flat rate basis.

The average water consumption per capita is decreasing in Fort Collins, as was shown in Figure G.3. One of the reasons is the increase of multifamily dwelling units which are required by law to install water meters. The sharing of yards yields savings in water.

The actual consumption of water is still greater than the equivalent in metered cities. A good example is the City of Boulder because of its geographic and demographic similarities. When Boulder installed meters, it had approximately the same characteristics as Fort Collins at the present time. At the end of meter installation in 1962, the consumption went down to 140 gpcd. The City of Boulder is currently using a value of 175 gpcd for projections.

The types of water rates in Fort Collins are:

1. Flat rates used in most of the residential zones of Fort Collins for single and duplex family units. The current rates are shown in Table G.2.

2. Metered rates are utilized in all new multifamily dwellings and for industrial and commercial users. The rates are summarized in Table G.3 and G.4. For the industrial and commercial users, the minimum rates are related to the piping diameters as shown in Table G.4.

Table G.2 City of Fort Collins Flat Rates for 1977

Fixed amount per unit	$96.00
Per each 100 sq ft over 9,000 add	0.05
Per each 100 sq ft under 6,000 deduct	0.05

Table G.3 Inside City Residences Metered Rates for 1977

Minimum charge up to 2,000 gallons:	
--First dwelling unit	$3.00
--Per each additional unit	1.80
--Per each additional 1,000 gallons, add	0.24

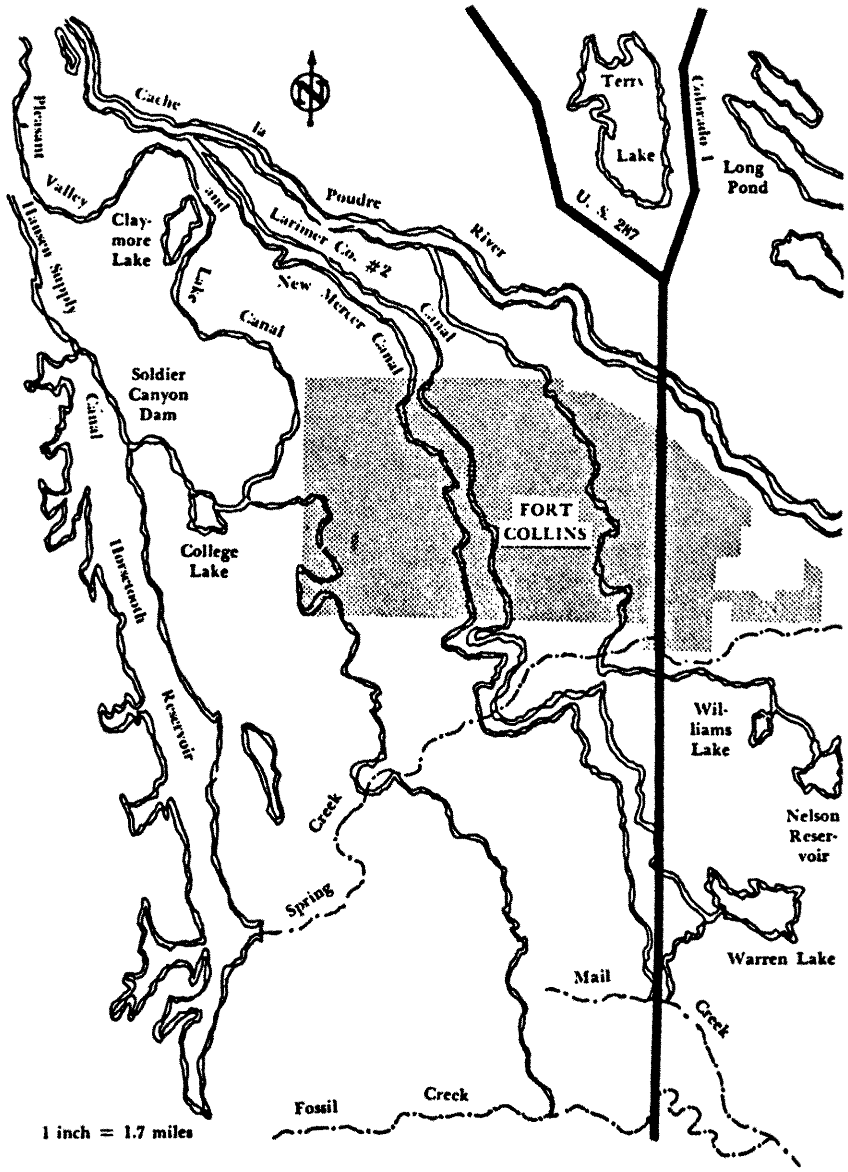


Figure G.6 Location of Main Ditches in Fort Collins Area.
(after Huszar et al.,1969)

Table G.4 City of Fort Collins Industrial and Commercial Users Rates for 1977

Minimum Charge up to 2,000 Gallons	
Meter Size (inches)	Monthly Minimum Charge ($)
.75	3.00
1	5.00
1.5	10.00
2	16.00
3	30.00
4	50.00
6	100.00
8	160.00
For each additional 1,000 gallons, add	0.24

The decision to install water meters throughout the city has economic and political implicators. The economic choices are between the costs of acquisition and treatment of new sources of water and the costs of installation and reading of water meters.

The scarcity of water is not considered because the city expands over agricultural lands which, in order to be annexed by the city, need to have three acre-feet of water per acre of surface, according to Anderson (1978).

The political aspect is more difficult to analyze because it is subject to personal values. Individuals against the implementation of water meters point out the possibility of turning the city brown because of the extra money needed to pay for maintaining the green color. This could have important consequences, especially in the zones inhabited by low income citizens. The solution is not easy and it is not the obejctive of this study. Nevertheless, with a little bit of imagination, it would be possible to implement a system that accounts for the irrigated surface. This mixed system would provide enough water to irrigate at a falt rate. Extra water utilized would be more expensive. This solution, although it may seem complex, is within the storage capactly of computer systems. In addition from a socio-political viewpoint, it is fairer; it avoids sharing the costs imposed by possible "bad users."

G.5.3 Other Alternatives

1. Restrictions: The impementation of restrictions are due to scarcity of water, or to avoid its wastage. The Water Utilities Department is concerned with this last point and utilizes night restrictions to avoid "lazy users" which leave the sprinklers on during the entire night. An exception has to be made for those users having automatic timers.

2. Improvements on irrigation methods: These improvements contemplate the use of timers as metnioned before and more effective sprinklers. With timers, besides the comfort for the user, the possibility of leaving the sprinklers on during the night, while at work, or just forgotten is avoided. Moreover, night irrigation, in connection with more effective sprinklers, will increase the percolation rate thereby reducing the evaporation losses.

G.6 New Facilities

New water system facilities include raw and filtered water distribution mains and water and wastewater treatment facilities.

G.6.1 *Raw Water Distribution*

The water treatment plant No. 1 at Poudre is sized for the water available at the Cache La Poudre River; therefore, no enlargements are projected. Water treatment plant No. 2 at Horsetooth has to be enlarged by 10 mgd each five years as already discussed. In order to cover future needs, the treatment plant inlet is being expanded during 1978. The present capacity of 32.8 cfs will be enlarged to 314 cfs or 203 mgd (8.9 m^3/s).

G.6.2 *Water Treatment Facilities*

The present capacity of both plants is about 44 mgd (1.9 m^3/s). From the studies done by the Fort Collins Water Utilities Department, based upon the population projections and average consumption already studied, it is necessary to enlarge the facilities by 10 mgd each five years. The first enlargement is necessary for 1979. There are works budgeted within that year to enlarge the capacity of plant No. 2 by 10 mgd, from 24 to 34 mgd (1.5 m^3/s). Plant No. 1 will remain with the same capacity although several modifications will be made to maintain or improve the plant effectiveness.

G.6.3 *Filtered Water Storage, Transmission, and Distribution*

During the next five years, enlargement of the filtered water storage is not scheduled. The transmission and distribution system has to be expanded to cover the new demands without affecting the pressure in the rest of the system. Adequate water pressure in the system is essential for fire protection. Several mains ranging from 12 to 24 inches are projected.

G.6.4 *Wastewater Collection*

New sewers have been built and are projected for developing areas. Southward expansion of the city will raise problems for the wastewater collection. The city is already close to the point where it will not be possible to reach the wastewater treatment plant by gravity.

G.6.5 Wastewater Treatment Facilities

From a study by John Blair (1978) with different population projections shown in Figure G.7, wastewater treatment needs are adequate until the year 2000. It will be necessary to use existing plants No. 1, No. 2, and the old No. 2. In the future symmetrical expansion of the new No. 2 will be required. The alternative of a regional development wastewater treatment facility to deal with the problem of southern expansion is feasible.

G.7 Effluent Discharge

New EPA regulations, which will be in effect in 1985 regarding water quality standards for the Cache La Poudre River, will require new solutions for the handling of effluents. There are two possible alternatives for attaining such standards: (1) improve the treatment processes by going to advanced wastewater treatment; or (2) avoid the discharge of the effluent into the river. The first method is expensive and is not considered in this study. For the second, two solutions are considered. These include the use of land treatment, the Rawhide Project, or a combination of both.

G.7.1 Land Treatment

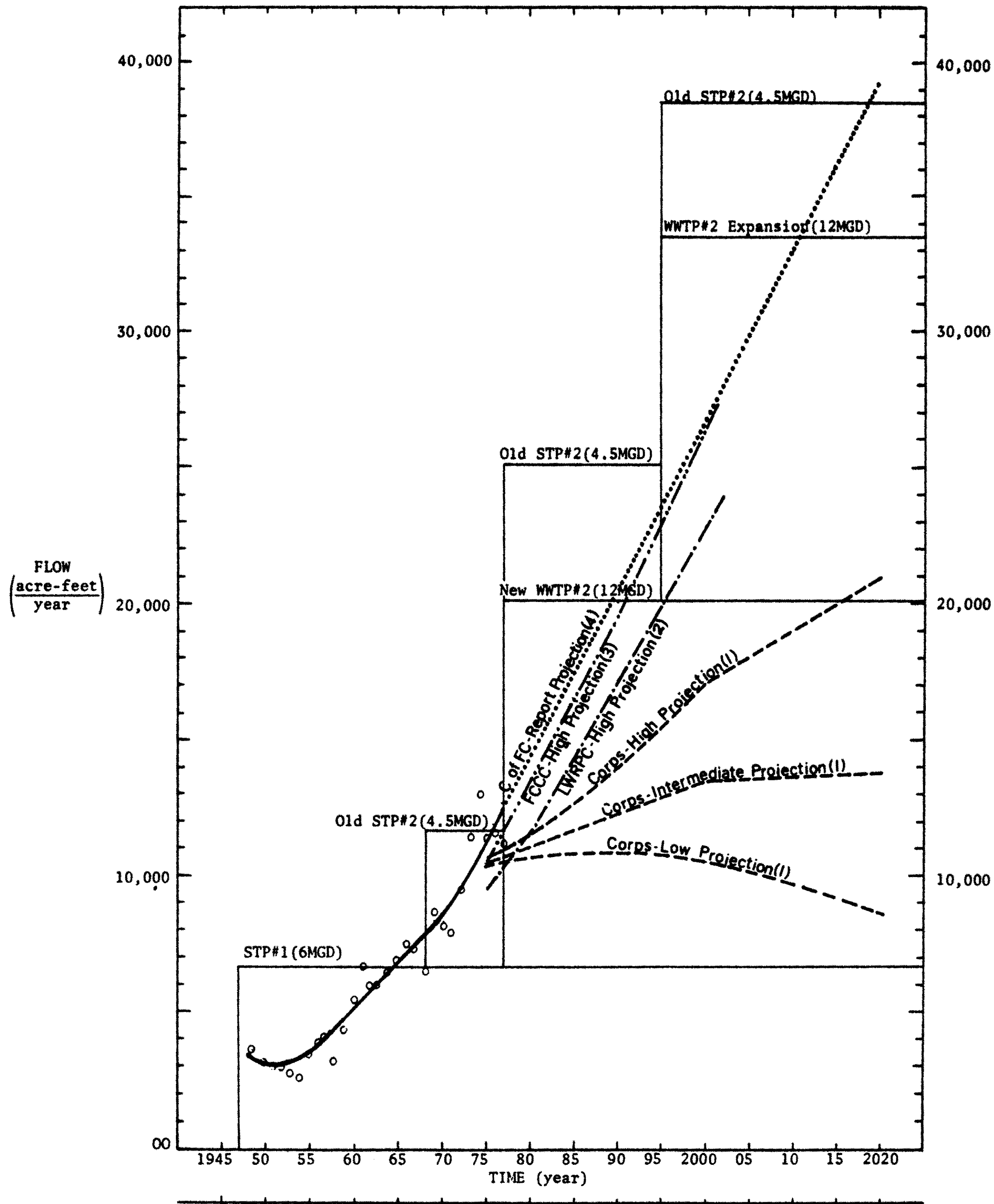
This alternative is the subject of the second part of this report where it will be reviewed more extensively.

G.7.2 Rawhide Project

This project would use the effluent of the City of Fort Collins for cooling purposes at the projected power plant of the Platte River Power Authority located about twenty miles north of Fort Collins.

Because of Colorado Water Law, the waters that will be taken out of the river, with almost zero return flow, have to be imported waters. For this purpose, the following sources are contemplated: (1) the waters owned by the city diverted from Michigan Ditch in excess of 1,000 acre-feet, and (2) the waters owned by the Water Supply and Storage Company which are diverted from Grand River Ditch. After the work is completed on Grand River Ditch and Long Draw Reservoir, a gain of 5,000 acre-feet is projected. This 5,000 extra acre-feet will be considered imported water.

The first 230 MW unit of the power plant is projected to be in operation in 1985. A firm water supply of 4,000 acre-feet per year will be required. The water will be pumped from the wastewater treatment plant No. 2 outlet to a reservoir that will be constructed at the plant site with a capacity of 12,000 acre-feet. The filling operations are intended to commence in 1981. In anticipation of its needs for water, Platte



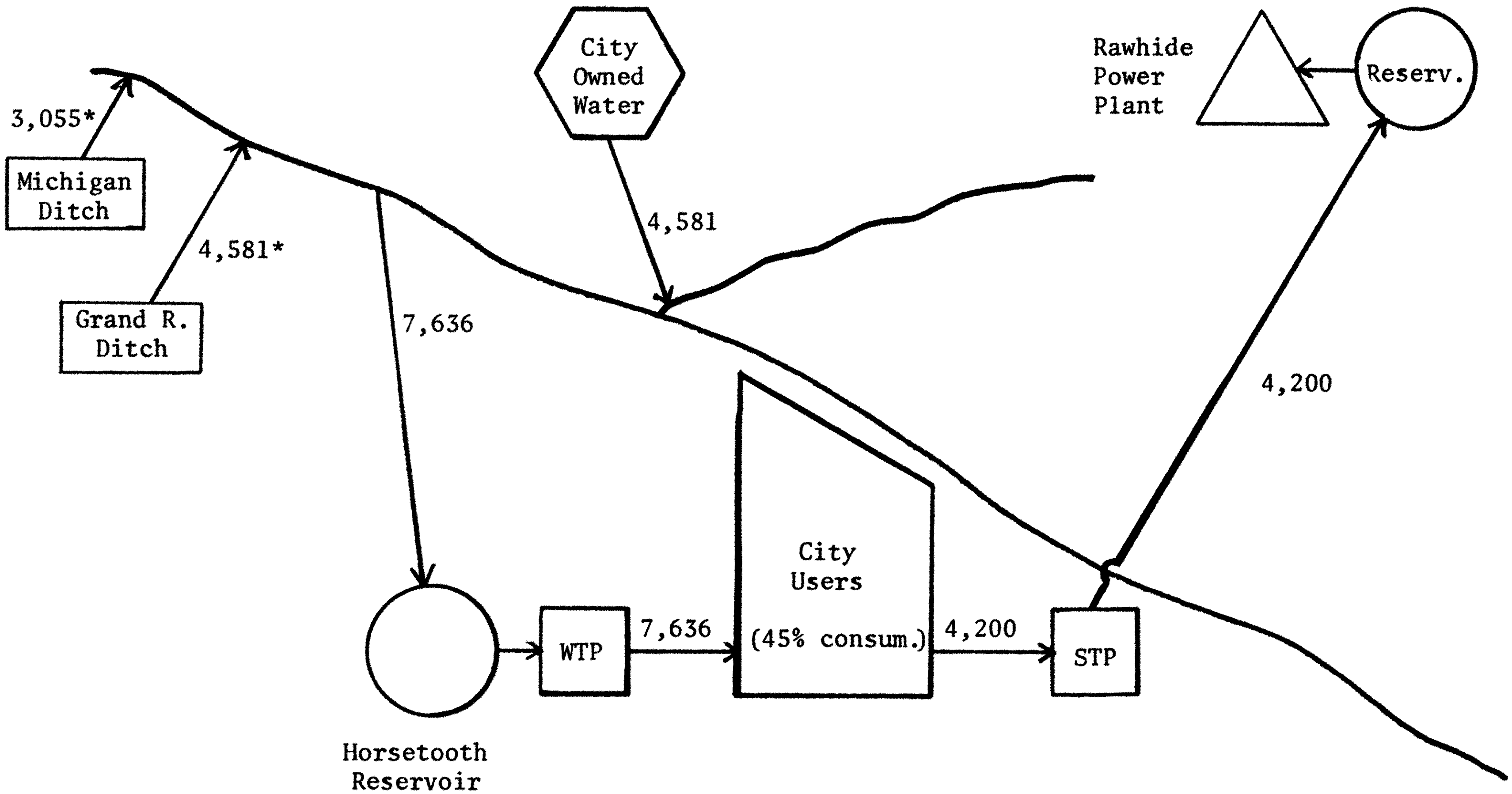
	13.5	14.9	19.7	25.0	43.3	59.1					
U.S. Army Corps of Engineers: Low						60.5	65.5	73.6	81.2	85.4	89.6
U.S. Army Corps of Engineers: Intermediate						61.1	66.9	77.4	90.3	98.0	105.7
U.S. Army Corps of Engineers: High						61.5	67.5	81.1	99.4	110.5	121.7
Larimer-Weld Regional Planning Commission						55.0	68.0	99.0	133.0		
Fort Collins Chamber of Commerce						61.0	79.0	114.0	153.8		
City of Fort Collins							75.6	107.4	139.4	(172.0)	(204.0)

POPULATION (x1000)

Figure G.7 Wastewater Treatment Facilities Projections. (after Blair,1978)

River Power Authority has contracted with the Municipal Sub-District, Northern Colorado Water Conservancy District, for 16,200 acre-feet of water from the Windy Gap Project.

A consumptive use by the city of 45 percent is considered in the Rawhide Project. Therefore, in order to have 4,200 acre-feet available for reuse, it is necessary to have originally 7,636 acre-feet at the treatment plant. This amount can be obtained by adding 3,055 acre-feet from the city and 4,581 acre-feet are exchanged by the same amount of city owned reusable water, available from the headgate of the Water Supply and Storage Company. A schematic is shown in Figure G.8.



*after 5% shrinkage

Figure G.8 Schematic of Rawhide Project